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A Salience Theory of Learning

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Synonyms

Comparative cognition; Emergent learning; Rational behaviorism

Definition

The perspective that responses are elicited by stimuli to which they have become associated or learned because they are reinforced remains strongly entrenched in psychological thought. Just what reinforcers are and how they operate, perhaps as agents that bond responses to stimuli, are unresolved issues. The most generally accepted definition of a reinforcer is that it is an event that increases the probability that a response will reoccur if it is reinforced. But that definition is circular and does not explain how reinforcement works. Here, we outline a perspective on learning called Salience Theory that offers a process by which learning occurs across instances of stimulus pairings and the resultant sharing of response-eliciting processes that occur.

Theoretical Background

Despite its popularity and robust history, this stimulus–response–reinforcement formulation has inherent weaknesses. How can radically new and creative behaviors suddenly occur in the absence of a training history that included those behaviors? How does the fixedness that inheres in response reinforcement give way to the emergence of new behaviors and concepts, such as complex musical compositions and groundbreaking inventions?

The Salience Theory of Learning proposes a new approach to account for the origins of novel, unexpected, and even intelligent behaviors and new abilities (e.g., competence in speech comprehension). It reformulates reinforcement and how it has its effects upon learning and behavior in terms of its salience, stimulus strength, and response-eliciting properties. Indeed, it formulates the contributions, the impact of all stimuli in the formation of our basic unit of learning, amalgams, in precisely those same terms.

We know that what is trained via specific reinforcement of specific responses does not necessarily constrain what is learned (Rumbaugh and Washburn 2003). How can this be according to Reinforcement Theory? What the subject learns might well be far more complex and even qualitatively different from the behavior that one specifically reinforced. For instance, a rhesus monkey (*Macaca mulatta*) was trained with reinforcement over the course of several months and thousands of training trials to control a joystick with its foot in a complex interactive computer task. Use of a hand was precluded, hence never trained. Only in a later test was the monkey given its very first opportunity to use either its hand or foot to do the task. Now, since all reinforced training had been with its foot, use of its hand should have been at most a remote probability. Yet, when given a choice, the monkey promptly used its hand, scoring significantly better than it had ever done with its foot.

Clearly, this finding is inconsistent with Reinforcement Theory. That the monkey used its hand might be said to reflect its massive and prior history in the use of its hand for fine manipulations of objects and foods, but that does not answer the stronger question of how the monkey knew how to use its hand skillfully.

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The answer to this stronger, more pointed, question is that the monkey somehow had learned about the task and principles of performing with precision by reinforced training with its foot. The effects of reinforced training were not limited to controlled use of the foot. The learning became more abstract and served the skillful use of its hand when that became an option in subsequent test.

Reinforcement Theory dates back more than 100 years to E. L. Thorndike and Alexander Bain. Today, advocates of controlling and modifying behavior testify to the apparent effectiveness of reinforcement and its pragmatic effects. Although we do not deny the seemingly special power of reinforcement in the acquisition and control of behavior, we suggest that it has no special power apart from its salience, its strength as a stimulus, and its response-eliciting properties as it enters amalgam formation with other contiguous stimuli that originate either from the external environment or internally. It thus stands to reason that it also will be the salience of any given stimulus and the strength of its response-eliciting properties that will determine its impact in amalgam formation – but always relative to the salience strengths and the response-eliciting properties of other stimuli with which it might form other amalgams.

The Salience Theory of Learning proposes an account of learning that does not have the extreme fixedness that inheres in the stimulus–response–reinforcement model, at least when the latter is taken at its face value. Behavior is too variable, too clever, too creative, and too versatile for it to be so constrained. Tolman (1948) observed this fact and concluded, as does Salience Theory, that expectancies and cognitions about what-leads-to-what emerge from the integration of past experiences including conditioning.

Stimulus–response and stimulus–stimulus associations are posited to have a basic role in our Salience Theory of Learning and Behavior, but not as instantiated by reinforcement as historically defined. Rather, associations that are induced among reliably and contiguously associated events are held to generate new composites that we term amalgams – our basic units of learning in Salience Theory. Amalgams are neither habits nor bonds. Importantly, all of the contiguous events that enter into the formation of a given stream of amalgam formations are posited to share interactively their saliencies and their response-eliciting properties. Thus, amalgams are somewhat different from the individual events that form them. Accordingly, amalgams might generate unique behavior, possibly apart from any single event that enters in their formation.

Salience Theory (Rumbaugh et al. 2007) embraces behavioral parameters from heritable and stereotyped instincts through conditioning and on to the emergence of highly complex behaviors that are adaptive. It merits emphasis that complex behaviors can be so novel, so complex, that their emergence through selective shaping and reinforcement is virtually impossible. Those complex behaviors and skills are called emergents, and they constitute a category of behavioral adaptations distinctly separate from the well-known respondent (i.e., Pavlovian) and operant dichotomy proposed mid-twentieth century by B. F. Skinner. Thus, Salience Theory proposes a trichotomy of learned behaviors: Respondent conditioning, Operant conditioning, and Emergents. Each of these categories has its own distinctive protocols and defining attributes (Rumbaugh et al. 2007).

Traditional learning theory has regarded both respondent and operant conditioning as contingent upon stimulus events that are in close temporal contiguity with the responses to be conditioned – the unconditional stimulus in the case of respondent conditioning and contingent reinforcement of the response in the case of operant conditioning. Rather than limiting emphasis to events that act solely upon responses, Salience Theory views organisms as constantly surveying their perceptual worlds as if foraging for stimuli that are important or salient along with other stimuli temporally or spatially contiguous with those salient stimuli. Thus, organisms are able to garner the resources needed to sustain life and learn adaptive behavior, while minimizing risk and conserving energy. Salient events, including those related to significant others (e.g., mothers, family members and cohorts) in a social group, provide the basis for observational learning from birth through maturity and the transmission of culture

Salience Theory illuminates both the antecedents and the consequences of learned and emergent behaviors, as does Reinforcement Theory. The theory is eclectic; it includes many components that are parts of other theories. It does not reject any body of empirical evidence and intends no derision of the giants of our time (see Marx and Hillix 1987, for an overview of our roots).

On the Parsimony of Salience Theory

Amalgam formation is similar to the initial learning stages of sensory preconditioning and classical conditioning. However, psychologists dating back to Thorndike have invoked a new process to explain instrumental conditioning, namely reinforcement. So there is an awkward discontinuity here going from the primitive association of two contiguous stimuli to the more complex operation of reinforcers.

There is an old and extensive literature on the awkwardness of the reinforcement explanation, including the problem of explaining how an event following a response can affect its probability. Furthermore, reinforcement implies an evolutionary discontinuity in the learning process in which the primitive association of two stimuli is amended by the conceptually more complex operation of reinforcement.

The advantage of the saliency approach is that both the evolutionary discontinuity and consequent lack of parsimony of the reinforcement approach disappear. There is just one fundamental process: amalgam formation. Amalgam formation underlies sensory preconditioning, classical conditioning, and most importantly instrumental conditioning and the formation of emergents.

Amalgam formation at its most basic level occurs when a highly salient stimulus (i.e., the unconditional stimulus) and a less salient stimulus (i.e., the conditional stimulus) come into either temporal or spatial contiguity. The impact of the unconditional stimulus is so strong and dominant in classical conditioning that the conditional stimulus comes to serve as an approximation of it. Thus, the conditional stimulus accrues salience and response-eliciting properties approximating those of the unconditional stimulus. To a lesser yet measurable degree, the conditional stimulus shares its salience and response-eliciting attributes with the unconditional stimulus. In operant conditioning, the reward is the most salient stimulus event. Response-produced stimuli produced by the correct response form an amalgam with the reward produced stimuli. The already existing high salience of the reward-related stimuli then accrues to the response-associated stimuli, thereby increasing the likelihood of the response. Thus, the subject learns how in a given situation it can obtain the resources for which it forages while minimizing risk and injury. As amalgams are incorporated into higher-level templates, emergent behaviors become possible.

Although great gaps of knowledge need to be filled by neuroscience and continuing behavioral research, Salience Theory advances the consilience of psychology, biology, and neuroscience (Naour et al. 2009; Rumbaugh et al. 2007).

Instincts, Respondents, Operants, and Emergents

We assume that organisms attend most closely to the most salient events in their perceived worlds and thus garner vital resources and minimize risk. To avoid circularity insofar as possible, we describe the major sources of natural and acquired facets of saliences. Briefly, they are as follows:

Genes – sign stimuli; releasers (e.g., the pecking of the red dot on mother's beak by gull chicks to induce her to regurgitate food)

Stimulus intensity – pressure, pain, sharp roar, bright lights, strength of sign stimuli

Past associations – conditioning; sensory preconditioning; classical and operant conditioning; conditioned reinforcers (Skinner 1938); and secondary reinforcers (Hull 1943)

Principles of perceptual organization – (e.g., closure, clustering of similar stimuli, induced motion, uniqueness/novelty)

Amalgams are posited as the basic units of learning. Metaphorically, they may be viewed as neural entries to a never-ceasing sequence of events and stimuli. In creating that record, salient events might serve as commands to "make an entry." The brains of all species have become honed to make these entries in such a way that the likelihood of adaptation and survival are maximized.

Salience Theory views the brain as generating an endless flow of amalgams that reflect experience as time flows on; the brain also organizes the amalgams into natural templates (e.g., readiness to learn different things within a general category.) and/or acquired characteristics (e.g., symbol-based, as with language, traffic signs, and language itself).

Salience Theory posits that as the brain works to resolve for the best fit among the amalgams and the templates to which they are assigned that emergents and even new skills might be given birth (Rumbaugh et al. 2007; Savage-Rumbaugh et al. 1993; Tolman 1948). They, in turn, might enable the performance of familiar tasks in more efficient ways and facilitate novel problem solving in an ever-changing environment. Thus, the accumulation of experience can contribute richly to the formation of a knowledge base.

By contrast, from the perspective of basic Reinforcement Theory, what is the etiology of new and creative behaviors (i.e., emergents) that have no training history? Their etiology in Reinforcement Theory is unlikely to involve a history of specific reinforcement because all responses, either elementary or highly complex and novel (e.g., a highly-complex emergent), must occur at least once before reinforcement can affect its reoccurrence. Salience Theory outlines how this problem is obviated.

Important Scientific Research and Open Questions

Might naturally salient stimuli not be blockable? Or might they be pre-potent or dominant as elements of compound CSs? Might they more readily enter into the formation of new amalgams than do arbitrary stimuli?

What is the loading of naturally salient stimuli vs. neutral stimuli in amalgam formation? How strong must an arbitrary stimulus be to be equal in effect to naturally salient stimuli?

Do the relative strengths of stimuli in sensory-preconditioning alter how they interrelate?

Can symbols functionally substitute for physical stimuli in compound CSs?

How does incorporation of a stimulus into one kind of amalgam impact its availability and function in other types of amalgams?

Does amalgam formation predict flash-bulb memory instatement?

Does amalgam formation account for perceptual discriminations as with new objects or in learning visual discrimination?

How does Salience Theory align with neural activity/recordings of areas of the brain in various kinds of contexts?

Acknowledgments

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Cross-References

► Abstract Concept Learning in Animals
► Analogical Reasoning in Animals
► Animal Learning and Intelligence
► Comparative Psychology and Ethology
► Intelligent Communication in Social Animals
► Language Acquisition and Development
► Learning and Numerical Skills in Animals
► Linguistic and Cognitive Capacities of Apes
► Reinforcement Learning
► Theory of Mind in Animals

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A Stability Bias in Human Memory

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Definition

Human memory is anything but stable: We constantly add knowledge to our memories as we learn and lose access to knowledge as we forget. Yet people often make judgments and predictions about their memories that do not reflect this instability. The term *stability bias* refers to the human tendency to act as though one's memory will remain stable in the future. For example, people fail to predict that they will learn from future study opportunities; they also fail to predict that they will forget in the future with the passage of time. The stability bias appears to be rooted in a failure to appreciate external influences on memory, coupled with a lack of sensitivity to how the conditions present during learning will differ from the conditions present during a test.

Theoretical Background

All memories are not created equal. Some memories feel strong, vivid, and familiar; others feel shakier and less reliable. People are generally confident in the first type of memory but unsure about the second. Behavior reflects this difference; for example, most people only volunteer to answer a question in class if they feel confident about their response.

The term *metacognition* refers to the process of making judgments about one's cognition and, frequently, about one's memory (Dunlosky and Bjork 2008). Metacognitive processes are used to distinguish accurate memories from inaccurate ones. A memory is only valuable to the degree that we can trust it, which makes metacognition vital in our day-to-day use of memory. Moreover, virtually all memory retrievals are associated with a feeling of certainty (or lack thereof). Thus, metacognition is a critical, and omnipresent, component of human memory.

Metacognitive judgments are often accurate. For example, your memory of what you ate for breakfast today is probably more accurate than your memory of what you ate for breakfast on this date 11 years ago, and it probably feels more accurate as well. It would be natural to assume that metacognitive judgments are made on the basis of the memory being judged – that is, that when confidence is low, it is *because* a memory is weak. The empirical evidence suggests otherwise.

Instead of being made based on memories themselves, metacognitive judgments appear to be made based on inferences about those memories. For example, if an answer comes to mind quickly and easily, people tend to judge that they know that answer well. This inference is usually correct. But it is an inference all the same, and when conditions are created that reverse this relationship – when answers that come to mind quickly are *less* memorable – people give high *judgment of learning* ratings to information that comes to mind quickly, *not* to information that is highly memorable (Benjamin et al. 1998).

If metacognitive judgments are inferential, what is the basis of the inferences? Koriat (1997) put forward a highly influential framework that has successfully accounted for a great deal of subsequent data. He proposed that three categories of cues influence metacognitive judgments. *Intrinsic cues* were defined as information intrinsic to the information being judged (e.g., the semantic relatedness of a question and its answer). *Mnemonic cues* were defined as information related to the learner's experience (e.g., the fluency with which an answer comes to mind). *Extrinsic cues* were defined as information extrinsic to the learner and the to-be-learned material (e.g., the number of times an item was studied).

A second key distinction, related to Koriat's (1997) framework, is between judgments based on direct experience and judgments based on analytical processes (Kelly and Jacoby 1996). Intrinsic cues and mnemonic cues tend to elicit *experience-based* judgments. That is, these cues (e.g., how easily one thinks of an answer) are part of the learner's experience at the time of the judgment. Metacognitive judgments are usually highly sensitive to a person's current experience. Thus, experience-based judgments often occur automatically.

Extrinsic cues, by contrast, tend to elicit more analytical *belief-based* judgments. For example, the number of times an item will be studied is not a salient part of the learner's experience while studying. Instead, responding to an extrinsic cue often requires applying one's beliefs about memory (e.g., I will do better on items I study more). Doing so does not tend to happen automatically. As a result, people regularly fail to make belief-based judgments, even when they should. Thus, people tend to be sensitive to experience-based cues but not belief-based cues.

It is important to be able to predict how future events will affect one's memory. For example, a student may need to predict the value of spending the rest of the day studying. Future events are extrinsic cues – they are external to the learner's current experience – and, as such, they require belief-based judgments. Thus, people should exhibit a stability bias: They should be relatively insensitive to the impact of future events on their memories.

Important Scientific Research and Open Questions

Koriat et al. (2004) investigated how sensitive people are to future forgetting. After studying a list of word pairs, their participants were asked to predict their likelihood of recalling the pairs on a cued-recall test (i.e., their ability to recall the second word in the pair when shown the first word). There were three groups of participants, who were told, respectively, that their test would take place immediately, a day later, or a week later.

Actual recall performance dropped off precipitously as the delay between study and test increased. Shockingly, predictions hardly changed at all. In other words, the participants demonstrated a stability bias: They acted as though they would remember just as much in a week as they would remember immediately. The predictions were highly sensitive to the degree of association between the pairs, which is an experience-based, intrinsic cue. But they were insensitive to retention interval, an extrinsic cue. In one extreme case, tests that would take place immediately and in one *year* elicited the same predictions.

A key change in the procedure greatly altered participants' predictions. When a single participant was told about all three retention intervals, their predictions became sensitive to retention interval. It appeared as though the participants believed that they would forget over time, but that they did not apply that belief in the first experiment. When they were told about all of the retention intervals, they began to apply belief-based judgments. Phrasing the question in terms of forgetting had a similar effect: Apparently, making the idea of forgetting salient was enough to make judgments sensitive to retention interval.

One potential implication of ignoring retention interval is extreme overconfidence. People tend to be overconfident in their memories in general. But when someone is overconfident about an immediate test, and is not sensitive to retention interval, their overconfidence is destined to grow. For example, assume you have a 70% chance of recalling a fact from your textbook if you are tested in 10 min. If you are tested in a week, that chance might decrease to 20%. If you judge that you have an 80% chance of recalling the fact at either retention interval, you will be overconfident immediately, but only by 10% points. A week later, you will be overconfident by 60% points. This increase in overconfidence with time has been referred to as *long-term overconfidence* (Kornell 2010).

The stability bias is not limited to forgetting. Kornell and Bjork (2009) investigated predictions about another seemingly obvious principle of memory, namely, that people learn by studying. Their participants were told that they would be allowed to study a list of word pairs between one and four times. They were asked to predict how they would do when they took a test on the pairs. The predictions were almost entirely insensitive to the number of study repetitions, again demonstrating a stability bias. The stability bias did not go both ways; people recognized the value of *past* studying, but underestimated the value of *future* studying. Like with forgetting, when the concept of learning was made salient, in a within-participants design, the predictions became more sensitive. Unlike forgetting, however, the predictions continued to underestimate the value of studying. As a result, across a number of different experiments, participants were overconfident in their current knowledge, but simultaneously *underconfident* in their learning ability.

One potential implication of undervaluing future study opportunities is that people might underestimate their own learning potential. For example, a student might look at a set of challenging course materials and decide to drop out of a class, assuming that he or she cannot learn all of the material. If this student is underconfident in his or her learning, he or she might be giving up in the face of a challenge that could be overcome.

Cross-References

► Confidence Judgments in Learning
► Cued Recall
► Metacognition and Learning
► Metacognitive Learning: The Effect of Item-Specific Experiences
► Overconfidence
► Self-confidence and Learning
► The Role of Stability in the Dynamics of Learning, Memorizing, and Forgetting

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A Tripartite Learning Conceptualization of Psychotherapy

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Synonyms

Behavior therapy; Cognitive-behavioral therapy; Counseling; Psychoanalysis; Psychological treatment

Definition

Psychotherapy is a complex interpersonal interaction, relationship, and method of treatment between a licensed mental health professional (most often a psychiatrist, psychologist, or social worker) and a patient aimed at understanding and healing the patient's emotional distress and suffering, most often evident by symptoms of anxiety or depression. Psychotherapy predicated upon learning theory assumes that a patient's maladaptive coping behaviors that have been unsuccessfully invoked by the patient to deal with his or her distress are learned behaviors that can, therefore, be unlearned through psychological treatment. The Tripartite Learning Conceptualization of Psychotherapy holds that there are multiple forms of learning involved in both the learning and unlearning of behavioral problems. In essence, there are three principal learning processes that are involved in psychotherapy: (1) learning to build and maintain a therapeutic alliance between the therapist and patient, (2) learning the use of a number of empirically tested techniques that have been found helpful to alleviate emotional distress, and (3) the gradual relearning of more adaptive behavioral responses to cope with life stressors. Each of these three processes takes place within one of three designated learning domains: the affective, cognitive, or behavioral learning domains.

Theoretical Background

Psychotherapy and Learning Processes

For over a half century, psychotherapy has been conceptualized as a learning process (e.g., Dollard and Miller 1950). Given this premise, it is expectable that multiple forms of learning are involved in this process. Mowrer (1947) was one of the first theorists to recognize the presence of multiple forms of learning in the acquisition and maintenance of "neurotic" (i.e., anxious) behavior. According to his "two-factor learning theory," neurotic anxiety, or fear of a harmless situation, is acquired and maintained via a two-step learning process. The two-factor learning theory of anxiety encompassed a combination of associative learning processes via classical conditioning and instrumental learning via operant conditioning. Mowrer noted the importance of associative learning in the initial *acquisition* of a fear response to a previously unfeared or nonthreatening stimulus. In addition, he cited instrumental learning in which the organism then learns to avoid the feared stimulus as critical in *maintaining* the fear response. The learned avoidance of the anxiety-provoking stimulus prevents the reduction of the acquired fear through subsequent experiences with the stimulus that would result in alternative, less fearful consequences. Because the avoidance deprives the patient of an opportunity to relearn alternative responses to the stimulus, acquired neurotic anxiety is resistant to extinction or change. In a similar manner, multiple forms of learning are involved in providing corrective experiences that take place in psychotherapy, using principles of learning to understand both the therapeutic alliance and the technical aspects of therapy.

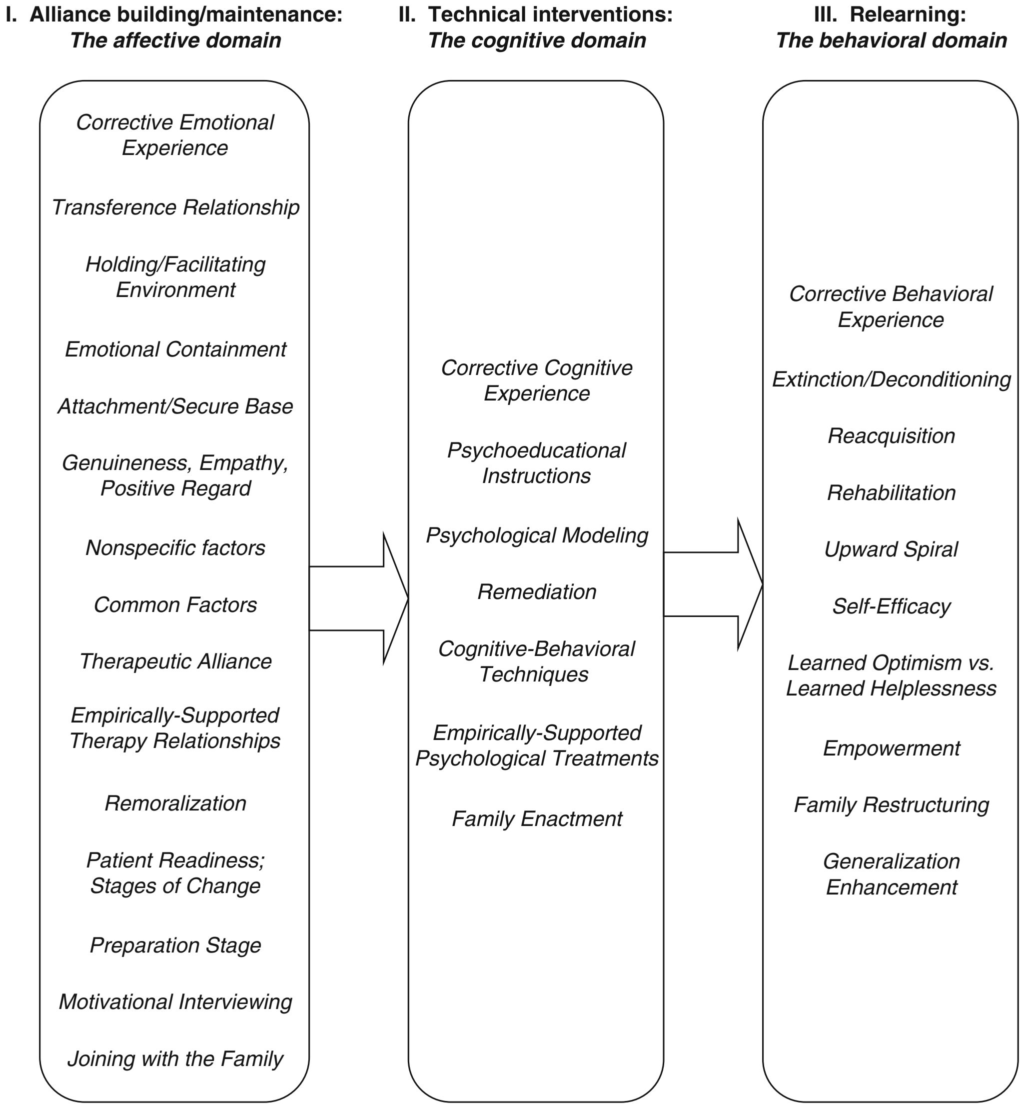
Contributions from Educational Psychology: Learning in Three Domains

In educational psychology, it has long been recognized that there is more than one type of learning. Bloom and his colleagues (e.g., Bloom et al. 1956) identified three domains of learning: cognitive (intellectual), affective (emotional), and psychomotor (behavioral). *Cognitive learning* involves the acquisition of factual knowledge and the development of intellectual skills, abilities, and thought processes. *Affective learning* involves the ways in which people emotionally process information and stimuli. Emotional learning and development are essential to the construction of the learner's feelings, values, and motives, and are at the foundation of one's receptivity to information. Finally, *psychomotor learning* involves behavior and activity connected with one's perceptual responses to inputs, to the activity of imitation (modeling, vicarious learning), and to the manipulation of one's environment (instrumental learning).

Therapeutic Learning in Three Processes

The Tripartite Learning Model of Psychotherapy (Scaturo 2005, 2010) proposes that there are three broad learning processes in therapy that correspond to the three learning domains noted above. The therapist's skill in facilitating these three types of learning in patients is basic to the process of psychotherapy, as well as to the therapist's acquisition of the technical skills necessary for becoming an effective psychotherapist of any given theoretical persuasion. These three treatment processes have been designated as *alliance building and maintenance*, *technical interventions*, and *relearning*. They are incorporated into the three learning domains as illustrated in Fig. 1. The factors relevant to the therapeutic alliance as described in a variety of theoretical approaches to psychotherapy are clustered together in Fig. 1a. Tacit emotional learning is at the core of the therapeutic alliance. The patient learns to associate expectancies for behavior change with aspects of safety and viability (i.e., hope) in the therapeutic context. In Fig. 1b, a number of well-documented cognitive-behavioral therapy (CBT) technical interventions are noted. These comprise the more proactive and directive interventions on the part of the therapist. Technical interventions tend to be targeted toward anxiety disorders and depressive disorders, as the two fundamental emotional states for which the instructional aspects of CBT have had demonstrated effectiveness. These interventions are designed primarily to engage cognitive learning processes: the patient receives therapeutic directives and homework (instructional learning), observes the therapist modeling and rehearsing behavioral alternatives (vicarious learning), and learns the needed coping behaviors and social/interpersonal skills. Finally, in Fig. 1c, newly relearned behaviors in therapy are ultimately performed by the patient in his or her everyday life. The more adaptive life consequences experienced through these alternative ways of coping with anxiety and depression bring about eventual self-generating reinforcements (instrumental learning, operant behavior).

Within the affective domain of learning, the general process of building and maintaining a constructive therapeutic alliance with the psychotherapist is primary with emotional learning as the key. The concept of the therapeutic alliance has been denoted in the psychotherapy literature with a wide variety of terms from a broad range of theoretical perspectives. These terms include, but are not limited to Freud's concept of the transference relationship; the holding environment; the notion of emotional containment; the corrective emotional experience; the facilitative conditions of genuineness, empathy, and positive regard; nonspecific or common factors in psychotherapy; the therapeutic alliance; empirically supported therapy relationships; the concept of remoralization; patient readiness; motivational enhancement and preparation for therapy; and joining with the family system. Within the cognitive domain of learning, a variety of psychotherapeutic technical interventions have been subsumed. These include a wide variety of cognitive-behavioral techniques for the treatment of anxiety and depression, modeling behaviors by the psychotherapist, psychoeducational interventions; the concept of remediation, empirically supported psychological treatment programs; and family enactment in family therapy sessions. Finally, within the behavioral domain of learning, the concept of relearning more adaptive behaviors in response to life stressors has been denoted as critical in psychotherapy. This relearning by the psychotherapy patient has been signified by the terms counterconditioning, extinction, and reacquisition of behaviors; rehabilitation; self-efficacy; the upward spiral; family restructuring; and generalization enhancement of newly learned behaviors over time and over a variety of problem situations. The interested reader is referred to Scaturo (2005, 2010) for a detailed discussion of these terms and their theoretical foundations.



A Tripartite Learning Conceptualization of Psychotherapy. Fig. 1 Tripartite learning conceptualization of psychotherapy (Scaturo [2010], adapted and reprinted with permission of the Association for the Advancement of Psychotherapy)

In sum, the understanding of psychotherapy here describes three important human processes that comprise this form of treatment: (1) building and maintaining the psychotherapeutic relationship and alliance mediated by affective learning; (2) intervening with empirically tested techniques such as verbal instructions, recommendations, and homework assignments/directives that provide cognitive learning to the patient about his or her difficulties; and (3) assisting the patient in making proactive behavioral changes in his or her life resulting in an instrumental relearning about the patient's problem areas in his or her life.

Important Scientific Research and Open Questions

Empirical support for the present three-part learning conceptualization of psychotherapy processes can be found in Howard et al.'s (1993) three-phase model of psychotherapy outcome. Their model postulated three phases of treatment outcome involving the concepts of "remoralization," "remediation," and "rehabilitation" that correspond conceptually to the three therapeutic processes designated in the Tripartite Learning Model of Psychotherapy. These authors studied a large sample ($N = 529$) patients at the time of their initial intake interview before beginning individual psychotherapy at the Institute of Psychiatry at Northwestern University's Memorial Hospital. Self-report data of the patients' subjective well-being, symptomatic distress, and life functioning was collected at the outset of treatment and re-administered following Sessions 2, 4, and 17. Sophisticated statistical analyses revealed that changes in subjective well-being, symptomatic distress, and overall life functioning scores over this period of time lent strong empirical support for the three-phase model described by the authors.

In addition, Howard et al. (1993) research has clearly demonstrated that these three phases of treatment are "sequentially causally dependent": *Remoralization* → *Remediation* → *Rehabilitation*. To the extent that the three components of the tripartite learning model correspond conceptually to Howard et al.'s three phases of psychotherapy, there is the implication that the components of the learning conceptualization are not only "tripartite" but also "triphasic": *Alliance Building/Maintenance* → *Technical Interventions* → *Relearning* (see Fig. 1). Thus, there is a notion of *progressive* clinical improvement from one phase to the next. That is to say, improvement in one phase *potentiates* improvement in the subsequent phases. The initial phases in psychotherapy appear to act as prerequisites for effectiveness in the succeeding phases of treatment. The tripartite learning explanation of therapeutic process further expands on Howard's model of therapeutic outcome and incorporates the notion of three learning domains – affective, cognitive, and behavioral – that occur along with one another to produce therapeutic change. Learning theory thus provides a common theoretical bridge for the essential therapeutic processes by which we may better understand the treatment concepts of broad range of theoretical perspectives pertaining to psychotherapy.

Cross-References

▶ Associative Learning
▶ Behavior Modification as Learning
▶ Bloom's Taxonomy of Learning Objectives
▶ Cognitive Learning
▶ Instrumental Learning
▶ Modeling and Simulation
▶ Operant Behavior
▶ Psychoanalytic Theory of Learning
▶ Psychodynamics of Learning

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AAVL

▶ Effects of Anxiety on Affective Learning

Abduction

▶ Metapatterns for Research into Complex Systems of Learning

Abductive Learning

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Synonyms

Explanatory inference; Inference to the best explanation; Retroduction

A

Definition

The word *abduction* comes from the Latin word *abducere*, which means "to lead away from." It is sometimes used interchangeably with the word *retroduction*, which comes from the Latin words *retro*, meaning "backwards" and *ducere* meaning "to lead." The term *abduction* is most commonly used to describe forms of reasoning that are concerned with the generation and evaluation of explanatory hypotheses. Abductive reasoning, then, is often portrayed as explanatory reasoning that leads back from facts to a proposed explanation of those facts. It is different from inductive reasoning, which is commonly concerned with descriptive inference that results in generalizations. The phrase "abductive learning" can be taken to cover a wide range of concerns where learning outcomes result from the employment of abductive reasoning. Abductive learning occurs widely in scientific, professional, lay, and educational endeavors.

Theoretical Background

Over 100-years ago, the philosopher-scientist, Charles Sanders Peirce (*Collected papers*, 1931–1958), referred to a form of reasoning that he called *abduction*. For Peirce, abduction involved the generation of new hypotheses that explained one or more facts. Peirce (1958, pp. 5.188–5.189) took abduction to have a definite logical form, which he represented in the following argument schema:

The surprising fact, C, is observed.
But if A were true, C would be a matter of course.
Hence, there is reason to suspect that A is true.

In this schema, C can be a particular event or an empirical generalization. A is to be understood as an explanatory hypothesis or theory, and C follows, not from A alone, but from A combined with relevant background knowledge. Finally, A should not be taken as true, but as plausible and worthy of further investigation.

Abductive learning takes a variety of forms. One common form is known as *existential abduction*, where the explanatory hypothesis or theory postulates the existence, but not the nature, of an entity thought to explain the relevant fact(s). For example, one might explain a number of symptoms of a common cold in terms of a viral infection without being able to say anything about the nature of the virus. In science, the multivariate statistical method of exploratory factor analysis is sometimes used to hypothesize the existence of underlying causal factors thought to explain correlated performance indicators. For example, general intellectual ability is hypothesized to explain correlated scores on subtests of an intelligence test (Haig 2005). Exploratory factor analysis, then, is a method of learning that facilitates the abductive generation of elementary plausible hypotheses that explain positive correlations of variables.

A second form of abductive learning is captured by a strategy of analogical modeling which exploits a type of abductive reasoning known as *analogical abduction* (Abrantes 1999). The reasoning involved in analogical abduction can be stated in the form of a general argument schema as follows:

Hypothesis H^* about property Q was correct in situation S1.
Situation S1 is like situation S2 in relevant respects.
Therefore, an analogue of H^* might be appropriate in situation S2.

This is a valuable reasoning strategy for learning about the nature of hidden causal mechanisms that are hypothesized or theorized in both science and everyday life. It is also an important means for assessing the worth of our expanded understanding of such mechanisms. Expansion of our knowledge of the nature of our theories' causal mechanisms is achieved by conceiving of these unknown mechanisms in terms of what is already familiar and understood. With the strategy of analogical modeling, one builds a model of the unknown subject or causal mechanism based on appropriate analogies derived from the known nature and behavior of the source. Two examples of models that have resulted from this strategy are the molecular model of gases, based on an analogy with billiard balls in a container, and the computational model of the mind, based on an analogy with the computer. These examples can be reconstructed to conform to the argument schema for analogical abduction presented above.

Another, and important, form of abductive learning is known as *inference to the best explanation*. Like existential abduction, inference to the best explanation justifies knowledge claims in terms of their explanatory worth. However, unlike existential abduction, inference to the best explanation involves accepting a hypothesis or theory when it is judged to provide a better explanation of the evidence than its rivals do. Paul Thagard (1992) has developed a detailed account of inference to the best explanation known as *the theory of explanatory coherence.* According to this theory, inference to the best explanation is concerned with establishing relations of explanatory coherence. The determination of the explanatory coherence of a theory is made in terms of three criteria: explanatory breadth, simplicity, and analogy. The theory of explanatory coherence is implemented in a computer program (ECHO), which is connectionist in nature. Judgments of explanatory coherence are employed widely in human affairs. For example, Charles Darwin argued for the superiority of his theory of evolution by natural selection on the grounds that it provided a more coherent explanation of the relevant facts than the creationist alternative of his time. And in courts of law, jury decisions are significantly governed by consideration of the comparative explanatory coherence of cases made by defending and prosecuting lawyers.

Important Scientific Research and Open Questions

Learning through abductive reasoning is as pervasive as it is important for generating, expanding, and justifying many of our knowledge claims. And yet, abductive reasoning, and the learning on which it depends, is not widely known. There is a major role for science education to promote and provide an understanding of how we learn through abduction. Researchers in science education are beginning to study abduction in different learning contexts, but there is much more to be done.

The processes of abductive learning through use of different research methods needs further investigation. The abductive methods of exploratory factor analysis and the theory of explanatory coherence were briefly considered above, as was the strategy of analogical modeling that employs analogical abduction. However, there are other research methods that involve abductive reasoning in ways that have not been fully articulated. The well-known qualitative method of grounded theory is a prominent case in point.

Finally, abduction is an important human ability. It seems to be complicit in perception and emotion, as well as cognition (Magnani 2010). Just how these spheres of human functioning exploit abductive processes deserves further intensive investigation. Additionally, the suggestive hypotheses about the history and biological origins of abductive reasoning are in need of further research. For example, did the powers of human abductive reasoning have their origins in the tracking behavior of hunter-gatherers, and is abductive reasoning an evolved adaptation (Carruthers 2002)? The answer to these and related questions are yet to be properly given.

Cross-References

► Abductive Reasoning
► Bayesian Learning
► Creative Inquiry
► Explanation-Based Learning

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Abductive Reasoning

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Synonyms

Hypothesis; Hypothesis generation; Inference to the best explanation; Retroduction

Definition

Abductive reasoning consists in applying norms underlying the generation of hypotheses.

Theoretical Background

Logic and reasoning are usually thought of in the realm of deductive reasoning which is concerned with preserving truth. A valid deductive argument is one for which true premises guarantee a true conclusion. Aristotle's syllogisms are familiar examples of such arguments. All A are B and C is an A lead to the conclusion that C is a B. All men are mortal and Socrates is a man requires that Socrates is mortal.

The hypothetico-deductive method provides a means of analyzing scientific reasoning. Given a hypothesis, predictions can be deduced from the hypothesis which is then tested by scientific experiments. However, as Karl Popper argued, the consequences of testing a hypothesis are quite different in the case of finding confirming as opposed to disconfirming evidence. Given a hypothesis (H) and a prediction (P), the underlying logic can be characterized as follows:

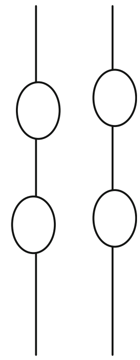
Confirmation		Disconfirmation	
Argument	Comment	Argument	Comment
If H then P	H implies P	If H then P	H implies P
P	The prediction occurs	Not P	The prediction does not occur
Therefore ?	H is confirmed, not proven	Therefore not H	H is certainly false

So disconfirmation conclusively establishes that a hypothesis is false (by the deductively valid *modus tollens* argument form) whereas confirmation does not prove the truth of the hypothesis (concluding that H is true given that P is true is known as the logical fallacy, *affirming the consequent*). Going beyond deductive logic, we might say that confirmation provides support of a hypothesis, perhaps increasing our confidence in the hypothesis, but it does not prove the hypothesis. Inductive logic is involved in coming to accept hypotheses, but such logic does not involve absolute proof. We could turn to probability theory, including Bayesian theory, to try to quantify the notion of confidence with inductive logic, but we cannot achieve the certainty associated with deductive logic.

This brief account of the hypothetico-deductive method starts with a hypothesis to initiate the work of the method. As C. S. Peirce noted in the nineteenth century (see Peirce 1940), a complete account of the method should also include an analysis of the origin of hypotheses, and he argued that a logic underlying hypothesis generation could and should be developed in addition to the extensive work on deductive and inductive logics. He proposed *hypothesis* and *retroduction* as names for this logic, but he later settled on *abduction* or *abductive logic* as parallel with deductive and inductive logic.

Peirce proposed that hypotheses originate in attempts to explain observed phenomena so the process starts with observations (O) and generates a hypothesis (H) such that "if H then O" which is to say that the observations follow from the hypothesis. We might call this the primary constraint for a hypothesis, the observations must follow from it. We might say that at this stage, a hypothesis is plausible, certainly not proven. A mundane example might be of assistance here. Say that you look out your window and observe that the street is wet. It might occur to you that it had rained. You have just generated a hypothesis to explain your observation. Note that just as with scientific hypotheses, the rain hypothesis is not necessarily true. The street may have become wet by some other means such as a street cleaning truck or a lawn sprinkler that went awry. Still the rain hypothesis is plausible, and it could be provisionally held and tested further.

Figure 1 shows another example. Taking the figure as observations to be explained, we can offer suggestions about the figure such as: "olives on toothpicks" or "onions on barbeque spits" or "balloons on strings." In other words, we are generating hypotheses to explain the observations provided by the figure.



Abductive Reasoning. Fig. 1 What is this?

Each of these suggestions has the form of a plausible hypothesis in that if the suggestion were true, the figure would follow. Consider still another plausible hypothesis, that the figure represents a bear climbing the other side of a tree. Most people find this hypothesis preferable to the others advanced. Some of the possible reasons for the preference are discussed later.

While abductive logic was originally proposed as an aspect of scientific reasoning, such reasoning can be seen in many human activities including perception, language comprehension, creativity, and problem solving. The advancement of an understanding of abductive logic can potentially impact many of these cognitive processes.

Important Scientific Research and Open Questions

Many have dismissed inductive and abductive reasoning as logic because there is no guarantee of the truth of the inferences as there is with deduction. Such arguments usually boil down to the realization that hypotheses (and theories) are underdetermined by data. There are always alternative hypotheses that account for any set of data so there is no compelling reason to accept any one of the alternatives. Inductive generalizations (e.g., "Swans are white") may prove to be false even after countless confirmations, and the best we can claim for generated hypotheses is that they are plausible which is far from a guarantee of their truth. The issue here is really what we want the term *logic* to mean. If we want logic to provide certainty, only deductive logic counts. Peirce thought that *logic* referred to correct thinking which may not always insure truth. Other writers such as Hanson (1958), Harman (1965), and Simon (1973) agree with Peirce, that there is a logic to discovery. Simon points out that we call a process *logical* when it satisfies norms we have established for it. On this view, the study of the logic of discovery involves identifying such norms. In a previous paper, we examined abductive reasoning in some detail (Schvaneveldt and Cohen 2010). The following factors are among those identified.

- *The Observations.* This amounts to the constraint that the observations follow from the hypothesis (If H then O) or (H implies O).
- *Economics.* Hypotheses that can easily be put to the test should have some priority. This is one of the criteria suggested by Peirce as he developed his thinking about abductive reasoning.
- *Parsimony.* Simpler hypotheses that fit the observations are preferred over more complex ones (also known as *Occam's razor*).
- *Aesthetics.* Considerations of beauty, elegance, symmetry, and attractiveness figure into entertaining a hypothesis.
- *Plausibility and Internal Consistency.* Hypotheses consistent with each other and with background knowledge are preferred over ones that lead to contradictions.
- *Explanatory Power (Consilience).* Consilience includes how much a hypothesis covers, how fruitful a hypothesis is in suggesting interpretations of observations, and the connections a hypothesis establishes between various observations. The bear climbing the tree hypothesis illustrates the ideas behind consilience. The bear hypothesis provides an explanation of the entire figure including an account of all of the lines and circles and why they are arranged in just the way they are. There are no coincidental details left over as there are with the other suggestions offered for interpreting the figure.
- *Pragmatics.* Goals and the context of situations influence the hypotheses generated.
- *Analogy.* Analogy consists of sets of relations found in a source domain that can be applied to a target domain. Analogies can suggest additional relations that might apply as well.
- *Similarity and Association.* Similarity is a weak constraint on abductive reasoning, but similarity of various kinds is often involved in suggesting hypotheses. Some basis of drawing a connection between observations and potential explanations can often be traced to a weak association of elements of the observation and a hypothesis or to common connections to intermediate elements from both observations and a hypothesis. In a study of insight in problem solving, Durso et al. (1994) found that critical associative connections underlying the solution of the problem often appeared before the problem was solved suggesting that arriving at a solution may be mediated by establishing critical connections.

Researchers in the field of artificial intelligence have developed and applied many systems to implement abductive reasoning in such areas as medical diagnosis, troubleshooting, problem solving, and language comprehension. These are still active areas of research with many different approaches to developing rigorous models of abductive logic.

Cross-References

- ▶ Abductive Learning
- ▶ Adaptive Memory and Learning
- ▶ Analogical Reasoning
- ▶ Creative Inquiry
- ▶ Creativity, Problem Solving and Feeling
- ▶ Creativity, Problem Solving, and Learning
- ▶ Deductive Reasoning and Learning
- ▶ Discovery Learning
- ▶ Inductive Reasoning
- ▶ Insight Learning and Shaping
- ▶ Logical Reasoning and Learning
- ▶ Problem Solving

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Abilities and Learning: Physical Abilities

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Synonyms

Fine motor skills; Gross motors; Motor skills; Reflexes

Definition

Capacity to engage in reflexive or voluntary goal-directed physical behavior.

Physical abilities serve an integral role for learning during early childhood. The type of learning the child engages in is directly related to the physical abilities that the child is able to draw upon while interacting with the world. With increased physical abilities, more complex learning occurs.

Theoretical Background

During early childhood, children learn how to interact with the environment through physical experiences. This process is largely constrained by developing physical abilities that the child possesses during the different stages of development. As children gain physical abilities the variety and complexity of interactions increases, which results in more complex forms of learning.

According to Piaget's cognitive-development theory, as children age, they build increasing complex schemes or associations between motor activity and the resulting physical experiences (Piaget 1936, 1963). Schemes are developed through direct physical interaction with the environment. The sensorimotor stage is the primary period in which children learn the necessary motor movements that allow them to interact with the environment. The sensorimotor stage occurs during the time from birth to approximately 2 years of age.

Another theoretical perspective that highlights the connection between physical abilities and learning is Gibsonian affordance theory (Gibson 1977). In this perspective, objects in the world have physical characteristics that provide intuitive clues as to the manner in which a person may interact with the object. The person requires little to no sensory processing to decipher the potential use of the object as a direct result of its physical composition. Infants are receptive to these affordances within the environment similar to adults. For example, a toy hanging above a child suggests it may be struck to swing back and forth. In learning, affordances serve a vital role by providing clues for potential physical interactions that elicit experiences the infant can build schemes from.

Young children are receptive to affordances, yet they may not have the physical capability to act on the provided affordances. In line with Piagetian theory, the physical capability to move one's body and limbs serves a crucial function for learning during the sensorimotor stage. There are several substages within the sensorimotor stage that are distinct from one another based on the interactions between physical and cognitive capabilities the child is able to draw upon to learn about the world.

A newborn child has very little experience interacting with the world. The primary mechanism for learning entails building new schemes through physical interaction in which the child's own motor activity generates novel experiences (Piaget 1936, 1963). In reaction to these novel experiences, the child attempts to repeat the motor activity that generated the initial experience in what Piaget termed a circular reaction. The reactions are circular because the child repeatedly attempts to elicit the same experience through motor activity. These physical interactions with the world are the fundamental components of learning during this stage of development. As the physical capabilities of the child increase, more controlled motor activities can be performed to generate more experiences and lead to learning experiences.

Important Scientific Research and Open Questions

In line with Piategian theory, during the early stages of infancy learning primarily revolves around building simple sensorimotor schemes. These simple sensorimotor schemes are comprised of action patterns for simple motor movements such as grasping. Grasping serves as a physical ability developmental milestone required for learning rudimentary environmental principles. For example, grasping allows children to learn the physical properties of objects such as the gravitational force exerted on a ball after released from the child's grasp. As the grasping physical ability becomes more refined, the child can learn to interact in complex ways with the environment. The child can now learn certain properties of specific objects, such as learning to roll a ball possessing the spherical shape affordance which suggests it can be rolled.

Following the grasping ability, the physical ability to crawl is a developmental milestone that allows children to learn more complex ways of interacting with the environment. The ability to crawl requires coordination of multiple schemes to generate the correct motor movements and a very basic ability to balance the body over the limbs. The ability to crawl assists the child in developing depth perception as a result of the optical flow experienced while moving throughout the environment. The environment must contain affordances to allow for depth perception development, such as physical objects that provide optical flow which are also within a close proximity to where the child is crawling. For example, if the child were crawling in a large room devoid of physical objects or markings on the floor or walls, there is nothing to serve as a point of reference which hinders the development of depth perception.

The physical ability of walking is a major developmental achievement that expands the learning opportunities for children. Learning to walk requires environmental affordances of open space with vertical handholds that the child can grasp to lift the body upright into a walking position. Furthermore, walking requires a multitude of coordinated schemes with a more advanced ability to balance than what is required for crawling. Upon learning to walk, the child can engage in a wide variety of exploratory learning. Not only has the horizontal plane in which the child can navigate significantly increased, but the vertical plane is expanded since the child can now reach higher when in an upright standing position. The freedom enjoyed by a walking child leads to safety concerns for parents. The areas in which the child explores now overlap with areas that previously only adults could access. This can create potentially dangerous situations because now the walking child can access areas that may contain dangerous objects such as cleaning chemicals, electrical appliances, and sharp knives and tools.

The ability to walk marks the tail end of the primary sensorimotor scheme development stage, which occurs at approximately 2 years of age. Throughout this early developmental period, the physical abilities of children serve as the primary component in the learning that occurs. During this time, children learn about their motor capabilities and the way these capabilities affect their surrounding environment. After mastering the physical ability of walking, the sensorimotor scheme building shifts from gross motor movements into a new developmental stage in which sophisticated motor schemes begin to develop that allow children to engage in highly coordinated and complex activities. In this later stage, children begin to learn the necessary motor schemes required for athletic activities, such as kicking or throwing a ball, climbing, and running. Additionally, fine motor schemes begin to develop, which allows the child to engage in activities that require a high degree of dexterity, such as drawing and writing.

Cross-References

- ► Affordances
- ► Piaget's Learning Theory
- ► Play, Exploration, and Learning
- ► Visual Perception Learning

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Abilities to Learn: Cognitive Abilities

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Synonyms

Aptitudes; Cognitive processes; Individual differences; Intellect; Traits

Definition

Cognitive abilities are aspects of mental functioning, such as memorizing and remembering; inhibiting and focusing *attention*; speed of information processing; and spatial and causal *reasoning*. Individual differences between people are measured by comparing scores on tests of these mental abilities. Tests of general *intelligence*, such as the Wechsler Adult Intelligence Test, are based on a broad sample of these mental ability tests, and measures of *aptitudes* for learning in specific instructional domains, such as mathematics, or language learning, are based on a narrower sampling of the domain-relevant abilities.

Theoretical Background

Theoretical and empirical research into the structure of memory by Hermann Ebbinghaus (1850–1909) and the functions of attention by William James (1842–1910) provided the foundations for the development of operational tests of cognitive abilities at the beginning of the twentieth century. The observation of a "positive manifold," or consistent positive correlations across multiple tests of abilities led Charles Spearman (1863–1945) to propose that a single general intelligence factor, termed "*g*," underlay performance on each of them. From this early work the field of *differential psychology* began, which examined the extent to which measured differences in abilities correlated with performance on tests of academic achievement, or lifetime success in an intellectual or performative domain. Based on these studies, and confirming Spearman's proposal, a large-scale factor-analytic survey of results has shown relationships among cognitive abilities to be hierarchically related at three levels or strata of increasing generality, with measures of separate cognitive abilities occupying the lowest, least general stratum, and "*g*" representing the single uppermost factor (Carroll 1993). Results of many studies have shown that "*g*" and higher *intelligence quotient (IQ)* – a score obtained from performance on various tests of intelligence – reliably predicts greater academic and lifetime success.

The measurement of cognitive abilities is only one facet of research in differential psychology concerned with identifying correlates of academic learning and lifetime success. Two other facets are the assessment of individual differences in *affect*, such as emotion and anxiety, and *conation*, such as self-regulation and motivation. It is widely acknowledged that academic achievement is the result of a complex interplay between cognition, affect, and conation. But in one sense cognitive abilities are clearly different from affective and conative factors, since the growth and decline of memory, attentional, reasoning, and other cognitive abilities show clear inverted U-shaped *developmental trajectories* across the life span, in contrast to affect and conation.

For example, it is well known that memory abilities follow such a trajectory. In early childhood children not only lack the ability to explicitly remember and recall prior events (long-term memory), but also to maintain memory for a current event while performing a simultaneous operation on the remembered information. The latter ability, termed *working memory*, has been shown to develop and increase in capacity throughout childhood and into adolescence, when it plateaus, and then to decline in aged populations. In a similar manner, other cognitive abilities, such as reasoning, processing speed, and spatial memory, have been shown to increase throughout *childhood*, to plateau in *adulthood*, and to decline during *aging* (Salthouse 2010).

Important Scientific Research and Open Questions

The extent of individual differences between children and adults in cognitive abilities is a major area of research in developmental psychology. This research aims to chart the time-course of the emergence and consolidation of cognitive abilities over the lifetime. It also aims to identify individuals at the low and high tail-ends of measures of abilities in these populations who consequently have what are judged to be marked deficits and talents in each ability domain.

Related to this, the extent to which individual differences in cognitive abilities influence learning in schooled and unschooled settings, for any population of learners, is a major area of research in *educational psychology*. There is evidence that cognitive abilities do not contribute equally to success in all areas of learning, and a major area of research is to identify what these ability-learning domain correlations are.

For example, in general, schooled academic achievement in domains such as mathematics increases during childhood in proportion to the measured increase in working memory capacity that children have at different ages (Dehn 2008). On the other hand, the precocious ability to learn a first or other language during infancy and early childhood (when compared to the relative failure of adults to learn languages) has been attributed to their lack of such well-developed working memory capacity and explicit memory ability. This has been termed the *Less-is-More Hypothesis* for child language learning. Lacking explicit working memory ability, infants are only able to remember immediately contingent sequences of sounds. This *associative learning*, drawing on unconscious implicit memory, has been argued to be the essential foundation for statistical processes of language acquisition. With the later emerged development of more reflective, conscious explicit and episodic memory, and greater control of attention allocation and reasoning ability (and the metacognitive awareness this gives rise to) associative implicit language learning is disrupted.

Such a developmental account of the growth of cognitive abilities, and the learning processes they facilitate and inhibit, fits well with evidence for the *Critical Period Hypothesis* (CPH) for language learning. The CPH claims that if languages are learned after the age of 6 years, then native-like levels of ability in them are unattainable. In other domains, however, such as the acquisition of literacy and mathematics, where explicit learning and memory are essential, then growth in explicit memory and reasoning abilities "across" populations of different ages, and for individuals with relatively greater strengths in these abilities "within" any age-matched population, lead to higher levels of academic achievement.

Other areas of research and theory that are important concern the influence of *cognitive disabilities* on schooled learning. For example, throughout childhood the ability to focus attention, voluntarily, on an event or object increases, as does the ability to inhibit attention to irrelevant events, noises, and other distractor stimuli. However, for some children these attention focusing and inhibiting abilities do not develop, with the consequence that the resulting *Attention Disorder Hyperactivity Deficit (ADHD)* has negative effects on academic progress. Those at risk of ADHD can be diagnosed during early childhood, using tests of the cognitive abilities to control attention and to inhibit attention to distractions. The extent to which such deficits in the ability to control attention are remediable is an important area of research. Interestingly, it has been found that bilingual children, who have the daily experience of switching between two languages during speaking and listening, show particularly good performance on tests of *cognitive control of attention*, when compared to monolingual counterparts. Therefore, experience plays a role in training the ability to focus, and switch attention between stimuli, though the relative contributions of experience and genetics to such abilities is not yet clearly known.

An area of much recent research and theory concerns the cognitive ability to successfully attribute intentions and beliefs to others that cause them to perform actions. This form of intentional reasoning emerges at around the age of 3 years during childhood, when children develop what is called a "*Theory of Mind*." Before this age children consistently fail a variety of *false-belief tasks*. For example, a researcher shows a child a packet of Smarties (a well-known container for sweets) then opens it to reveal it is empty. The researcher then asks the child what a second child will think is inside the container if he/she shows it to them. The child invariably replies "nothing" showing that they cannot distinguish their own current mental understanding from that of a second child. With development, children begin to successfully distinguish their own understanding of the world from that of others. However, this ability does not develop in all children, with the consequence that they may be diagnosed as "autistic." *Autism*, and lack of theory-of-mind ability, has been shown to affect first language development, and also social interaction and schooled learning, in negative ways. For example, lacking a theory of mind, autistic children do not understand the conceptual meaning of different psychological verbs used to refer to others' mental states, such as "he/she *wonders/believes*." These verbs are accompanied by complex subordination in all languages, e.g., "he wonders whether (subordinate clause)"; "she believes that (subordinate clause)." Consequently, autistic children do not use syntactic subordination in their first language as much as non-autistic children, and their development of complex syntax is negatively affected by comparison with non-autistic peers. As with ADHD, the remediability of this cognitive disability, and the relative contributions of genetics and experience to it, continue to be researched.

Two summary points need to be made in conclusion, regarding the issues raised above, and the relationship between cognitive abilities and instructed learning. Firstly, cognitive abilities do not facilitate learning independently of the conditions under which the material to be learned is presented in instructional contexts. *Learning conditions*, for example, can predispose learners to learn incidentally (unintentionally and on many occasions implicitly, without awareness) or explicitly (with intention and awareness). In the domain of instructed second language acquisition (SLA), for example, different combinations of cognitive abilities, or *aptitude-complexes*, have been shown to facilitate *incidental learning* (unintentionally acquiring knowledge of the second language) versus *explicit learning* (intentionally understanding pedagogic explanations of language) (Robinson 2005). Many details of the optimum levels of cognitive abilities within such complexes remain to be explored for incidental versus explicit second language learning, and for learning of other domains that provide for incidental exposure to content, versus explicit instruction about content. This is a fundamental area of current research into cognitive abilities with applications to learning and instruction.

The term "aptitude complex" was coined by Richard E. Snow (1936–1997), and Snow's lifetime of work points to a final summary implication of research into cognitive abilities for learning. Snow argued throughout his career (e.g., Snow 1994) that aptitudes for learning from instruction are many and varied, but not infinite. On the one hand, Snow argued – in the way described above – that cognitive abilities differentially facilitate learning under some, versus other conditions of instructional exposure. But he further argued that cognitive abilities *only* contribute to aptitudes for learning *in combination* with other affective and conative coordinates of learning processes. Much current theory and research, across domains of language, science, mathematics, and other areas of education, is concerned with identifying what these multidimensional cognitive-affective-conative complexes are, and the extent to which they contribute to success during instructed learning (Shavelson and Roeser 2002). If they can be theorized, and measured, then learners with strengths in one or another aptitude complex can be matched to instructional interventions and learning conditions that draw optimally on them. This research can be expected to continue, and should contribute much to our increased knowledge of the role of cognitive abilities in learning.

Cross-References

▶ Aptitude-Treatment Interaction
▶ Attention Deficit and Hyperactivity Disorder
▶ Implicit Learning
▶ Intelligence and Learning
▶ Language Acquisition and Development
▶ Motivation and Learning: Modern Theories
▶ Statistical Learning and Induction
▶ Working Memory

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Ability Determinants of Complex Skill Acquisition

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Synonyms

Aptitudes and human performance; Cognitive abilities and skill; Individual differences and learning; Intelligence and skill; Performance gains; Performance trajectories; Skill development; Skill growth; Skill improvement

Definition

► Skill is the level of proficiency on specific tasks. It is the learned capability of an individual to achieve desired performance outcomes (Fleishman 1972). Thus, skills can be improved via practice and instruction.

Although skills differ in many ways, important distinctions can be made in terms of *complexity*. Task complexity is described via differences in component, coordinative, and dynamic complexity (Wood 1986). *Component complexity* concerns the number of distinct acts and processing of distinct information cues involved in the creation of task products. Much of the empirical literature on complex skill acquisition involves tasks comprised of both cognitive and perceptual-motor components. *Coordinative complexity* concerns how different acts, information cues, and task products are interrelated. *Dynamic complexity* concerns how acts, information cues, and task products or their relationships change across time. Dynamic complexity can also be thought of as the degree of inconsistency in information-processing demands. Thus, a ► Complex action learning can be defined in terms of the proficiency required for task performance that contains an amalgamation of strong component, coordinative, and dynamic complexity.

► Acquisition is a process, internal to an individual, which produces a relatively permanent change in a learner's capabilities. Acquisition is distinct from the execution of skill in that acquisition is observed through increases of successive performances during practice and instruction or training. Skill acquisition typically requires adaptive interaction with the learning environment to detect information and to respond in a correct and timely manner. The process of acquisition produces behavior that is less vulnerable to transitory factors such as fatigue or anxiety (Davids et al. 2008). Skill acquisition is studied by examining performance changes over time and practice. Skill acquisition research is longitudinal by nature, involving repeated measures of performance over a large number of trials or training sessions.

► Ability refers to a general trait, reflecting the relatively enduring capacity to learn tasks. Although fairly stable, ability may change over time primarily in childhood and adolescence through the contributions of genetic and developmental factors (Fleishman 1972). In the psychological literature, abilities have been grouped in many different ways. Early taxonomies of human ability were concerned with those abilities utilized during motor-skill performance. For example, Fleishman's early research on the *ability requirements approach* differentiated between 11 perceptual-motor and 9 physical-proficiency abilities. Subsequent research distinguished between more than 50 abilities underlying human learning and performance. Many of these abilities have been categorized as cognitive in nature. Other abilities have been categorized as more physical, psychomotor, or sensory-based.

Although many taxonomies of human ability exist, two common ability specifications include general mental ability and broad-content abilities (Ackerman 1988). ► General mental ability (also commonly referred to as general cognitive ability, general intelligence, or *g*) is defined as the factor common to tests of cognitive ability and is theorized to be the ability to efficiently acquire, process, and use information (also commonly referred to as *fluid intelligence*).

Broad-content abilities describe a class of abilities which pertain to the general content of a given task. For instance, a task primarily composed of oral or written components might require the broad-content ability termed verbal ability. Two other broad-content abilities in skill acquisition research are numerical and spatial ability. Additionally, perceptual-speed and psychomotor ability are frequently investigated in studies of skill acquisition (Ackerman 1988). ► Perceptual-speed ability refers to speed of processing information. Psychomotor ability refers to the speed and accuracy of motor responding. Regardless of the type or taxonomy, greater ability generally leads to faster acquisition of skill and higher levels of performance.

Theoretical Background

In 1926, Snoddy proposed the *power law of practice* which predicts a linear relationship between the logarithmic functions of practice amount and performance. The theory predicts a quadratic or decelerating trend such that gains in performance slow over time. However, the theory was not widely accepted due to observations of skips, jumps, and other short-term observable phenomena in learning curves presumably due to factors outside the theory's consideration (Davids et al. 2008). Although not stated at the time, this criticism might be viewed as the earliest recognition of individual differences affecting the learning process.

Around this time, Fitts and Posner developed their *theory of motor learning*. This three-stage model describes gradual changes during a continuous learning progression. The first stage, named the *cognitive stage*, is characterized by the learning of discrete pieces of information, and performance is often variable and error ridden. During the second, the *associative stage*, the distinct knowledge gathered in the first stage is assimilated, and performance is more consistent and less error ridden. Both task complexity and learner abilities contribute to varying lengths of time across individuals in this stage. The third, the *autonomous stage*, requires extensive practice to achieve and is characterized by few errors and minimal mental effort (Davids et al. 2008). These stages can also be thought of in terms of *novice*, *journeyman*, and *master* stages of skill acquisition.

Fleishman's work became important because he developed a taxonomy describing individual differences in perceptual-motor performance when learning theory lacked useful taxonomies. Using a combination of experimental and correlational approaches, he sought to link the concepts of aptitude measurement, learning and training, and human task performance. In general, Fleishman's research showed that (a) changes occur in the specific combinations of abilities contributing to performance over the course of skill acquisition, (b) such changes are progressive and systematic and become stabilized, and (c) the importance of task-specific ability increases over the course of skill acquisition.

With the advent of *information-processing theories*, researchers started focusing on specific cognitive processes associated with skill acquisition. For example, such theories highlight how learners move from cognitively intense *closed-loop* systems, where a learner utilizes feedback to help direct current action, to less cognitively demanding *open-loop* systems, where a learner does not utilize feedback as much, when forming a compiled schema, production, or sequence of discrete actions to achieve a desired effect in context (Davids et al. 2008).

Important Scientific Research and Open Questions

A more recent cognitive theory, Ackerman's *dynamics of ability determinants* (Ackerman 1988) integrates the results of previous work. Ackerman's model includes three stages of skill acquisition (namely, cognitive, associative, and autonomous), but adds a component showing how different abilities contribute to each of the three stages. Various task-, person-, and situation-related factors dictate the relative importance of various abilities during each time point of acquisition, but the factors of complexity and consistency are the most prominent. Complexity, particularly component and coordinative, primarily moderates the relationship between cognitive ability and performance, whereas inconsistency in information-processing demands primarily moderates learning-stage progression.

For complex yet consistent tasks, Ackerman suggests early skill acquisition will depend primarily on cognitive abilities – general and broad-content – because everything is new and learners must continually process new information. As a learner progresses to later stages of skill acquisition, cognitive ability will either remain or decrease in its contribution toward acquisition. For inconsistent tasks, cognitive ability should continue to contribute because performers must continually process inconsistencies. For consistent tasks, learners get better at processing the consistent information as acquisition progresses, and the contribution of cognitive ability thus declines. Perceptual-speed ability is particularly important during the middle of skill acquisition. As the production systems generated in the first *cognitive* phase are fine-tuned in the second *associative* phase, perceptual-speed ability becomes important but less so once the task becomes largely automatized in the final *autonomous* phase. If a task is perceptual-motor in nature, psychomotor ability should have a stronger role in the final stage of skill acquisition. Production systems are largely automatized at this stage, and therefore, it is psychomotor ability that determines further skill acquisition (Ackerman 1988).

Complex tasks require the creation of more production systems which increase the contribution of cognitive ability toward skill acquisition but attenuate that of perceptual speed. This is because attention is utilized for increased system production while perceptual speed is not as effective across many uncompiled productions. Consistency moderates learning-stage progression because without some consistency learning is not possible. Therefore, inconsistency slows acquisition. For example, a learner may never progress beyond the first stage of learning in an extremely inconsistent task, suggesting that cognitive ability will strongly contribute to performance no matter the degree of practice (Ackerman 1988).

Because skill acquisition differs depending on task complexity and consistency, high- and low-ability learners might converge in performance over the course of practice and instruction. The prediction of decreasing interindividual variance in performance across time is consistent with the *lag hypothesis* in that slower learners lag behind faster learners but may catch up given additional practice and instruction. That is, high-ability learners display stronger linear and quadratic relationships between practice and performance (i.e., reach asymptote more quickly) than their lower-ability counterparts. The opposite hypothesis involving divergence, termed the *deficit hypothesis*, *fan-spread effect*, or *Matthew effect*, describes increasing interindividual variance. Put another way, the high-ability learners display a smaller quadratic relationship between ability and performance than their lower-ability counterparts. Less complex and more consistent tasks typically portray a lag pattern. More complex and inconsistent tasks require more cognitive resources, which may prevent some learners from ever progressing beyond earlier stages of acquisition. Divergence in performance is especially likely for tasks that are largely dependent on declarative knowledge yet do not involve a finite domain of knowledge than on tasks which primarily require speed and accuracy of motor responding (Ackerman 2007).

There is still much to study and clarify. *Growth curve modeling* (e.g., *hierarchical linear modeling, random coefficients, or mixed effects*) and *spline* models are more sophisticated analytic procedures that overcome limitations of previously used analyses which primarily involved correlational and factor-analytic approaches. Much of the past research utilized a time-slice approach to examine the contributions of ability to acquisition by only showing relationships between ability and performance at discrete points in time. Contributions to actual growth (i.e., improvements in skill) needed to be inferred. The more sophisticated analyses allow for growth to be modeled explicitly and allow for the direct examination of ability contributions toward growth.

As a current example of using a more sophisticated analytic approach, Lang and Bliese (2009) used *discontinuous mixed-effects growth modeling* and examined the effects of general mental ability on two types of adaptation or transfer: transition and reacquisition adaptation. *Transition adaptation* refers to an immediate loss of performance following task changes, and *reacquisition adaptation* refers to the rate of relearning after task changes. Analyses indicated general mental ability was positively related to transition adaptation but showed no relationship between general mental ability and reacquisition adaptation. In other words, the findings showed higher general mental ability corresponded to greater losses in performance during a change period. These findings suggest the possibility that high-ability learners either reach automaticity faster, and therefore do not process task changes as quickly, or simply learn more and therefore have more to lose when a task changes. These findings contradict commonly held beliefs that individuals with high general mental ability are better able to adapt to fundamental environmental changes. However, despite greater losses during transition and no advantage in reacquisition, higher-ability learners continued to outperform their lower-ability counterparts both during and after task changes.

Research has addressed much in the development of skilled performance. Changes in variance among individuals during skill acquisition can now be reliably predicted. Both practice and abilities explain variance in skill acquisition. Practice explains more variance than abilities, but the effects of practice depend upon the ability levels of learners. The role of abilities during early skill acquisition is generally known. However, there is still much to discern, particularly in terms of relating abilities to later stages of skill acquisition and skill adaptation. Additionally, prior knowledge (i.e., *crystallized intelligence*) and non-ability *trait complexes*, which refer to a combination of interests, personality, motivation, and self-concept traits, also appear important, and should be investigated in future research (Ackerman 2007).

Cross-References

- ► Abilities and Learning: Physical Abilities
- ► Abilities to Learn: Cognitive Abilities
- ► Complex Action Learning
- ► Evaluation of Student Progress in Learning
- ► Expertise
- ► Intelligence and Learning
- ► Longitudinal Learning Research
- ► Qualitative Learning Research

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Ability Grouping

► Cooperative Learning Groups and Streaming
► Effects of Tracking and Ability Grouping on Learning

Ability-Based

► Competency-Based Learning

Abnormal Aggression

► Psychopathology of Repeated (Animal) Aggression

Abnormal Avoidance Learning

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Synonyms

Avoidance behaviour; Individual differences; Psychopathology

Definition

Avoidance of aversive events is of critical importance for an organism's chances of survival. Many organisms are thought to experience fear in anticipation of an aversive event, such as an electric shock, and tend to show two types of associated behavior. First, they may show "species-specific defensive responses" (SSDR): innate defensive responses such as freezing. Second, they may learn to perform particular actions to reduce or abolish the likelihood of the shock, either cued by a predictive conditioned stimulus (CS: see, e.g., Solomon and Wynne 1953) or performed without the control of a CS (Sidman 1953). Acquisition of the avoidance response is usually enhanced if it is compatible with an SSDR.

Theoretical Background

The presence of avoidance responses during a CS that predicts an aversive event has been seen as somewhat problematic for models of learning in which action selection was purely driven by stimulus–response associations: it is not immediately clear how the absence of an aversive event, which would result from a successful avoidance response, can reinforce behavior unless the expectancy caused by the aversively conditioned CS drives learning. Mowrer's two-factor theory (Mowrer 1951) has perhaps become the most influential contribution to understanding of the role of expectancy in avoidance behavior: its central explanatory mechanism being the absence of a predicted aversive outcome reinforcing behavior. However, it should be noted that the observation of avoidance responding in the absence of experimentally controlled discriminative cues has been problematic for these kinds of theories (Sidman 1953), and it remains possible that much of the experimental observation of avoidance behavior results from responses, which reduce the likelihood of shock.

It is consistently observed that pretreatment with inescapable or otherwise uncontrollable shocks can interfere both with later escape performance and avoidance learning, a phenomenon known as learned helplessness (LH). For example, pretraining a dog with inescapable shock impaired both avoidance learning (avoidance responses following the CS) and escape (avoidance following the shock) (Overmier and Seligman 1967). The LH effect, which is demonstrable in humans and various species of animal, has been important for gaining an understanding of depression, a widespread psychiatric disorder characterized by cognitive negative biases, and a reduced capacity to experience reinforcement. The parallel has been based at least in part on similarities between the motivational state caused by LH to that observed in depression, and to the finding that escape performance following uncontrollable stress can be enhanced by antidepressant treatment and also exercise.

Obsessive-compulsive disorder (OCD) is an anxiety disorder, characterized by obsessional thoughts and persistent, stereotyped behaviors (compulsions). Compulsive behaviors can be associated with a relief from anxiety. In addition, they can show a complex but repetitive and organized structure. These features of compulsive responding in OCD are to some degree compatible with the notion that they are avoidance responses which have not been extinguished. Extinction of avoidance behavior in experimental situations can be difficult and fear is expected to increase during presentation of the CS if avoidance is prevented. From this perspective therefore, it is not surprising that the repeating of compulsive behaviors by patients with OCD can reduce anxiety. Furthermore, avoidance responses are also strikingly stereotyped (Solomon and Wynne 1953).

Recently, a paradigm for human neuropsychological research has been developed by Michael Frank and colleagues in which approach and avoidance performance is directly compared in the context of the same task. The participants learn three pairs of concurrent probabilistic discrimination problems, each with different stimulus-reinforcement contingencies, until they reach a performance criterion. In the first pair, one of the stimuli is rewarded on 80% of the times it is selected, the other 20%; the second pair are reinforced 70% and 30%, respectively; the third, 60% and 40%. A subsequent test phase is conducted when all permutations of the stimuli are presented, in the absence of feedback. The dependent measures of interest are the quality of approach performance (picking the most reinforced (80%) stimulus rather than another), and avoidance performance (not selecting the least (20%) reinforced stimulus). In its short life, this task has offered many insights into human learning performance, principally about the role of dopamine in learning. In normal participants, substantial variation in the relative performance of approach and avoidance discrimination has been observed. This variance seems to be accounted for, at least in part, by genetics (Frank et al. 2007). In particular, an allele (C957T polymorphism) of the gene coding for dopamine D2 receptors modulated the level of test phase avoidance performance: the C allele, which results in reduced levels of postsynaptic D2 receptor expression, predicted poorer avoidance performance. The implication of D2 receptors in this task is notable in the light of the observation that impulsive rats also show a reduced density of striatal D2 receptors, show heightened drug seeking, and continue to respond for cocaine despite contingent aversive stimuli, compared to less impulsive rats (see Everitt et al. 2008 for review). The continuation of drug seeking despite increasing cost, in this case manifest as punishment, is a hallmark of addiction, and it may be that a faliure of avoidance learning accounts for the heightened risk of transition to addiction in impulsive individuals.

Important Scientific Research and Open Questions

Despite a heritage extending back at least to the work of Solomon and colleagues, the study of avoidance learning as a way of understanding psychopathology remains at the peripheries of biological psychiatric research. Appetitive procedures tend to be more common, perhaps for pragmatic or ethical reasons. Nevertheless, avoidance procedures have been used in the context of the study of addiction and depression, and it is suggested that they might provide unique insight into the psychological and neurophysiological processes underlying depression, OCD, and addiction. Dopamine D2 receptors represent a possible neurobiological substrate of abnormal avoidance learning and a candidate target for drug therapies.

Cross-References

- ► Avoidance Learning
- ► Drug Conditioning
- ► Effects of Anxiety on Affective Learning
- ► Expectancy Learning and Evaluative Learning
- ► Fear Conditioning in Animals and Humans
- ► Impulsivity and Reversal Learning
- ► Learned Helplessness
- ► Learning Mechanisms of Depression
- ► Stress and Learning

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Absence of a Consequence

► Inhibition and Learning

Absolute Accuracy

► Calibration

Absolute Judgment

Identification of stimuli that vary along a single, sensory continuum.

Absorption

► Openness to Experience

Absorptive Capacity and Organizational Learning

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Synonyms

Administrative capacity; Appropriability

Definition

Cohen and Levinthal (1990) introduced the notion of absorptive capacity as the firm's ability to value, assimilate, and apply new knowledge for improving organizational learning. The notion of absorptive capacity refers to the capacity of a recipient to assimilate value and use the knowledge transferred. The higher the absorptive capacity, that is, the better the organization (for instance, a firm) is at understanding the knowledge received and thus unlock and capture the intrinsic value of such knowledge and apply it for commercial purposes. This is related to the concepts of strategic knowledge serendipity and strategic knowledge arbitrage (Carayannis et al. 2006). Kim (1998) identified two components of absorptive capacity, namely prior knowledge and intensity of effort, and distinguished between the ability to learn new knowledge and the ability to use new knowledge in problem solving.

Theoretical Background

Absorptive capacity can be conceptualized as a dynamic capability pertaining to knowledge acquisition and its systematic use to enhance a firm's ability to compete successfully with other firms (Zahra and George 2002). From the perspective of organizational learning absorptive capacity is a limit to the rate or quantity of scientific or technological information and knowledge that an organization can effectively and productively internalize and use.

If such limits exist, they provide, for example, one incentive for firms to develop internal R&D capacities. R&D departments can not only conduct development along lines they are already familiar with, but they also have formal training and external professional connections that make it possible for them to evaluate and incorporate externally generated technical knowledge into the firm better than others in the firm can. In other words a partial explanation for R&D investments by firms is to work around the absorptive capacity constraints they are confronted with.

Actually, the creation and transfer of knowledge within an organization has increasingly become a critical factor in that organization's success and competitiveness. Studies done in various organizations found that the two main knowledge activities that need to be balanced are the creation of knowledge and the transferring of knowledge across time and space. Many organizations are now concentrating their efforts on how knowledge can be transferred throughout the organization.

According to Cohen and Levinthal (1990), there is a positive relationship between R&D and firms absorptive capacity. These authors also emphasize the importance of prior experience to absorptive capacity or the *context of sense-making* in that the ability to evaluate and utilize outside knowledge is largely a function of the level of prior related knowledge.

Zahra and George (2002) have extended the notion of absorptive capacity as introduced by Cohen and Levinthal and described it as a set of organizational routines and processes with four distinct components, namely acquisition, assimilation, transformation, and exploitation. Acquisition and assimilation combine to represent potential absorptive capacity, and transformation and exploitation forms realized absorptive capacity. Matusik and Heely (2005) developed a new definition of potential absorptive capacity by distinguishing three dimensions of absorptive capacity: (1) the firm's relationship to its external environment; (2) the structures, routines, and knowledge base of the main value creation group; and (3) the individual's absorptive capacity. The ability to absorb external knowledge depends on the ability to recognize the value of new external knowledge.

Argote and Ingram (2000) argue that the organization's design and structure contributes to knowledge being embedded in sub-networks of people, tasks, and tools and, thus, influences a firm's absorptive capacity. In addition geographic and cultural proximity may influence the ability to identify and evaluate external knowledge. Arrow's (1973) argument that shared experiences and patterns of communication and interaction among firms are likely to occur among firms located in the same geographical area with the same environmental context. Therefore, the institutions, which represent the environment in which firms operate, may lead to losing knowledge because of an inability of the parties to understand each other. All in all, the absorptive capacity of a firm can be compared to the human brain's capacity to absorb data, process information, and retain and use knowledge and in that sense a better understanding of the nature and dynamics underlying how and why absorptive capacity develops and evolves may be critical to enable more effective and efficient leading and managing of organizations, large and small, public and private.

Important Scientific Research and Open Questions

In recent years some efforts have been done in identifying important dimensions and constraints of absorptive capacity. Sometimes this led to far-reaching reconceptualizations of the notion of absorptive capacity and its particular role for strategic management and human performance development of organizations (see, for example, Zahra and George 2002).

Additionally, there was a substantial increase of empirical studies on absorptive capacity. For instance, Carayannis and Alexander (2002) showed empirically, through longitudinal, time-series-data-based analysis that there can be too little as well as too much technological learning taking place in firms. This is directly related to their intrinsic absorptive capacity in that learning activities may initially improve performance, but that there is some limit to a firm's absorptive capacity for learning. Larger increments of technological learning begin to depress performance, until a new critical point is reached and performance again improves. This suggests the presence of an optimal learning absorption bandwidth for each firm, where learning activities should not exceed the absorptive capacity of the firm but also must be sufficient to sustain improved performance.

A promising path toward a new theory of the firm is to focus on the role of organizational learning in competitive advantage (Edmondson and Moingeon 1996). This research focus is supported by the recent examination of the nature of knowledge, and how the acquisition and integration of knowledge leads to the development of new competencies through organizational transformation (Nonaka and Takeuchi 1995). These processes of knowledge-based transformation are organizational learning activities. The result of improved organizational learning is enhanced "strategic flexibility" (Sanchez 1993), meaning that the firm faces a greater range of potential options for action which can then be leveraged to achieve a better fit to its competitive environment. Such a view of organizational learning is analogous to the general concept of learning advanced by Huber (1991): "An entity learns if, through its processing of information, the range of its potential behaviors is increased" (p. 89). Thus, a learning-based theory of the firm would advance our understanding of the dynamic construction of competitive advantage by focusing on the ways that organizations and the people therein generate, process, and alter their explicit knowledge and tacit skills, as well as the paths of change that such styles of organizational cognition can follow... and [thereby] create questions and motives for further research on the dynamics of the creation and evolution of firm core competencies.

Cross-References

- ► Embodied "Inter-learning" in Organizations
- ► Human Resource Development and Performance Improvement
- ► Human Resources Development and Elaboration Strategies
- ► Learning Technology
- ► Organizational Change and Learning
- ► Technological Learning

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Abstract Concept Learning in Animals

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Synonyms

Abstract representation; Higher-order learning; Relational concept learning

Definition

Abstract concept learning, including relational and numerical concept acquisition, provides a foundation for higher-order learning. The learning of abstract concepts involves judgment of a relationship between stimuli based on a common rule (e.g., identity/nonidentity, above/below, smaller/larger, greater than/less than). Concepts are considered abstract when they are not dependent upon any particular stimulus features, but rather on relationships instantiated between them. If these rules of relatedness are applied to entirely novel stimuli, an abstract concept is assumed to be acquired in the form of a mental representation. Abstract concepts are distinguished from other concepts (i.e., perceptual and associative concepts) in that they are not limited to perceptual similarity, but transcend several domains to allow for the application of a common rule (for comprehensive reviews, see Katz et al. 2007; Thompson and Oden 2000; Zentall et al. 2008).

Theoretical Background

Abstract concepts, due to their independence from stimulus features, are considered the basis for high-order cognition in human and nonhuman animals, allowing for consideration apart from a particular case or instance. In his learning-intelligence hierarchy, Thomas (1980) placed conceptual abilities in the highest three levels of an increasingly complex eight-level ordinal scale of learning. Levels 1–5 included more basic stimulus–response learning from habituation to discrimination learning. Levels 6–8 outlined a continuum of conceptual abilities from the ability to make class distinctions based on physical similarities, a skill present in many nonhuman animals. At the opposite end of this continuum lies the capability to act on class distinctions based *not* on physical or functional similarities, the most abstract of concepts.

Not unlike more basic perceptually based categories, abstract concepts allow one to transfer learning to new stimuli or contexts. This transfer for abstract concepts, however, is not limited to contexts that are perceptually or associatively similar, allowing for an almost indefinitely broad application of a commonly learned rule. The cognitive advantage of the ability to learn abstract concepts is that it provides efficient and functionally adaptive responding toward novel objects due to membership in an already familiar class.

Concepts can be formed with varying degrees of abstraction. At the most basic level, perceptual concepts share a considerable number of physical features in common with one another (e.g., *green* or *car*). Family resemblance theory, the classification of instances of a category based on some of the many physical traits they may share, accounts for learning of perceptual concepts. With increasing levels of abstraction, class members share fewer characteristics in common making discrimination via perceptual features less probable along the continuum of conceptual abstraction. Fully abstract concepts then are those that do not share any specific features in common (e.g., *same* or *three*). Whereas family resemblance theory explains how perceptual concepts are learned, the means by which abstract concepts are learned are less concrete and cannot be accounted for by these generalization processes.

Abstract concept learning, on the other hand, is emergent, resulting in the judgment of a relationship between stimuli not attributable to stimulus–response associations. Because these concepts rely on abstract thought (a level of thinking removed from the present) language and symbolic representation have been implicated as likely mediating mechanisms through which the learning of abstract concepts can be accomplished. With little known of the specific representational capacities of nonhuman animals without language, investigations of abstract concept learning have stimulated the interests of comparative and cognitive psychologists.

Important Scientific Research and Open Questions

Roberts and Mazmanian (1988) investigated concept acquisition at varying levels of abstraction in three different species: humans, pigeons, and squirrel monkeys. Subjects viewed photographic stimuli of animals within predetermined categories at three levels of abstraction (basic, intermediate, and high) choosing keys corresponding to in-category and not-in-category. Humans correctly chose the in-category slides with around 90% accuracy for all three levels. Monkeys and pigeons, however, were less successful at certain levels of abstraction. Monkeys were significantly better at making the discriminations at low (e.g., kingfisher vs other bird) and high (e.g., animal vs nonanimal) levels. Pigeons only successfully acquired the most basic concept: they discriminated only kingfishers from all other slides. When the problem was made more abstract by requiring subjects to identify birds in general or animals in general, the category may have become too broad or abstract for the animals to learn a simple rule for identifying individual exemplars. These findings support the theory that many nonhuman animals learn concepts by responding to a small set of features in pictures that look similar.

Because of their close relatedness to humans, great apes provide a logical model for further investigation of abstract concepts. Vonk and MacDonald (2002) presented gorillas with stimuli similar to Roberts and Mazmanian at three increasing levels of abstraction in a two-choice discrimination task. Gorillas performed well, acquiring discriminations at three levels more analogous to human behavior, providing little support for control by stimulus features. These results suggest a conceptual basis for categorization by gorillas.

Whereas some abstract concepts may grow out of perceptual classes as in the studies described above (i.e., extended family resemblance), abstract relational concepts cannot. Relational concepts are not derived from the physical characteristics or perceptual properties of stimuli themselves. Unlike both physical and associative concepts, singular stimuli cannot be sorted into a relational class. Rather, relational concepts require the existence of at least two items. Relational concepts, such as *same/different* and *above/below* involve a comparison of the relationship between (or among) two or more objects. These concepts thus do not depend on any absolute perceptual properties of stimuli, but rather are entirely based on the relation between them.

Discrimination of *same* from *different* pairs of stimuli (e.g., AA vs BC) has proven difficult for many nonhuman animals. Wasserman and colleagues were inspired by these difficulties to devise a *same/different* relational concept learning task for pigeons utilizing multiple-item arrays (e.g., AAA vs BCD). Wasserman et al. (1995) provided evidence that pigeons could learn the relational concept by generalizing the rule to novel stimuli. Pigeons viewed arrays of 16 computer icons and responded to one of two keys designated for either *same* or *different*. Whereas the inclusion of 16 icons in each array is more than the amount of perceptual information necessary for a relational concept, the successful discrimination of these displays still provides convincing evidence that a more generalized concept for sameness and difference has been learned. However, with a reduction in the number of items, pigeons demonstrated marked difficulty in discriminating at all displays of less than 8 icons each. The amount of between-item perceptual variability accounted for this depreciation in performance at each successively lower level.

Rhesus monkeys, unlike pigeons, seem less affected by the number of items in stimulus arrays when discriminating *same* from *different*. Although an increase in perceptual variability (and judgment of the contrast between them) seems to be required for rhesus monkeys to learn the abstract relational concepts of *same* and *different*, they do not appear to be detrimentally affected to the extent that pigeons and baboons do. Flemming et al. (2007) reported that rhesus monkeys rapidly learned to discriminate between eight-element arrays, owing success to the perceptual variability of stimuli. Subsequent tests with smaller arrays (including 2-item pairs) indicated that although initially important for acquisition of the concept, the amount of perceptual variability was not a variable on which monkeys based their subsequent discriminative choices. Not only did monkeys choose a corresponding relational pair in the presence of a cue, but they also chose the cue itself in the presence of the relational pair, in essence labeling those relations, indicating strong conceptual understanding of the relations. Having attributed symbolic-like qualities to the relations for *same* and *different*, rhesus monkeys appeared capable of relational reinterpretation in the form of a mental representation.

Evidence for the use of symbols by nonhuman animals to represent abstract concepts can be seen definitively in token-trained chimpanzees. Premack (1983) trained a chimpanzee to label identically and nonidentically related pairs of stimuli with plastic tokens. For instance, in the presence of two novel identical objects placed concurrently on a board, the chimpanzee labeled them by placing her previously trained token for *same* on the board as well. In the presence of two novel different objects, she selected her plastic token for *different*. These tokens also were used to demonstrate that the chimpanzee could reason analogically (see entry on Analogical Reasoning in Animals).

Perhaps one of the clearest examples of abstract concept use in humans is in the domain of numerical cognition. Adult humans come to use number concepts flexibly across an almost unlimited range of situations. Numbers can be used nominally (player #10 on a soccer team), ordinally (third house on the left), cardinally (three blind mice) and arithmetically (four score and seven years ago). Number concepts transcend all physical properties of stimuli. For example, there is no limit to what can be designated using the concept *five* – fingers, friends, months, meters, cars, colors, etc. – and yet there are no defining perceptual features of these sets that make them equivalent except their *fiveness*. Numerical concept learning is not restricted to humans. A variety of animals can use numerical concepts in judging the relations between stimuli on the basis of choosing more or choosing less. Some animals can label novel arrays of items with a numerical tag such an Arabic numeral, or create sets of arrays on the basis of a given numerical tag. They can evaluate arithmetic operations on sets of stimuli, and mentally combine sets and represent the resulting numerical magnitude (see Boysen and Capaldi 1993; Brannon and Roitman 2003; Harris et al. 2010; see entries on Accounting and Arithmetic Competence in Animals and Learning and Numerical Skill in Animals). Thus, numerical concepts, like those for sameness and difference or other relational properties, confirm the existence of abstract concept formation in animals.

Cross-References

- ▶ Accounting and Arithmetic Competence in Animals
- ▶ Analogical Reasoning in Animals
- ▶ Animal Learning and Intelligence
- ▶ Comparative Psychology and Ethology
- ▶ Concept Learning
- ▶ Learning and Numerical Skill in Animals
- ▶ Reinforcement Learning

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Abstract Representation

- ▶ Abstract Concept Learning in Animals
- ▶ Abstraction in Mathematics Learning

A

Abstraction

► Exemplar Learning and Schematization in Language Development
► Learning by Chunking

Abstraction in Mathematics Learning

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Synonyms

Abstract representation; Mental abstraction; Metaknowledge

Definitions

Mathematical objects include concepts, relationships, structures, and processes. In mathematics learning, the term abstraction is used in two senses: *An abstraction* is a mental representation of a mathematical object. *Abstraction*, without an article, is the mental process by which an individual constructs such an abstraction. The term derives from the Latin *abstractum*, literally "drawn out."

Abstraction in mathematics learning takes many forms. At the most elementary level, called *empirical abstraction*, learners recognize that some objects, situations, or experiences are similar in a particular way that distinguishes them from others. The essence of this similarity is then drawn out to form a mental object in its own right. In *horizontal mathematization*, symbols are used to create a mathematical object that expresses the underlying structure of a given situation. In *vertical mathematization*, a new object is invented to pull out the essence of a number of horizontal mathematizations.

Theoretical Background

Abstraction has been a discussion topic since the days of Aristotle and Plato. A frequent approach has been to regard abstraction as the drawing out of common features, a process generally known as *empirical abstraction*. Richard Skemp (1986) defined a mathematical concept as "the end-product of . . . an activity by which we become aware of similarities . . . among our experiences" (p. 21), and his definition could well apply to other mathematical objects. This view of abstraction is broader than empirical abstraction in the Piagetian sense: Mathematical concepts are abstracted from underlying mathematical structure, not from superficial characteristics. It would appear that many elementary mathematical concepts (e.g., numbers, circles, angles, fractions, and rates of change) may be initially learned by empirical abstraction.

A different form of abstraction occurs when a problem solver uses a mathematical object to analyze a problem set within a familiar situation. In this process, called *horizontal mathematization*, diagrams and symbols may be used to represent the essential underlying relationships and the irrelevant aspects of the problem are ignored. The resulting abstract representation (e.g., an equation or a graph) is often referred to as a *model* of the given problem situation. Constructing a model can often involve the idealization of an approximate result. The power of a good mathematical model is that it can be manipulated (e.g., by solving an equation) to suggest problem solutions. However, these solutions may be rejected or modified when the previously ignored irrelevant aspects are taken into consideration (e.g., when an equation leads to a negative length).

Learning horizontal mathematization not only results in valuable problem-solving skills, it reinforces the learner's existing mathematical abstractions by testing their application. It also leads to the learning of mathematical terminology and such standard procedures as written computation and methods of solving equations. Most importantly, it can introduce a learner to a world where mathematics can be treated without reference to any concrete applications.

Another third important form of abstraction in mathematics learning is *vertical mathematization.* As the name implies, this process leads to the formation of one or more new mental objects at a higher level of generality. For example, after horizontally mathematizing a number of situations where one variable changes at a constant rate in relation to a second variable, students may form the concept of a general linear relation $y = ax + b$ which includes an infinity of specific cases.

Vertical mathematization is similar to empirical abstraction in that the new abstraction may be drawn from several examples, but it is different in that the new object is defined in strict mathematical terms. For example, empirical abstraction from contexts such as doubling can lead to the idea of repeated multiplication, and horizontal mathematization may lead to the definition of a^n as "*a* multiplied by itself *n* times." This definition is sufficient to define a^1, but it cannot cope with a^0, a^{-1}, or $a^{1/2}$, which have no existence in common experience. These symbols only take on a meaning when a^n is defined theoretically. For this reason, vertical mathematization is essentially the same as *theoretical abstraction* (Davydov 1990). It is so different from empirical abstraction and horizontal mathematization that it requires nothing less than a complete reorganization of a learner's conception of mathematics (Tall 1991).

Vertical mathematization may be repeated, creating a hierarchy of abstractions. For example, exploration of graphs may lead to the concept of a coordinate plane. Later, coordinates may be similarly applied to 3-dimensional space. Successive vertical mathematizations then lead to the ideas of an *n*-dimensional space and then a general vector space. In this way, even the most extreme mathematical abstraction can be ultimately traced back to experience. This is probably why what appears to be highly abstract mathematics can sometimes find valuable everyday applications for which it was never designed.

Important Scientific Research and Open Questions

Mitchelmore and White have investigated the role of empirical abstraction in the formation of a number of elementary mathematical concepts. For example, Mitchelmore and White (2000) described how young children form an abstract angle concept as a result of recognizing deep similarities between a range of superficially different contexts such as corners, slopes, and turns. Other topics investigated include decimals, percentages, and ratios.

Horizontal and vertical mathematization is strongly featured in the curriculum developed by the Dutch movement called *Realistic Mathematics Education* (Boero et al. 2002). In their curriculum, students learn mathematics through contextual problem solving. For example, students initially solve simple equation-like problems using their own invented strategies. Then they learn to use algebra to solve more complex problems for which more sophisticated strategies are required.

A theoretical model of vertical mathematization, called the RBC+C model (Hershkowitz et al. 2007), postulates four epistemic actions: recognizing (identifying relevant previous constructs), building-with (working with these constructs to solve a problem), constructing (integrating previous constructs to form a new construct), and consolidating (using the new construct until it becomes freely available). The model has been applied to the analysis of older students' learning in several topics, including rates of change and functions.

Other researchers have questioned the whole concept of abstraction on a variety of grounds: How can one learn a concept by abstracting commonalities across a number of cases without already having learnt the concept needed to recognize these commonalities? In what sense is an abstraction "higher" than the knowledge on which it is based? If abstraction consists of the acquisition of context-independent knowledge, how can it possibly be of any value in specific contexts? These and similar philosophical questions are gradually being resolved by recognizing that different kinds of abstraction occur at different levels of mathematical development and that the products of these processes are closely related.

Meanwhile, there are many psychological and pedagogical questions needing further investigation: How precisely do children and students make the various kinds of abstractions described above while learning specific mathematical topics? How does teacher pedagogy affect the abstractions children make? In teaching a new mathematical abstraction, is it more efficient to explore several similar situations or a single situation in depth? How does interaction between learners contribute to abstractions?

Cross-References

► Mathematical Learning
► Mathematical Models/Modeling in Math Learning
► Mathematics Learning Disabilities

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Academic Achievement Motivation

► Achievement Motivation and Learning

Academic Anxiety

► Fear of Failure in Learning

Academic Difficulties

► Delinquency and Learning Disabilities

Academic Engaged Time

► Academic Learning Time

Academic Fear

► Fear of Failure in Learning

Academic Learning Time

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Synonyms

Academic engaged time; On-task behavior; Student engagement

Definition

Academic learning time (ALT) is the amount of time students are actively, successfully, and productively engaged in learning relevant academic content. *Academic engaged time* and *student engagement* are typically used interchangeably. Each is a broader term that encompasses not only the quantity of time spent on an academic task (i.e., learning time), but also related cognitive and emotional learner-centered variables such as self-motivation, initiative, and self-regulation (Gettinger and Ball 2008). *On-task behavior* is a narrow term, most often associated with "paying attention." Observable indices of on-task behavior can include behaviors such as completing assignments, participating in discussions looking at the teacher, or listening to peers. Research on the association between time-related variables (e.g., student engagement time, on-task time) and school performance affirm that time spent in learning is a crucial factor that influences achievement. In one of the earliest reviews on the relationship between time and learning, Fredrick and Walberg (1980) found that the correlation between time spent in learning, particularly ALT, and achievement ranged from 0.13 to 0.71, depending on how time was operationalized and measured.

Theoretical Background

Interest in academic learning time can be traced to John Carroll's (1963) model of school learning. The major premise of Carroll's model is that learning is a function of two time variables: (a) time spent in learning, and (b) time needed for learning (Carroll 1963). Carroll's model can be expressed in a simple mathematical equation: degree of learning = f [time spent/time needed]. Simply stated, the degree to which a learner succeeds in learning a task is dependent on the amount of time he or she spends in relation to the amount of time he or she needs to learn the task. The closer individuals come to achieving equilibrium between the amount of time they require for learning and the amount of time they actually engage in learning, the higher their level of mastery.

Carroll identified five factors that influence either "time spent" or "time needed" in his model. Three factors influence *time needed* for learning: (a) student aptitude, (b) the student's ability to understand instruction, and (c) quality of instruction. Two factors affect *time spent* in learning: (a) time allocated for learning, or opportunity to learn, and (b) perseverance, or the amount of time the learner is engaged in learning. According to Carroll, the relationship between these latter two factors and student learning is linear. Specifically, the degree of learning will be lower to the extent that adequate learning time is not provided and/or that students are not adequately engaged in learning.

By placing time as a central variable in learning, Carroll's model laid the foundation for the development of the construct of ALT. Theoretical conceptualizations of ALT identify five constituent components. The first is *available time*, which represents the total number of hours or days that potentially can be devoted to instruction. The second component, *scheduled or allocated time*, is the amount of time a teacher schedules for instruction in each content domain. Scheduled time represents the upper limit of in-class opportunities for students to be engaged in learning. The process by which scheduled time is converted into productive learning time depends on classroom instruction and management practices, as well as student characteristics. Scheduled time can be further broken down into noninstructional or instructional time (the third component of ALT). *Instructional time* is the amount of scheduled time directly devoted to learning and instruction. *Noninstructional time*, by contrast, is the portion of scheduled time that is spent in nonclassroom activities, e.g., lunch, recess, or transitions. Whereas a 60-min period may be scheduled for instruction, some portion of that time is often consumed by noninstructional activities having little to do with learning. Multiple events may reduce the amount of scheduled time that is converted to actual instructional time, including student and teacher interruptions, transitions, or early dismissals. Within instructional time is the fourth component of ALT, on-task or engaged time. *Engaged time* is the proportion of instructional time during which students are cognitively and behaviorally on-task or engaged in learning, as evidenced by paying attention, completing work, listening, or engaging in relevant discussion. Engaged time includes both passive attending and active responding. Finally, a certain percentage of engaged time, or time-on-task, represents the amount of time during which learning actually occurs; this is *academic learning time*. Thus, ALT is the time during which students are engaged in relevant academic tasks while performing the tasks at a high rate of success. The qualities of both relevance and success are critical for discerning ALT. Neither succeeding at irrelevant tasks nor failing at relevant and worthwhile tasks contributes to effective learning. Students gain the most from learning time when they experience a balance of high and medium success on meaningful learning activities. Whereas each of the five learning time components – available time, allocated time, instructional time, engaged time, and academic learning time – demonstrates some relationship with student outcomes, ALT has been shown to have the strongest link with school learning and achievement (Ben-Peretz and Bromme 1991).

The earliest and most extensive research program to examine the relationship between time and learning and to provide empirical support for the importance of ALT was the Beginning Teacher Evaluation Study (BTES) conducted in the 1980s (Denham and Lieberman 1980). Although the original purpose of the BTES was to evaluate beginning teacher competencies, the focus shifted toward identifying teaching activities and classroom conditions that promote student learning. Based on observations in classrooms over a 6-year period, BTES researchers developed an operational definition and measurable index of ALT. Specifically, they operationalized ALT as the amount of time a student spends engaged in academic tasks of appropriate difficulty, i.e., tasks on which students achieve 80% success or accuracy.

The BTES used ALT as both a measure of teaching effectiveness and an index of student learning. In attempting to identify the key components of effective teaching, BTES researchers discovered that a high level of ALT can be taken as evidence of effective teaching. Furthermore, one of the most significant findings from the BTES project was that ALT has a strong influence on students' academic achievement. Beyond engagement in academic tasks, BTES researchers investigated how students' success rates during engagement affect their later achievement. It was found that the proportion of time during which academic tasks are performed with high success is positively associated with level of student learning. Likewise, when students experience low success rates in school activities, they have lower achievement. In evaluating the interactions between teachers and students during instruction, the BTES data suggest that more frequent substantive interactions (such as teachers presenting information, closely monitoring students; work, and providing performance feedback) between the student and the teacher are associated with higher levels of ALT. Higher levels of ALT, in turn, contribute to achievement. In sum, the BTES findings provided evidence that ALT, and the teaching behaviors and classroom processes that enable students to accrue high levels of ALT, have a strong influence on academic learning and student achievement.

Important Scientific Research and Open Questions

The link between time and learning remains one of the most enduring and consistent findings in educational research. Simply allocating more time for instruction, however, may not necessarily increase ALT or contribute to better learning outcomes. Thus, important questions continue to guide scientific research concerning ALT. First, to what extent can differences in achievement among learners be explained by time spent in learning, specifically ALT? And, second, what factors in the design and delivery of instruction maximize time spent in learning (ALT) and, in turn, achievement.

To the extent that research underscores the need to maximize ALT, investigators must continue to address what can be done to enhance or increase ALT for all learners, particularly learners who may be at risk for school failure. Making good use of existing time, whereby students experience high success on meaningful tasks, is more likely to substantially increase both ALT and student achievement than simply allocating more instructional time (e.g., lengthening the school day or year). Current knowledge about evidence-based strategies to maximize ALT derives from effective teaching research that documents strategies to actively involve students in learning (Gettinger and Stoiber 2009). Effective teaching research may be organized into three broad categories, depending on the research paradigm: (a) process–product paradigm, which delineates teachers behaviors that are associated with student engagement; (b) classroom–ecology paradigm, which considers the structural and organizational features of learning environments that are associated with student engagement; and (c) mediating-process paradigm, which focuses on students' cognitive–behavioral activities that mediate the relationship between teacher behaviors or classroom environment and student engagement. Across all paradigms, it is evident that factors with the greatest impact on ALT relate more to quality than to overall amount of time allocated for teaching and learning. These factors include: (a) effective classroom management on the part of the teacher to minimize down time or time spent attending to disruptions and disciplinary issues; (b) effective teaching strategies to engage students in learning and ensure success on relevant content; and (c) student-initiated strategies, such as self-management, to sustain students' engagement in learning and task completion. A combination of these factors may be the key to increasing ALT for all students. Despite this knowledge base, research on time use in schools estimates that less than half of scheduled learning time is devoted to instruction, that engagement rates among students average only 45–50%, and, most critically, that students in many elementary classrooms may accrue only 1 h per day of ALT. Thus, the challenge for future research is to work toward translating the evidence base into effective school-based practices. Simply put, if schools can find ways to enable students to spend more time actively engaged in learning (i.e., to increase ALT), academic achievement will increase.

Cross-References

► Academic Motivation
► Climate of Learning
► Conditions of Learning
► Evidence-Based Learning
► Field Research on Learning
► Individual Learning

- ► Learning by Teaching
- ► Motivation to Learn
- ► Motivational Variables in Learning
- ► Self-Determination of Learning

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Academic Motivation

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Synonyms

Achievement motivation; Drive; Impulse

Definition

Motivation comes from the Latin word *moveo*, meaning to move, stir, agitate, provoke, or affect. Motivation answers the questions: Why do people act? Why do they behave in a given manner? Why do they continue or discontinue their behaviors? Motivation can be defined as the process responsible for the initiation, intensity, and persistence of behavior. Motives are causes that produce certain effects or actions (including inaction). The source of a person's motivation may be *intrinsic*, derived from internal processes, and/or *extrinsic*, the result of external forces. Likewise, individuals can be impelled to act by conscious and nonconscious motives. Academic motivation refers to the cause of behaviors that are in some way related to academic functioning and success, such as how much effort students put forth, how effectively they regulate their work, which endeavors they choose to pursue, and how persistent they are when faced with obstacles (Schunk et al. 2008).

Theoretical Background

Psychological theories have explained human motivation in divergent ways. In *Principles of Psychology*, the text that led American psychology for well over 50 years, William James pointed to instinct and impulse as driving forces behind human action. Instincts, James contended, quickly give way to habits, which lead people to behave in predictably similar ways in the future. From a Freudian perspective, people are motivated by the result of innate impulses and inhibitions that are largely unconscious and uncontrollable. Theorists such as Clark Hull, on the other hand, framed motivation in terms of needs that lead to drives, which in turn bring about drive-reducing behavior. In this view, humans are generally driven toward the hedonic ends of experiencing satisfaction and avoiding pain. Behaviorists, who dominated American psychology for much of the twentieth century, sought to predict behavior not by examining internal states but by exploring relationships between observed behaviors and environmental stimuli. Radical behaviorists such as Skinner rejected the notion that cognitive processes mediate the influence of external stimuli on individuals' responses. From Skinner's perspective, individuals are motivated to act as a result of reinforcing or punishing environmental conditions.

In the latter part of the twentieth century, scholars began once again to characterize motivation as evolving from the interplay of both internal and external forces. Unlike behaviorism, these theories emphasized learners as agents of their own motivation and behavior. Theorists such as Jean Piaget and Leon Festinger contended that learners are naturally motivated to resolve the cognitive dissonance that results from their exposure to information that is at odds with their previous conceptions. Cognitive disequilibrium is the impetus to regulate one's learning and to construct new knowledge.

In his model of achievement motivation, John Atkinson proposed that motivation could be measured as the multiplicative effect of learners' needs, expectancies, and values in a given domain. Abraham Maslow, a humanist, suggested that humans are motivated first and foremost by fundamental needs such as safety, love, and belongingness. These needs are contingent on the availability of certain external factors in the social environment. When their fundamental needs are fulfilled, people become primarily motivated by intrinsic needs to grow and to reach their higher potential (e.g., motivated by altruism, justice, and self-actualization).

Albert Bandura proposed a social cognitive view of motivation in which academic functioning can be seen as the product of reciprocal interactions among personal (i.e., cognitive, affective, biological), behavioral, and environmental determinants. His *social cognitive theory* emphasizes the role of cognitive, vicarious, self-regulatory, and self-reflective processes in human motivation, thought, and action.

Important Scientific Research and Open Questions

Present-day research on academic motivation is rooted in the broader psychological theories mentioned above. Scholars typically examine one or more core motivation constructs, such as the beliefs students hold about themselves and the outcomes of their efforts, the goals they pursue, and the attributions they make for their successes and failures (Elliot and Dweck 2005). We briefly describe several such constructs and summarize general research findings from recent research.

Self-Beliefs. Many scholars have theorized that students' self-beliefs have a profound influence on their academic behaviors. Academic self-beliefs are particularly attractive to educators because they point to an aspect of motivation that may be altered. Students beliefs are often highly interrelated and frequently overlap (see below). Most fall under the broad umbrella of *academic self-concept*, or perceptions of oneself as a student. Self-concept is hierarchically structured such that individuals' general self-view comprises an academic, social, and physical self-concept. Students may even view themselves differently in different academic domains. *Self-efficacy*, one of the most studied self-beliefs, refers to a task-specific judgment of one's academic capabilities (Bandura 1997).

Self-concept and self-efficacy have generally been shown to predict student achievement, self-regulation, persistence, and effort. On the other hand, *self-esteem*, which refers to one's global sense of worth as a person, is often unrelated to these outcomes, due to its lack of measurement specificity. Some have examined students' *possible selves*, or their beliefs about what they will likely, or ideally, become in the future. Future time perspective researchers point to differences in the degree to which students look to their future goals and argue that these differences may account for variation in academic motivation.

Attribution Theory. Attribution theorists examine learners' causal explanations for their success and failures. Bernard Weiner has characterized individuals' attributions on three dimensions. *Locus* refers to the location of the cause, whether internal or external. A student who performs poorly on a test may externalize her failure by attributing it to external causes such as a biased teacher or an unfair test. The cause of an event may also be characterized in terms of its *stability* according to whether it is viewed as permanent or changeable. A student who blames a stomach bug (unstable cause) for his poor performance may not be as forlorn as one who insists that the failure was due to an inability to comprehend the material (stable cause). The final characteristic refers to whether the cause was within someone's *control.* A student may credit her teacher for a passing grade but may believe it was the result of favoritism (controllable cause). Attribution theorists study the various biases that students may have in interpreting their experiences and identify the ways in which students' interpretations influence their subsequent emotions and behaviors.

Expectancy-Value Theory. Expectancy-value theorists have demonstrated that students' choice, persistence, and performance can be explained by their beliefs about how well they will do on academic tasks and the extent to which they value those tasks (Wigfield and Eccles 2002). People's *outcome expectancies*, their judgments of the consequences that their behavior will produce, have been shown to influence engagement, persistence, and performance. *Value* is assessed as the degree to which an academic activity is perceived as useful, important, interesting, and of relatively low cost. Both expectancies and values are highly susceptible to socialization influences. For example, girls who have been exposed to repeated messages that mathematics is a male domain often lower their expectations for success in mathematics.

Goals. Many theorists emphasize goal setting as an important motivational process. Students who actively select and plan behaviors in pursuit of clearly identified academic objectives are more engaged and therefore acquire skills more quickly. Certain types of goals are more effective for promoting motivation. Proximal (short-term) goals that are specific and sufficiently challenging bring about better results than do distal (long-term) goals that lack specificity or that are too lax or strenuous. Cooperative goals can also enhance academic motivation.

Goal orientation theorists contend that the general orientations individuals have toward their academic and social endeavors helps explain their achievement behavior. Learners can be oriented toward developing competence and mastery in academic activities or by a desire to demonstrate their competence through their performance in front of others. They are said to hold either an approach or an avoidance orientation toward these goals. For example, students may study with the goal of understanding the topic and incorporating it in their future work (mastery approach goal). Alternatively, their aim may be to attain a high grade or to appear superior to peers (performance approach goal). Still others might try to avoid appearing unintelligent or inferior to peers (performance avoidance goal). Mastery approach goals are associated with higher academic achievement and motivation; avoidance goals of any type are inversely related to achievement and motivation and are therefore most maladaptive. The relationship between performance approach goals and these variables is less consistent, however. Also, because the reasons for which students act stem from multiple (and sometimes contradictory) goals, teasing out the relationship between any particular goal orientation and one's achievement has presented a challenge for motivation researchers.

Implicit Theories of Ability. One outgrowth of this work has been Carol Dweck's emphasis on students' implicit theories of ability or intelligence. According to Dweck, students who believe that intelligence is fixed (i.e., cannot be changed) are more likely to view failure as a sign of low intelligence and engage in a host of self-defeating behaviors when their competence is called into question. Those who believe that intelligence is malleable (i.e., can be expanded as a result of their efforts) take a more adaptive approach to learning and rebound from their mistakes.

Self-Determination Theory. Deci and Ryan (2002) proposed that people are motivated by their innate need to feel competent, autonomous, and related to others. When the learning setting supports the satisfaction of these needs, learners are more intrinsically motivated and self-determining. Conversely, overly controlling learning environments that offer little opportunity for mastery and relatedness promote either extrinsic motivation or no motivation at all.

Academic motivation researchers continue to chart new directions for a better understanding of the whys of academic-related choices and behaviors (see Urdan and Karabenick 2010). Given the general findings that the motivation constructs described above are good predictors of achievement, researchers are currently turning to the antecedents of these beliefs and judgments. In addition, many scholars have pointed to the need for more cross-cultural work to shed light on whether motivational processes operate similarly among diverse groups of learners. New research methods are also permitting researchers to track changes in motivation over time, which permits a deeper understanding of what predicts upward and downward individual motivation trajectories.

One shortcoming in the academic motivation research to date is that it offers few direct implications for improving teaching practice. Researchers must continue to focus on helping teachers to determine what they can do in practice to motivate all students. Examining the ways in which new technological tools promote new means of engagement will also be an important area of inquiry for academic motivation researchers. Testing the relative contribution of internal (agentic) forces and external forces (such as from parents and peers) will also help clarify what motivates learners. A closer examination of teachers' motivation has also been linked to many aspects of students' academic motivation and performance. Researchers have therefore focused not only on the goals, attributions, and beliefs of students, but those of teachers as well. Likewise, researchers are beginning to investigate the effects of teachers' motivation on attrition. Part of this work involves examining the ways in which school and institutional policies enhance or undermine teachers' and students' motivation.

Cross-References

► Academic Motivation
► Achievement Motivation and Learning

▶ Assessment of Academic Motivation
▶ Attribution Theory of Motivation
▶ Cross-Cultural Studies on Learning and Motivation
▶ Goal Theory/Goal Setting
▶ Motivation and Learning: Modern Theories
▶ Motivation, Volition and Performance
▶ Motivational Variables in Learning
▶ School Motivation
▶ Understanding Intrinsic and Extrinsic Motivation

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Academic Motivation of At-Risk Learners

▶ Learning Motivation of Disadvantaged Students

Academic Outcomes

▶ School Climate and Learning

Academic Phobia

▶ Fear of Failure in Learning

Academic Process

▶ Alignment of Learning, Teaching, and Assessment

Academic Procrastination

Dilatory behavior in academic situations.

Academic Self-Efficacy

▶ Self-Efficacy for Self-Regulated Learning

Academic Socialization

▶ Socialization-Related Learning

Accelerated Learning

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Synonyms

Acceleration; Accelerative learning; Compressed curriculum; Early entrance; Full-year acceleration; Grade-skipping; Radical acceleration; Telescoping

Definitions

Accelerate comes from the Latin words *ad* meaning "toward" and *celer* meaning "fast" or "rapid." Therefore, accelerated learning is learning which occurs at a more rapid rate. Today, the umbrella term ▶ acceleration is more often used to cover all accelerated learning. ▶ Accelerative learning includes a particular strategy popular in language teaching at the end of the last century. Suggestive accelerative learning and teaching (SALT) was described as using the learner as a resource to increase the rate of learning. ▶ Grade-skipping (USA) or ▶ full-year acceleration (UK) is the practice of accelerating a student by moving them a full year (or more) ahead of their chronological age-peers. ▶ Radical acceleration is where a student is accelerated more than 2 years ahead of age-peers. ▶ Telescoping is the shortening of a course of study; for example, where a year's course is covered in one semester thereby accelerating the learning. Curriculum compacting is similar to telescoping, but usually refers to a reduction in introductory activities, allowing a course of study to be covered at a faster pace. ► Early entrance occurs when a student is admitted to school or university a year or more earlier than age-peers, thereby accelerating their learning. All the above are terms for accelerated learning.

Theoretical Background

Acceleration is a strategy often associated with gifted learners. The alternative to accelerated learning is age-grade or social placement. Prior to the mid-nineteenth century, the idea that gifted students should remain with their chronological peers was not widely held. In China's Tang Dynasty (circa 618 BC), child prodigies were summoned to the Imperial Court for special education. Later (circa 400 BC), in the times of Plato, Socrates, and Aristotle, the expectation was that student performance would determine the placement level and the time taken to graduate. That situation continued for centuries. By the early twentieth century in many Western developed countries however, mandatory school attendance coupled with increased immigration and children no longer being required to work, had led to increased enrolment and graduation rates. The Depression of the 1930s was the final influence in solidifying a rigid age-grade placement structure (Kulik and Kulik 1984). This "social placement" soon became the norm, primarily as a method to control the movement of a growing number of students through the school system. It should be noted that age-grade grouping is, in the history of education going back over 2,000 years, a relatively recent phenomenon covering, at most, the last 150 years.

It is acknowledged by researchers that there is a problem with the inconsistency of terminology of acceleration. The definition of accelerated learning has changed throughout the last 100 years to suit the practice in favor at the time. The aim was to circumnavigate the comparatively new "lock-step" system of rigid grouping according to age. During the 1930s, interest in acceleration waned. The Depression meant that there was little need to finish schooling early to enter a very limited job market. The saying "early ripe, early rot" was coined to describe what would happen to children who were accelerated. Teachers and administrators persuaded parents of the gifted that their children would suffer socially and emotionally and would be condemned to lives of "loneliness and despair." Not surprisingly, these pronouncements discouraged parents from seeking acceleration for their children.

Important Scientific Research and Open Questions

It would appear that in countries around the world, whenever the government of the day determines that the talent pool needs a boost, acceleration comes back into favor. Lewis Terman (1877–1956) first used the term "► radical acceleration" in an address to alumni. The descriptor was used in explaining the achievements of several students who had entered Johns Hopkins University (JHU) 3 or more years earlier than usual. There is the theme of interest following the successful launch of Sputnik by the Soviet Union. US President John F. Kennedy then put out a call for America's "best and brightest" to assist the goal of landing a man in the moon by 1970. In the 1970s interest in acceleration continued. Julian Stanley (1918–2005) initiated his *Study of Mathematically Precocious Youth* (SMPY) in 1971 at JHU, Baltimore, Maryland. He was inspired by Browning's famous lines: "Ah, but a man's reach should exceed his grasp, or what's a heaven for?" Stanley utilized acceleration for his programs for talented youth; forming fast-paced mathematics classes, followed by similar classes in science, and later into the humanities.

Daurio (1979) carried out a comparative study of acceleration from 220 sources. He found that there were no data to refute the efficacy of acceleration for gifted students. He also found that accelerated students performed at least as well as, and often better than, "normal-aged" control students on both academic and nonacademic measures. Furthermore, he found considerable evidence that acceleration had been advantageous to gifted students. Daurio, however, reported much resistance to the practice. He perceived the negativity to be based on preconceived notions and irrational grounds, rather than on an examination of the evidence.

Kulik and Kulik (1984) in their meta-analysis found accelerated students achieved as well as equally gifted older students in the higher classes. According to their findings, acceleration promoted students' intellectual development in the majority of cases. Kulik and Kulik concluded that the accelerated students outperformed the matched non-accelerands of the same age by almost a full year. The median effect size was 0.80 for the results with same-age control groups.

Levin (1996) found that acceleration was also an effective strategy for "at-risk" students. Levin's Accelerated Schools Project found that high-content instruction resulted in significant gains as opposed to the traditional methods of remediation. This project was aimed at pre-elementary level and involved the whole school in "unity of purpose; responsibility for decisions and their consequences; building on strengths" (p. 336).

The research exposes the myth of acceleration causing long-term social and emotional harm to students. There is evidence however of the opposite, namely when gifted students are not permitted acceleration and are retained in age-grouped classes, they become frustrated and despondent. There is evidence that this "grade retention" can be extremely damaging to not only academic outcomes but also to the long-term social and emotional welfare of gifted students.

Hattie (2009) compiled a synthesis of over 800 ► meta-analyses, consisting of over 50,000 studies relating to educational achievement. He presented a league table consisting of contributions by the student, home, teacher, teaching approaches, school, and curricula as defined by their ► effect-size; that is, the difference each contribution made to educational achievement, listing them in order of effectiveness. The meta-analyses identified acceleration with an effect-size of 0.88, as the fifth highest contribution to student achievement, in a table of 138 factors The league table showed that it is important to not only examine what leads to successful learning, but to see what works better than other strategies/interventions/contributions.

Colangelo et al. (2004) compiled a comprehensive research report on acceleration which is available in two volumes and translated into eight languages. It can be downloaded from http://www.accelerationinstitute.org/Nation_Deceived/.

Acceleration is often reported as "cost free"; however, this is not the case as the cost to schools can be substantial. The schools lose the years of funding that the students save by being accelerated. This factor has been suggested as a reason why administrators in general have been reluctant to utilize accelerated learning.

The researchers note that although accelerated learning is not the answer in every case, the significant academic benefits for students have been confirmed and the myths about social and emotional harm have been exposed. Why then is acceleration a seldom utilized strategy in educational systems around the world? As pointed out by Gold (1965), "no paradox is more striking than the inconsistency between research findings on acceleration and the failure of society to reduce the time spent by superior students in formal education" (p. 238).

Cross-References

- ► Aristotle
- ► Assessment in Learning
- ► At-Risk Learners
- ► Boredom of Learning
- ► Depression and Learning
- ► Effect-size
- ► Learned Helplessness
- ► Meta-analyses
- ► Peer Learning Groups
- ► Rapid E-learning
- ► Rapid Learning in Infants
- ► Retention and Learning
- ► Suggestopedia and Learning
- ► Zone of Proximal Development

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Acceleration

► Accelerated Learning

Accelerative Learning

► Accelerated Learning

Acceptance

The attitude of acceptance means a warm regard for a person of unconditional self-worth, of value no matter what his or her condition, behavior, feelings. It means a respect and liking for the other as a separate person, a willingness for him or her to possess their own feelings in their own way (Rogers 1961).

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Accommodation

In cognitive and developmental psychology this theoretical term refers to the process by which existing mental structures and behaviors are modified to adapt to new experiences. Beyond this, accommodation may also refer to the physical process by which the eyes increase their optical power to focus on an object as it draws near. Generally, accommodation refers to cognitive processes of restructuring existing knowledge in order to be able to understand a new phenomenon, which would not otherwise fit, e.g., in changing one's understanding of chemical reactions in the light of new theories of atomic structures.

Accounting and Arithmetic Competence in Animals

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Synonyms

Animals; Approximate number system; Counting; Mathematics; Numerical cognition; Numerosity

Definition

Many nonhuman species show accounting abilities. *Accounting* here refers to the capacity to track, remember, and compare sets of items on the basis of their quantity or number. *Arithmetic competencies* refer to the ability of animals to deal with arithmetic operations on stimulus sets: these include addition and subtraction. These competencies are related to the same capacities commonly seen in humans, and they can refer to discrete or continuous quantities. Most research has dealt with addition operations, and some research has examined how animals deal with subtraction operations. Some species show compelling abilities to deal with such operations, and they do so in situations where they compare sets of things or label sets with symbols (e.g., numerals). However, animals that can deal with arithmetic operations do so in ways that suggest they represent number approximately rather than exactly, and this difference suggests a qualitative difference between animal abilities and those of humans who have been exposed to formal mathematics. Despite this, animal performances in arithmetic situations are highly similar to those of humans in situations where formal mathematical systems are not present or are not accessed.

Theoretical Background

Many nonhuman species are capable of dealing with quantitative information. The skills that have been demonstrated range from simple choices between food sets to comparisons among arbitrary stimuli on computer screens (see Boysen and Capaldi 1993). Some animals even map quantity information onto symbols such as Arabic numerals. Some tasks require that animals account for arithmetic operations that are performed on sets of items, and to use the outcomes of those operations to support decision making. To date, these operations primarily have involved additions of items to sets, or in some cases subtraction of items.

Perhaps some of the best evidence for arithmetic competence in animals comes from Boysen and her colleagues' work with chimpanzees (e.g., Boysen and Berntson 1989). These chimpanzees learned to label arrays of things by pointing to Arabic numerals. In some tests, they had to move to multiple locations and mentally add the number of items they saw in those locations to provide the correct label. Successful performance showed combinatorial, enumerative processes at work within a symbolic matching task. In other cases, animals have combined the values of arbitrary numerical symbols in a quantity comparison task such as making choices between pairs of numerals, each of which represented a number of food items.

Most tests of animal accounting do not use symbolic stimuli but instead use food items. In one of the earliest experiments, Rumbaugh et al. (1987) showed that chimpanzees could combine sets of food treats and judge which of two pairs of treats contained the larger amount. To do this, the chimpanzees had to sum the contents of each pair of treats in order to maximize the amount of food they obtained. The chimpanzees succeeded, indicating an ability for rudimentary summation.

More formal addition operations can be presented when subsets of items are added to containers at different points in time. Much of this work has been done with great apes using a quantity judgment task where animals choose one of the resulting sets. In one study using this method (Beran 2001), two chimpanzees watched as food items were dropped, one at a time, into two opaque containers. Then, an additional set of items was added to each container so that the chimpanzees had to update their representation of the quantities in each container before they would make a choice. Both chimpanzees performed at high levels, and they continued this even when three separate sets were added at a different time. These chimpanzees even observed and remembered the effects of adding bananas over 20 min of time into two containers, and they picked the larger number of bananas at very high levels, indicating that they understood the effects of each addition to the set sizes they were comparing. More recent tests have confirmed that other great apes and even some monkeys can succeed in making these judgments of summed sets of food items.

Other animals can accommodate additive operations that they see, and they respond when the number of items they are shown after an addition does not match what it should be. For example, monkeys stared longer at a small set of items when it differed in number from what they had seen placed behind a screen. Such performances are quite similar to those reported for human infants and are not limited to primates. Rugani et al. (2009) showed that newly hatched chicks could observe items being added to or removed from one of two areas behind a screen and then select the larger amount at the end of the trial. This seemingly required the ability to account for elements that appeared and disappeared, one by one, in order to perform the task successfully. Pepperberg (2006) also reported that a grey parrot was able to verbally label the quantities 0–6 when individual items were sequentially uncovered and the parrot had to sum the total quantity.

Tests that involve subtraction of items are less prevalent in the comparative cognition literature, and success is less widespread among animals for this operation. Brannon et al. (2001) showed that some pigeons could subtract in a test in which they were required to compare a constant number with the number remaining after a numerical subtraction. Sulkowski and Hauser (2001) reported that when items were subtracted from one of two sets being compared monkeys showed some ability to accommodate the subtraction operation. However, in the Beran (2001) study only one of two chimpanzees successfully responded to trials in which items were first added to two containers but then a single item was removed from one of the containers. This might mean that accounting abilities of animals might be less efficient for subtraction operations than for one-by-one additive manipulations. From an evolutionary perspective, this suggests that dealing with reductions in quantities that must be judged or remembered is a more difficult task, a suggestion also supported by the developmental course of early arithmetic abilities in children.

Critically, the performance of animals in nearly all tests of arithmetic competence indicates that animals represent quantities and numbers differently than do adult humans. Humans make use of a formal number system that is infinite in its scope, linearly represented (e.g., the mathematical distance between 2 and 3 items is the same as that between 2,976 items and 2,977 items), and given to use in formal mathematical systems. Animals, however, make use of an approximate number (or quantity) system whereby the representations that are formed are somewhat fuzzy and inexact. This is likely the result of how those numbers or quantities are processed. For example, one idea is that as each item is encountered, it leads to the addition of a magnitude into an accumulator mechanism, and this mechanism then holds in memory an approximate representation of the sum total. As the amount or number of things gets larger, the representation becomes less exact, leading to easier confusion with regard to comparison tasks or labeling tasks. It is for this reason that comparing 22 items to 24 items is far harder for animals than comparing two items to four. This approximate number system seems to be widespread phylogenetically, with evidence of its existence in many animals including apes, monkeys, lemurs, horses, dogs, chicks, parrots, elephants, ants, salamanders, fish, bees, and likely many more candidates. This system is thus evolutionarily very old. It is even used by adult humans when testing procedures prevent formal counting routines and the blockage of exact numerical representations. For example, when articulatory suppression techniques are introduced that prevent humans from counting, performance on tasks like those described above looks remarkably similar to the performance of nonhuman animals. This shared approximate representation of number and quantity is therefore a critical aspect of comparative cognition.

Important Scientific Research and Open Questions

Despite the many competencies outlined in this article, it is still true that nonhuman mathematical competencies fall far short of those of adult humans (or even older children). Animals seemingly do not come to use a formal system for representing exact numerosity that is necessary for the emergence of more advanced mathematics. Although they show sensitivity to arithmetic operations, show some ability for simple counting, and do a good job of tracking and accounting for various quantities in ways that support good decision making, they ultimately reach a plateau that humans move well beyond (at least in literate, numerate cultures). It is this last point that is an important one, as the role of culture in the emergence of advanced mathematics is only now being more clearly understood. For this reason, one can speculate that nonhuman animals may not yet have tapped into their full capacity for mathematics.

Animals share with humans an approximate number system that serves them well in many of the situations that they may face. Any creature that can tell the difference between eight pieces of food and five pieces, or that can tell the difference between two predators and three on the horizon has a better chance to survive and reproduce. And, knowing that items removed from a set changes the quantitative value of that set also supports survival, at least when the numbers of items are small enough. However, what happens next in human development is that we learn to map symbols onto these representations, and then we learn to manipulate those symbols in ways that eventually support our advanced mathematical competencies. Pigeons and chimpanzees are unlikely to learn trigonometry or calculus. But, appropriate environmental circumstances might lead to greater capacities than currently demonstrated, much as has been found in the domain of language learning by animals. Thus, it remains to be seen what greater capacities might one day be exhibited by nonhuman animals. An important next step in this research area is to provide animals with the type of environment that supports the emergence of more complicated mathematical skills. Taking a longitudinal perspective on mathematical development in animals, and providing animals with the structured routines that promote the development of mathematics in children could provide new insights into the evolutionary foundations of mathematics and the emergence of even greater accounting abilities in animals.

Cross-References

► Abstract Concept Learning in Animals
► Analogical Reasoning in Animals
► Animal Learning and Intelligence
► Comparative Psychology and Ethology
► Concept Learning
► Learning and Numerical Skill in Animals
► Reinforcement Learning

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Achievement Criteria

► Learning Criteria, Learning Outcomes, and Assessment Criteria

Achievement Deficits of Students with Emotional and Behavioral Disabilities

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Synonyms

Behavioral disorders; Externalizing and internalizing behavior; Mental health disorder; Serious emotional disturbance

Definition

Emotional and behavioral disabilities (EBD) and the terminology used to classify associated disorders, such as serious emotional disturbance and mental health disorders, resist easy and precise definition and identification (Nelson et al. 2004). EBD is an umbrella term for a group of social and emotional function disorders that limit students' social, academic, and vocational success.

Theoretical Background

Most EBD can be grouped under one of two broad bipolar dimensions: internalizing and externalizing (Achenbach 2001). Internalizing EBD involve behavioral deficits representing problems with self that are inwardly directed away from the external social environment. Internalizing EBD are often self-imposed and frequently involve behavioral deficits and patterns of social avoidance. As with externalizing behavior, these behavioral manifestations often result in difficulties with social, academic, and vocational functioning. The most common internalizing syndromes include obsessive compulsive disorder, generalized anxiety disorder, social anxiety, separation anxiety disorder, posttraumatic stress disorder, and child/adolescent depression. Examples of internalizing behavior problems include:

- Having low or restricted activity levels
- Not talking with other children
- Being shy
- Being timid or unassertive
- Avoiding or withdrawing from social situations
- Preferring to play or spend time alone
- Acting in a fearful manner
- Not participating in games and activities
- Being unresponsive to social initiations by others
- Not standing up for one's self

Externalizing refers to all EBD outwardly directed by the student toward the external social environment. These behavioral manifestations often result in difficulties with social, academic, and vocational functioning. The most common externalizing syndromes include conduct disorder, oppositional defiant disorder, attention deficit/hyperactivity disorder, and adjustment disorder. Examples of externalizing behavior problems include:

- Displaying aggression toward objects or persons
- Arguing
- Forcing the submission of others
- Defying the teacher
- Being out of the seat
- Not complying with teacher's instructions or directives
- Having tantrums
- Being hyperactive
- Disturbing others
- Stealing
- Not following teacher- or school-imposed rules

Finally, substantial research suggests that students with EBD who exhibit externalizing behavior are more likely to experience academic difficulties (Hinshaw 1992; Nelson et al. 2004; Timmermans et al. 2009). The findings of this research consistently indicate that externalizing behavior appears to be related to academic achievement difficulties, while internalizing ones are not.

Important Scientific Research and Open Questions

Achievement Difficulties

A large diverse body of literature has documented that students with EBD are likely to evince significant academic achievement difficulties (Nelson et al. 2004; Timmermans et al. 2009). It is important to note before going on that the achievement difficulties of these students are *not* associated with cognitive impairment (Nelson et al. 2004). Just more than 1% of children who receive special education services for EBD are reported to have an intellectual disability (Wagner et al. 2005).

A majority of the studies regarding the academic achievement of students with EBD conducted in school settings have compared their performance with other populations (Wagner et al. 2004). Students with EBD consistently show moderate to severe (>1 standard deviation) academic achievement difficulties relative to normally achieving students (Wagner et al. 2004). Wagner and colleagues (2004), for example, used data from the Special Education Elementary Longitudinal Study (SEELS) and the National Longitudinal Transition Study – 2 (NLTS-2) first wave of the School Characteristics, Student's School Profile, and found a sample of second grade students with EBD performed one or more standard deviations below normally achieving peers in vocabulary, listening comprehension, spelling, social science, and science. Furthermore, the prevalence of academic achievement difficulties among students with SBD in school settings also has been studied (Greenbaum et al. 1996). Reported prevalence rates of academic achievement problems among students with EBD in school settings have ranged from 60% to 97% (Nelson et al. 2004). The prevalence of academic achievement problems among students with SBD also has been assessed over time (Greenbaum et al. 1996). Greenbaum and colleagues (1996) sampled from all youth with EBD across six states. The percentage of students reading below grade level at intake (ages 8–11), 4 years later (ages 12–14), and 7 years after intake (ages 15–18) was 54%, 83%, and 85%, respectively. The percentage of children performing below grade level in math at intake, 4 years later, and 7 years after intake was 93%, 97%, and 94%, respectively.

Hypothetical Causal Models and Associated Open Research Questions

Hinshaw (1992) proposed four possible models to explain the covariation between externalizing behavior and academic achievement difficulties that has proven to be robust over time. The important open research questions center on identifying a model to explain this covariation. The four possible models proposed by Hinshaw include:

1. *Academic achievement difficulties lead to externalizing behavior.* This model requires a history of learning failure that precedes the emergence of externalizing behavior. The causal relationship between academic achievement difficulties and externalizing behavior may be influenced by additional variables such as frustration, lowered self-image, demoralization, or lack of school attachment, and consequences of poor achievement that may mediate subsequent externalizing behavior.
2. *Externalizing behavior leads to academic achievement difficulties.* In this case, externalizing behavior prior to school entry is viewed as primary. Externalizing behavior interference with proper classroom behavior might be the key mediator of academic achievement difficulties. For this model to be viable, the early externalizing features predict subsequent academic achievement difficulties independently of poor readiness skills, which might accompany externalizing behavior.
3. *Externalizing behavior and academic achievement difficulties lead to the other.* This bidirectional model acknowledges that both of the previous unidirectional models occur simultaneously.
4. *Underlying variables result in both externalizing behavior and academic achievement difficulties.* Antecedent variables such as intraindividual (e.g., temperament, language difficulties) or environmental (e.g., discordant homes, large family size) results in externalizing and academic achievement difficulties. Because this model requires that they causally precede the association, preliminary evidence for third variables would include the joint presence of externalizing behavior and cognitive

difficulties in early years. More comprehensive investigations would require prospective, longitudinal evaluations that include sensitive measures of the hypothesized causal variables and their statistical control in analyses of explanatory factors.

Cross-References

► Abnormal Avoidance Learning
► Anxiety, Stress and Learning
► At-Risk Learners

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Achievement Goal Orientations

► Age-Related Differences in Achievement Goal Differentiation

Achievement Goal Theory

Students' purposes in learning influence the nature and quality of their motivation and engagement in learning.

Achievement Motivation

A desire to excel at learning tasks which is related to pride in accomplishments.

Cross-References

► Academic Motivation
► School Motivation

Achievement Motivation and Learning

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Synonyms

Academic achievement motivation; Needs for achievement

Definition

The word *motivation* comes from the Latin word "*motivus*" (i.e., a moving cause), which represents the underlying mechanism to instigate and sustain goal-directed activities. From a behavioral-cognitive perspective, motivation can be defined as the force that gives directions to both mental and physical activities, energizes purposeful engagement, and enhances the tendency to persist for attainment. In the learning context, various constructs and operational definitions in relation to achievement motivation have been proposed and developed (cf. Murphy and Alexander 2000). In general, both researchers in learning sciences and practitioners in education (e.g., teachers, counselors, and educational administrators) tend to accept the concise definition of achievement motivation as the learner's striving to be competent in effortful activities (Elliot 1999). In this vein, achievement motivation is usually characterized by the following indicators: (a) setting up certain standards for unique attainment within the current study period or in the long term, (b) pursuing satisfactory outcomes or excellence in the acquisition of specific knowledge and skills,

(c) evaluating performance based on self-monitoring and feedback, and (d) expressing a certain degree of affective attachment to the processes of goal attainment.

Achievement motivation was discussed by William James as early as in 1890 and conceptualized by Henry Murray as needs for achievement in 1938; subsequently, empirical and theoretical work has been intensively and systematically conducted by a number of contributing researchers, including David C. McClelland, John W. Atkinson, Bernard Weiner, John G. Nicholls, Martin L. Maehr, Allan Wigfield, Jacquelynne C. Eccles, Martin V. Covington, Paul R. Pintrich, Carol S. Dweck, and Andrew J. Elliott, just to mention a few (cf. Elliot 1999; McClelland et al. 1989).

In the literature, there are two types of measurement employed to identify achievement motivation. The first type of measurement adopts projective techniques that can be used to examine implicit motives. A typical instrument is a collection of picture-story tests such as the Thematic Appreciation Test (TAT), in which an individual is required to view a series of ambiguous pictures and make up a story for each picture or answer a series of questions such as "what is happening," "what has led up to this situation," "what is wanted," "what can be done", and "what will happen." The TAT raters then score the responses in line with various criteria listed in the test guidelines and categorize the person on strength of achievement motives. According to McClelland et al. (1989), because of activity incentives (i.e., the pleasure derived from the test activity itself), the implicit motives represent spontaneous and often subconscious motivational system that is associated with affective experiences. However, tests on implicit motives are often low in reliability, time-consuming, and fairly costly (e.g., substantial training is needed for a qualified psychologist to be specialized in projective tests).

The second type of measurement uses self-report questionnaires administered in structured, nonambiguous, culturally defined, and achievement-related situations to examine explicit motives. The reason to label this as an explicit measurement approach is: while participants often do not know the ultimate purposes of the first type of approach, they are generally aware of the specific aims of the second type of approach. For example, when students are required to rate items like "My goal in this class is to get a better grade than most of the students", "I just want to avoid doing poorly in this", "I desire to completely master the material presented in this class" in a five-point Likert scale, they are aware of what they are answering. Because of social incentives contained in the achievement motivation questionnaires, self-attributed motives are based on both cognitively and emotionally elaborated constructs and predict immediate responses to structured learning situations (McClelland et al. 1989). It is relatively easy to check and compare the psychometric parameters of results obtained from explicit achievement motivation measures, and a large amount of data can be conveniently collected via online or paper–pencil survey. However, self-reports may have some threats to validity, such as subjectivity and social desirability. It is encouraging that in recent years some attempts have been made (a) to combine both implicit and explicit achievement motivation measures in comprehensive investigations, and (b) to examine the predictive value of achievement motivation in relation to other broad and well-established constructs such as reasoning and Big Five characteristics (e.g., Ziegler et al. 2010).

Theoretical Background

Theoretical framework of achievement motivation has been proffered, expanded, and modified for over a century, ranging from behavioral to social cognitive perspectives (Elliot 1999). In a substantial review, Murphy and Alexander (2000) have identified a corpus of 20 academic achievement-related motivational terms that can be grouped into four clusters: (a) *goal*, including ego-involved goal, task-involved goal, learning goal, mastery goal, performance goal, work-avoidance goal, and social goal; (b) *intrinsic versus extrinsic motivation*; (c) *interest*, including individual interest and situational interest; and (d) *self-schemas*, including agency, attribution, self-competence, and self-efficacy. In the contemporary educational psychology literature on achievement motivation, the following approaches appear to be the most prominent and fruitful (Elliot 1999; Low and Jin 2009): self-determination theory, expectancy-value theory, social learning theory in self-efficacy, and goal-setting theory. It should be pointed out (and will be illustrated later) that the above-mentioned approaches are not mutually exclusive but rather complementary to each other.

According to self-determination theory, there are two types of motivation, extrinsic and intrinsic.

Whereas individuals with high extrinsic motivation exert their effort in order to obtain external rewards, learners having strong intrinsic motivation tend to see that the major incentives are from fulfilling a task or taking a course per se (e.g., just because it is interesting). Motivation is conceptualized as a continuum with the intrinsic at one end and the extrinsic at the other, and a person may have mixed motivations. Intrinsic motivation (e.g., enjoying doing an assignment just because it is challenging) to a certain extent reflects a basic human need for competence and self-determination. Due to positive environmental influences and personal learning experience, it is possible for a learner who is initially motivated by external incentives to gradually gain the feelings of competence and thus become internalized with the learning tasks. For example, some students who do not fully understand the importance of an e-learning course may at first put "just enough" effort (e.g., log into their accounts to download and read basic course information); after a period of learning, they may gain more content knowledge, possess better learning skills, and develop a sense of control over this type of learning mode; eventually they may become more self-determined in their e-learning of the course.

The notion of self-efficacy, derived from social learning theory, refers to a person's perceptions of his or her own capabilities in tackling a task to attain desired outcomes. Self-efficacy is task-specific and thus related to a unique environment (e.g., a student feels being able to submit a passable drama assignment with text and video attachments). Individuals with low self-efficacy for an achievement task tend to avoid attempting it; those with high self-efficacy would exert great effort and perseverance even when encountering difficulties in the execution of their task. Research in a variety of areas (such as work, sports, and self-regulated learning) reveals that self-efficacy is one of the best predictors of performance. There is growing evidence to support the proposition that self-efficacy plays a key role in web-based learning in different education settings.

According to the expectancy-value model of achievement motivation, the main motivational determinants are (a) ability beliefs (e.g., "If you were to list all the students in your class from the worst to the best in Math, where would you put yourself?"), (b) expectancies for success (e.g., "How well do you expect to do in math this year?" and "How good would you be at learning something new in math?"), and (c) the components (including usefulness, importance, and interest) of subjective task values (e.g., usefulness – "Compared to most of your other activities, how useful is it for you to be good at math?", importance – "Compared to most of your other activities, how important is what you learn in math?", and interest – "How much do you like doing math?"). This expanded model has taken into account some related constructs in other achievement motivation theories, such as self-efficacy, intrinsic and extrinsic motivation, and interest. To some extent, those factors are related to task performance and choice.

Research in goal-setting on the whole reveals a positive relationship between the levels of goals and performance. Higher goals tend to be associated with higher levels of effort and performance. In addition, it appears that setting specific, difficult goals is a more productive strategy than just urging individuals to do their best. This is because the do-your-best strategy lacks an external framework of reference, whereas specifically defined, relatively difficult targets can reduce ambiguity in goal-oriented actions. Furthermore, if timely feedback is provided and individuals have the opportunity to participate in the goal-setting process, goals in line with relatively high standards of performance can enhance self-efficacy and raise motivation. An expanded motivation model, derived from wider social cognitive perspectives, can be used to integrate goal-setting and self-efficacy: (a) the goal setting process influences both self-efficacy and personal goal; (b) self-efficacy also shapes personal goal; and (c) both self-efficacy and personal goal are determinants of performance (Low and Jin 2009).

During recent years, researchers have attempted to identify different types of achievement goal orientations, which are regarded as one of the foundations of learning motivation (Elliot 1999; Low and Jin 2009; Murphy and Alexander 2000). Theoretically, there are four types of goal orientations: learning (mastery) orientation, learning avoidance orientation, performance orientation, and performance avoidance (learned-helplessness) orientation. Among them, the learning (mastery) orientation, which is characterized by a desire to increase one's competence by mastering new skills, appears to be conducive to positive learning experiences and outcomes. In contrast, performance orientation, which refers to a desire to merely demonstrate one's satisfactory outcomes (usually indexed by the rating of performance, whether formal or informal), may have less positive impact on learning, especially on endogenous pleasure and in-depth understanding; both learning avoidance orientation and performance avoidance orientation have negative impact on achievement. Furthermore, research shows that students having mastery orientation are more likely to be engaged in self-regulated learning (Elliot 1999). In multimedia environments, students with mastery orientation when facing failure or difficult situations tend to adopt an adaptive response pattern, which is characterized by using more resources on their tasks, spending more time for problem-solving, and seeking more information to form new strategies (Low and Jin 2009). Researchers also suggest that the cognitive load theory, which examines the effectiveness of instruction and learning (see chapters on *Modality effect* and *Redundancy effect*), can be further developed to investigate how to help learners set up proper and challenging goals that are specific to the task. For instance, perceived teacher goals, student goals, and appropriate learning strategies should be incorporated in an efficient way (e.g., using worked examples) to reduce the demands on working memory in problem-solving or reading comprehension.

Important Scientific Research and Open Questions

The bulk of achievement motivation studies accumulated over a century provides rich resources for contemporary research. However, the diversity of achievement motivation approaches raises challenges, tasks, and a number of open questions for current and future researchers. The following sections will highlight some important issues in this field.

Constructs and instruments – As pointed out by Murphy and Alexander (2000), motives for academic achievement can be analyzed as drives (an internal state or needs) or goals (purposeful, directional, and meaningful pursuits). While various measures and scales are available for motivational constructs (McClelland et al. 1989; Ziegler et al. 2010), integrative, validated instruments corresponding to an expanded, comprehensive theoretical framework, for example, the achievement goal theory or the expectancy-value theory can be further developed.

Snapshot versus longitudinal research – Most studies on academic achievement motivation are snapshot, cross-sectional. Only a few studies are multilevel, longitudinal. There are clues indicating a decline in achievement motivation with age; large-scale research using representative samples and multipoint measures should be conducted to scrutinize the mechanisms (e.g., whether this phenomenon is due to school transition or peer pressure). Also, mastery-oriented students may allow personal interest to dictate their study efforts, overspend their attention, time, energy, and other resources on favored topics, and neglect other essential parts of the course content, thus jeopardizing their immediate school results (e.g., exam scores). Whether these students will attain any creative achievements in the future can only be answered by a follow-up investigation. The time frame is also a crucial factor in designing longitudinal research. For instance, there is evidence showing that the positive effect of achievement motivation training may not be noticeable in 6 months but will be significant in 1.5 years. In this case, sufficient, long-term research commitment is essential for a rigorous investigation on the effectiveness of motivational interventions.

Cultural, social-economic, and gender factors – Cultural background and parental expectations may influence the perception of achievement. It is a challenging task for researchers to adopt tests using appropriate cues to elicit achievement imagery across cultures or to design an achievement motivation inventory applicable to different cultural environments. The early research trend examining children's needs for achievement in a middle-class-biased performance setting or using gender-biased material and procedures to test the hypothesis that women do not want to be achievers but want to be liked has been noticed by the research community and to some extent rectified. In this regard, naturalistic studies and ethnographic approaches should be encouraged to examine issues associated with achievement motivation.

Neural mechanisms of academic achievement motivation – From a psycho-neurological perspective, achievement motivation must engage working memory to process the information of what has been achieved and what needs to pursue in order to attain ultimate goals. It is of interest to examine particular brain activities related to expectation and rewards during learning. Using a 3.0 T functional magnetic resonance imaging (fMRI) technique, Mizuno et al. (2008) conducted a series of experiments to inspect the association between the self-reported academic achievement motivation and the cortical activities corresponding to academic reward. They suggest that the putamen may be the critical region activated for governing achievement motivation. Research in this direction appears promising.

Changes in learning environment and learners' study habit due to technological advancement – The rapid development in information technology (both hardware and software) during recent decades has been significantly shaping learning environments and this accelerated technological advancement has great impact on learners' study habits in the OECD countries and many developing countries, such as searching information for assignments via Internet or intranet at home rather than going to the library, joining a virtual forum after a tutorial, and playing wii games instead of entering a nearby gym for a break during study. The impact of such ecological changes in modern education on learners' motivation needs to be carefully assessed (Low and Jin 2009). On the one hand, academic achievement motivation can be enhanced by timely online feedback and by interesting multimedia simulations or presentations (see *Modality effect*). On the other hand, a student's enthusiasm may be hindered due to technological anxiety or the goal-setting process can be distorted by the encounter of irrelevant, "seductive" information in the cyber space. It is therefore important to improve instructional design and implement training for self-regulated learning in order to foster constructive achievement motivation.

Cross-References

- ► Academic Motivation
- ► Attribution Theory of Motivation
- ► Modality Effect
- ► Motivation, Volition and Performance
- ► Redundancy Effect
- ► Self-Organized Learning
- ► Self-Regulated Learning
- ► Stress and Learning

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Achievement Motivation Enhancement

► Motivation Enhancement

Achievement Motivation Intervention

► Motivation Enhancement

Acknowledgment

► Attribution Theory in Communication Research

Acoustic and Phonological Learning

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Synonyms

Speech category learning; Speech perceptual learning

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Definition

When people learn to perceive the sounds of languages, they may do so on at least two bases: Acoustic learning indicates that the differentiation among sounds is based on increasing sensitivity to small acoustic distinctions which are then used to label tokens reliably. In phonological learning, the differentiation among sounds is based on increasing categorization. In this mode, subjects become less attuned to within-category acoustic distinctions, suggesting cognitive restructuring.

Theoretical Background

In most circumstances, listeners appear to extract meaning from speech in an effortless and successful way. It is assumed that in order to achieve this remarkable performance, listeners decompose the speech flow into a sequence of segments that are mapped onto phonological categories (vowels and consonants). A major issue is how this categorization is achieved in spite of the large variability exhibited by speech sounds both within and across speakers. Early speech perception research provided a major key to understanding this process by showing that there was a nonlinear relationship between acoustics and perception, at least for a category of speech sounds referred to as stop consonants (whose realization involves a complete closure of the vocal tract, e.g., /d/ or /t/). When a gradual change was made to an acoustic parameter that allows one consonant to be perceptually differentiated from another (e.g., the duration of the interval from stop release to vowel onset, which is shorter in /da/ than in /ta/), listeners were found to respond to this change in a nonlinear way, with an abrupt shift from one perceived category to the other as the acoustic parameter reached a critical value. In addition, discrimination between speech stimuli proved to be significantly better across this perceptual boundary than on either side of it, even when the size of the acoustic change was identical – a phenomenon called *categorical perception* (Liberman et al. 1967). Note that the acoustic region in which perceptual change occurs is defined by the phonetic categories of the listener's native language. For example, for the same continuum, English listeners discriminate two categories (/ba/ vs. /da/) whereas Hindi listeners discriminate three (Werker and Lalonde 1988).

Because adults are capable of learning new languages, they are also capable of learning to distinguish nonnative contrasts. However, different nonnative distinctions are not equally easy (or equally difficult) to learn to perceive. Adults have considerable difficulty discriminating, identifying, and hence learning nonnative phonetic categories that overlap perceptually with a single phonetic category in their native language. These tend to be assimilated by listeners to their native categories. For example, American English–speaking adults have been found to perceptually assimilate both Hindi dental and retroflex stops to their native /d/ category. In other words, native speech sound categories can be likened to a perceptual filter through which nonnative speech sounds are processed. Recent research has revealed that this also extends to the perception of speech sounds in a nonnative regional variety of the listener's native language. Perceptual assimilation does not apply, however, to nonnative speech sounds that are very different from native ones. Adults can be quite adept at perceiving and learning contrasts that do not have near equivalents in their native language (e.g., so-called click consonants in Zulu for English-speaking listeners can easily be perceived as distinct on a purely acoustic basis). In general, an adult listener's ability to perceive or learn nonnative distinctions is thought to be constrained by the similarity or dissimilarity of the new sounds to native ones, with the native sound defined as a formal element in an abstract phonological system (Best et al. 1988).

Similarity to an existing native category is not the only determinant of whether a nonnative contrast can be perceived reliably by adult listeners. The specific training regime used also can significantly affect sensitivity to nonnative contrasts. For example, adult Japanese monolinguals, who show a strong tendency to assimilate both English /r/ and /l/ consonants to their native post-alveolar flap consonant category, can improve their ability to discriminate between /r/ and /l/ following training that entails them being exposed to a large variety of instances of /r/ and /l/. In general, learning is facilitated when the training set is characterized by a great deal of acoustic variability instantiating a given category, that is, when the training set more closely imitates actual language experience (Lively et al. 1993).

One possible mechanism for assimilation is the notion that categories organize themselves around so-called prototypes that emerge as the result of the listener's repeated exposure to the speech sounds in their language. A prototype is the best exemplar in each category and can be thought of as occupying the center of that category. This causes a warping of the perceptual space around the prototypes, such that listeners have greater difficulty discriminating between speech sounds close to the same prototype than between speech sounds that have the same acoustic difference but are situated further from a prototype. Such a phenomenon has been referred to as the perceptual magnet effect because speech sounds located in the vicinity of the prototype seem to be perceptually attracted to it (Kuhl 1991). In this theoretical framework, perceptual boundaries between speech sound categories are to a certain extent conditioned by how prototypes are distributed in the perceptual space. An important consequence of this is that although it is attuned to native speech sound categories from an early stage, the listener's perceptual system remains plastic enough throughout adulthood to adjust, to a certain extent, to within-language acoustic variation and to nonnative speech sounds.

Important Scientific Research and Open Questions

There is a great deal of individual difference in the ability to learn to discriminate nonnative contrasts, or nonnative from native ones, even among individuals with similar language backgrounds. Some people are able to perceive nonnative sounds reliably and distinctly in adulthood without any training, or to learn them quickly with limited training. For others, learning to hear these distinctions is slow and effortful or even highly unlikely. Empirically, individual differences are generally identified in the character of pretraining identification and discrimination test performance and by the relationship between pre- and post-training performance on the same measures. An open question is whether some listeners perceive novel speech sounds in a speech-specific manner, whereas others can focus on the sounds themselves and attend more to their physical/acoustic characteristics.

Evidence for this comes from recent work that extends the topic of investigation from what is learned to how it is learned. In this dynamical view, the emphasis is on what individual subjects perceive and how that evolves over time, rather than on an idealized description of the language sound system. Individual subjects utilize distinct modes of learning, based either on becoming more attuned to small acoustic distinctions between stimuli or becoming less attuned to within-category acoustic distinctions (suggesting cognitive restructuring). Acoustic learning is accompanied by a gradual adjustment of the individual's perceptual space over the learning sessions without the abrupt transition typically involved in forming a new phonological category (Tuller et al. 2008). This finding leads to important questions regarding the functional neural substrates underlying the perception of native versus newly learned, nonnative speech sounds, and more specifically, regarding possible differences in neural functional connectivity among individuals who successfully learn new speech sounds using an acoustic basis, those who learn using a phonological basis, and those who do not learn even after extensive training.

Another productive avenue may be to explore why learning is facilitated when the training set contains a great deal of acoustic variability. Although the notion of a perceptual magnet provides a putative mechanism for incorporating the many acoustic instantiations of a sound into what becomes essentially a fuzzy category, it is certainly not the only possibility. For example, recent recasting of speech categories into dynamic terms suggests that variability should be evaluated as expressing the relative stability of categories, which is in turn related to their learnability. In this view, the evolution of variability during training, not mean variability over some time frame, may be a more appropriate metric for how learning takes place. The aim is to understand how acoustic learning and phonological learning, dynamic and symbolic descriptions, continuity and discreteness, can coexist.

Cross-References

► Bilingualism and Learning
► Categorical Representation
► Computational Models of Human Learning
► Individual Differences
► Language Acquisition and Development
► Language Development and Behavioral Methods
► Linguistic Factors in Learning
► Phonological Representation
► Psycholinguistics and Learning

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Acquired-Drive Experiment

An experiment in which, in a first phase, subjects (often, rats) undergo Pavlovian fear conditioning of a conditioned stimulus (CS) to an aversive unconditioned stimulus (US; typically, a shock). In a second phase, the CS is presented and subjects are allowed to perform a response that terminates it. In that phase, the US never occurs, regardless of the subjects' actions. Learning of the response is usually considered evidence for the idea that CS termination can reinforce avoidance responses, as proposed by two-factor theory. Acquired-drive experiments are sometimes called escape-from-fear (EFF) experiments, because terminating the CS is assumed to provide an escape from the fear associated with the CS.

Acquiring and Using (Generic) Knowledge

► Learning and Understanding

Acquiring Organizational Learning Norms

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Synonyms

Knowledge management; Learning organization

Definition

Learning organizations, as organizations, consist of organizational norms that enable and constrain certain learning styles, being more or less single- (error correction) or double-loop (innovation) learning. Configurations of learning norms are called *learning prototypes*. Organizational learning capabilities thus are appropriate matches of learning needs and organizational learning norms. **The adjustment of learning prototypes to changing environmental learning here needs is called *deutero learning*.**

Theoretical Background

Organizational learning is a major topic for organization studies, because it is about how organizations can gain a better action repertoire in increasingly complex and dynamic environments by expanding their knowledge base. For these environments, it is not the knowledge itself, but the learning capabilities that determine effectiveness. These capabilities have been summarized under the concept of "the learning organization" as organizational arrangements that (1) provide people with direct feedback to their performance, (2) decentralize and reduce bureaucracy to support initiatives and creativity, (3) emphasize expertise development, (4) get people to contribute to the organizational knowledge base, and (5) create open communications with least defensiveness. *Environmental complexity* and *dynamics* are the main sources of *learning needs* to cope with while developing effective learning organizations. These learning organizations, as organizations, consist of organizational norms that enable and constrain certain learning styles, being more or less single- (error correction) or double-loop (innovation) learning. Configurations of learning norms are called *learning prototypes* here. Organizational learning capabilities thus are appropriate matches of learning needs and organizational learning norms. **The adjustment of learning prototypes to changing environmental learning needs is called *deutero learning*.** As a consequence of the organizing process that is involved in deutero learning, adjustments of the learning prototype might become difficult. Therefore, it is important to ask what problems organizations have in moving to another learning prototype when their learning needs change. Figure 1 summarizes the propositions mentioned here.

Organizational Learning Needs and Styles

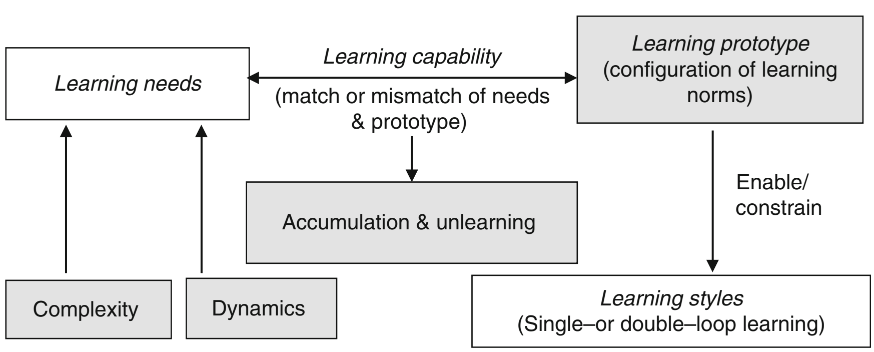
Although many authors on organizational learning show the importance of organizational learning, they seldom consider the learning needs. Four approaches to learning needs are: (1) *knowledge gap* analysis for identifying strategic knowledge needs, (2) classification of *problems* to select operationally required knowledge and skills, (3) coping with organizational tremors and jolts by anticipation, response, and adjustments of behavioral reportoires, and (4) *decisional uncertainty* (contingency) measurement. The last approach is further elaborated below.

The result and objective of organizational learning is the creation of *action–outcome* knowledge (explanations, predictions, and means-end theories). Two problems affect this action–outcome theory development process, namely, the complexity (requiring adding factors to understand what is going on) and the dynamics of the environment (requiring frequent changes of factors in the action–outcome theory). Table 1 provides a classification of learning needs. In this classification, dynamics is a stronger determiner of learning needs than complexity, because high dynamics in a simple situation will continuously require high learning efforts. High complexity in a stable situation, however, will lead to declining learning needs because no changes of the action–outcome theory are required at a certain level of comprehension.

According to Argyris and Schön (1978), two *styles* of learning (also named learning depth) exist. The single-loop learning (SLL) style aims at adaptation by effectively using existing actionoutcome theories. This requires learning, because the decision maker needs to recognize a problem and select an "appropriate" mode of coping with the problem, within the constraints set by the action–outcome theory (e.g., an optimization goal). The double-loop learning (DLL) style wants to develop and innovate existing action–outcome theories based on experiences with the ineffectiveness of their application.

Stable and simple environments do not require much DLL. The environment is low risk, and therefore discourages the search for innovations. When the environment becomes more dynamic and complex, more active development and innovation (DLL) is required, because too many unresolved problems will appear.

The need to retain and reuse existing knowledge (SLL) complicates the unlearning of obsolete knowledge, which is often required in DLL. Nevertheless, it may contribute substantially to efficiency, reliability, and quality of products and services. Additionally, DLL is enabled but also limited by (often tacit) learning norms. It has been stated often that organizations might much more profitably invest in DLL instead of SLL, because of the higher returns for intellectual and creative activities. Unfortunately, according to Argyris and Schön (1978), reduced openness in



Acquiring Organizational Learning Norms. Fig. 1 Basic concepts related to learning needs and learning capabilities

Acquiring Organizational Learning Norms. Table 1
Learning norms

Organizational dynamics	Organizational complexity	
	Simple	Complex
Static	Low learning needs	Moderately low learning needs
Dynamic	Moderately high learning needs	High learning needs

communication, domination of some people over others, and tricks in protecting one from being hurt and evaluated negatively are dominant learning norms in (western) organizations that obstruct effective DLL. The organizational learning literature has put many efforts in reversing this "model I" (Argyris and Schön) set of learning norms.

Learning Prototypes and Learning Norms

Learning prototypes are configurations of learning norms that match a level of learning needs. In *simple-static* environments, organizations have to deal with a small number of similar factors and components that remain basically the same. In such environments, the learning needs are low and consequently organizations need not put much effort in developing an explicit learning policy. High stability and simplicity make that learning in small organizations be done efficiently and effectively by one person or a small group, and that in large organizations it is useful to develop formal procedures of knowledge handling to divide the learning load (Hedberg 1981). The dominant learning style is single-loop and the learning is task-motivated, well-structured, part of formal procedures, and planned. This prototype could be named *bureaucratic learning.*

Organizations in *complex-static* environments have to deal with large numbers and dissimilar factors and components that remain basically the same. In such environments, learning needs are moderately low. The high complexity means that learning activities must be split up among several experts. Because the environment is stable, not many major changes (indicating DLL) in the action–outcome theories happen, or they happen only after extensive formal learning procedures. Because the role of experts is so vital here, the corresponding learning prototype could be named *expert learning.*

In *simple-dynamic environments*, organizations have to deal with a small number of similar factors and components that are in a continual process of change. Consequently, the organizational learning needs are moderately high. The high dynamics require that people are given much support and individual responsibilities to detect and correct errors (SLL), but also to discover new solutions for new and unknown problems (DLL). The required innovative capabilities and creativity can only be reached when people are not constrained by formal rules or hierarchies, and when learning may happen everywhere in the company. Because the problems are often not too complex, individuals can do a lot at solving them when they are given sufficient latitude and problem-solving autonomy. The related learning prototype, therefore, could be named *dispersed* learning, and has been described previously as a learning lab.

In *complex-dynamic* environments, organizations have to deal with many and dissimilar factors and components in continual change. These environments have high learning needs and require strong decentralization and high job specialization. Because of the high complexity and dynamics, much DLL must happen (in R&D and innovation processes) besides the large amount of SLL by correcting errors in the existing business. The organizational learning policy clearly states how much attention to both has to be given. The organizational structure (called hypertext organization) enables to switch intentionally between learning styles, and management styles are such that all people at all levels in the organization are motivated and responsible regarding learning (called "middle-up-down management"). Because of the complexity of combining the sometimes–conflicting demands of single-loop and double-loop learning, formal rules exist about the learning responsibilities, but at the same time enough flexibility exists. The related organizational learning prototype could be named the *knowledge-creating company.*

The learning norms that configure the mentioned learning prototypes consist of:

- *Procedural learning norms* concern the sharing, dissemination, and handling of information for organizational learning, and influence the actual use of information systems and communication media for organizational learning. In this context, the effectiveness of formal (IT/rule-based) media is discussed against informal media (face-to-face, social media, and interpersonal understanding).

- Learning *action norms* are the incentives to act on the basis of new insights. It is well known that great new insights are often difficult to put into action, often because learning activities do not necessarily lead to win-win situations for all people involved.
- Learning *responsibility norms* have to be well established, as otherwise learning might not occur effectively in relation to the learning needs and policy.
- The *learning policy norms* consist of statements concerning (1) the development of an organizational learning infrastructure (e.g., information technologies, budgets, and experts); (2) the development of core competencies; (3) the basic organizing principles for the learning process, like (de-)centralization, internal democracy, incentives for creative thinking; and (4) the role of organizational learning in relation to other organizational activities and priorities. The learning policies must be implemented in learning responsibilities, action, and procedural norms (Wijnhoven 2001).

Table 2 summarizes the mentioned propositions about the learning needs, learning prototypes, and learning norms.

Learning Capabilities

The previous section has described organizational learning capabilities as matches of needs and norms. Because there is a trend for increasing complexity and dynamics in almost all industries, mismatches happen frequently and organizations have to acquire the appropriate learning capabilities. The required changes of the learning norms often are preceded by a sense of crisis. To solve this crisis, new learning capabilities must be acquired. This requires the *accumulation* of learning norms as well as *unlearning* of inappropriate ones.

It might be argued that any movement to another learning prototype type aims at solving specific problems in the learning process. Starting at the bureaucratic learning prototype, the increase of complexity requires the introduction of experts, who concentrate and maintain the knowledge resources and can solve complex problems by applying more advanced knowledge. This solution of the *complexity crisis* might however lead to new problems when the complexity increases even more. In very high complexity levels, it is needed to have several experts collaborate to solve one big

Acquiring Organizational Learning Norms. Table 2 Expected effective patterns of learning needs, learning norms, and learning prototypes

Learning needs: / Learning norms	1: Low	2: Moderately low	3: Moderately high	4: High
Identity and policy norms	Centralized and formal learning aiming at SLL	Planned division of learning labor	Culture and budgets support innovation, creativity, and innovativeness	Internalized SLL and DLL policies, carefully coordinating learning initiatives
Responsibility norms	SLL by specialists	SLL by many people, but functionally organized. DLL by experts	DLL by many, unorganized	DLL and SLL. Switch between both is well organized. Hypertext organization
Action norms	Task motivation	Expertise acquisition for payment and job security	Incentive system; extra rewards for knowledge creation	Internalization of learning policies
Procedural norms	Formal	Formal	Informal	Formal and informal
Learning prototype	Bureaucratic learning	Expert learning	Dispersed learning	Knowledge creation company

problem. Collaboration of experts is a problem in itself when they are used to work individually or when it is hard to find out who has what expertise and how collaboration should be organized. Overcoming the problems of the *expertise assembly* thus requires combinative capabilities that, for instance, can be created by the explicit development and management of a shared organizational knowledge base.

Starting at the bureaucratic learning prototype in simple environments again, the increase of dynamics requires higher *speed of problem solution* than this type can provide. Decentralization of responsibilities and resources is a powerful means to realize this and leads to what we called the dispersed learning prototype. This dispersed prototype, however, easily underutilizes dispersed expertise, and the learning activities may be poorly aligned with the business intent.

The knowledge-creating company incorporates both managerial (middle-up-down) and structural (hypertext organization) aspects required to facilitate and coordinate learning in high complex and high dynamic environments.

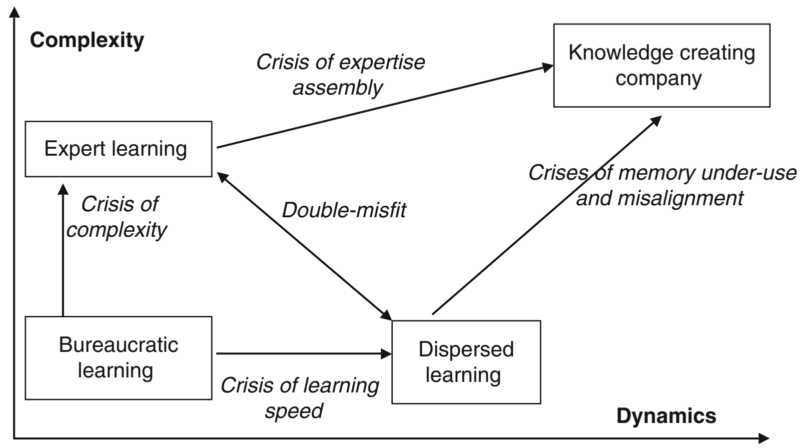
The previous considerations all describe how organizations can become *effective* learning organizations, and it is stated that the knowledge-creating company can handle high complexity *and* dynamics. In some cases, however, the learning needs may be lower and even decline. In such environment, the knowledge creation prototype may still generate the required knowledge (and thus is effective); however, the knowledge creation could have been done in a more efficient way as well. Table 3 also shows some other misfits and related problems. Figure 2 summarizes the relations between learning needs, learning prototypes, and learning crises.

Important Scientific Research and Open Questions

To understand the required learning norms, it is necessary to first assess the learning needs of an organization. This entry proposed to continue previous work of Duncan and Weiss, consisting of a complexity- and dynamics-based learning needs measure. If we want to design learning organizations while coping with

Acquiring Organizational Learning Norms. Table 3 Learning prototypes and indicators of learning needs mismatches

Learning need \ Prototype	Bureaucratic	Expert	Dispersed	Knowledge creation
Low	Match	Overhead	Overhead	Overhead
		Knowledge adoption problems because of the mental distance of experts from the application field	Inefficiencies in primary process	Complex coordination and too frequent changes in work groups
Moderately low	Crisis of complexity	Match	Learning coordination problems (too much delegation, lack of overview)	Loss of concentrated expert groups
Moderately high	Crisis of complexity and crisis of speed	Crisis of speed	Match	Task force groups are not needed because problems will be solved in the business groups
High	Crisis of complexity, crisis of speed, crisis of knowledge consistency, and crisis of solution assembly	Crisis of speed, crisis of solution assembly, and crisis of knowledge consistency	Crisis of knowledge consistency and crisis of solution assembly	Match



Acquiring Organizational Learning Norms. Fig. 2 Levels of learning and learning prototypes

the specific type of knowledge required, knowledge gaps analysis and problem types–based learning needs measures are important too. Particularly interesting on this respect too is that many knowledge sources are in the organization's external environment, thus requiring collaboration, acquisition, market procurement, or external consultancy (Kraaijenbrink and Wijnhoven 2008). The prototypes defined here still may be valid but the inclusion of external partners requires some extra learning norms to motivate effective knowledge creation and avoid the risks involved. Additionally, it is known that knowledge is a very heterogeneous asset (Mingers 2008), which implies that the maintenance and development of some action–outcome theories may require very different prototypes. These may nevertheless be governed by one overarching prototype to keep consistency and realize effective collaboration of learning efforts.

This entry also described the problems of moving from one prototype to another depending on changes in an organization's learning needs. In that case, the organization has to acquire learning capabilities or reduce learning needs (e.g., via mergers, regulation of the existing industry, or codifying work procedures).

Two remarks for the research agenda may be important to make here. First, the main parameters in the prototype design (learning needs and learning norms) are still in need of rigorous operationalization and measurement. These measures will help in assessing organizational learning capabilities and evaluating the propositions mentioned in this entry. Second, the idea of a "one best solution," like knowledge creation prototype, may be unwise when it leads to the inefficiencies predicted by this theory. Although, effectiveness of learning is more important than its efficiency, inefficient learning may use too many resources, reducing the opportunities of effective learning in the end. In the information age, it is important to study information technology's impact and contributions to organizational learning efficiency, which indirectly impact organizational learning effectiveness (McLure-Wasko and Faraj 2005).

Cross-References

- ▶ Absorptive Capacity and Organizational Learning
- ▶ Acquiring Organizational Learning Norms
- ▶ Adaptation and Learning
- ▶ Deutero Learning
- ▶ Organizational Change and Learning
- ▶ Reorganization and Learning
- ▶ The Learning Organization
- ▶ Workplace Learning

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Acquisition

► Internalization

Acquisition of Depression

► Learning Mechanisms of Depression

Acquisition of Expertise

► Development of Expertise
► Development of Expertise and High Performance in Content-Area Learning

Acquisition of Fact Knowledge

► Fact Learning

Acquisition of Knowledge

► Individual Learning
► Psychology of Learning (Overview Article)

Acquisition of Schemas

► Schema Development

Acquisitive Learning

Starts by focusing on observable behavior of the learner and involves the idea that behavior can be changed by feedback from the environment. This kind of learning is associated with reproducing desirable behavior defined in measurable outcomes.

ACT - Adaptive Control of Thought

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Synonyms

ACT-R

Definition

ACT (Adaptive Control of Thought) is a cognitive architecture based on the assumption of a unified theory of mind. The goal of this cognitive theory is to explain how human cognition works and what the structures and processes of human memory, thinking, problem solving, and language are. The core of ACT is a production system with a pattern matcher that works on memory and perceptual-motor modules via buffers. The current version of adaptive control of thought (ACT-R) is based on the principle of rationality of the human mind. Simulations with ACT-R allow for predicting typical measures in psychological experiments like latency (time to perform a task), accuracy (correct vs. false responses), and neurological data (e.g., FMRI-data).

Theoretical Background

Starting from the HAM-model (Human Associative Memory), John Anderson developed the Adaptive Control of Thought theory in several steps, resulting in a first major version ACT* (Anderson 1983). Besides other approaches like SOAR (Newell 1990), it was one of the most recognized attempts to formulate a cognitive architecture according to the idea of a unified theory of mind (Newell 1990). ACT* is a production system with a memory for production rules describing procedural knowledge, a declarative memory representing declarative knowledge in terms of cognitive units, and a working memory that serves as a connection to the outside world that holds elements being currently in the focus of attention. Cognitive elements entering working memory are sources of activation that spreads to related cognitive units in the declarative memory. The strength of cognitive units increases every time a unit created in working memory is made permanent or updated in the declarative long-term memory. The production system continuously tries to apply production rules. A pattern-matching process matches production rules against active structures in the working memory. The production rule firing fastest with respect to five conflict resolution principles will be applied resulting in creating new units in working memory and/or creating new production rules or tuning already existing production rules. The strength of production rules increases with each successful application and decreases in case the application of the production rule fails. Procedural learning in ACT* works according to Fitts' steps of skill acquisition. In a first declarative step, general production rules are used for an interpretive application of declarative knowledge. In the second step, new knowledge is compiled by composition and proceduralization of rules. In the final third step, productions are further tuned by generalization, discrimination, and strengthening processes. ACT* has been applied successfully to human skill acquisition, to predict variants of the fan effect, or to the development of intelligent tutoring systems.

The introduction of the principle of rationality ("The cognitive system operates at all times to optimize the adaptation of the behavior of the organism," Anderson 1990, p. 28) led to a major revision of the ACT theory. Anderson (1990) formulated the "Rational Analysis" of human cognition, a mathematical approach mainly based on the Bayes Theorem. The new version of the cognitive architecture was called "Adaptive Control of Thought – Rational" (ACT-R). The underlying mathematical calculations of the functionality of ACT-R are now based on the assumptions of the Rational Analysis of cognition (Anderson 1993).

In subsequent years, ACT-R has been augmented with perceptual and motor capabilities (Anderson and Lebiere 1998) and with the introduction of modules and buffers (Anderson et al. 2004). Modules can theoretically be mapped to brain systems. Buffers hold temporarily active structures to allow the interaction between the procedural memory module on the one side and the declarative memory module and the motor-perceptual modules on the other side.

Important Scientific Research and Open Questions

The cognitive architecture ACT (ACT*, ACT-R) has been used to create models in a lot of different domains. The results of simulation runs with these models have been compared to behavioral data from experiments with human subjects. In principle this works as follows. For a simulation, a specific ACT model is created (programmed) with general assumptions about human cognition included with the ACT architecture on the one side and specific assumptions about the particular domain on the other side. This ACT model allows for specific predictions for experiments in the particular domain. Simulation runs with the ACT model result in data that can be compared to the respective quantitative measures (latency, accuracy, FRMI data) from experiments with groups of human subjects.

ACT has been used successfully to develop models in domains like memory and attention (e.g., the fan effect of interference, primacy and recency effects in list learning, and serial recall), natural language understanding and production, modeling human behavior and skill acquisition in dynamic tasks and complex problem solving, and in education (e.g., the cognitive tutors developed at the Pittsburgh Science of Learning Center). This research resulted in hundreds of scientific publications in major journals, edited books, and monographs.

In recent studies, ACT-R has been used in the field of cognitive neuroscience. Patterns of brain activation during imaging experiments have been successfully compared to predictions from simulation runs with respective to ACT-R models (e.g., Anderson et al. 2004).

The ACT theory is under steady development as can be seen from the long history of different implementations as described above. Many groups of researchers spread over the whole world create and test specific cognitive models. The source code of the ACT-R implementation and further information about ACT-R is freely available from the ACT-R website (http://act-r.psy.cmu.edu/).

Cross-References

► Cognitive Skill Acquisition
► Human Cognitive Architecture

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Act of Presentations

► Representations, Presentations, and Conceptual Schemas

Acting the Situations

► Role-Play and the Development of Mental Models

Action Enquiry

► Action Research on Learning

Action Inquiry

► Action Learning

Action Learning

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Synonyms

Action inquiry; Action modality; Action reflection learning

Definition

Action learning is one of a family of action inquiry approaches to problem solving and learning. It is a way of learning with and from others in the course of tackling difficult issues, typically involving a small group of people (*action learning set*) meeting together to tackle difficult issues through questioning one another, experimentation, and reflection. Action learning is employed for a variety of individual and organizational development purposes as well as to address broad systemic and societal problems. It is a mode of inquiry with particular value for situations where people want to change something about their situation at the same time gain greater insight into both the issue and their own practice. It is not a simplistic "learning by doing" as sometimes mischaracterized.

Action learning is best described as an approach or ethos that has most or all of the following features:

- *A task:* a problem or opportunity that needs action taken. This may be a collective issue or individual. Learning and development are greatest when issues are multi-faceted, with unclear boundaries and several stakeholders, rather than puzzles that have a simple technical right answer.
- *People – action learners:* a group of people (typically 4–8, though can be more or less) who want to see the problem addressed and voluntarily work together in sets of peers. The set takes responsibility for organizing themselves and develops their own capacity to solve problems.
- *Doing:* The action learners have the capacity to take action not just diagnose the situation. They are prepared to experiment.

- *Formal instruction is insufficient:* external training, instruction, or expertise (*P*) is not relied upon.
- *Questioning* as the main way to help participants define their tasks/problems and reflect on their assumptions.
- *Reflection and feedback:* with the support and challenge of peers in the set, action learners review their experimental attempts to address the task, reflect on their actions, review their assumptions, and receive feedback.
- *Profound personal development* results from reflection upon action.
- *Organizational development* results where action learners are drawn from across an organization or network and focus on organization or systemic problems.
- *Facilitators* (also termed coach or set advisor) are commonly though not always used. Their role is to model the peer challenge/critical friend behaviors, to help the group establish ground rules and develop questioning, reflective, and inclusive team practices.

Theoretical Background

The power of action learning is rooted in both the underlying theories of learning, as well as its theory of action (*praxis*).

Theory of Learning

Reg Revans is widely accredited as the originator of action learning, starting with his work in the 1940s UK coal industry and Belgian Inter-University Programme (Revans 1982). When pit managers had problems, he encouraged them to meet together in small groups, on-site, and ask one another questions about what they saw in order to find their own solutions, rather than bring in "experts" to solve their problems for them. Revans' formative influences included his early training as a physicist at Cambridge University in the late 1920s, where he encountered Nobel-prize winning scientists meeting weekly, not to display their achievements, but to learn from one another through "describing one's very ignorance and, more than that, in trading it with others equally ready to confess their own."

Action learning, as developed by Revans, grew from a mid-twentieth-century disenchantment with positivism and prevailing cultural beliefs in the dominance of expertise, which fostered the conviction that, unless problems can be solved by a purely technical solution, there is more learning to be had through action being taken by those involved with an issue. Key was a synergy between learning and action "there can be no learning without action and no (sober and deliberate) action without learning." In other words learning through activity is essential, which makes action learning both an example of *experiential learning (Dewey, Kolb)* as well as an early form of *work-based learning (Raelin)*.

Action learning is based on adult learning theory that adults learn from taking action and reflecting on real issues that are of direct concern to them (*andragogy (Knowles; Boud)*). The search for fresh questions and "q" (*questioning insight*) is seen as more helpful than access to expert knowledge or "p." Learning happens through asking questions, investigation, experimentation, and reflection, rather than through reliance on external expertise.

Revans captured this theory of learning with the equation:

$$L \text{ (learning)} = P \text{ (programmed knowledge)} + Q \text{ (questioning insight)}$$

Based on assumptions of *social learning* action learning creates a setting where peers challenge and learn through interaction with one another, thereby encouraging *double loop learning* (Argyris and Schon): learning about the values and assumptions that underlie their actions. *Learning set* members learn the value of a good question for opening up different perspectives. Individuals working alone can limit their own learning by their mental models and unconscious patterns of behaviors.

As a consequence of *opportunistic and incidental learning* (Marsick and Watkins) provoked by taking action, and reflected on systematically within the action learning set, participants develop meta-skills such as self-insight, wider organization-political understanding and influencing abilities, as well as skills for learning how to learn (*Deuterolearning*, Bateson).

Interlocking Systems of Alpha, Beta, and Gamma

Individual learning and institutional change were conceived by Revans as being symbiotic through the interconnection of three systems:

- *Alpha* – strategy system: a person's context including their value system, external environment, and internal resources available
- *Beta* – decision cycle: application of scientific method through steps of survey, trial, action, audit, consolidation, or, now more commonly encapsulated in, Plan-Do-Review
- *Gamma* – learning system: the person's reflexivity in the sense of their awareness of their own tacit assumptions, mental frameworks, and awareness of others

System alpha, with the individual and organizational values, is the factor most likely to obstruct learning and effective action.

Theory of Action (Praxis)

Action learning can be seen as resting on two particular perspectives: *critical realism* and *pragmatism* (Pedler 1997). From critical realism, it rejects positivist assumptions that the world can be known, measured, and predicted with precision, but also eschews a purely social constructionist viewpoint that reality is no more than the language and discourses that we use to communicate. Thus action learning takes some things as being real (e.g., social problems with genuine effects) while acknowledging that our way of knowing can only be through the language we have to communicate about it. The debt to pragmatism (Dewey) is evident in Revan's System Beta and the characteristic action learning questions asked in pursuit of the best practicable solutions that enable people to make meaningful changes in their organizations, communities, and societies: "What are you trying to do? What is stopping you? Who could help you?"

More recent theorizing of the potential of action learning draws from *communities of practice* as well as to other areas or organization theory such as *actor network* and *organizational discourse.*

Applications

In current times there are many varied interpretations and applications of action learning across the world (O'Neil and Marsick 2007). The focus traverses a spectrum from *performativity* (giving priority to achieving business results through problem-resolution) through to *transformational learning* (emphasizing radical personal and/or organizational change). Organizations sponsor action learning to address open-ended problems, such as stimulating innovation. Public service bodies employ it to promote inter-agency collaboration on persistent social problems. Action learning finds frequent application in development programs, both in-company and academic, particularly post-graduate degrees and with individuals who have a level of discretion in their roles. Some practitioners/writers have found action learning has most value when practiced in conjunction with other related action strategies that also produce knowledge from collaborative action on challenging issues, notably *action research* (Zuber-Skerritt 2009).

Critical Action Learning

Critical action learning (CAL) is a development of conventional action learning because it aims to promote a deepening of critical thinking on the daily realities of participants; key to this process is the emphasis on collective as well as individual reflection. It attempts to supplement an individual's experiences of action (learning from experience), with the reflection of existing organizational, political, and emotional dynamics created in action (learning from organizing).

CAL has a number of distinguishing features, including: its emphasis on the way that learning is supported, avoided, and/or prevented through power relations; the linking of *questioning insight* to complex emotions, unconscious processes, and relations; and a more active facilitation role than implied within traditional action learning.

Key Features of Critical Action Learning

Valuing Practical Intelligence

CAL also eschews positivist and technicist approaches to research and practice, valuing instead, *phroenesis* (knowledge derived from practice and deliberation) and *metis* (knowledge based on experience). But such practice is always undertaken in a context of power and politics, which inevitably gives rise to conflict and tension. Hence CAL is a process in which knowledge is acquired through its relevance to the real-life engagements and tensions of the participants.

Critical Collaboration

Action learning has usually viewed the "action learning set" as the primary vehicle for collaboration, addressing work-based issues through questioning and reflection. The action learning set, then, serves as a mechanism or vehicle for self-governance, shared decision making, and problem solving which encourages people to own and be responsible for their actions. Criticality enters the fray when explicit recognition is accorded to the manner in which context, power, and emotion shape the scope for learning. Action learning sets are beset with the range of inequalities, tensions, and emotional fractures that characterize groups, organizations, and societies. Vince's (2004) concept of "organizing insight" illuminates the importance of critical collaboration because from this perspective, action learning sets become arenas for the interplay of emotional, political, and social relations. CAL affords an opportunity to examine "the politics that surround and inform organizing. . .to comprehend these politics it is often necessary to question these political choices and decisions, both consciously and unconsciously" (Vince 2004, p. 74). Through the process of *interactive governance* (Ram and Trehan 2010), collaboration allows the practical intelligence of groups of actors to be pressed into service in order to resolve matters of concern to them, in order to collectively propagate change within their organizations.

Critical Reflection and Change

While reflection focuses on the immediate, presenting details of a task or problem, critical reflection is directly concerned with promoting a process of critical reflection on the emotional and political processes that attend dynamics; importantly, it aims to implement the fruits of that reflection within practice both inside and outside the group. By adopting this more expansive approach, critical reflection can create new understandings by making conscious the social, political, professional, economic, and ethical assumptions constraining or supporting one's action in a specific context. Thus critical reflection blends learning through experience with theoretical and technical learning to form new knowledge constructions, and new behaviors and insights (Rigg and Trehan 2008).

Facilitation

Within critical action learning, the role of facilitation occupies interesting territory. In CAL, the role of facilitation is designed to support participants to explore with some intensity their assumptions and emotions about the issues under consideration. Equally important is the capacity to illuminate the ways in which participants reinforce behaviors or power relations that sustain *learning inaction*.

Important Scientific Research and Open Questions

- What are the characteristics of participant readiness and organization readiness for action learning?
- What kinds of issues benefit from action learning?
- Whom is it not suited for?
- How can it be best combined with other forms of development intervention (e.g., 360, 1–1 coaching)?
- Why is it so powerful?
- How can facilitator independence best be encouraged?
- What are the conditions or effective virtual action learning?
- Linking individual and organizational learning
- Critical action learning
- In what contexts are there benefits to combining action learning with other action modalities, such as action research, but also *participatory research*, *action science*, *developmental action inquiry*, *cooperative inquiry*, and *appreciative inquiry*.
- The continuing problem of definition

Cross-References

▶ Actor Network Theory and Learning
▶ Adult Learning/Andragogy
▶ Collaborative Learning and Critical Thinking
▶ Communities of Practice
▶ Deuterolearning
▶ Discourse
▶ Experiential Learning
▶ Learning Set Formation and Conceptualization
▶ Social Learning
▶ Work-Based Learning

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Action Modality

► Action Learning

Action Neuroimaging

► Neurophysiological Correlates of Learning to Dance

Action Plan

► Action Schemas

Action Possibility

► Affordance

Action Reflection Learning

► Action Learning

Action Regulation

► Neurophysiology of Motivated Learning

Action Regulation Theory

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Synonyms

ART

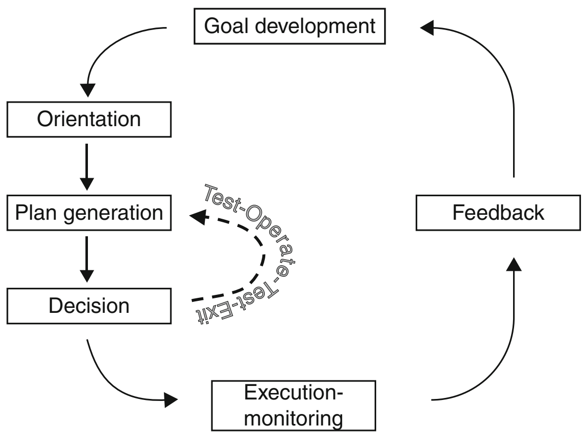
Definition

Action Regulation Theory (ART) is a psychological theory that looks at how individuals achieve their goals through processes of action and regulation. The theory is particularly useful for understanding organizational design and workflow analysis where flaws and hindrances in work procedures can be identified.

Theoretical Background

Action Regulation Theory (ART) is a cognitive theory, the preponderance of which is drawn from work in Germany and Scandinavia. It is based upon a conflux of ► Lewin's Field theories and the fundamentals of ► Activity Theory proposed by ► Leont'ev and ► Vygotski; however, where Activity Theory looks at *activities*, which comprise sets of actions, ART focuses on *specific actions*. An action is described as goal-oriented behavior (without a goal there is no cause for action), which is coupled with an inherent feedback cycle. This allows for the concept of action as a pseudo-iterative process. ART is concerned with the structure of goals and sub-goals, which are guided within a hierarchical framework of plans, monitoring, and feedback. These components of action are regarded as links between mental representations and the material and social environment. Thus, ART can be seen as a part of Activity Theory.

A practical analogy of action in this context could be a situation where, on a film set, if the sound technician requires a clearer sound image, he would instruct the *boom operator* to move the microphone closer to the object for a clearer audio recording. Referring to Fig. 1, the boom operator will *develop the goal* (and decide among other competing goals) – *I want to move the microphone closer to the bird's nest*. Next, she will *orient* herself by collecting information about the situation, and capturing and analyzing relevant signals



Action Regulation Theory. Fig. 1 The action process

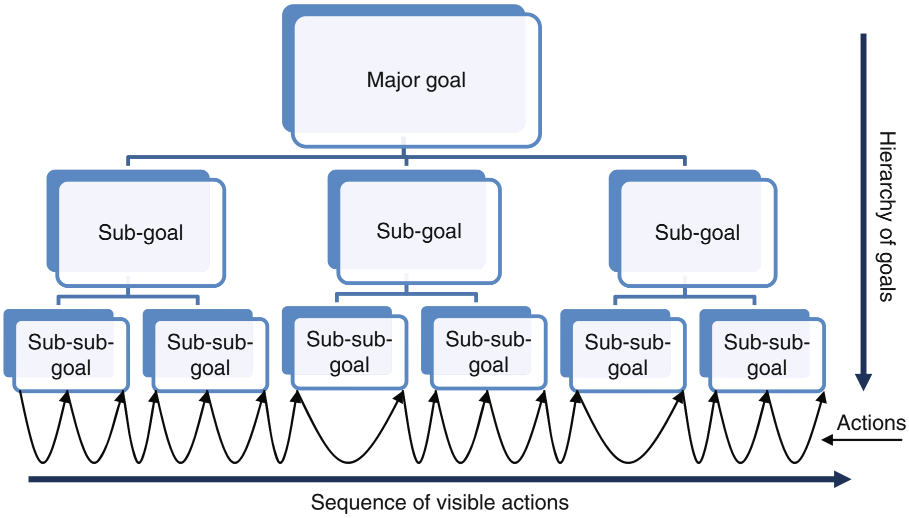
leading to a probable prognosis – *The wind is blowing and the branch is moving*. The signals relate to acquired models and knowledge the grip has gained through experience and training. The analysis will then lead to *generation of plans*; while this is usually constructed before the action is executed, it is not always comprehensively conceived and is usually a simple sub-goal with various levels of contingency – *I will rest the boom on the upper branch; if the branch is too flimsy, I will support the weight by readjusting my balance. Decision* is usually a subconscious commitment to execute the plan. It may include an iterative process of TOTE: Test-Operate-Test-Exit, where the process between plan and decision is being continuously fine-tuned. *Execution and monitoring* is the point at which the subject interacts with the object and both positions are altered – *The boom operator moves the microphone closer to the nest. Feedback* completes the action. It provides the subject with information regarding progress toward the goal and can be extrinsic or intrinsic – *The sound technician receives an improved sound level and advises the boom operator that the position is good.*

Put more simply, an action is stimulated by a goal, which motivates the actor toward action, which consequently requires the anticipation of future conditions and results in a need for an action plan. The process is complete with feedback providing a basis for comparison and learning.

While the above describes the "action" part of ART, "regulation" comes from the structure of actions and possible alternatives. This is because the actions are structured in a hierarchical system. Figure 2 illustrates the regulation process, taking into account the hierarchic-sequential manner of action regulation. Firstly, a goal is set. Then, working down, sub-goals are devised leading to actions. Completion of a set of actions will satisfy a sub-sub-goal or a sub-goal, which will eventually achieve the major goal. A parallel can be made to going from higher levels (the intellectual level) to lower levels (the sensorimotor level) in the human muscular–nervous system.

Through action, the theory allows the measurement and understanding of individuals' motivations and self-directed action toward goal completion. Through regulation, the theory measures the various learning and cognitive behaviors of individuals in the approach to, and management of, work options. Together, an implementation of ART will measure the efficiency of human–technical interaction in the workplace or organization by monitoring and reducing work hindrances.

The real value of ART lies in its ability to measure stresses or errors in the work system. Assuming that individuals are active and goal oriented, and they dynamically engage with their environment. Any failure to achieve a goal, which is potentially unavoidable, is due to an error. As human error is avoidable, errors arising through ART are assumed to be systemic and are due to misalignments within the sociotechnical system. Such sociotechnical flaws are known as work hindrances as they tend to disrupt stable activity in the average person resulting in stress factors. These stress factors are characteristics of the work task that hinder the regulation of mental processes because of poor technical or organizational design. In their study of stress in the workplace, Greiner et al. (1997) found four stress factors: barriers – the extent to which the work performance is impeded or interrupted because of work obstacles; time pressures – the measure of how fast the worker has to work to complete the assigned task under average work conditions, without barriers; monotonous working conditions – conditions that demand continuous visual attention, in combination with repetitive movements or information processing for at least 30 consecutive minutes; and time binding – the amount that worker autonomy is modified due to considerations over time and scheduling, regardless of time pressures. Work characteristics that are highly characteristic of stressors such as these will impede the task at hand, and force workers to try and cope with the situation, and will induce fatigue and poor occupational health and efficiency.



Action Regulation Theory. Fig. 2 The hierarchic-sequential regulation of action

ART addresses organizational analysis from a perspective that treats the organization as a ► system. A system is a complex arrangement of components which relate, directly or indirectly, in a stable or semi-stable causal network. The two important elements within this arrangement are control and structure (Burrell and Morgan 1979). *Control* requires the change of energy in one activity at one level in order to achieve meaningful activity at a higher level. To achieve this level of interference requires routes of communication that link activities and levels together. Humans are an implicit component in all social and work organizations. They link into the system through knowledge, providing a medium of interaction between the tool and the material being transformed, forming complex human activity systems. *Structure* comprises those elements within the human activity system that are either permanent or that will change slowly or occasionally. As such, structure, in terms of organization, includes hierarchy, reporting structure, rules and procedures, task design, lines of communication, and physical layout (Bond 2000).

The systems view of organizational design can be metaphorically referred to as organic or organistic as the system, in a macro sense, is reminiscent of its biological counterpart, both of which comprise systems and subsystems that symbiotically interrelate. However, for the organization, in an organic design structure, the human element is the natural systemic flaw. As Haberstroh states, humans exhibit "low channel capacity, lack of reliability, and poor computational ability," but on the other hand humans also have some desirable characteristics: "The strong points of a human element are its large memory capacity, its large repertory of responses, its flexibility in relating these responses to information inputs, and its ability to react creatively when the unexpected is encountered" (Haberstroh 1965, p. 1176). The challenge therefore is to design the organizational system so that it tolerates human weaknesses, while harnessing human strengths.

Important Scientific Research and Open Questions

Action Regulation Theory provides a basis for measuring and optimizing the human–technical interface in the workplace. Taking a systems perspective of organization, the theory builds on the work of Lewin with his force-field analysis and the work of Vygotski with Activity Theory, as well as the various approaches to Sociotechnical Systems Theory. ART is divided into two complementary approaches to analysis. Firstly, work processes are observed according to their capacity to allow human variation toward task action, and how this action assists or impedes workflow. Secondly, work processes are observed according to their ability to constrain or promote cognitive regulation and creativity, enabling workers to learn and innovate their way to more constructive and efficient outputs.

Overall, ART ultimately measures work impediments called hindrances and aims and tries to reduce these. ART provides a systematic method for analyzing organizations based on worker activity and work flow. It is a method that has been largely overlooked in non-European countries, but it is a method that may have merit in other parts of the world.

Cross-References

- ▶ Activity Theory
- ▶ Field Theory of Learning
- ▶ Sociotechnical Systems
- ▶ System

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Action Research

▶ Teaching Experiments and Professional Learning

Action Research on Learning

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Synonyms

Action enquiry; Practitioner research; Practitioner-based research; Practitioner-led research

Definition

Action research is carried out by teacher researchers with the motivation to know the intricate operational details of their particular schools, the way they teach, and the quality of their students' learning. Action research aims to facilitate insight, develop a teaching practice that is reactive and reflective, positively impact the school community and the educational environment, as well as help students be better learners (Mills 2003). Action research is further described as

▶ a form of collective self-reflective enquiry undertaken by participants in social situations in order to improve the rationality and justice of their own social or educational practices, as well as their understanding of those practices and the situations in which the practices are carried out. (Kemmis and McTaggart 1988, p. 5)

Action research on learning is research in the sense that teachers investigate their professional practice to develop better understanding on teaching and student learning and improve educational practices by developing a plan for action or change. By considering the practitioner and participants of an action research, action research promotes learning by reflecting on experience.

Theoretical Background

Kurt Zadek Lewin (1890–1947), a social psychologist interested in improving the social organization of groups and communities, developed the concept of action research in 1945 (Somekh and Zeichner 2009). Stephen Corey was a leading voice for promoting action research in education in the United States and thus action research was first introduced as a methodology in education research in 1949 (Somekh and Zeichner 2009). Action research is elegantly defined by Mills (2003) as

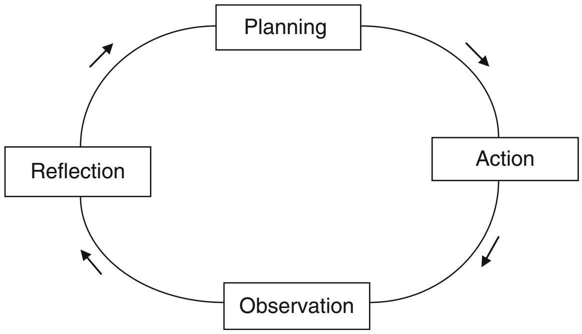
▶ any systematic inquiry conducted by teacher researchers to gather information about the ways their particular school operates, how they teach, and how well their students learn. The information is gathered with the goals of gaining insight, developing reflective practice, effecting positive changes in the school environment and on educational practices in general, and improving student outcomes. (Mills 2003, p. 4)

Kurt Lewin, Stephen Corey, Lawrence Stenhouse, Wilf Carr, and Stephen Kemmis were the first leaders in promoting the use of action research in educational and organizational change and the use of spiral cycle for action research: planning, action, observation, reflection and then re-planning, further implementation, observing, and reflecting (Kemmis and McTaggart 1988; Somekh and Zeichner 2009). Kemmis and McTaggart (1988) describe action research as "to plan, act, observe and reflect more carefully, more systematically, and more rigorously than one usually does in everyday life; and to use the relationships between these moments in the process as a source of both improvement and knowledge" (p. 10). Figure 1 demonstrates the spiral or cycle for action research, which involves planning, action, observation, and reflection (Kemmis and McTaggart 1988).

The cycles of action research (Kemmis and McTaggart 1988) steps can be summarized as below:

- Planning: This stage involves problem identification, systematically analyzing the problem, formulating research questions, outlining a strategic plan for action to address the identified problem.
- Action/implementation: This stage involves implementing the strategic and some intervention or action to address the problem.
- Observation/evaluation: This stage involves observing the outcomes of the strategic plan and evaluating the action taken in the previous phase with appropriate methods and techniques.
- Critical reflection: This stage involves reflecting critically on the results of the evaluation and the whole action and identifying a new problem and the process to start all over again.

The action research cycle illustrates an ongoing decision-making process. Action research on learning is conducted by teachers by using the action research cycle. The cycle supposes that teachers are the researchers in their own classrooms to investigate and understand the students, their learning, and the social context.



Action Research on Learning. Fig. 1 Cycle for action research

According to McNiff et al. (2003),

> action research is about individual's learning, in company with other people . . . Action research has both a personal and social aim is an improvement of your situation . . . Your report is an account of how your learning developed through studying your practice within the situation, and how your learning influenced the situation . . . What does matter is that you show your own process of learning, and explain how your new learning has helped your work within the situation. (p. 13)

McNiff et al. (2003) further state that

> action research aims to develop educative relationships to enable all participants to learn and grow. Action research is an intervention in personal practice to encourage improvement for oneself and others . . . It is a practical form of research, which recognizes that the world is not perfect and that professional values have to be negotiated. (p. 19)

The aim of action research is to foster the practitioners' better understanding of their practices, practical improvement, innovation, and development of social practice.

Kemmis and McTaggart (1988) suggest that the fundamental components of action research include the following: (1) developing a plan for improvement, (2) implementing the plan, (3) observing and documenting the effects of the plan, and (4) reflecting on the effects of the plan for further planning and informed action. Based on Kemmis and McTaggart (1988) formulation of action research, Mills (2003) developed the following framework for action research:

- Describe the problem and area of focus.
- Define the factors involved in your area of focus (e.g., the curriculum, school setting, socioeconomic factors, student outcomes, and instructional strategies).
- Develop research questions.
- Describe the intervention or innovation to be implemented.
- Develop a timeline for implementation.

- Describe the membership of the action research group.
- Develop a list of resources to implement the plan.
- Describe the data to be collected.
- Develop a data collection and analysis plan.
- Select appropriate tools of inquiry.
- Carry out the plan (implementation, data collection, and data analysis).
- Report the results and suggestions.

Action research on learning can be used in various areas of education such as school development, curriculum development, evaluation of learning and teaching activities, classroom process, special programs, on-site management, parent participation, and parent education.

Important Scientific Research and Open Questions

The action researcher learns by actively working on problems and then reflecting upon and questioning this experience in the system. Moreover, the action researcher develops ownership on learning and also develops leadership by implementing solutions to the problems and delivering results with others. Therefore, using action research on organizational learning and organizational change has been widely popular.

Reason (2001) emphasizes four important characteristics of action research as summarized below:

1. The primary purpose of action research is to develop practical knowing embodied moment-to-moment action by research/practitioner, and the development of learning organizations – communities of inquiry rooted in communities of practice.
2. Action research has a collaborative intent: a primary value of action research strategies is to increase people's involvement in the creation and application of knowledge about them and about their worlds.
3. Action research is rooted in each participant's in-depth, critical, and practical experience of the situation to be understood and acted in . . . Action research practitioners take into account many different forms of knowing – knowledge of our purposes as well of our ideas, knowledge that is based in intuition as well as the senses, knowledge expressed in aesthetic form . . ., and practical knowledge expressed in skill and competence.
4. Action research aims to develop theory, which is not simply abstract and descriptive but is a guide to inquiry and action in present time (p. 184).

Reason (2001) identifies three broad strategies of action research practice and emphasizes that the most compelling and enduring kind of action research engages the following three strategies:

- First-person action research/practice skills and methods address the ability of the researcher to foster an inquiring approach to his or her own life, to act awarely and choicefully, and to assess effects in the outside world while acting.
- Second-person action research/practice addresses our ability to inquire face-to-face with others into issues of mutual concern – for example, in the service of improving our personal and professional practices, both individually and separately. Second-person inquiry is also concerned with how to create communities of inquiry or learning organizations.
- Third-person research/practice aims to create a wider community of inquiry involving persons who, because they cannot be known to each other face-to-face (say, in a large, geographically dispersed corporation), have an impersonal quality (p. 182).

Somekh and Zeichner (2009) investigate how action research theories and practices are remodeled in local contexts and used to support educational reform. From an analysis of 46 publications from the period 2000–2008, five "variations" in the globalized theory and practice of action research are identified as below:

1. Action research in times of political upheaval and transition: The political nature of action research is very obvious when it is conducted in contexts where there has been a radical change of government in the recent past. Major ideological reorientation in the publicly declared vision of a new political system brings with it hopes for improvement that are nearly always unrealizable in the near future. Action research, particularly when it draws upon critical values . . .provides a starting point for working to realize the vision (p. 12).
2. Action research as a state-sponsored means of reforming schooling: During the second half of the 1990s, there was a move in several countries in East

Asia to introduce policies that formally adopted action research as a strategy for school reform. This can be seen as a response to a perceived need to encourage greater creativity and entrepreneurship in the workforce at a time of growing economic global competition (p. 14).

3. Co-option of action research by Western governments and school systems to control teachers: In recent years, the influence of neoliberal and neoconservative policies on state school systems . . . has created a situation where there has been an increased focus on treating teachers as technicians or educational clerks rather than as reflective professionals. Teachers' ability to exercise their judgment in their classrooms and to maintain control of the direction of their professional development has been eroded (p. 15).
4. Action research as a university-led reform movement: Universities in many countries are working in partnership with schools and governments to use action research as a strategy for educational reform. Often, this is through innovative projects involving school–university partnerships; often, it is through the work of graduate students who carry out action research in their own school as part of higher degree study (p. 15).
5. Action research as locally sponsored systemic reform sustained over time: In some cases, action research has been organized by teachers themselves as a local and teacher-directed form of professional development for individuals and has then been incorporated into reform efforts on a broader scale within school districts (p. 18).

To summarize, action research on learning is viewed as a practical and a systematic investigation in order to inform what is known about learning and to improve educational practices such as teaching methods and curriculum design. Action research is a reflective process using cyclical with four interrelated stages: plan, act, observe, and reflect. Action research method is best carried out with collaboration between researcher and other participants. Also, action research uses both qualitative and quantitative methods. According to Dewar and Sharp (2006), action learning is supported by the existence of colleagues who work together in solving real-world problems. Colleagues carry out the action research process within a framework, which provides the process with structure. The framework ensures that particular principles are held, that participants commit to be responsible for their own learning, and that they process emotional consequences of the situation. When one speaks of effectiveness of action research, encouragement of critical thinking, creative problem-solving, and self-development are inferred (Dewar and Sharp 2006).

Action research encourages practitioners to produce new knowledge, rather than merely use existing knowledge. Dewar and Sharp (2006) state that

- action research emphasizes the production of knowledge and action directly useful to practice and the empowerment of people, at a deeper level, through the process of constructing and using their own knowledge. Action research is thus deliberately concerned with the processes of development, improvement, and continuous learning. (p. 221)

Action researchers draw attention to the notion of commitment for rigorous examination and critique of researcher's own practice. Action researchers should be aware of the difficulties of conducting action research such as time demands, adequate research methods skills for a valid study, and the risk of ending up with non-generalizable. The most important notion of action research is that action research should be applied to the development of teaching and learning as its potential is identified.

Cross-References

► Experiential Learning Theory
► Learning Cycles
► Learning Spiral

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Action Schemas

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Synonyms

Action plan; Enactive schema

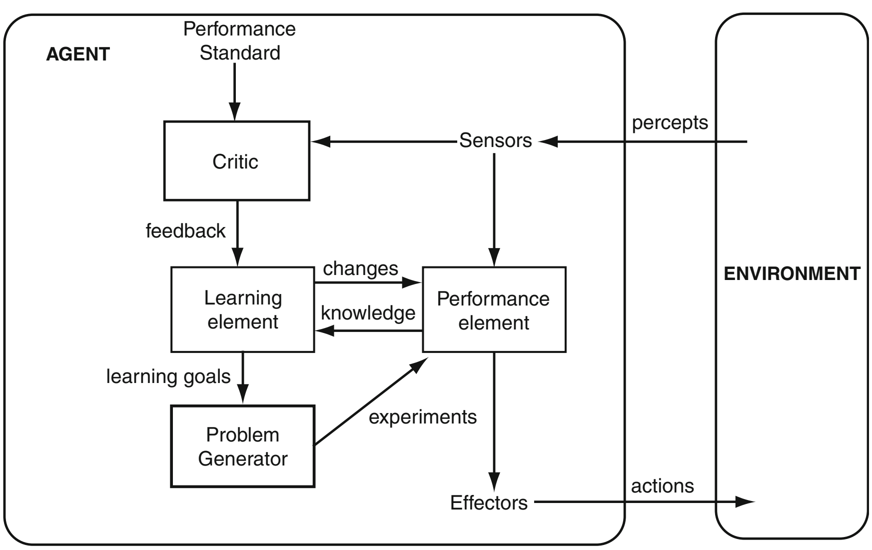
Definition

The term action schema(s) refers to a central concept of Piagetian epistemology and intellectual development as well as to a variety of techniques and languages for modeling sequential decision-making problems within the realm of machine learning and artificial intelligence (AI). In both fields of application, the basic assumption is that intelligent systems are active beings, that impact consciously and intentionally their environments. As a means of action regulation, the *schema of an action* is defined as the structured whole of the universalized characteristics of this action, i.e., the characteristics which enable intelligent systems to repeat the action and apply it to new contents. Closely related with actions schemas is the concept of *action slips* defined as the performance of actions which are not intended but carried out.

Theoretical Background

Piaget argued that infants acquire knowledge of the world by repeatedly executing action-producing schemas. Infants organize their sensuous and motor activities continuously to more complex and generalizable action schemas as "active organizations of lived experiences" (Piaget 1936, p. 332). Whatever is transposed, generalized, or differentiated in an action, everything that is common to each of the repetitions of an action contributes to the formation of such an action-producing schema. When an infant begins to grab deliberately at objects in the environment, it develops a simple action schema through repetition. When it begins to throw its pacifier onto the ground in the expectation that mommy or daddy will pick it up and give it back, it is developing a specific action schema, which involves testing conditions against a standard. This of course requires for the infant to fix the characteristics of individual actions and the objects involved permanently in knowledge memory and to abstract continually from the concrete objects by isolating and consolidating the invariant characteristics of objects and situations. Referring to Piaget's conception of schemas, it can be said that action schemas are the building blocks of information processing from perception to the organization of concepts.

"At each level, perception is bound up with action schemata at a higher order, and that these structures



Action Schemas. Fig. 1 Overall structure of a learning agent (Bringsjord 2011, http://kryten.mm.rpi.edu/SEP/index8.html) can influence those of perception. This would mean that knowledge of objects cannot be considered as being “first” perceptual and “afterward” super-perceptual. All knowledge of objects is a function of those action schemata to which the object is assimilated; and these range from the earliest reflexes to the most complex elaborations acquired by learning” (Inhelder and Piaget 1958, p. 6).

In order to correspond with the different levels of abstraction and generalization of schemas, Norman and Shallice (1986) suggest a hierarchy of schemas, which bring about actions. At the highest level is an abstract schema related to intention, and at lower levels are concrete schemas of those actions necessary to achieve the intention. A schema is translated into action when its level of activation is high and when the situation triggers off action. This idea corresponds with a three-level theory of action control: When a stimulus triggers only one particular action schema, that action is performed automatically. When a particular stimulus triggers several action schemas, the strongest activated schema inhibits the competing schemas in a semiautomatic response-selection process, which is called *contention scheduling*. This process is supervised by a control process, the so-called supervisory attentional system (SAS). When a ► habitual action is triggered, but inappropriate, the SAS increases the activation of a more appropriate action schema. As a consequence, the SAS can override contention scheduling in the case that a new response to familiar stimuli or a stop of performing a habitual action is necessary.

This explanation corresponds with the theoretical model of Hasher and Zacks (1979) concerning controlled and automatic processing of information. These authors argue that some processes become automatic through continuous practice, whereas others are innately automatic (e.g., encoding information about spatial location, timing, and frequency of stimuli to be processed). This model suggests also several reasons for *action slips*, which can be defined as the performance of actions that are not intended. In everyday life, action slips are often related to absentmindedness; that means these slips occur due to a lack of attention to what we are doing. Accordingly, action slips are regularly related to the automatic/attentional distinction (e.g., Reason 1992). The automatic mode is controlled by action schemas or plans, whereas the conscious control mode uses attentional processing. When using the automatic mode, conscious control is only necessary when switching from one practised routine to another. Failure to switch into attentional mode means that an inappropriate schema has been activated. Following Reason (1992), there can be different errors in schema activation resulting in action slips. First, there could possibly be an *error in forming the original intention* (e.g., intending to go to work on a Sunday). Secondly, there could be *errors in the activation of appropriate schemas*; i.e., the wrong schema could be activated or an appropriate schema could lose its activation. Finally, there could be *errors in the triggering of active schemas*, so that an action is triggered by the wrong schema.

To eliminate such errors is a central objective of action schemas in the field of *machine learning and artificial intelligence* where they are referred to intelligent ► agents that should operate in unfamiliar domains. Indeed, an agent must learn how its actions affect an environment with changing states, and it is unsure about the exact state before or after the action. Current methods assume full observability (e.g., learning planning operators) and reinforcement learning (Sutton and Barto 1998). In the field of machine learning, the term *action schema refers* to a wide variety of techniques and languages (e.g., STRIPS language) for modeling sequential decision-making problems. At the core of these approaches are the formalization of a problem and the development of tractable algorithms. For instance, Amir and Chang (2008) have proposed an algorithm called *Simultaneous Learning and Filtering* (SLAF) to learn more expressive action schemas using consistency-based algorithms. The fundamental basis is often the infusion of logical knowledge representations into the area of machine learning. Regularly, an action schema comprises a controller, a representation of the dynamics of executing the controller, and one or more criteria for stopping executing the controller.

Important Scientific Research and Open Questions

The term *action schema refers* to a wide range of applications in psychology and machine learning. In psychology, it can be traced back, first of all, to Piaget. However, an analysis of Piaget’s work on action schemas may evoke some conceptual confusion due to the fact that there is no clear distinction between action schemas and sensorimotor schemas. Sometimes, it happens that both theoretical terms are used synonymously or alternating

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at one and the same page (see, for instance, Inhelder and Piaget 1958). In consequence, it remains unclear what exactly may be the difference between action and sensorimotor schemas in Piaget's epistemology. Nevertheless, action schemas play a significant role in cognitive psychology with regard to the distinction between controlled and automatic processing.

Hasher and Zacks (1979) list several criteria for automaticity that can also be considered as features of action schemas: Automatic processing due to the activation of a schema is unaffected by the intention to learn, practice, concurrent task demands, age, arousal, and individual differences. Although this theoretical conception suggests several reasons for action slips, it lacks sufficient empirical support, especially with regard to the functions of action schemas. Furthermore, schema activation and schema construction are two different problems as Bransford (1984) has pointed out. While it is possible to activate existing schemas with a given topic, it does not necessarily follow that a learner can use this activated knowledge to develop new knowledge and skills. Nevertheless, by describing action outcomes at a conceptual level, action schemas provide a fundamental basis for the generalization of actions to various situations and tasks.

This notion of action schemas is also at the core of current approaches in the area of machine learning and artificial intelligence. However, similar to psychology, several techniques for acquiring action schemas have been widely studied in terms of theoretical efficiency (via the notion of *sample complexity*). Consequently, we can find numerous theoretical models concerning the functions of action schemas but only little empirical research on it.

Concerning the use of action schemas within the realm of AI, a problem consists in overcoming the need to manually maintain action schemas within agents, which limits their autonomy. At the moment, this problem is approached by embedding agents with the ability to infer detailed specifications of action schemas from examples (mostly supplied by a trainer or instructor). The main result of this procedure is that an agent can induce detailed specifications of an action schema from single action traces automatically, without requiring intermediate state information for each training example. However, current methods of enabling agents to apply action schemas presuppose full observability and reinforcement learning.

Cross-References

- ► Action Regulation Theory
- ► Automaticity in Memory
- ► Motor Schema(s)
- ► Reinforcement Learning
- ► Schema Development
- ► Sensori-Motor Schema(s)

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Action-Based Learning

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Synonyms

Activity-based learning; Collaborative learning; Cooperative learning; Experiential learning; Goal-based learning; Interactivity; Inquiry-based learning; Learning and action; Learning by doing; Problem solving; Problem-based learning; Scenario-based learning

Definition

Action-based learning refers to all learning that is orchestrated by some activity on the part of learners. These activities can take the form of motor or psychomotor actions, and occur in a variety of contexts including "individualized self-paced," and "cooperative or collaborative group-based" educational settings. In an individualized self-paced educational context, a learner could be acting alone and at their own pace, interacting with learning resources, creating objects, or solving problems. In group-based educational settings, learners could be working together cooperatively (i.e., working on different activities toward the achievement of a common goal), or working collaboratively (i.e., working together toward the achievement of a common goal).

Theoretical Background

Action-based learning theory is grounded in the belief that learning is most effective and efficient when it is orchestrated around meaningful activities. Such activities require learners to be actively and meaningfully engaged with the learning process and the learning resources, as opposed to being passive recipients and consumers of data and information (see Naidu 2007).

Action-based learning has a number of advantages over more didactic approaches to teaching. The obvious advantages of action-based learning include a deeper level of engagement with the learning process, enhanced motivation to learn, greater enjoyment of the learning experience, a deeper understanding of the subject matter and increased retention, and a more positive, accepting, and supportive relationship with peers.

There are numerous models of action-based learning. Prominent among these are *problem-based learning* (Barrows and Tamblyn 1980), *inquiry- or goal-based learning* (Schank 1997), *scenario-based learning* (Naidu 2010), and *adventure learning* (Doering 2006). At the heart of these models of *action-based learning* is a problem or a goal which the learners are required to solve or address. The selection of the problem or scenario is determined by the desired learning outcomes for students. The best problem situations and scenarios are those that are authentic and most closely represent reality.

The problems, scenarios, and adventures in these models of action-based learning serve as the essential anchors for the desired learning to take place. The attendant learning activities provide the scaffolds for the development and retention of the targeted skills and competencies (see The Cognition and Technology Group at Vanderbilt 1990).

The first activity that learners encounter in these problem situations or scenarios is a *critical incident*. These critical incidents often take the form of an accident, a crisis, or any such occurrence. They serve as the *precipitating events* for a string of actions. Upon encountering this event, learners are presented with a mission or goal in relation to it and required to act upon it in order to resolve the problem (see Schank 1997).

The next set of activities in the learning process within this context can be as open-ended or structured as necessary. The level of structure and guidance selected depends upon a range of factors to do with the nature of the subject matter, the desirable learning outcomes, and the competency level of the learners. In some instances, a greater degree of structure and guidance may be more necessary than in others.

In all instances, however, the learning process is orchestrated with a series of carefully designed learning activities which guide learners to the achievement of their mission in the learning context, and ultimately their learning goal or outcome. Learners may carry out all or some of these activities either individually or in groups. This will depend upon the targeted learning outcomes and the nature of the learning activities. Learners will be taking actions, making decisions and informed choices in relation to these learning activities in order to demonstrate their knowledge and understanding of the problem and the subject matter. Their ability to address the problem satisfactorily and resolve it will be a proof of their learning achievement.

Important Scientific Research and Open Questions

Misconceptions around action-based learning relate to different perceptions of what constitutes *action*. Some people have argued that action within the context of action-based learning must entail learners actually performing a physical action. Others have argued that such actions do not need to entail a physical operation to count as action (see Schank 1997; Naidu 2007).

There are many types of actions, and these can occur at various times and levels in a learning context. They may involve learners actually building, creating, or drawing something. But they can also include learners watching a video clip and based on an examination of or reflection upon this resource, taking actions or making decisions about an incident or a problem. All of these types of actions would constitute valid and legitimate *learning actions* (see Schank 1997; Naidu 2007).

Action-based learning can be a very resource-intensive exercise. For it to be effective, action-based learning requires a great deal of detailed and careful planning and guidance throughout the learning and teaching process. This poses serious, but not insurmountable, challenges to its implementation in large groups and in online and distance education contexts.

Is action-based learning suitable for the acquisition of all kinds of skills and competencies, and understanding of all forms of subject matter? If action-based learning is so good for learning and teaching, then why are we all not doing it, and doing a lot more of it? Why do we continue to see so many instances of poor teaching practice?

Answers to these questions and some of the challenges of implementation of action-based learning in large classes and in online and distance education contexts lie in very careful planning and orchestration of the learning activities. Fortunately, an increasing number of online tools are becoming available and affordable to help implementation of action-based learning in large classes and in online and distance education contexts.

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Active Avoidance

Performing a behavior that prevents an aversive outcome from occurring. Contrast with passive avoidance.

Active Learning

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Synonyms

Effective learning; Learning by doing; Meaningful learning

Definition

Active learning refers to instructional techniques that allow learners to participate in learning and teaching activities, to take the responsibility for their own learning, and to establish connections between ideas by analyzing, synthesizing, and evaluating. Bonwell and Eison (1991) define active learning as anything that involves learners in doing and thinking about what they are doing. Active learning is more focused on cognitive development than the acquisition of facts and transmission of information. The role of the learner is not being a passive listener and note taker. The learner's role is being involved in learning activities such as discussions, reviewing, and evaluating, concept mapping, role playing, hands-on projects, and cooperative group studies to develop higher-order thinking skills such as analysis, synthesis, and evaluation.

Theoretical Background

Active learning is sometimes referred to the Socratic Method that is the teaching style of Socrates (Ellerman et al. 2001). The Socratic Method introduces a problem and directs the conversation back to key points to allow students discover the answers of the problem and the content while avoiding lecturing. The Socratic Method engages students in interacting with the teacher and other students (Ellerman et al. 2001).

In more recent centuries, active learning has emerged as a prominent approach to learning and teaching based on the work by John Dewey (1858–1952) and others, who provide historical precedents for *constructivist learning theory. Constructivist learning* claims that learners do not just absorb information. Instead, learners construct information by actively trying to organize and make sense of it in unique ways. Dewey (1966), a reformer in educational policy, argues that schools should not focus on repetitive, rote memorization and that they should be engaged in real-world, practical training to be able to demonstrate their knowledge through creativity and collaboration. According to Dewey, students should be involved in meaningful activities and apply the concepts they are trying to learn. Dewey (1966) uses the term active learner, stressing that learning is an active process in which learners construct their own meaning. In other words, learning is not a passive acceptance of presented knowledge by teachers, but is constructing meaning. Constructing meaning happens in the mind; therefore, educators should design both hands-on activities and mental activities to promote meaning construction. Dewey (1966) emphasizes that learning happens through reflective activities as a product of critical thinking. Learners should reflect on what they understand. The role of the teacher is to direct students to engage in instructional activities, discover the material, think about what and why they are doing, and reflect on application of the content in the real life. Mayer (2004) explains the intersection of constructivist learning and active learning:

> A common interpretation of the constructivist view of learning as an active process is that students must be active during learning. According to this interpretation, passive venues involving books, lectures, and online presentations are classified as non-constructivist teaching whereas active venues such as group discussions, hands-on activities, and interactive games are classified as constructivist teaching. (Mayer 2004, p. 14)

Active learning promotes *cooperative learning* in order to overcome competitive nature of education. Cooperative learning can be viewed as a subset of active learning in which students work together in small groups to maximize their own and each other's learning (Johnson et al. 1991). Cooperative learning techniques use more formally structured small group activities such as research projects, presentations, panel discussions, active review sessions, role playing, and developing a concept map. Cooperative learning should be distinguished from another subset of active learning which is called *collaborative learning*. Collaborative learning refers to instructional activities in which both learners and instructors engage in a common task where each individual, both learner and instructor, depends on and is accountable to each other, and is placed on an equal footing working together. Cooperative learning techniques include designing assignments, choosing texts, presenting material to the class, collaborative writing, joint problem solving, debates, and study teams. Another form of active learning is *discovery learning* in which learners are free to work in a learning environment with little or no guidance (Mayer 2004).

According to Bell and Kozlowski (2008), active learning approach is typically conceptualized by contrasting it to more passive approaches to learning with two key aspects of the active learning approach:

> First, the active learning approach gives people control over their own learning. That is, the learner assumes primary responsibility for important learning decisions (e.g., choosing learning activities, monitoring and judging progress). In contrast, passive approaches to learning focus on limiting the learner's control and having the instructional system (e.g., instructor, computer program) assume primary responsibility for learning decisions . . . Second, the active learning approach promotes an inductive learning process, in which individuals must explore and experiment with a task to infer the rules, principles, and strategies . . . In contrast, more passive approaches to learning assume that people acquire knowledge by having it transmitted to them by some external source . . . Hence, the key distinction is one of active knowledge construction versus the internalization of external knowledge. (Bell and Kozlowski 2008, p. 297)

Active learning techniques allow learners to mediate and control learning by engaging in meaningful social interactions with other students and teachers. The role of the teacher is to promote collaboration, interaction, reflection, experimentation, interpretation, and construction.

Important Scientific Research and Open Questions

In the classroom, active learning can be initiated and facilitated through particular instructional techniques, such as exercises for individual students, writing reflections, reviewing other's work, assessing the materials, questions and answers, using the Socratic Method, giving immediate feedbacks, discussions, cooperative groups, developing concept maps, developing comprehensive lists of the concepts, role playing, group presentations, and games. Bonwell and Eison (1991) state that some characteristics of active learning include more than talking, listening, writing, and reading:

> Students are involved in higher-order thinking (analysis, synthesis, evaluation) . . . Greater emphasis is placed on students' exploration of their own attitudes and values. (Bonwell and Eison 1991, p. 2)

A learner-centered approach to instructional design views learners as active participants in their own learning experience. Therefore, Bell and Kozlowski (2008) emphasize that active learning approaches not only give people control over their own learning but use formal instructional design elements to shape cognitive, motivational, and emotional learning processes that support self-regulated learning (Mayer 2004). Bell and Kozlowski (2008) describe active learning as a conceptual approach to learner-centered training design by describing the distinctive characters of active learning approach:

> At a general level, the idea that the learner should be an active participant in the learning process is not unique to the active learning approach; it cuts across a number of educational philosophies and approaches, such as experiential learning and action learning . . . However, the active learning approach is distinctive, in that it goes beyond simply "learning by doing" and focuses on using formal training design elements to systematically influence and support the cognitive, motivational, and emotional processes that characterize how people focus their attention, direct their effort, and manage their affect during learning. (Bell and Kozlowski 2008, p. 297)

Bell and Kozlowski (2008) conducted a comprehensive examination of the cognitive, motivational, and emotional processes underlying active learning approaches; their effects on learning and transfer; the core training design elements (exploration, training frame, emotion control) and individual differences (cognitive ability, trait goal orientation, trait anxiety) that shape these processes. Bell and Kozlowski (2008) conclude that exploratory learning and error encouragement framing have a positive effect on adaptive transfer performance and interacted with cognitive ability and dispositional goal orientation to influence trainees' meta-cognition and state goal orientation. Bell and Kozlowski (2008) emphasize that active learning approach is valuable not only for the development of complex skills and adaptive performance but also for support of self-directed learning initiatives.

As a summary, the benefits of active learning (Bell and Kozlowski 2008; Bonwell and Eison 1991; Johnson et al. 1991; Mayer 2004) can be summarized as below:

- Promote developing higher-order thinking skills and adaptive performance.
- Support self-directed learning.
- Promote students' interaction with each other and teachers.
- Allow students to think about and process the information.
- Allow students to connect the content to real life.
- Promote a more positive attitude toward the subject matter.
- Allow students to build group study skills and communication skills by working together.
- Promote alternative forms of teaching and assessment.
- Promote critical reflection and taking control of own learning.

Bonwell and Eison (1991) report barriers of using active learning techniques in instruction such as faculty self-perception and influence of educational traditions:

> Certain specific obstacles are associated with the use of active learning including limited class time; a possible increase in preparation time; the potential difficulty of using active learning in large classes; and a lack of needed materials, equipment, or resources. Perhaps the single greatest barrier of all, however, is the fact that faculty members' efforts to employ active learning involve risk – the risks that students will not participate, use higher-order thinking, or learn sufficient content, that faculty members will feel a loss of control, lack necessary skills, or be criticized for teaching in unorthodox ways. (Bonwell and Eison 1991, p. 3)

Educators at all levels have tried to improve their instructional practices through experimenting with active learning techniques. However, the teachers' knowledge and skills on using active learning techniques are limited to their personal experiences. Therefore, teachers should gain a proper understanding in order to create effective instructional activities and to incorporate active learning techniques in the classroom instruction.

Cross-References

► Brainstorming and Learning
► Constructivist Learning
► Cooperative Learning
► Dewey, John (1858–1952)
► Socratic Questioning
► Supervised Learning

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Active Learning Strategies

► Collaborative Learning Strategies

Active Memory

► Working Memory and Information Processing

Active Structural Network

► Semantic Networks

Activities of Daily Living

► Learning Action Affordances and Action Schemas

Activity- and Taxonomy-Based Knowledge Representation

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Synonyms

Competence-based knowledge space theory

Definition

► *Competence-based Knowledge Space Theory* (CbKST) provides a formal framework for structuring and representing domain and learner knowledge and has been successfully applied as a cognitive basis for intelligent educational adaptation in technology-enhanced learning. To enhance applicability of this theoretical framework for pedagogical stakeholders, it has been elaborated in terms of better alignment with the today's educational practice. The basic assumption of CbKST is the existence of a basic set of skills taught by learning objects and required for solving problems of a knowledge domain. The definition of skills in the sense of CbKST has been elaborated to incorporate the current tradition of activity-oriented conceptions of learning objectives and instructional planning. In this way, a relation to educational taxonomies for learning objectives can be established. The resulting activity- and taxonomy-based framework and skill representation can be utilized to empower access and interface functionalities of learning systems.

Theoretical Background

Education today is characterized by learner-centered approaches to instruction that increasingly acknowledge and focus on what the learner does (Marte et al. 2008). For instructional planning in terms of designing units of learning (i.e., lessons, courses), learning objectives play an essential role, which precisely specify the knowledge and competence that are expected to be acquired. Learning objectives express the intended learning outcome and what learners will be able to do as a result of instruction (Anderson et al. 2001). The description refers to the learning content on a conceptual basis, as well as to concrete activities relating to this content. Learning objectives are not only crucial for designing and planning instruction, but also for assessing learning outcomes.

To enhance instructional planning, teaching and learning, and assessment, a range of pedagogical frameworks and *educational taxonomies* have been developed for classifying learning objectives. The most popular and influential taxonomy among them was devised by Bloom and later revised by Anderson et al. (2001). This taxonomy is intended as a tool for matching objectives, activities, and assessments related to a unit of learning, as well as for identifying possible options and procedures for instruction. The revised version of the taxonomy comprises six categories – remember, understand, apply, analyze, evaluate, and create – which form a cumulative hierarchy of levels of cognitive processing that represent successively more advanced and complex cognition. A range of action verbs can be linked with each of the individual categories, serving the description and association of concrete learning activities with the levels of the taxonomy. In addition, a second dimension of the taxonomy represents a continuum from concrete to abstract knowledge – conceptual, procedural, and metacognitive knowledge. Together, both dimensions form a useful representation for instruction and assessment.

CbKST (Albert and Lukas 1999; Heller et al. 2006) is a knowledge representation framework that is able to incorporate the activity-oriented understanding of teaching and learning and is based on the original formalization of Knowledge Space Theory (KST). In KST (Falmagne and Doignon 2011), a knowledge domain is represented by a set Q of problems. The subset of problems that a person is able to solve constitutes the *knowledge state* of this individual. Mutual dependencies between the problems of a domain (which may be captured by a so-called *prerequisite relation*) restrict the number of potential knowledge states that actually can occur. The collection of the possible knowledge states, including the empty set Ø and the whole set Q, is called a *knowledge structure*. In a knowledge structure, a range of different learning paths from the naïve knowledge state to the expert knowledge state are possible, which can be exploited for realizing meaningful teaching and learning sequences and personalizing learning paths. Furthermore, a knowledge structure is at the core of adaptive assessment procedures for efficiently identifying the current knowledge state of an individual.

While KST focuses purely on observable behavior, CbKST explicitly refers to the cognitive constructs in terms of fine-grained descriptions of abilities underlying this behavior. Its basic assumption is the existence of a set of skills that are relevant for solving the problems of a specific knowledge domain, and that are taught by learning objects of the respective domain. The *competence state* is represented by the subset of skills that a learner has available. It is not directly observable but can be inferred on the basis of the observable problem-solving behavior. Skill assignments establish the connection between observable behavior (performance) and underlying skills (competence). The relation between assessment problems and skills is realized by associating each problem with a collection of subsets of skills sufficient for solving it and, vice versa, by associating to each subset of skills the set of solvable problems. The associated subsets of problems constitute the knowledge states of the knowledge structure induced by this mapping. The relationship between skills and learning objects is established in a similar manner. Each learning object of a domain, on the one hand, is associated with a subset of skills required for understanding it and, on the one hand, with a subset of skills taught by this learning object. When explicitly modeling dependencies between the skills of a knowledge domain, a *competence structure* can be established in analogy to a knowledge structure.

Important Scientific Research and Open Questions

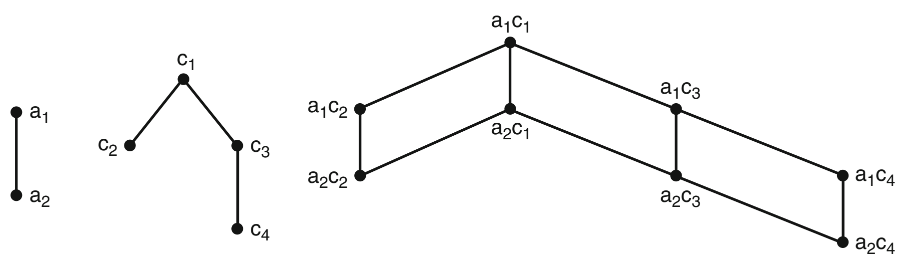
The skills modeled in CbKST can be understood as fine-grained learning objectives. To clearly align the skill representation of CbKST with the current educational practice of defining learning objectives, skills can be defined as consisting of two components, an action verb and one (or several interrelated) concept(s) (Heller et al. 2006). A skill from elementary geometry, for instance, could be "to apply the Pythagorean Theorem," which is made up of the activity "apply" and the concept "Pythagorean Theorem." The action verbs used for this skill definition can be matched with the revised Bloom taxonomy and in this way a connection between CbKST and educational taxonomies of learning objectives can be established (Marte et al. 2008).

This harmonization can be exploited by using the educational taxonomy as a basis for structuring skills. The hierarchical structure of the taxonomy provides information on dependencies between action verbs. For the action verbs "apply (a_1)" and "state (a_2)," for instance, dependencies may be identified by matching them with the categories of the taxonomy. While "state" can be linked to the category "remember," "apply" naturally relates to the category "apply." As, according to the taxonomy, the category "apply" refers to more advanced cognitive processing than "remember," this information can be translated into a prerequisite relationship in terms of CbKST – i.e., "remember" is a prerequisite for "apply." The classification of activities into the categories of the educational taxonomy is of course not always straightforward and there is a need for defining clear principles for this process.

The concepts covered by the skills of a knowledge domain also feature structural information. This information can be derived, for example, from domain ontologies (e.g., concept maps) or curriculum maps. For the concepts "Altitude Theorem (c_1)" and "Pythagorean Theorem (c_2)," for example, it may be identified that the Pythagorean Theorem is a prerequisite for the Altitude Theorem and therefore the concepts are usually taught in this order.

To combine the structural information on both components of skills, the *component-attribute approach* suggested by Albert and Held (1999) can be applied. Originally developed for systematically constructing and structuring problems, this approach can be applied to establish skills on the basis of predefined sets of action verbs and concepts for a knowledge domain and the structures on both components. The two skill components are understood as dimensions; and the individual concepts and, respectively, action verbs are understood as attributes or values these dimension can take on. Skills can be formed by combining attributes across components (whereby not necessarily each of these combinations will result in a possible or relevant skill). For a given domain, for example, there might be a component C with the concepts c_1, c_2, c_3, and c_4 and a component A with the action verbs a_1 and a_2. Assuming that for each component the attributes are ordered, a structure on the skills can be built by forming the direct product of the components using the principle of component-wise ordering. An illustration of our example is given in Fig. 1. As can be seen, for the skill (a_1c_2) the skill (a_2c_2) is a prerequisite, whereas for skill (a_1c_3) the skills (a_2c_3), (a_1c_4), and (a_2c_4) are prerequisites. The established structure can be interpreted as a prerequisite relation on the subset of skills (i.e., combinations of actions and concepts) that can actually occur, or are considered. In some knowledge domains, it may be necessary to describe one skill with a set of interrelated concepts, which then requires to adopt somewhat different principles for structuring the skills.

The activity- and taxonomy-based skill representation can be utilized in the context of technology-



Activity- and Taxonomy-Based Knowledge Representation. Fig. 1 Structures on a set of action verbs {a_1, a_2} and a set of concepts {c_1, c_2, c_3, c_4}. Ascending line sequences in the graph on the right side represent the resulting prerequisite relation on the skills enhanced learning for the creation of units of learning and for effective feedback mechanisms (Marte et al. 2008). A teacher or learner may choose the skill(s) to be addressed in teaching and learning. This selection can then be translated into a set of suitable learning objects that cover the respective skill(s) based on the underlying skill assignments. It may furthermore be identified whether an individual learner possesses the skills required for understanding the learning object and – if needed – present learning objects teaching those prerequisite skills. In this way, a structure of learning objects and thus a collection of possible learning paths is recursively built up that match the individual's current needs. The selection of the scope of a unit of learning may be facilitated via the educational taxonomy, by only choosing the desired level of skills (i.e., cognitive processing level of the action verbs involved) and the main concepts that should be targeted. Apart from that, the presented framework provides a basis for visualization as well as aggregated feedback mechanisms giving learners and teachers an overview of the learning progress made and the spectrum of skills covered. The retrieved information on the skills covered or achieved so far may be used for identifying prevalent skills with respect to cognitive processing levels or concepts, for determining skills left out, for supporting reflection on the current status of learning in relation to others, or on existing competence gaps in comparison to a defined learning goal.

Cross-References

► Adaptive Learning System
► Bloom's Taxonomy of Learning Objectives
► Knowledge Representation
► Learning Objectives
► Visualizations and Animations in Learning Systems

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Activity Theories of Learning

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Synonyms

Cultural-historical activity theory; Social-constructivist learning theory

Definition

Activity theories of learning is a generalized term for learning theories that are based on the general "activity approach (paradigm, outlook, framework)" initially introduced by Russian/Soviet psychologists L. Vygotsky, A. Leontiev, S. Rubinstein, A. Luria and further developed by their disciples and followers both in Russia and in the West (V. Davydow, V. Zinchenko, J. Wertsch, M. Cole, Y. Engeström, et al.).

Theoretical Background

On the basis of the main principles of the activity paradigm – such as the object-relatedness and meaningfulness of human activity, interrelations between its internal and external components and its tool-mediated nature, activity development – a three-level structure of activity (activity – action – operation) results with *activity* being connected with a motive, *action* linked with a specific goal, and *operation* a structure related to the specific conditions (Leontiev 1978). The representative of the *first generation of the activity-oriented learning theorists* (D. Elkonin, V. Davydow, P. Galperin, J. Lompscher, N. Talyzina, et al.) considered human learning processes in two interconnected but nevertheless different respects: (1) learning as a universal mechanism for the appropriation of social experience by an individual (Galperin 1992; Talyzina 1981) and (2) *learning activity* as a special form of the social activity of personality

(Davydow 1999). The latter issue is highlighted in the entry ▶ Learning Activity in this Encyclopedia.

The basic assumption of the activity theory of learning is that "types of knowledge towards which the learning process is directed then appear both as the motivation, in which the student's need for learning has become objectified, and the activity's objective. In cases when students do not have such a need they either will not be engaged in learning or else will be learning in order to satisfy some other need. In such a case learning ceases to be an activity since instead of meeting a particular need – the acquisition of knowledge – it merely serves as an intermediary objective. In such a case learning is an *action* realizing some other activity; the knowledge that serves as the action objective does not serve as a motivation, since it is not knowledge which activates the learning process" (Talyzina 1981, p. 45).

Important Scientific Research and Open Questions

Learning is understood within the framework of the activity paradigm as a universal mechanism for the appropriation of social experience by an individual characterized by the following parameters: (1) As a necessary component of any activity, human learning represents the process by which the subject changes under the influence of object-related content. Thus, learning is a process in which the individual appropriates historically formed *means (tools) of activity.* (2) As these means are first presented to the learner in a hidden and abbreviated form, it is necessary to "externalize" them in order for the learner to understand how they function. Only then can the learning process start by means of a step-by-step *internalization* procedure (appropriated/internalized mental actions, concepts, images, representations, etc.). (3) The core element of the learning process is formation (appropriation) of actions (mental, perceptual, motor, and verbal). Human actions and images reflect, and are the product of, both human needs and the demands and conditions of the objective situation. Any human action maybe characterized by a set of primary and secondary properties. The following properties are considered to be *primary*: (a) the composition of the action's objective content, (b) the extent to which essential elements of the problem situation are differentiated from nonessential elements, (c) the degree to which the action has been internalized, and (d) "energetic" (speed and enforcement) parameters. The *secondary* properties are: (a) reasonability, (b) generalization, (c) consciousness, and (d) criticism. The secondary properties are the result of specific combinations of primary properties. Both primary and secondary properties represent socially estimated and evaluated qualities of human activities and may refer to any sort of activity, whether individual or collective, material or mental (Galperin 1992). The final values of these properties determine the specific action and/or image that are formed. Galperin considered the values of the properties to be the direct outcomes of action formation conditions. He therefore defined a system of conditions that guarantees the achievement of prescribed and desired properties of action and image. It is called the "*system of planned, stage-by-stage formation of mental actions*" or the *PSFMA system* and includes *four subsystems*: (1) the conditions that ensure adequate motivation for the subject's mastering of the action, (2) the conditions that establish the necessary orientation base of action, (3) the conditions that support the consecutive transformations of the intermediate forms of action (materialized, verbal) and the final end transformation into the mental plan, and (4) the conditions for cultivating or "refining through practice" the desired properties of an action (Galperin 1989). Each subsystem contains a detailed description of related psychological conditions, which include the motivational and operational areas of human activity (see also the entry on ▶ Internalization in this Encyclopedia). The PSFMA system represents a complete nomothetic set of psychological conditions which stand behind the learning processes, and any specific case of learning maybe considered as a result of "subtracting" one or the other condition from the complete list. Accordingly, absent elements of the PSFMA system maybe easily found and inserted. The system enables a principle of differentiating diagnosis and correction to be practically implemented in the learning/teaching process.

Not all of the subsystems have been developed and operationalized to an equal extent; the first subsystem, for instance, has not been described in as explicit a manner as the other three. Similarly, not all areas of learning are equal well developed within the framework of the PSFMA approach. Thus, many primary and secondary school subjects dominate over higher education disciplines and cognitive ("pure" intellectual, perceptual) action formation has been studied in much more detail than, e.g., socio-moral action formation. There are relatively few examples of PSFMA being applied to the conditions of real human activity (professional, military, sporting, etc.) acquisition; however, these cases clearly demonstrate what is missing in the concrete PSFMA model, in which the formation of isolated actions is considered separately from the entire structure of the corresponding activity (for more details, see the entry on ► Mental Activities of Learning in this Encyclopedia).

The *second (current) generation of the activity-oriented learning theorists* pays additional attention to the extension and expansion of the approach elaborated by their predecessors. Due to the fact that activity theories of learning went international in the 1980s, the cultural dimension of learning is taken into account not only declaratively by these theorists but also with respect to learning in concrete cultural settings (E. Elbers, M. Hedegaard, W. Wardekker, et al.). In addition, several authors have called attention to the necessity of developing conceptual tools to understand dialogue, multiple perspectives and voices, and networks of interacting activity systems (Engeström 1999; Sannino et al. 2009). Engeström considers expansion as "a form of learning that transcends linear and socio-spatial dimensions of individual and short-lived actions, . . . learning is understood in the broader and temporally much longer perspective of a third dimension, that is, the dimension of the development of activity" (Engeström 1999, p. 64).

Meanwhile, in recent decades, Russian scholars have continued to concentrate on exploring the age-related peculiarities of learning processes (L. Obuchova, G. Burmenskaya, et al.), clarifying the role of adult–child and child–peer communication in the facilitation of learning processes (V. Rubtsov, G. Zuckerman, et al.), and deepening the regularities of the mental action transformation (especially with regard to its final phases, such as automatization and simultaneouzation) as the core learning processes considered through the prism of the activity paradigm (A. Podolskiy, et al.).

In addition to studies on the traditional issues (traditional with respect to the activity framework), such as the interrelation between development, learning, and instruction (G.Burmenskaya, L.Obuchova, et al.) and the problem of bridging a gap between theoretical activity-related learning models and real instructional technology (A. Podolskiy, et al.), quite new directions which open broad perspectives for further theoretical, empirical, and applied research have appeared, such as "learning to learn" (J. Hautamäki, et al.), an application of the activity framework to the area of human–computer interaction (V. Kaptelinin, B. Nardi, et al.), and the so-called systemic-structural activity theory (SSAT), which endeavors to analyze and design the basic elements of human activity (tasks, tools, methods, objects, and results) as well as the skills, experience, and abilities appropriated by the subjects performing it (G. Z. Bedny, W. Karwowski, D. Meister, et al.).

An especially important task for future research is to establish conceptual and historical relations between the activity theory of learning and such promising and heuristic directions in learning theory and practice as "*anchored learning*," "*cognitive load theory*," "*learning by doing*," "*scaffolding learning*," and "*situated cognition*," "*socio-constructivist models of learning*."

Cross-References

- ► Cultural-Historical Theory of Development
- ► Internalization
- ► Learning Activity
- ► Learning and Training: Activity Approach
- ► Mental Activities of Learning
- ► Zone of the Proximal Development

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Activity Theory

- ► Cultural-Historical Theory of Development
- ► Learning and Training: Activity Approach

Activity-Based Learning

Activity-based learning is the acquirement of concepts through activities that involve the concept to be learned. In the field of language learning it involves the assumption that language must be scaffolded by social activity in terms of action, interaction, manipulation, and so on. Technology need to be integrated in the process of language learning (Van Lier 1998).

Cross-References

► Action-Based Learning

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Actor Network Theory and Learning

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Synonyms

Learning technology; Online learning; Web-based learning

Definition

E-learning is learning through the use of technologies. It is growing at a rapid pace. Today, more organizations are taking up e-learning. However, the design of a usable and effective e-learning environment is not trivial. Recent theories of learning have moved from a behavioral approach toward a learner-centered, constructivist epistemology grounded in concepts of situated learning and distributed cognition and social historical – cultural notions of the mind. Recent technological developments such as the World Wide Web have enabled researchers to explore the use of these technologies to support a variety of teaching and learning approaches. Technology has been increasingly used to support the design of constructivist learning environments for learning. Terminology such as *learning environment* has emerged as a powerful perspective in providing meaningful learning and presenting the transfer of knowledge to real-life situations.

Theoretical Background

An Overview of Actor Network Theory

Michael Callon (1986), Bruno Latour (1986), and John Law (1992) developed the actor network concept. The primary tenet of actor network theory (ANT) is the concept of the heterogeneous network. An actor network consists of, and links together, both technical and nontechnical elements. This concept is based on the recognition that actors build networks combining technical and social elements. In ANT, actors can be defined as entities that serve as intermediaries between other actors. Actors can be humans, but also include technology, text and organizational groups. There is no difference between human and materials or the social and the natural (Callon 1986).

ANT is a heterogeneous amalgamation of conceptual, textual and actors. Actors in ANT, known as actants, are any agent, collective or individuals that can associate or dissociate with other agents. Actants enter into network association that in turn defines them, names them, and provides them with substance, action, intention, and subjectivity (Callon 1986). It is via the networks that actants derive their nature and develop as networks. The main difference between actors and actants is that only actors are able to put actants in circulation in the system.

In ANT, the social and technical aspects are treated as equally important. ANT denies that purely technical or purely social relations are possible. Instead, it considers the world to be full of hybrid entities (Latour 1986) containing both human and nonhuman components. Actors in ANT include both human beings and nonhuman actors (such as technology) that make up a network to be studied (Callon 1986). In ANT, innovators attempt to create a forum, a central network in which all the actors agree that the network is worth creating and maintaining. Numerous actors within an organization may be involved in a different process of translation, each with its own unique characteristics and outcomes. Each actor will have its own view of the network and its own set of objectives and goals. The process of translation seeks to align these goals with those of other candidates for the network and to create a set of shared goals. Michael Callon (1996) has defined four moments of translation.

Latour (1998) argues those actors are defined solely by their ties to other actors. Actors can be technical artifacts ranging from the smallest components to the largest. The building of an actor network is to overcome the resistance of other actors and try to weave them into network with other actors (Law 1992). The challenge is to explore how actor networks come to generate effects like organizations, industrial structures, and innovation. ANT examines the motivations and actions of human actors that align their interest with the requirements of nonhuman actors. It can be used to investigate the process whereby the respective interests of different human and nonhuman elements are aligned into a social and technological arrangement of artifacts. The core of ANT is the process of translation (Callon 1986; Latour 1986). The important negotiation is translation, a multi-factored interaction in which actors (a) construct common definitions and meanings, (b) define representatives, and (c) co-opt each other in the pursuit of individual and collective objectives. Both actors and actants share in the reconstruction of the network of interaction, leading to system stabilization.

Actor's interests may vary widely. They may encourage or constrain the technology. Establishing the technology requires the aligning of the interests of actors within the network. This involves the translation of those interests into a common interest in adopting and using the technology. The translation of the network is achieved through common definitions, meaning, and inscription attached to the technology.

Translation

Translation explains how artifacts become a result of negotiations between the involved subjects. ANT can be used as a theoretical lens to study the development and adoption of service innovation. Different interpretations influence the construction of an artifact.

1. *Problematization.* This comprises the definition of the problem. During problematization, a primary actor tries to establish itself as an obligatory passage point (OPP) between the other actors and the network, so that it becomes indispensable. The OPP is in the primary actor's direct path while others may have to overcome obstacles to pass through it (Callon 1986).
2. *Intéressement.* This is the moment of translation defined by Callon (1986). Interéssement, or "How allies are locked in place" uses a series of processes that attempt to improve the identities and roles defined in the problematization on the other actors. According to Law (1992), it means interesting and attracting an actor by coming between it and some other actors. This is the process of recruitment of actors – creating an interest and negotiating the terms of their involvement. The primary actor works to convince the other actors that the roles it has defined them are acceptable. Where there are groups of actors with the same goal, these can be represented by a single actor.
3. *Enrolment.* Enrolment is when another actor accepts the interests defined by the primary actor. This is the third moment. It is how to define and coordinate the role. This leads to the establishment of a stable network of alliances. It requires more than one set of actors imposing their will on others for enrolment to be successful. In addition, it also requires others to yield. (Callon 1986). Actors accept the roles that have been defined for them during intéressement. Enrolment means the definition of roles for actors in the newly created actor network.
4. *Mobilization of allies.* This fourth stage is the point where enrolled actors are given the tools of communication and are able to themselves create an interest in the network or to create subnetworks. This is the final moment. Mobilization occurs as the proposed solution gains wider acceptance and an even larger network of absent entities is created through some actors acting as spokespersons for others (Tatnall and Burgess 2002).

Inscription. A process of creating technical artifacts (tools) that would ensure the protection of an actor's interests. It refers to the way technical artifacts embody patterns of use. According to Akrich and Latour (1997), inscription is the act, or process, which actors perform on other actors, shaping their attitudes and properties. The properties and attributes of any actors (or networks) are a result of a complex inscription process by human and nonhuman actors. Human actors are able to inscribe onto nonhuman actors. Conversely, nonhuman actors are able to inscribe onto human actors. This is the translation carried out via actor's inscriptions that enable the actor to transfer its attributes and properties to other actors in its immediate topologies. Inscription and translations are in constant flux. It is iterative in nature, therefore enabling a relative stability in the corresponding network.

Benefits of ANT for e-Learning

There are several benefits to using ANT for e-learning. These include the following:

- ANT allows us to have an open-ended array of things that need to be aligned including work routines, incentive structures, system modules, and organizational roles.
- ANT is appropriate for preparing design strategies by aligning the interests of the actor network, i.e., having all their influences fit together.
- ANT allows aligned interests to be inscribed into durable materials (Law 1992).
- ANT also introduces the concept of "black-boxing" (sealed actor networks).

ANT for designing e-learning system

It is my belief that ANT provides us a conceptual framework for designing learning systems. In ANT, many things, human and nonhuman, have influence on each other. This is ideal for designing e-learning systems because we can align the interests of the actor network by having their influences fit together. The alignment of the network is obtained through the process of translation and inscription.

The design of an e-learning involves getting answers to the questions, "Who will use it, how they will use it, and what service processes are involved?" The methodology for ANT requires the recording of actors' interactions, connections, and effects (Latour 1986). Interactions between actors also need to be traced through documents, skills present or developed, money, and control structures. The complexity of the network can then be assessed. This may influence strategies for aligning the actor network with desired outcomes. The university e-learning actor network involves interaction with a variety of human and nonhuman actors. The physical network of ICT and fiber-optic infrastructure of the Internet cannot be separated from the social and human networks involving administrators, professors, lecturers, students, clerks, technicians, and parents. The technical and social networks must be considered together. The faculty network is a network of heterogeneous actors including the Internet network, offices, professors, lecturers, and students. The network also includes documents and texts that support the faculty in their teaching.

Perceptions of the usefulness of the technology as well as ease of use should also be considered. Relationships between actors in terms of current communication, level of trust, power distribution, resource control, and influence should be considered. This also includes relationships between actors and local economic and natural resources. The importance of relationships or connections between actors or groups of actors needs to be examined because the strength of these connections may influence enrolment strategies.

Building of an e-learning system is a social process involving both the users and developers. The system developed is a result of the social negotiations among Director of university, the staff members, business partners, students, and managers. While not formally involved in the service design, customers or users' actions have important consequences in the development process. We believe that it is important to consider all actors' points of view in order to better understand the system requirements and identity. This identity is the result of meaning given to the learning system by different actors.

Important Scientific Research and Open Questions

There is little research done to use actor network in e-learning. Central to the theory is the identification of stakeholder's e-learning. The identification of the stakeholder's interests is also important. The question is how do we identify their interests? This includes both organizational and individual. Organizational interests concern their political and social interests arising from their job roles in the organization. Individual interests concern personal interests such as status, career progress, and job security. Looking at interests involves an examination of the stakeholders' rational, organizational, and individual interests.

Another question is the identification of interaction between stakeholders.

It is important to identify stakeholder interactions; the relationships between stakeholders in terms of extent of communication, power, trust, resource control, and influence must be investigated. The question of how to negotiate conflicts between stakeholders needs to be resolved by negotiation in order to align the actors to the network. Finally, there is the alignment of stakeholder's interests with other stakeholders.

ANT has the potential to be used as a tool for e-learning development and adoption. However, research is needed to find out how this can be achieved.

Cross-References

- ▶ Constructivist Learning
- ▶ Design of Learning Environments
- ▶ e-Learning, Recent Trends of Research
- ▶ Engagement in Learning
- ▶ Individual Differences in Learning
- ▶ Inquiry Learning
- ▶ Learner Preferences and Achievement
- ▶ Learning in the Social Context
- ▶ Lifelong Learning
- ▶ Meaningful Verbal Learning
- ▶ Network Learning/Networked Learning
- ▶ Online Collaborative Learning

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Actor-Critic

A general-purpose reinforcement-learning model that has two components: the critic and the actor. The critic learns the values of stimuli or situations and calculates prediction errors. The actor learns associations between stimuli or situations and responses (i.e., S-R associations). The values of stimuli or situations in the critic and the strengths of S-R associations in the actor are both updated using the prediction errors calculated by the critic.

ACT-R

▶ ACT (Adaptive Control of Thought)

Actualized Affordance

Refers to the real properties of the environment.

Actualized Interest

Actualized interest is another way of conceptualizing personal or individual interests as a psychological state manifested by prolonged, focused engagement and positive feelings. Actualized interests involve both the stored knowledge and stored value a person holds for a particular object, experience, or activity. Actualized interests are thought to arise from the interaction between a child's personal characteristics and dispositions, and the conditions or features of a situation that elicit interest.

Actualizing Tendency

This is the inherent tendency of the organism to develop all its capacities in ways that serve to maintain or enhance the organism. It involves not only the tendency to meet what Maslow terms "deficiency needs" for air, food, water, and the like, but also more generalized activities. It involves development toward the differentiation of organs and functions, expansion in terms of growth, expansion of effectiveness through the use of tools, expansion and enhancement through reproduction. It should be noted that this basic actualizing tendency is the only motive that is postulated in the theoretical system.

Adaptability and Learning

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Synonyms

Adjustment; Evolutionary educational psychology; Evolutionary psychology; Human behavioral ecology; Regulation

Definition

Recent work has proposed adaptability as a means of understanding young people's capacity to deal with new, changing, and/or uncertain situations (Martin 2010). Adaptability seeks to articulate concepts that reflect young people's adaptive regulation in the face of uncertainty, change, or novelty. In the academic domain, adaptability ("academic adaptability") reflects regulatory responses to academic novelty, change, and uncertainty that lead to enhanced learning outcomes. Unlike concepts such as resilience and coping that predominantly focus on surviving, "getting through" and "getting by," adaptability is focused on active regulation of an individual to evince enhanced outcomes (not simply to "get through" or "get by"). It has also been proposed that regulation efforts take place across three core domains of functioning: cognition, affect, and behavior (Martin 2010). Accordingly, "adaptability" is formally defined as the capacity to adaptively regulate cognition, emotion, and behavior in response to new, changing, and/or uncertain conditions and circumstances. Thus, individuals who are adaptable are proposed to be capable of purposefully and effectively adjusting their thought, emotion, and behavior repertoires to give rise to a positive trajectory on target phenomena such as learning and achievement (Martin 2010; for cognate perspectives, see Bandura 2001; Covington 2000; Schulz and Heckhausen 1996; Zimmerman 1989).

Theoretical Background

Across a human life span, the world will undergo substantial change. Today, change and variability are evident on economic, geopolitical, sociocultural, climatic, technological, medical, and other fronts. To effectively negotiate this fluid and variable world, groups and individuals will be required to learn and achieve in spite of, or because of, these changes. Indeed, a failure to do so may perpetuate or exacerbate gaps in learning and achievement trajectories, significantly threatening the ongoing functioning of particular groups and individuals. Although consideration of change (and how humans deal with it) dates back to figures such as Lao Tzu and the Buddha, recent institutional (e.g., OECD, UNESCO, World Bank) and individual (e.g., Martin 2006) commentaries suggest the twenty-first century will bear witness to macro- and micro-transitions and transformations of a kind never before experienced.

In terms of macro change, to varying degrees and in a variety of ways: industry will be reshaped around environmental demands and pressures; medical advancements (particularly in regenerative medicine) will extend the human life span; pharmaceutical developments will present new possibilities for human performance and functioning; communications technology will be reshaped around fiber optics and extreme bandwidth; high-level globalized computing networks will accelerate information production and application; new technologies will allow greater access to cultural phenomena; and, expansion of electronic databases and resources will transform education and learning (e.g., Martin 2006). An individual's adaptability will be critical to learn and achieve through these macro-level changes (Martin 2010).

There are also many micro and domain-specific changes facing individuals and groups. In the education domain, tasks and challenges change in nature and degree on a frequent basis; in the work domain, there are ongoing changes in markets, demand, and competition; in sport there is the need for continual adjustments to different opponents and performance conditions; in the performing arts (e.g., music), there is the need for a broad and flexible skill set to quickly orient to new performance pieces and productions (Martin 2010). Individuals and groups who are able to learn and achieve through these micro-level changes will be those best placed to seize the opportunities of the twenty-first century. Again, adaptability is proposed to be important to learning and achievement through these micro-level changes (Martin 2010).

Here, three lines of research and theory are proposed to inform the adaptability construct. The first is evolutionary (educational) psychology that has examined the factors related to mind that assist students to adapt to the learning and achievement demands in their academic lives (Geary 2008). The second is based on human behavioral ecology that seeks to explain adaptation in situated and behavioral terms (Barrett et al. 2002). The third relates to a motivational framing of adaptability and learning (Bandura 2001; Covington 2000; Zimmerman 1989).

Evolutionary psychology seeks to explain evolution in terms of the psychological mechanisms that are needed to survive, with the mind viewed in terms of the domains or modules relevant to meeting the challenges of the environment. From an evolutionary psychology perspective, the mind is comprised of psychological adaptations and predisposed mechanisms for learning that survive because they solve problems that individuals are presented with (Geary 2008). Of the various perspectives and contributions under the evolutionary psychology banner, perhaps the closest to context-relevant (e.g., school) learning and achievement is that proposed by evolutionary educational psychology (Geary 2008). According to Geary, evolutionary educational psychology seeks to explain how evolved biases in learning and motivation influence individuals' capacity and motivation to learn academic subject matter and academic skills. Evolutionary educational psychology proposes two psychological systems that are relevant to adaptation and learning. Primary (folk) psychological systems are what have an evolutionary basis and involve processing information related to self, others, and group dynamics (Geary 2008). Secondary psychological systems are what are acquired through individuals' interactions with their environment. Secondary systems are typically what underpin performance environments such as school in which culturally relevant skills and knowledge are taught and learnt (Geary 2008).

One line of evolutionary work that more explicitly accommodates the role of context and social environment is that proposed by human behavioral ecology (HBE). HBE has been described as a more "functional" approach to human learning (Barrett et al. 2002), arguing for relatively rapid changes in behavior through interaction with environment in the course of adaptation (Barrett et al. 2002). In contrast, evolutionary psychology argues that adaptation occurs slowly and that this poses problems because the world has changed faster than the brain and behavior can adapt to it (Barrett et al. 2002). HBE, then, has been portrayed as more pragmatic and tied to readily observable changes in learning.

The third line of work summarized here as relevant to adaptability and learning is that proposed under a motivational framework. According to Zimmerman (1989), young people become increasingly capable of initiating and directing their personal attributes with a view to attaining a particular educational (or other) outcome. Thus, they do not merely participate in the academic process; rather, they actively engage and operate on it. In various ways and to varying degrees, they learn that there is a reciprocal dialog between their personal faculties (cognitive, emotional, and behavioral) and contextual stimuli (see also Schulz and Heckhausen 1996). Similarly, Bandura (2001) asserts that dynamic and proactive cognitive and behavioral enablement equips individuals with the personal resources required to select and create successful approaches to manage new and changing life challenges. Likewise, Covington (2000) has provided input on the cognitive, behavioral, and affective regulatory processes in which young people engage to help them function through their academic lives. Together, these motivational perspectives suggest that learning and achievement in the academic domain involve proactive (re)assessment and regulation of one's cognitive, affective, and behavioral functions and processing.

Important Scientific Research and Open Questions

When considering learning in a very general form (e.g., adjustment of a species to a new environment; development of social structures; invention of tools and implements etc.), theorizing on the role of adaptability has a long history (see Barrett et al. 2002; Geary 2008 for reviews). However, the present discussion has sought to integrate adaptability into the field of academic learning and achievement and also introduced motivational (cognitive, affective, behavioral) perspectives to this issue. Hence, there are new questions to address as we seek to explore the potential of this perspective on academic adaptability to explain learning in the academic domain.

Some of these questions are as follows: (a) What is the conceptual scale, scope, and limits of the adaptability construct in relation to academic learning and achievement? (b) In what specific ways do cognitive, behavioral, and emotional factors differentiate children and young people's adaptability and responses to change and transition? (c) What are the causes and consequences of adaptability in learning and achievement settings? (d) What is the role of adaptability in assisting children and young people to learn and achieve through life transitions, new environments, and marked personal and social uncertainties? (e) What implications does adaptability hold for assisting young people to innovate and problem solve in tomorrow's world? (f) Do changes in adaptability lead to changes in subsequent learning and achievement outcomes? (g) What sort of cross-cultural profiles of adaptability exist and what are the implications of this for models of learning? (h) What is the relative mix of trait vs state vs context in "explaining" children's and young people's adaptability and does this have implications for learning? (i) What are the neurological and genetic bases of adaptability and how can knowledge generation in this domain assist learning and achievement? These and other questions will be vital for progressing research, theory, and practice in the area of adaptability and its interface with evolutionary, motivational, and educational psychologies.

Cross-References

► Motivation, Volition and Performance
► Resilience and Learning

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Adaptation

► Habituation and Sensitization
► Socialization-Related Learning

Adaptation and Anticipation: Learning from Experience

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Synonyms

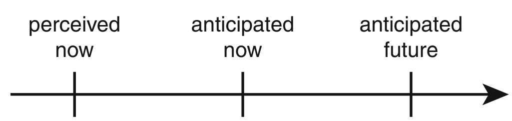
Adaptive and anticipatory learning; Experiential learning

Definition

All forms of learning have an anticipatory component, either implicitly because it adapts the organism for the future or explicitly by supporting predictions of the future. Both forms of ► anticipatory learning can be controlled by the value of the future state (see Fig. 1), but can also occur independently of any value.

Theoretical Background

A basic form of learning that exists in nearly all animals is ► Pavlovian conditioning where the organism learns to anticipate a discrete event, such as the presentation



Adaptation and Anticipation: Learning from Experience. Fig. 1 The control of anticipatory learning by the future state of a stimulus, based on one or several cues. These cues may either be discrete such as short sounds or consist of the whole the situation or environment where the organism is situated in the case of ► context conditioning. Although often incorrectly described as the result of a repeated pairing of the cue and the anticipated stimulus, Pavlovian conditioning depends critically on a ► contingency in learning and occurs only when there exists a predictive relationship between the stimuli (Rescorla 1988). In most demonstrations of Pavlovian learning, the predicted event consists of the presentation of an innately significant stimulus. However, Pavlovian learning also occurs when a relationship is set up between two stimuli without any innate value, for example, in a ► sensory preconditioning experiment (Brogden 1939).

Although it is possible to consciously know about the predictive relationship, Pavlovian learning can occur without any conscious recollection or understanding and animals are able to learn ► eyeblink conditioning even if their cerebral cortex is removed. This can be contrasted with ► episodic learning where an organism learns about a particular event or episode that it is later able to consciously recollect. This ability can be used for episodic foresight, where past experiences are used to anticipate future events or the consequences of an action (Osvath 2010).

In ► operant learning, and its technical counterpart ► reinforcement learning, the organism learns to behave in a particular way because that behavior leads to a positive outcome. Although the future consequences determine the behavior, there is no explicit anticipation of these consequences. Operant learning is thus anticipatory only in an implicit way. Any discrepancies in the value between the expected and actual outcome will lead to new learning, but the expected outcome is only available once the behavior has been performed. It does not guide it directly.

Anticipation is also necessary for perception. Consider an organism that attempts to predict the position of a moving object based on a sequence of previous observations of the object. The organism should learn a function from a number of observed positions in the past to the estimated position right now. Any of a number of ► learning algorithms could learn such a function by minimizing the prediction error over time. The learned function constitutes an anticipatory model of the object motion (Balkenius and Johansson 2007).

We now add the constraint that the perception of the object, including its localization, takes T time units. In this case, the problem translates to estimating the position from observations that are T time units old. In addition, this means that the organism only has access to the prediction error after T additional time steps, that is, learning has to be set off until the error can be calculated and the estimate of the objects current position has to be remembered until the actual target location becomes available.

Because sensory processing takes time, an organism will never have access to the position of a moving object until after a delay. Any action that is directed toward the object position will thus have to depend on the predicted location rather than the actual one.

This is further complicated by the fact that any action directed toward the predicted location will also take some time to execute. For example, if an action is performed with constant reaction time, an action directed at the current position will miss the target, since once the action has been performed, the object will be at a new position. Consequently, the system needs to anticipate the position of the object already when the action is initiated.

In summary, for perception, the organism needs to keep track of the target in three different time frames. The first consists of the currently observed set of positions that can be called the perceived now. The second is the anticipated now. This is the actual position where the object is, but this is not yet accessible. Finally, any action must be controlled by the anticipated future.

The predictions resulting in the anticipated now may or may not be correct, but there is no way for the organism to correct these predictions until at a later time, when the true sensory input becomes available. At this time, it is possible to adapt the earlier predictions using ► online learning to the actual sensory input, something that requires that the earlier anticipation, as well as the sensory information used for it, should still be available. This implies that at every moment, the sensory input is used both to anticipate the future and to adapt earlier predictions, but because of processing delays, it cannot be used to code for the current state of the external world.

The role of anticipation is also easily seen in tasks such as catching a ball that involves ► sensorimotor adaptation. It involves at least the following components that can be divided into a visual pursuit and a catch component. Even to just visually focus on the ball, its trajectory needs to be anticipated (Balkenius and Johansson 2007). Since visual processing and the eye movements following it are not instantaneous, it requires prediction to determine where the ball is right now.

Similarly, eye movements cannot be based on the anticipated now, but must be controlled by the anticipated future. Looking at a moving object therefore requires that the organism simultaneously maintains sensory information at five different timescales: the current sensory input, the anticipated now and future, and previous predictions of the now and the future. By combining information at the different time frames in an appropriate way, it is possible both to change the currently anticipated now and to make future predictions more accurate.

Assuming the gaze system is correctly tuned, via some feed-forward mechanism, the temporal unfolding of the ongoing interaction with the visual target contains the information needed to predict the location of the ball in the future, but the task for the hand is not to move to any arbitrary point along the predicted trajectory of the ball. Instead, the sensorimotor system must direct the hand to the location where the ball will be once the motor command to reach that location has been executed. This introduces an additional type of complexity, since the time in the future when the hand will catch the ball depends on properties of the arm and hand as well as on the ball. Although this is strictly also true for eye movements, the physical lag of the system becomes more critical for arm movements.

In technical systems, the mechanisms required are often implemented as Kalman filters. Such filters have also been suggested to be the basis for the human ability to understand dynamical events and the actions of other people (Kawato 1999).

Important Scientific Research and Open Questions

It is clear that anticipation plays a large role in many behaviors and that it is essential to anticipate events and the consequences of actions. However, it is not known what mechanisms lie behind these abilities or how they develop. For example, infants are not initially able to predict even very simple movements, but gradually acquire this ability during their first months of life. It is possible that this anticipatory ability is learned as a direct prediction of future states from previous states, but it is also possible that anticipation makes use of internal simulation of the world. In the latter case, anticipation would depend on fairly complex models of regularities in the environment.

An outstanding question is to what extent species other than the human can learn to anticipate the future. Even though many animals perform behaviors that prepare them for the future, such as caching food for the winter, it is not obvious that such behaviors are motivated by an anticipatory ability. Nor is it necessary that such behaviors are learned. However, there is an increasing amount of empirical evidence that points toward the existence of anticipatory learning abilities in primates (Osvath 2010).

Another area of research addresses how technical systems, including robots, could become equipped with ► anticipatory learning abilities. By learning to anticipate future states of the world, a robot does not need to be as fast as if it is unprepared to everything that happens.

Cross-References

- ► Adaptation and Learning
- ► Anticipation and Learning
- ► Anticipatory Learning
- ► Anticipatory Learning Mechanisms
- ► Conditioning
- ► Expectancy Learning and Evaluative Learning
- ► Sensorimotor Adaptation
- ► Unconscious and Conscious Learning
- ► Unconscious Learning

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A

Adaptation and Learning

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Synonyms

Biological function of learning; Ultimate explanations of learning (contrast with proximate explanations)

Definition

Adaptation is a ubiquitous term, used in the humanities and sciences alike, to refer to the act or process of changing – or, indeed, to the change itself – so as to become better suited to a new situation, or in a new application. For example, dark adaptation is a physiological process, whereas a film adaptation is the product of a change. In evolutionary biology, too, adaptation refers either to the evolutionary process whereby a population becomes better suited to its environment, typically through natural selection; or, to any trait that increases an individual's chances of leaving descendants. The use of the term to mean the evolutionary process was for some time the preferred usage; however, the word adaptation is used so frequently in the literature to refer to a trait, per se, as to become equally acceptable.

Theoretical Background

The capacity to learn, like any other behavioral or morphological trait, can be studied from multiple perspectives: Questions that address the *proximate causes* of a trait, like the ability to learn, are those that attempt to understand (a) the underlying mechanisms that control the trait (how it works), or (b) the development of the trait within the individual's life span (how it comes about and changes over time). On the other hand, questions that invoke an *ultimate analysis*, explore (c) the biological function, or adaptive value, of the trait (why animals possess it), or (d) some aspect of the trait's evolutionary history (e.g., whether close relatives and their common ancestor possess it).

Ultimate analyses of animals' learning abilities currently abound in the literature (Dugatkin 2009), demonstrating the adaptive value of learning in many different species, and many different behavior systems. For example, juvenile coho salmon learn odors associated with their natal stream and use those cues to guide them during migration. Human and nonhuman animals alike learn to avoid any novel food that is followed by illness, forming a strong *taste aversion* to those substances. Norway rats also learn which novel foods might be safe, and which might be poisonous, by interacting closely with returning foragers, whose fur and breath contain residues of previously eaten food. To determine the quality of a potential territory, juvenile anole lizards rely on the choices of conspecifics, a phenomenon called *conspecific cueing*. Exposure to conspecifics also benefits long-tailed tits, a European woodland bird: Juveniles learn to identify the "churr" call of their parents, and then later, as adults, use this learned template to recognize close relatives, whom they will help in raising young if their own breeding attempts fail. Finally, the prodigious spatial learning abilities of many food-storing birds enable them to return to locations where they have cached food, avoiding sites that they already have emptied.

Although all of the examples mentioned thus far have involved vertebrates, learning also has been studied extensively in invertebrates, especially insects (Dukas 2008), in which the capacity to learn has been demonstrated in multiple species from all major insect orders. In most insects – indeed, in animals generally – the capacity to learn appears to be an adaptation that helps guide them as they actively search for, or attempt to avoid, food, mates, hosts, and predators. However, recent reports demonstrate that sedentary insects also are capable of learning. Not surprisingly, given this burgeoning literature, present thinking is that the capacity to learn may be universal in all animals possessing a nervous system (Dukas 2008; Greenspan 2007).

Despite its currently favorable reception, this ultimate approach to learning is a relatively recent pursuit. With the exception of song learning, imprinting, and search image formation, early ethologists not only were more interested in instinctive behavior, but also tended to see behavior as being primarily hard-wired. (Indeed, Hailman's 1969 *Scientific American* paper, provocatively entitled "How an instinct is learned," was intended to highlight a very different view of how gull chicks obtained food by "instinctively" pecking at the red spot on their parents' beaks.) Although another group of researchers, namely experimental psychologists, also were interested in learning, as a group they actively eschewed the study of function for many years.

In the mid-1900s, when the conditioning procedures of ► Ivan Pavlov and ► B. F. Skinner became a cornerstone of experimental psychology, the study of learning was nearly exclusively a study of proximate mechanisms. Although the function of learning always has interested researchers – indeed, it was a recurrent theme in Pavlov's writing – adaptive value did not figure prominently in experimental psychology until two watershed developments forced consideration of the issue. Beginning in the late 1960s, the discovery of biological ► constraints on learning (Hinde and Stevenson-Hinde 1973) demonstrated rather dramatically how animals' adaptations to their environments drove, shaped and, thus, constrained what and how they were able to learn. No less important was the success of neo-Darwinian evolutionary analyses in the newly emerging field of behavioral ecology (what some regard as the successor to ethology).

Today, the study of adaptation and learning increasingly blurs the boundaries between animal learning psychology and behavioral ecology (Shettleworth 2009). Nonetheless, many contemporary researchers address functional questions in the context of two basic kinds of learning that, at one time, were the exclusive purview of psychologists: *Nonassociative learning* involves learning from a single-stimulus experience; whereas *associative learning* results from procedures involving two events (Papini 2008). Although many no longer hold the view that nonassociative and associative learning involve different underlying mechanisms, the associative vs. nonassociative nomenclature continues to be used widely. Indeed, the nomenclature continues to be used even as researchers debate whether associative learning involves learning an association, per se, rather than learning the contingency relationship itself, or something about the temporal relationship.

In nonassociative learning, an individual responds to a single stimulus, say a loud noise, and that response decreases (*habituation*) or increases (*sensitization*) with repeated exposures to that same stimulus. Habituation, which is found in animals as diverse as planaria and primates, as well as in many different behavior systems, prevents individuals from wasting time and energy in behavior that is ineffective, unnecessary, or inappropriate (Shettleworth 2009). For example, in many territorial fish and bird species, a territory owner reacts to the sight or sound of its neighbors by immediately approaching the common boundary and engaging in a species-typical territorial display; however, this energetically costly response dissipates with repeated exposures to those same neighbors over the breeding season, freeing territorial males to find food, court females, or protect young. Similarly, all animals, humans and nonhumans alike, immediately orient toward novel visual and auditory stimuli, the function of which is to detect potential danger, but soon cease orienting if the stimuli don't reveal a threat. Nonetheless, the need for vigilance is not sacrificed to the need for response economy. Many characteristics of habituated responses demonstrate how finely balanced is the process to take full advantage of the benefit to cost ratio. For example, habituated responses show *spontaneous recovery*, a return to initial levels of responding following a stimulation-free interval. In addition, presentation of a novel stimulus, virtually any new event, can *disinhibit*, or restore, the habituated response abruptly to its initial level. Finally, habituation is unfailingly stimulus-specific, generalizing little to other, even similar, stimuli.

Repeated presentations of a stimulus also may produce an increase in responding, sensitization, before the response begins to habituate. Unlike habituation, sensitization is not at all stimulus-specific and typically occurs when the repeated stimulus is of high intensity or aversive. Also, unlike habituation, sensitization has been observed only in multicellular organisms with at least a rudimentary nervous system. From a functional point of view, it's easy to understand why sensitization, which often functions as a kind of danger alert system, not only might precede habituation as the first phase of a biphasic process to assess potential danger, but also might generalize more broadly than habituation.

Pavlovian conditioning, also known as *classical conditioning*, is a type of associative learning procedure in which the experimenter arranges a contingency between a relatively neutral stimulus (e.g., the sound of a bell) and a *reinforcer*, a stimulus already possessing some hedonic value (e.g., a morsel of food). From a functional perspective, Pavlovian conditioning has been characterized as the ability to detect cause and effect in the environment and, subsequently, to prepare for imminent, biologically important events (Hollis 1982, 1997; Domjan 2005). For example, in Japanese quail and blue gourami fish, males learn to recognize cues that accompany sexual opportunities, enabling them to identify a possible mate. In addition, these cues elicit physiological responses that increase sexual arousal and enhance sexual behavior, providing a direct reproductive benefit in the form of more eggs and young. Similarly, several species of territorial fish, rats, and mice learn to recognize imminent signals of invading male rivals, using these signals to mount a more vigorous, and ultimately more successful, territorial defense. Such cues not only direct males to locations that, in the past, have been especially vulnerable to invasions, but also they are thought to play an important role in "winner" and "loser" effects, wherein winners are more likely to win subsequent fights while losers are more likely to stay losers. Finally, learned cues that reliably accompany the injection or ingestion of a wide variety of drugs – e.g., alcohol, caffeine and heroin – elicit a compensatory response, one that opposes the physiological effects of the drug and thus attenuates drug-related deviations from homeostasis. In individuals who have acquired tolerance to large doses of potentially lethal drugs – which, itself, is the manifestation of Pavlovian conditioning – the learned compensatory response prevents overdose.

Another kind of associative learning procedure is *instrumental conditioning*, sometimes called *operant conditioning* or trial-and-error learning, in which the experimenter arranges a contingency between some aspect of an animal's behavior and the delivery of a reinforcer. From a functional perspective, instrumental conditioning appears to play an important role in the natural foraging behavior of honeybees and cabbage white butterflies, which learn through prolonged trial and error how to extract nectar efficiently from flowers. Indeed, the conditions for instrumental learning exist in just about any naturalistic situation in which behavior becomes increasingly proficient or more refined through repeated practice, such as the food begging of gull chicks, mentioned earlier.

An implicit assumption in learning as an adaptation, is that the benefits of learning, such as those described above, are offset by its costs. Compared to a hard-wired response that is available on the very first occasion that the circumstances require it, learned behavior necessarily involves "start-up costs," that is initial inefficiencies and response errors while the behavior is being learned. Learned behavior also entails "machinery costs," costs that result from whatever physiological mechanisms are required to support learning. Given these costs, the capacity to learn – the ability of animals to adjust their behavior to their current, local environment – is expected to evolve only when two conditions are met (Stephens 1993): (1) Biologically important events, say the location of food or the characteristics of mates, must be relatively stable within an individual's lifetime. That is, learning provides no benefit if what is learned is no longer useful on subsequent occasions. However, (2) those same events must not remain stable from one generation to the next. That is, if the world remains constant, a hard-wired response is a better bet.

Important Scientific Research and Open Questions

Environmental predictability is posited to be a critical factor in whether learning is expected to evolve. However, given how widespread is this trait, the question no longer can be which *species* have evolved the capacity to learn, but rather which behaviors, or behavior systems, rely on learning. Thus, an open question is how, in many animals, their nervous systems, parts of which subserve several different behavior systems, permit flexible behavior in some systems and fixed responses in others.

Although the two kinds of associative learning described above, namely, Pavlovian and instrumental conditioning, involve different procedures, their operational differences do not necessarily imply that they are governed by different underlying mechanisms. External stimuli inevitably accompany every instrumental learning procedure and, thus, the animal may learn about the Pavlovian relationship between stimuli, rather than the instrumental relationship between response and reinforcer. But the debate about underlying mechanisms reflects a proximate, rather than an ultimate, question and thus does not have any direct bearing on the function of learning. Perhaps not surprisingly, then, researchers reporting their functional analyses of learning increasingly omit the terms "Pavlovian" and "instrumental" conditioning, preferring to use the word "associative learning" – or, in many cases, simply "learning" – instead.

Cross-References

- ► Anticipatory Learning
- ► Anticipatory Schema(s)
- ► Associative Learning
- ► Biological and Evolutionary Constraints of Learning
- ► Comparative Psychology and Ethology
- ► Conditioning
- ► Evolution of Learning
- ► Habituation and Sensitization
- ► Invertebrate Learning
- ► Learning and Instinct
- ► Nonassociative Learning
- ► Operant Behavior
- ► Operant Learning
- ► Pavlov, Ivan P. (1849–1936)
- ► Pavlovian Conditioning
- ► Risk-Sensitive Reinforcement Learning
- ► Skinner B. F.
- ► Skinner B. F. (1904–1990)
- ► Social Learning in Animals
- ► Spatial Learning
- ► Tinbergen, Nikolaas (1907–1988)

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Adaptation to Learning Styles

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Synonyms

Aptitude–treatment interaction; Cognitive styles; Learning preferences; Tailored instruction

Definition

Teachers readily admit that every student is different, yet most instructional activities require all learners to complete the same tasks. Resolving this disconnect requires that instruction be individualized to the needs of each student. The process of modifying activity in response to contextual requirements (in this case, an individual's needs) is called adaptation. Adaptation requires that some type of assessment be performed, and that a change occur in response to that assessment. Sometimes, adaptation occurs without conscious thought or planning, as when a tutor senses that a learner did not understand a concept and explains it again in a different way. Yet most often when we speak of instructional adaptations, we refer to deliberate adjustments to the instructional design (instructional content, methods, or presentation) intended to optimize learning.

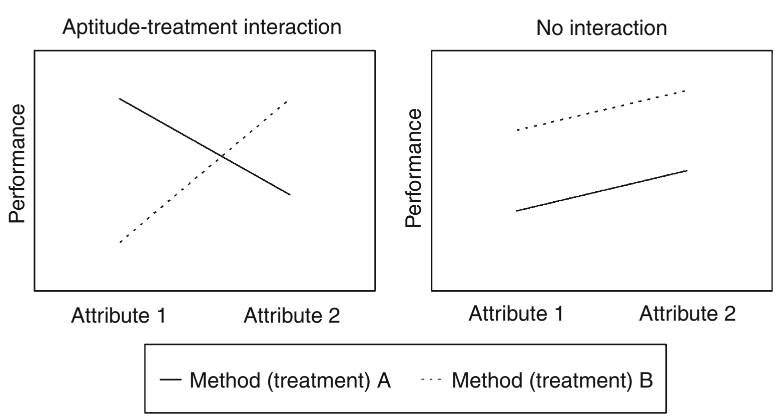
When considering the various aptitudes that educators could assess and then use to adapt instruction, learning and cognitive styles frequently surface as possibilities. Learning styles are "general tendencies to prefer to process information in different ways" (Jonassen and Grabowski 1993, p. 233). Cognitive styles are "characteristic approaches of individuals in acquiring and organizing information" (ibid., p. 173). Learning and cognitive styles are superficially similar but theoretically distinct in that learning styles refer to preferences (typically self-reported), while cognitive styles refer to actual mental operations (typically measured using more objective tests).

Before an adaptation can be justified, educators must have evidence that such adaptations make a difference – that learning outcomes (e.g., effectiveness, efficiency, or satisfaction) vary depending on both the educational intervention and the learner characteristic (aptitude). Such effects are termed aptitude–treatment interactions. An aptitude–treatment interaction (see Fig. 1) occurs when a student with attribute 1 (e.g., active learner) learns better with instructional approach A than with approach B, while a student with attribute 2 (e.g., reflective learner) learns better with instructional approach B. If all students learned better with approach B, there would be no interaction and no need for adaptation.

Theoretical Background

Hundreds of learning styles have been described, including the popular frameworks described by Kolb (active-reflective and concrete-abstract dimensions), Jung (extroversion-introversion, sensation-intuition, thinking-feeling, and judging-perceiving), Felder and Solomon (active-reflective, sensing-intuitive, visual-verbal, and sequential-global dimensions), Dunn and Dunn (environmental, sociological, emotional, and physical factors), and Grascha and Riechmann (avoidant-participant, competitive-collaborative, and dependent-independent dimensions). Cognitive styles comprise a distinct but related set of stable traits that learners employ in perceiving, processing, and organizing information. Dozens of cognitive styles have been described, each with its own theoretical framework, but most can be grouped in one of three broad clusters: field dependent-independent (e.g., Witkin's model, related frameworks include wholist-analytic, serialist-wholist, leveling-sharpening, and analytical-relational), visualizer-verbalizer (e.g., Richardson's model, or verbalizer-imager), and visual-haptic (e.g., Lowenfeld's model). Both learning and cognitive styles refer to how information is processed; the key difference is that learning styles represent learner perceptions and preferences, while cognitive styles reflect actual abilities, skills, or tendencies. While the theoretical and measurement differences are not trivial, for the purposes of discussing adaptation we can reasonably interchange these constructs, and I will use learning styles to refer to both learning and cognitive styles.

Teachers have long been intrigued by the idea that individual learner propensities such as learning styles could help them more effectively reach learners. Adaptation can occur at the curriculum level ("macro-adaptation," for example, directing learners to a specific course or curriculum based on an aptitude) or at the level of moment-by-moment instructional events ("micro-adaptation," for example, using different teaching approaches for learners with different aptitudes). Except for the cases of learner knowledge (e.g., accelerated or remedial pathways) and formal learning disabilities, macro-adaptation has generally not been shown to work effectively in practice. Micro-



Adaptation to Learning Styles. Fig. 1 Aptitude-treatment interaction occurs when a learner attribute predicts different outcomes for different treatments (teaching methods). In the example on the *left*, learners with attribute 1 perform better using teaching method A than with method B, while learners with attribute 2 perform better using method B. Interaction is present, and adapting the method so that learners with attribute 1 get method A and those with attribute 2 receive method B would enhance learning. In the example on the *right*, both groups perform better with method B. There is no interaction and adaptation is unnecessary adaptations have likewise proven difficult in the typical classroom setting, where teachers must simultaneously meet the needs of multiple learners. Thus, recent attempts to demonstrate the feasibility and effectiveness of adaptation have frequently used computer-assisted instruction (CAI) (Cook 2005). Not only does CAI makes individualization more feasible than in the past, but adapting CAI to specific learner characteristics could potentially optimize the benefit from CAI.

Unfortunately, despite great hopes (and often great hype), adaptation to learning styles has generally failed to produce meaningful and consistent results. This may be in part due to a paucity of studies designed to explore aptitude–treatment interactions. Most research studies involving learning styles look for correlations between styles and outcomes, but fail to explore the interaction between style and instructional method. Moreover, even studies that do explore such interactions often lack an a priori theoretical foundation that would predict the observed outcome. The implications of such post hoc interpretations are less powerful than those from theoretically grounded, hypothesis-driven studies. Finally, results are inconsistent from study to study, and the most rigorous studies have nearly always failed to find significant interactions. Based on these findings, it is difficult to recommend adaptation to learning styles at this time.

Important Scientific Research and Open Questions

Questions greatly outnumber the facts in learning styles research, and rigorous, theory-based, hypothesis-driven research could contribute greatly to the field. First, how important are learning styles? Many authors have suggested that the effect of learning styles is small relative to the impact of instructional methods (see, e.g., Merrill 2002). They argue that the greatest learning gains will come from the use of effective instructional methods and careful alignment of instructional methods with learning objectives; once this has been done, the incremental gain from adapting to learning styles is minimal. Stating this in terms of the aptitude–treatment interaction model, these authors propose a main effect from instructional methods but little or no interaction with learning styles. As noted above, appropriately designed studies are few and inconsistent, but most fail to confirm the hypothesized interaction between intervention and learning styles. The absence of evidence to suggest interactions could be attributed to a paucity of appropriately designed studies (see below for research considerations). However, existing evidence cannot disprove the primacy of instructional methods over cognitive and learning styles, and suggests that the influence of styles is at best weak and inconsistent (see Pashler et al. 2008 for an extended discussion of this issue).

Second, how should we adapt in response to a given style? Most researchers have hypothesized that instructional designs should take advantage of learning style strengths and compensate for weaknesses. For example, reflective learners would be provided instruction that emphasized reflection, while active learners would learn using active instructional methods. However, there are two alternative perspectives worth considering. First, some view the nondominant learning style as a weakness, and argue that instead of tailoring instruction to accentuate the dominant style teachers should design instruction to target and strengthen weaknesses (akin to weight training to build strong muscles). Related solutions include consciously attempting to change the style, and teaching learners strategies to help them overcome style limitations. Second, several of the theories from which learning styles have derived emphasize that the most effective learning involves balanced use of all styles rather than emphasis on one. For example, Kolb hypothesized a learning cycle with four stages corresponding to the four styles listed above. Learners might prefer to enter the cycle at one stage, but effective learning requires passage through all four stages of the cycle. Finally, even assuming that playing to the learner's strengths is the right approach, theories are vague, and empirical evidence is virtually nonexistent to provide support upon which to base adaptations.

Third, to what should we adapt? Given the nearly countless learning and cognitive styles that have been identified, the choice of one measure over another seems rather arbitrary. Moreover, there are other cognitive aptitudes with stronger empirical or theoretical support for adaptation than learning styles. For example, evidence is both substantial and fairly consistent that adapting to learner baseline (prior) knowledge can improve learning efficiency without sacrificing learning outcomes. Spatial ability has shown promise in a few studies, although outcomes have been inconsistent. Likewise, preliminary evidence suggests that adaptation in response to learner motivation is beneficial. Perhaps, if educators are going to attempt adaptation, they should explore one of these other aptitudes first.

Finally, to those anxious to embark on rigorous study of adaptation to learning styles, it is helpful to learn from the mistakes and warnings of earlier researchers (see Curry 1999; Cronbach and Snow 1977 for details). I will summarize briefly the most salient of these. Perhaps the greatest challenge in this field is the multiplicity of theories, constructs, and instruments developed to explain and measure learning styles. In addition to the issues of selecting one style over another and planning the proposed adaptation (noted above), researchers often inappropriately attempt to apply a single theory or instrument across a range of educational settings when different style frameworks might be more appropriate. Second, learning style instruments generally have little evidence to support the validity of score interpretations. Scores from self-report instruments often show high reliability, but this does not indicate they accurately measure a meaningful construct. Third, effective adaptation may require response to multiple learner characteristics simultaneously; focusing on one aptitude (e.g., one learning style) at a time may be insufficient. Yet different aptitudes may themselves interact in complex ways, thus further complicating an already difficult problem. Fourth, adaptation is most likely to benefit those with a strong tendency toward one style or another (e.g., the extremes of the spectrum). Yet nearly all research in the field includes participants with "intermediate" styles or (worse) dichotomizes learners using the midpoint of the scale. Researchers will be more likely to confirm hypothesized relationships when participants have been selected to clearly represent the style in question. Fifth, there is often little difference between the two interventions intended to target specific styles. This is perhaps a combination of two issues noted above – the decision to employ strong instructional methods before considering styles, and the lack of clear evidence and theory to guide learning style-guided instructional designs. Sixth, because learning styles research explores interactions rather than main effects, defensible results typically require relatively large samples (typically 200 or more participants, unless an "extreme-groups" design is employed); smaller studies are likely underpowered and yield falsely-negative findings. Seventh, in most cases, learning styles studies should be analyzed using regression analysis (i.e., as illustrated in the figures above). Ideally, the more familiar *t*-test or analysis of variance should only be employed when using an extreme-groups design.

In summary, adaptations in response to an individual's learning style are not supported by presently available theory or evidence. While future research may provide insights into this intriguing field, at present educators and their students may benefit from focusing first on employing effective instructional methods that align with course objectives and learning needs. Carefully planned theory-based research in adaptive instruction is much needed.

Cross-References

- ► Adaptation and Learning
- ► Adaptive Blended Learning Environments
- ► Adaptive Instruction Systems and Learning
- ► Adaptive Learning Systems
- ► Adult Learning Styles
- ► Aptitude-Treatment Interaction
- ► Cognitive and Affective Learning Strategies
- ► Learning Style(s)
- ► Multiple Intelligences and Learning Styles
- ► Styles of Engagement in Learning

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Adaptation to Weightlessnes

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Synonyms

Space adaptation

Definition

Ability to gradually modify sensorimotor functions in order to restore adequate perceptual and behavioral performance in the absence of gravity. This is a special case of sensorimotor adaptation, in which the distortion is a change of the force environment.

Theoretical Background

When the human body is exposed to weightlessness, several sensory, central, and motor functions are adversely affected. At the sensory level, otolith organs no longer provide information about the gravitational vertical as a fundamental reference for self-orientation, skin receptors do not register foot-ground contact forces since the downward pull of gravity is absent, and proprioceptive information about body posture deteriorates due to receptor unloading. At the central level, spatial orientation is degraded due to the mismatch between unchanged visual but changed vestibular, tactile, and proprioceptive cues, which can result in sensations of uncertainty about being "right side up" or "upside down," feelings of unreality, and in the incapacitating symptoms of space motion sickness. At the motor level, the lack of ground contact destabilizes body posture, and limb unloading dramatically changes the relationship between motor commands and their behavioral consequences. The impact of weightlessness on subjective well-being, spatial perception, and motor performance is most pronounced during transient exposure (e.g., parabolic flight and onset of spaceflight). Most symptoms subside during prolonged exposure as a sign of adaptation, and aftereffects often emerge upon return to earth. It is important to understand the principles of sensorimotor adaptation to changed gravitational environments in order to define the risks associated with spacecraft operations and to design effective countermeasures.

Important Scientific Research and Open Questions

The adverse effects of weightlessness on *body posture* are compensated by a plastic central reinterpretation of sensory inputs, and the reprogramming of postural responses to allow movement in a microgravity environment. Aftereffects upon return to earth include postural and gait instability, which are partly compensated by an increased reliance on vision. Postflight changes in otolith-spinal reflexes manifest as deficits in many preprogrammed motor responses, such as those stabilizing posture after a voluntary jump. Recovery from short-duration missions (5–13 days) follows a double exponential, with rapid improvements during the first 8–10 h and a more gradual return to preflight levels over the next 4–8 days. Recovery from long-duration missions takes about 2 weeks. This prolonged time course has considerable implications for operational tasks after landing on a planetary surface, including rapid emergency egress from a landing vehicle.

The central reinterpretation of sensory inputs from the vestibular organs has adverse effects on *gaze stabilization* by the vestibulo-ocular reflex, and thus degrades eye–head coordination and visual target acquisition. This manifests as an increased incidence of saccadic eye movements, a reduced dynamic visual acuity, and blurred vision during the first days of weightlessness and of reexposure to a gravitational environment. These deficits pose problems for astronauts especially during entry, approach, and landing on planetary surfaces, as they could adversely affect tasks such as instruments reading, locating switches on a control panel, or evacuating a vehicle in suboptimal visual conditions.

Manual skills are considerably degraded in weightlessness. Depending on circumstances, movement speed, accuracy, and/or the cognitive costs of performing the skill can be affected, which led to the formulation of a three-factor hypothesis: Manual performance reflects a trade-off between speed, accuracy, and cognitive expenditure, and astronauts therefore can make a strategic decision which of these factors to protect in weightlessness at the expense of the other factors. For example, routine activities may favor the decision to slow down and reduce accuracy, while tasks considered to be critical may encourage the decision to recruit additional cognitive resources and conserve speed and accuracy. During prolonged spaceflight, simple and well-practiced manual skills adapt within a few hours, while complex and novel skills do not fully recover even after several months. Adaptive improvement draws heavily on cognitive resources and shows only limited aftereffects upon return to earth, which suggests that it is largely based on cognitive workaround strategies rather than on a sensorimotor recalibration.

The absence of gravitational cues about the vertical adversely impacts *spatial orientation*. Some astronauts resort to an egocentric frame of reference ("down is where my feet are"), while others prefer an allocentric frame ("down is where I see the spacecraft floor"). A change of the reference frame can be induced by external events, for example, when a fellow astronaut floats by in a different orientation; this change can be accompanied by strong sensations of discomfort. Somatosensory signals can partly substitute for the missing gravitational cues; however, they are degraded by weightlessness and thus can induce misjudgments of self and surround orientation. When persons are free floating, somatosensory information about contact forces is absent as well; eye closure in this situation eliminates all sense of one's own position in space, and leaves only a sense of relative body configuration. This lack of any spatial anchoring is distinct from the sense of free falling, experienced, for example, when jumping from a chair on earth. Anecdotal evidence suggests that spatial orientation gradually normalizes during prolonged spaceflight, but the time course of improvement and its underlying mechanisms remain to be elucidated.

It is still largely unknown to what extent adaptation to weightlessness depends on mental factors such as workload and stress, and on the interior design of space habitats. For example, interlinked spacecraft modules with different cues for "up" and "down" are known to provoke spatial disorientation and nausea, and thus may impair the ability to adapt. It is also unknown to what extent deficits observed in weightlessness reflect loss of certain functions, and to what extent they are signs of an ongoing adaptive remodeling process. Another open issue relates to the role of morphological changes: it has been demonstrated that exposure to weightlessness dramatically increases the number of synapses in the otolith organs, and that it modifies the brain's topography particularly in the somatosensory and cerebellar cortex. While these structural changes may facilitate adaptation, they may be difficult to rescind upon return to a gravitational environment, and thus may delay recovery.

Cross-References

- ► Motor Learning
- ► Motor Learning, Retention, and Transfer
- ► Motor Skill Learning
- ► Neural Substrates of Motor Learning
- ► Sensorimotor Adaptation
- ► Sensorimotor Learning
- ► Task-dependent Motor Learning

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Adaptive Agents

► Cognitive Modeling with Multiagent Systems

Adaptive Evaluation Systems

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Synonyms

Adaptive testing; Computer adaptive testing

Definition

Adaptive evaluation systems are computer-based systems for measuring the performance of individuals or of teams by tailoring the presentation order or type of screen affordance provided by the system based on ongoing user responses or response patterns in order to match the assessment level to that of the learner or team. Adaptive evaluation systems are nearly synonymous with computer adaptive testing for summative assessment (e.g., Guzmán and Conejo 2002), but for formative assessment, adaptive evaluation systems comprise the decision-making engines used in adaptive learning systems (e.g., intelligent tutors). Computer adaptive tests and intelligent tutors perhaps represent opposite ends of a continuum regarding what is knowledge, how it is measured, and what is the need or purpose of evaluation. Note that adaptive evaluation systems have high development costs and other inherent potential disadvantages and may be only marginally more efficient or effective than similar nonadaptive evaluation systems, and so development cost versus benefit must be considered.

Theoretical Background

Computer Adaptive Testing

Large-scale testing dates back to at least the civil service examinations in China in 200 BC, but the practice was only institutionalized in the west in the twentieth century. The concept of adaptive testing was formalized in the 1940s as a method for trained interviewers to tailor a test, such as the Stanford–Binet, to the test taker. Computer adaptive testing is a natural evolution of the confluence of aspects of these and other testing advances along with the advent of computers for test delivery in the 1960s.

Four components of computer adaptive test architecture are generally recognized including the item pool, the item selection method, a method to calculate the examinee's ability, and a stopping rule (Reckase 1989). The quality of the item pool is a critical element of an adaptive test. The item pool must contain a sufficiently large number of field-tested and validated items to accurately distinguish between test levels and sublevels. Item selection and ability estimation refer to the mathematical calculations used to calculate the probability of a test taker answering a test item correctly, to estimate the examinees ability, and to select subsequent test items. The algorithms used for item selection and ability measurement are based on item-response theory. The stopping rule is used to establish the criterion for test termination. The criterion is usually established according to the number of test items completed, the required test measurement accuracy, or a combination of both.

In practice, computer adaptive tests tailor the presentation of test items for each test taker based on their item-by-item performance to reduce the test length while maintaining assessment precision. The software selects test items (typically multiple choice questions) dynamically from a large bank of items based on the system's current estimate of the examinee's ability, and that estimate is updated after every response. If a question is answered correctly, the next test item is more complex, but if an item is answered incorrectly, an easier item is presented next, thus no two individuals will see exactly the same set of test items. In this way, the system converges on test items that are at the examinee's level and then stops the test.

From the examinee's view, the test is moderately difficult throughout, with few easy or difficult items. In this way, the computer adaptive test system in some sense "learns" about the examinee, and the test score obtained reflects the highest difficulty level of items that the learner can answer correctly. The best-known computer adaptive test may be the Graduate Management Admission Test (GMAT) which is completed by more than 200,000 people annually (Rudner 2010). An extensive collection of the computer adaptive test literature (currently over 1,400 published manuscripts) is available from Weiss (2010).

Cost benefit is an important consideration in computer adaptive testing (and possibly in adaptive assessment systems). Triantafillou, Georgiadou, and

Ecomides (2008) identified several benefits and limitations of computerized adaptive test systems. The primary benefits include test-taking efficiency and increased examinee motivation, while limitations include cost versus quality issues. For example, by 1997, the item pool for the GMAT included more than 9,000 items at an estimated development cost for each item of US$1,500–2,500 (Rudner 2010). The design, use, and size of item pools create other issues. Poorly constructed item selection can lead to uneven use distribution with the result that sophisticated algorithms must be developed to avoid under- or overexposure and distribution. Overexposure that occurs when test items are completed by a high percentage of examinees compromises test security, while underexposure that results when items are used infrequently inflates item pool development costs. Accurate examinee comparison is based on the assumption that test versions are comparable in terms of difficulty and content coverage, and this can only be confirmed by extensive field tests of the items and the system. Risks associated with a security breach encourage the use of small pools which exacerbates the issues of exposure, sampling, and cost. Because of the high development costs, these systems should be scalable to a large audience.

Adaptive Assessment Systems as a Component of Adaptive Learning Systems

Adaptive evaluation systems are fully embedded components of most adaptive learning systems (i.e., intelligent tutors) but also exist at some level in simulations and educational games. Adaptive learning systems in general require the maintenance and interaction of four models, the expert model that consists of the information to be learned (e.g., the knowledge structure of the domain or of experts in the domain), the student model that tracks and learns about the student (i.e., their structural knowledge or schema), the instructional model that actually conveys the information, and the instructional environment that is the user interface for interacting with the system. Compare these four models to the four components of computer adaptive tests above. The student model is the adaptive assessment system of adaptive learning systems.

An early use of the term "adaptive evaluation system" is as a component of the Unit Conduct-of-Fire Trainer (UCOFT) developed in the 1980s. UCOFT is a high-fidelity simulation trainer that provides practice for a gunner and tank commander team on various gunnery tasks. The trainer delivers preprogrammed firing exercises from a large library of exercises and includes an adaptive evaluation system (e.g., Geiger 1989). The adaptive evaluation system scores performance and controls team progress through a training matrix of firing activities. Each engagement exercise is scored as "strong" or "needs work" in the skill areas of target acquisition, reticle aim, and system management. When the crew performs satisfactorily, the system increases the complexity of the next exercise. The UCOFT tied adaptive evaluation to course sequencing and exemplifies the relationship of the formative application of adaptive evaluation. Although not commonly practiced, the information generated by the adaptive learning system to describe the "state" of the student model could be externally reported to show both learning over time while using the adaptive learning system as well as on exit to indicate the final performance level of the learner. Thus, we propose that adaptive learning systems should be modified, and in some cases this is easily accomplished, to provide assessment and evaluation reports. This modification must be done with care so that evaluation does not negatively influence the learning environment.

Important Scientific Research and Open Questions

First and foremost, the meaning of adaptive evaluation systems is shifting in concord with changes in acceptance of what constitutes knowledge, what artifacts represent knowledge (e.g., multiple-choice items, essays, inquiry comments, social interactions, questioning strategies), and what is evaluation; for example, from empiricism which focuses on mastery of individual knowledge elements that together constitute a whole to sociocultural views that value engagement with content through inquiry, the social aspects of learning, and even participation in the evaluation process itself which all require consideration of a larger context. In this discussion, it is important to distinguish between assessment which is the measurement of knowledge, skills, attitudes, and beliefs and evaluation which is ascribing a value to individuals or teams based on those measurements and other evidence. Framed differently, the current trend in adaptive evaluation systems may be away from a very narrow focus on measuring just a few kinds of knowledge elements, toward a much broader view that includes making evaluations of people (deciding, judging) based on many different but concomitant kinds of knowing within settings.

As learning and work becomes increasingly collaborative within learning communities, assessment and evaluation will likely follow suit. Thus, assessment and evaluation may shift from the individual to both the individual and the team level of analysis. Research will likely focus on how evaluation systems can adapt to learning teams, for example, by including and tracking not just one but multiple student models in the adaptive system. Such adaptive assessment and learning systems would require significant automation of the analysis of students' interactions with the system and with each other through the system. Such complex systems may be fairly distant at this time.

Cross-References

► Adaptive Game-Based Learning
► Adaptive Learning Systems
► Group Cognition and Collaborative Learning
► Intelligent Tutoring
► Peer Learning and Assessment
► Shared Cognition and Group Learning
► Simulation-Based Learning

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Adaptive Game-Based Learning

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Synonyms

Adaptive instruction; Artificial intelligence; Cognitive modeling; Gaming; Learner supports; Scaffolding

Definitions

Shute and Zapata-Rivera (2008) define adaptive learning systems as hard and soft technologies that adjust content presented to the learner using methodologies such as cognitive modeling and/or sensory input. Commercial games generate optimal challenge and engagement levels through the use of artificial intelligence (AI) systems that make adjustments to the game based on player behavior. Game-based learning (GBL) has the potential to provide effective learning experiences for players by including adaptive strategies for learning and engagement outcomes. The rationale for GBL has roots in long-standing learning theories such as intrinsic motivation (Malone and Lepper 1987), play theory (Rieber 1996), and problem solving (Jonassen 1997). While the concept of GBL is not new, advances in technologies that facilitate programming and dissemination of digital games have made it easier for GBL to be developed and implemented across multiple domains and audiences.

Critical design issues are surfacing as a result of the increased interest in and feasibility of GBL development. A major issue centers on the design of a game that is not only engaging but that also employs sound pedagogical approaches for achieving learning outcomes. Adding another level of complexity to this issue, GBL environments are generally digital, self-paced games where control measures are designed through programming and then packaged. This particular modality requires designers to attend to automated pedagogical affordances that support the development of knowledge and which account for as much player variability as possible. One way to accomplish this is through the construction of adaptive GBL environments (e.g., Van Eck 2006; Adcock et al. 2010).

Adaptive GBL environments are designed to adjust to a player's developing knowledge base by changing goal structure, complexity of problems, and game narratives. The origin of adaptive GBL lies in the desire to provide authentic, meaningful learning experiences in the context of an educational game. Based on prior work in intelligent tutoring system (ITS) design, these environments work by modeling the learners knowledge and following verified pedagogical principles such as increasing problem set complexity and removing of supports or scaffolds to facilitate schema construction based on each learner's level of understanding (e.g., Anderson et al. 1985; Graesser et al. 1999; Van Eck 2006).

Theoretical Background

Adaptive Instruction

Research in learning and cognition over the years has demonstrated that for instruction to be effective, it must account for differences in learner characteristics, including prior knowledge and metacognitive ability (e.g., Gagne et al. 2005). Researchers have been studying adaptive instruction for more than half a century (e.g., Skinner's programmed instruction and teaching machines 1958) in an effort to provide instruction that adapts to individual learners and also does so without human intervention, although this is not a requisite of adaptive instruction. Skinner's (1958) teaching machine is an early example of adaptive instruction that shaped learners' responses through behavior principles and presented material based on patterns of learner errors. While learners were in control of the pace of their learning, progress was managed by the system so that mastery had to be demonstrated before the learner could advance in the instruction.

Human tutoring is perhaps one of the most effective means of adapting instruction to the individual because it allows for both behavioral principles (as with programmed instruction) and social cognitive approaches to learning (i.e., Palincsar 1988). However, one-to-one tutoring is not practical as a universal approach to teaching, which is why researchers in the 1970s began exploring machine-based tutoring in the form of ITSs. According to Hartley and Sleeman (1973), ITSs essentially rely on three components: the expert model, the student model, and the tutor. The expert model approximates both the content knowledge of an expert in the given domain and the structure or organization of that knowledge. The tutoring system uses the expert model as a source of knowledge and structure for that information. The goal of the system is to reduce the disparity between the expert model and what the learner knows (the student model), which it develops during the tutoring session by tracking what the student says that is correct, incorrect, or irrelevant. Each time the student articulates something, the system compares what was said to what it knows about the structure and content of the domain (the expert model) and determines how closely the two are aligned. It then modifies the student model to reflect its best guess about what the student knows and selects the best pedagogical response that it believes will reduce the gap between the student model and the expert model.

There are several examples of ITSs (e.g., Andes, Atlas, PACT, Sherlock, Why Tutor, Why2, LISP, Stat Lady, Geometry Tutor, Smithtown, and AutoTutor) with a long history of evaluation and testing that shows they can be effective in a variety of domains including computer literacy (Graesser et al. 1999), algebra, geometry, computer languages (Anderson et al. 1985; Bonar and Cunningham 1988; Koedinger et al. 1997; Schofield and Evans-Rhodes 1989), and physics, (Gertner and VanLehn 2000; Graesser et al. 1999), resulting in learning gains, reduction of instructional time, or both. Human tutors produce learning gains of between 0.4 and 2.3 standard deviations when compared to traditional classroom instruction (Graesser et al. 2001). ITSs produce learning gains of between 0.3 and 1.0 standard deviations (Corbett et al. 1999), indicating that ITSs, while not as effective as human tutors, do produce significant learning gains.

In the 1980s, researchers also began to experiment with other forms of adaptive instruction using desktop computers. Advances in computing technology and software allowed for the development of self-paced computer-based instruction (CBI). While not as powerful as ITSs, CBI had the advantage of being faster and cheaper to develop. Attempts at individualizing and adapting instruction followed several paths, including goal orientation and expertise. Among the more significant and well-known research in this area was Tennyson's (1980a, b) work on the role of learner control during instruction and the provision of advisement (an analog of the function performed by the tutor in ITSs). CBI that allowed complete learner control over the instruction (path, sequence, number of practice examples, etc.) was found to be ineffective because of poor metacognitive skills among learners. Tennyson showed that adaptive control (where the program used learner performance to determine things like the optimal path, number of examples or practice items worked, and amount and type of feedback) is more effective than learner control. However, learner control is both preferred by learners and is itself related to building metacognitive and evaluative skills in learners, something adaptive instruction (like programmed instruction) cannot do. To explore ways to provide enough information to learners for them to effectively manage their own learning and effectively build schema (i.e., under learner control), researchers looked to advisement, or "coaching," in CBI.

Pedagogical Support for Learners

To facilitate schema development in self-directed adaptive environments, learners must be presented with the correct level of instructional support based on cognitive requirements. This mimics the tutor–student relationship described by Lev Vygotsky's (1978) Zone of Proximal Development (ZPD). In *Mind in Society*, Vygotsky proposed that learning is a social process. He contended that by learning through social interaction with someone possessing a deeper understanding of the domain, learners can make more progress than would be possible in independent study by operating at an optimal level of challenge within their ZPD. The ZPD is a perceived area of schema development opportunity where, with the proper cognitive supports, the learner can develop an effective schema. Traditionally, these cognitive supports are provided in the form of pedagogical strategies employed by a peer/tutor. With advances in instructional technologies such as ITSs automated systems that provide effective cognitive supports have been possible for many years and are now feasible additions to GBL.

In their review of studies examining discovery-based constructivist learning environments, Kirschner et al. (2006) stress the importance of supporting knowledge construction with instructional supports. Findings from their review showed that learners who do not receive the proper level of instructional scaffolding or support do not learn as deeply as learners receiving the correct level of support. Ideally this support should adjust as learners develop expertise in the domain of study.

In the context of serious game design, learning is conceptualized as a gradual progression from shallow to deep knowledge within a domain and, once sufficient content knowledge is mastered, as support in learning to think like an expert. Research suggests that this is a difficult thing to achieve in a player-driven exploratory environment such as a GBL (i.e., Kirschner et al. 2006), but with the proper attention to the design and implementation of adaptive technologies, it should be possible to create expert thinkers through serious gameplay.

Artificial Intelligence and GBL

Serious games refer to a broad range of games, including those for health, attitude, social change, and education. The aspect of serious games we address here is the subset of games for educational purposes, or GBL. Because there is no single disciplinary research base to rely on for GBL, researchers have looked to many different disciplines such as the learning sciences, communication, media studies, and anthropology when defining games (Becker 2010). GBL environments are, at their core, exploratory learning environments designed around the pedagogy and constraints associated with specific knowledge domains and the instructional strategies and constraints of video games. GBL is growing in popularity and has been cited as a means of providing learning environments aligned with situated learning that are conducive to the practice of problem solving (e.g., Van Eck 2006; Hung and Van Eck 2010). Serious games are more than simple multimedia instructional environments. Many complex elements go into a well-designed game. Elements of narrative, fantasy, pedagogical structure, and competition are critical for game effectiveness. Affordances such as custom avatars, inventories, nonplayer character interactions, tool sets, reflection journals, and collaborative spaces present multiple opportunities to create pedagogically meaningful learning environments.

By their nature, games are already adaptive (e.g., multilevel play, multiple story lines). Gameplay involves many subgoals that lead up to resolution of the larger goal of winning the game. After the accomplishment of each subgoal, a well-designed game should advance the player to the next level. As they advance through each level of the game, the complexity and affordances increase while support for gameplay (e.g., help from nonplayer characters) decreases. While this behavior is considered adaptive, most games lack the ability to diagnose and adjust to the players' existing knowledge base, while providing the correct metacognitive supports. This can be problematic when designing GBL environments, as supports must keep learners well within their ZPD for effective knowledge development. In other words, the development of games for specific learning goals requires an awareness of the mechanisms used by games so that designers can design appropriate feedback, advisement, and learner support that do not disrupt gameplay. Some have argued for the integration within games of existing technologies (e.g., ITSs and pedagogical agents,) using theories and models that are contextualized to gameplay (e.g., Van Eck 2006) to solve this issue.

One key to adaptive environments is to correctly infer the knowledge of the student. In GBL environments, doing this without interrupting a learner's engagement in the gameplay presents a critical challenge. Traditional assessments do not work in these environments, and designers must rely on embedded assessments that do not interrupt gameplay yet continue to support the activities critical to the pedagogy of the learning environment (Shute et al. 2009). Using AI methodologies termed "stealth assessments" based on approaches such as evidence centered design (ECD) and Bayes nets (Shute et al. 2010), GBL environments can be designed to effectively collect and analyze a valid model of student knowledge development without disrupting gameplay. Evidence derived through various player actions in the game are aggregated and used to make inferences about learner models and schemas, similar to the tutoring module in ITSs. This evidence from each stage of gameplay is fed back into the system to optimize challenge and to document learning for administrators and teachers.

Important Scientific Research and Open Questions

Because the concept of adaptive GBL is fairly new, many important questions still remain (e.g., Van Eck 2006). First of all, the means for designing and integrating stealth assessments into games using AI engines is a critical area of exploration. Existing ITS and tutoring models rely on dyadic interactions that are not appropriate for game environments, and current dialogue components of ITSs are not sufficiently sensitive to the context of games. The process of structuring AI models for GBL is made more challenging by the need to incorporate ECD, which presents its own design challenges (e.g., we do not yet have established models that map gameplay to specific cognitive constructs and learning behaviors). Additionally, AI models for GBL must be easily adaptable and modifiable if they are to be employed across the full range of educational settings and audiences. It also remains to be seen whether a game can be designed to not only present content accurately in an open-ended problem space but also to engage the learner. In other words, just because it is possible to create an adaptive GBL environment that is fun, pedagogically sound, and adaptive enough to facilitate effective schema acquisition and assimilation does not mean we can achieve this goal. These are just a few questions researchers will need to explore to realize the promise of truly adaptive GBL environments.

Cross-References

► Adaptive Learning Systems
► Games-Based Learning
► Learning with Games
► Schema Development

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Adaptive Instruction

► Adaptive Game-Based Learning

Adaptive Instruction Systems and Learning

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Synonyms

Expert system; Intelligent tutoring systems

Definition

Adaptive instructional systems refer to any form of instructional approach adopted to highlight the accommodation of individual differences so as to facilitate users' knowledge acquisition. Learners in an adaptive learning context are provided with alternative procedures and strategies for instruction. They have sufficient time to study a variety of learning resources.

In order to satisfy the needs of both individuals and groups, the implementation of adaptive instruction can be either individual-based or group-based, and can occur either in the classroom or in a computer-based environment. With the popularity of technology, adaptive instruction systems have been widely applied in a computer-based context in which the system can support the communication between the user and the system by distinguishing each user's characteristics and adapting the target content to his or her knowledge level, goals, and other characteristics.

Theoretical Background

The call for emphasizing adaptive instruction can be mainly traced back to Piaget and Vygotsky's perspectives of knowledge acquisition. According to Piaget (1973), instruction should aim to highlight students' individual generation of equilibration; that is, it should encourage students to actively build their own version of understanding, rather than to passively receive direct transmission of information. A teacher's role is "to create the situations and construct the initial devices which present useful problems to the child. . . . [and] to provide counter-examples that compel reflection and reconsideration of overhasty solutions" (Piaget 1973, p. 16). As Vygotsky (1978) indicated, a learner's mental development consists of two levels: the actual developmental level and the zone of proximal development. The former refers to the state at which a person can solve problems independently, whereas the latter describes the state at which one still relies on facilitation from either instructors or peers to solve problems. Suggestions drawn from Vygotsky's theory indicate that instruction should take learners' individual zone of proximal development into consideration and provide adaptive scaffolding to help students progress to the actual developmental level. These educational researchers have proposed a critical idea that instruction needs to value individuals' differences and offer appropriate scaffolding.

Due to differences in the resources and constraints of teaching environments, adaptive instruction systems are implemented in a variety of ways. Lee and Park (2008) categorized approaches of adaptive instruction systems into five major types:

1. Macro-level adaptive instruction: This approach, unlike the lock-step teaching in the traditional school context, is to adapt instruction at the macro-level by allowing each student to determine his/her own learning goals, depth of the target content, and relevant resources. A good example is Keller's Personalized System of Instruction (Keller 1968) in which the instructional materials are divided into sequential units for students to acquire at their own pace of learning. If needed, learners can seek facilitation and evaluation from student proctors. Since there is no time limitation on studying each unit, students can move to the next unit whenever they demonstrate mastery of the unit performed.
2. Aptitude-treatment interactions (ATI): This approach is to adapt instructional procedures and strategies (treatments) according to students' different characteristics such as intellectual ability, learning styles, or anxiety (aptitudes).
3. Micro-level adaptive instruction: The main feature of this approach is to utilize on-task rather than pre-task measurement to diagnose the students' learning behaviors and performance so as to adapt the instruction at the micro-level. Typical examples include one-on-one tutoring and intelligent tutoring systems. This approach is the most directly focused on students' needs of the five categories.
4. Adaptive hypermedia/Web-based systems: This approach refers to computer-based instructional systems that adapt the instruction according to the choices that each user has made. With the integration of Web resources into the design of the system, the distinct activities, according to Brusilovsky (2001), include adaptive presentation (e.g., offering relevant, classified, and comparative information) and adaptive navigation support (e.g., adaptive link sorting, hiding, and annotation).
5. Adaptive systems supporting specific pedagogical methods: This approach refers to the systems that are developed under the guidance of specific pedagogical methods (i.e., constructivist learning and collaborative learning) in order to promote deeper understanding, such as supporting alternative perspectives and processes of learning. Thus, these systems may depend heavily on a more complex system intelligence to perform.

Although the five approaches are presented above, Lee and Park (2008) further indicate a possibility that some may overlap with each other or that an adaptive instruction system may utilize more than one approach.

Important Scientific Research and Open Questions

Adaptive instruction systems have had a long history which, according to Lee and Park (2008), can be categorized into two periods. The first period refers to the duration of the eighties and early nineties. The system design of this period primarily focused on the acquisition of conceptual knowledge and procedural skills, and was mainly guided by two objectivism-oriented assumptions (Akhras and Self 2002). "There is an objective knowledge to be learned that can (in principle) be completely and correctly represented in the system, and the whole can be learned from the learning of its parts" (p. 4). Thus, compared with instructors in the traditional classroom setting, the system seemed to have a limited range for implementing teaching strategies. The second period refers to the late nineties at which time researchers began to integrate more complex theoretical frameworks and pedagogical approaches into the development of the system. For instance, to fulfill constructivist perspectives of learning, Akhras and Self (2002) suggested that adaptive instruction systems should be modeled in terms of situations rather than knowledge structures so that learning opportunities can arise from affordances of situations rather than from the prespecified teaching strategies.

Although the combination of complex pedagogical approaches and adaptive instruction systems has a great potential to enhance knowledge acquisition, there are still a number of emergent factors that need more research to explore. For example, students' epistemological beliefs may guide their metacognitive and cognitive activities. It is valuable to investigate ways to tailor instruction as well as scaffolding according to learners' different levels of epistemological beliefs. In addition, the previous studies have indicated that collaborative learning activities may generate possible conceptual conflicts by encouraging learners to reflect on and articulate their ideas. Thus, how to offer effective instructional strategies that optimize collaborative learning in an adaptive instruction system may be an important topic for future research. Further, motivation components play an essential role in guiding the process of knowledge building. A number of studies have identified the positive impact of game-based learning (GBL) on fostering students' motivation and academic performance. It may be helpful to integrate GBL ideas into the design of adaptive instruction systems so as to promote students' enthusiasm for the learning activities.

Cross-References

► Adaptive Blended Learning Environments
► Adaptive Evaluation Systems
► Adaptive Game-Based Learning
► Adaptive Instruction Systems and Learning
► Adaptive Learning Systems
► Adaptive Learning through Variation and Selection

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Adaptive Intelligent Web–Based Teaching and Learning

► Distributed Technologies

Adaptive Learning

► Impulsivity and Reversal Learning
► Learning with Expert Advice
► Meta-learning

Adaptive Learning Environments

► Adaptive Learning Systems

Adaptive Learning Systems

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Synonyms

Adaptive learning environments

Definition

Adaptive learning systems (often called adaptive learning environments) aim at supporting learners in acquiring knowledge and skills in a particular learning domain. The goal is to enhance the individual learning process with respect to speed, accuracy, quality and quantity of learning. A wide range of different adaptation techniques is used in current adaptive learning environments. The application of these techniques is based on information about a particular learner stored in an individual learner model.

Theoretical Background

Adaptive learning systems can be traced back to two different points of origin, the research in intelligent tutoring systems on the one side and the growing interest in web-based learning on the other side. Along with the progress in machine learning and artificial intelligence, intelligent tutoring systems have been developed. These systems are aimed at supporting the learner in his or her learning process similar to human tutors. Though a lot of very successful systems have been developed (with a culmination in the nineties of the last century) and are still used and further developed (e.g., the knowledge tracing tutors of the group at the Pittsburgh Science of Learning Center (Koedinger and Corbett 2006)), many of these systems have been tested and used only in laboratory settings. A more widespread implementation of intelligent tutoring systems failed to appear because the effort and costs to develop such powerful systems turned out to be too high with respect to the learning outcome. In parallel to the development of intelligent tutoring systems, the emergence of the World Wide Web led to a permanently growing use of the Web as a learning medium. However, in the beginning, mainly texts were presented in web pages simply changing the medium from textbooks to pages displayed on a computer screen. Also, adding interactivity to the web pages and constructing elaborated hypertexts often proved not to show an advantage over traditional learning settings. This led to the introduction of adaptation techniques to learning systems resulting in more or less individual learning support. Current adaptive learning systems cover a wide range of adaptivity from simple systems supporting only some aspects of adaptation and with only rudimentary knowledge about the learner on the one side to elaborated learning environments like intelligent tutoring systems on the other side.

All types of adaptive learning systems base their adaptive supporting decisions on a more or less elaborated type of learner model. These learner models comprise *stereotype*, *overlay*, *case-based*, and *Bayesian* learner models.

- *Stereotype user models* are simple learner models that categorize learners at hand of features mostly gathered from information about the learner in advance. For example, the preferred learning style of the learner, the self-estimation of the learner about the topics to be learned or about prerequisite skills (novice, advanced, expert), the motivation to learn, or even handicaps may be used to adapt the presentation of texts, illustrations, and animations, to select exercises, or to compute an appropriate learning path. Typically, stereotype learner models remain relatively stable over time and are updated only at major events, e.g., when completing a learning course. These learner models can easily be used in standardized adaptation techniques in learning management systems (e.g., Paramythis and Loidl-Reisinger 2004).
- *Overlay user models* are used most often in adaptive learning systems. An overlay model describes the learner's knowledge with respect to a model of the concepts and skills of a domain to be learned. That is, the user model is an overlay of the domain

model (de Bra 2008). Simple overlay models indicate only different levels of knowledge about a domain concept or skill (e.g., known, not known, not yet visited). More complex overlay models may describe the user knowledge in different layers (e.g., visiting status, performance status, inference status, and self-estimation status as used in ELM-ART (Weber and Brusilovsky 2001)). Typically, information for updating overlay models stem from observation of visiting pages in a course, of working at exercises and tests, and of solutions or solution steps to problem-solving tasks.

- *Case-based user models* have been used in some intelligent tutoring systems, e.g., in ELM-ART (Weber and Brusilovsky 2001). Such individual cases can be used as examples for correct solutions or how similar problems have been solved when presenting feedback to the learner during problem solving.
- *Bayesian user models* are used in many intelligent tutoring systems. Especially Bayesian knowledge tracing has been proved successful in several “cognitive” tutors (Koedinger and Corbett 2006).

According to Brusilovsky (2001), the adaptation methods used in most adaptive learning systems can be assigned to the main categories *adaptive presentation*, *adaptive navigation support*, and *adaptive curriculum sequencing*. These are completed by methods for *adaptive problem-solving support* (Weber and Brusilovsky 2001).

- The method *adaptive presentation* (or *content adaptation*) adapts the presentation of the content of a page to the user’s goals, knowledge, and other information (e.g., learning style) stored in the learner model. In a system with adaptive presentation, the pages presented to a user are not static but adaptively generated or assembled from different pieces. For example, expert users may receive more detailed and deep information, while novices receive additional explanations or according to a user’s learning style, presenting more text or more pictures and animations may be preferred.
- The method *curriculum sequencing* (also referred to as instructional planning technology) provides the learner with a sequence of knowledge units to learn that is best suited to his or her learning goals with respect to their already existing pre-knowledge. It may also plan the sequence of learning tasks (examples, questions, problems, etc.) to work with. Such an optimal sequence may be planned in advance of a course based on a stereotype learner model. Or it can be computed on the fly while learning with the system and depending on the outcome of working on exercises, tests, or problem-solving tasks.
- The method *adaptive navigation support* supports the learner in orientation and navigation through a course. In hypermedia systems, changing the appearance of visible links typically does this. The system can adaptively sort, annotate, or partly hide the links of the current page to simplify the choice of the next link. Adaptive navigation support can be considered as an extension of curriculum sequencing into a hypermedia context. It shares the same goal – to help learners to find an “optimal path” through the learning material. At the same time, adaptive navigation support is less directive than traditional sequencing: it guides students implicitly and leaves them with the choice of the next knowledge item to be learned or next problem to be solved.
- *Adaptive problem-solving support* is typically found in intelligent tutoring systems. The adaptive system analyzes solutions to problem-solving tasks or even observes learners while interactively generating the problem solution. The result of the analysis describes which concepts or skills the learner already possesses or lacks of. It is used to update the learner model and to provide the learner with extensive feedback. Examples of such intelligent tutoring systems are the knowledge-tracing tutors (Koedinger and Corbett 2006) or the hybrid case–based approach in the adaptive programming tutor ELM-ART (Weber and Brusilovsky 2001).

Important Scientific Research and Open Questions

Adaptive learning systems typically fall into the area of R&D systems with placing emphasis both on research and development aspects. The development of intelligent tutoring systems was dominated by research on central questions concerning the adequacy of different types of user modeling, the role of tutoring components, or the effects of learning with tutorial systems compared with individual human tutoring. Though this basic research still holds for current intelligent tutoring systems as well as for adaptive learning systems in general, the shift to developing larger educational environments and, therewith, concentrating more and more on technical aspects of these systems, led to favor usability and evaluation studies of these systems.

Ongoing research is presented at major conferences, e.g., UMAP (User Modeling, Adaptation, and Personalization) (formerly User Modeling UM and Adaptive Hypermedia AH), AIED (Artificial Intelligence in Education), ITS (Intelligent Tutoring Systems), and EC-TEL (European Conference on Technology Enhanced Learning). A lot of journals concerning learning and technology-enhanced learning publish papers on research and development of adaptive learning systems. Major papers are published in the journals IJAIED (International Journal of Artificial Intelligence in Education) and UMUAI (User Modeling and User-Adapted Interaction).

The importance of R&D in adaptive learning systems can be seen by the fact that the seventh framework programme (FP7) of the European Commission supports projects on technology-enhanced learning with a special focus on adaptive learning. One prominent example of a project funded in this European framework programme is GRAPPLE (de Bra et al. 2008). The goal of GRAPPLE is to integrate adaptive learning as a standard feature of general learning management systems. The role of adaptive learning in e-learning standards is one of the current open questions in the development of general e-learning environments (Paramythis and Loidl-Reisinger 2004).

Another open question in current research on adaptive learning systems concerns the role of adaptive support in cooperative learning. It is investigated whether and how cooperative learning can be enhanced by adaptive systems. This comprises questions on how groups of learners and their activities can be modeled and how these models can be used to support the collaboration of learners, e.g., assigning special roles to learners according to different levels of expertise and intervening the learning process by proposing co-learners that may help with their specific expertise.

Present adaptive learning systems were dominated by the results of the cognitive turn in psychology and pedagogy. That is, the development of adaptive systems (especially intelligent tutoring systems) was dominated by research on the role of mental representations and cognitive processes in learning neglecting the importance of motivation and emotion in learning processes. Therefore, an emerging topic in the research on adaptive learning systems is the investigation of the role of emotions and motivation in learning, how different emotional and motivational states can be detected automatically by a learning system, and how learning systems can adapt to emotional and motivational states of the learner.

Cross-References

▶ Adaptability and Learning
▶ Adaptation and Learning
▶ Adaptation to Learning Styles
▶ Bayesian Learning
▶ Collaborative Learning
▶ Intelligent Tutorials and Effects of Learning
▶ Interactive Learning Environments
▶ Learning Style(s)
▶ Neural Network Assistants for Learning

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Adaptive Learning Through Variation and Selection

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Synonyms

Trial-and-error learning

Definition

Adaptation through variation and selection is a process of creating *diversity of solutions* to some *problem* followed by *selection* of the proper one. In this paradigm, learning occurs by generation of tentative solutions and selection of the effective variant that is retained in memory.

Theoretical Background

The most powerful theory to explain numerous adaptations we observe in Nature is the theory of evolution. The basic mechanism in this theory is selection of heritable variations. Better adapted individuals have more offspring who inherit parental characters and in this way beneficial variations of the phenotype are spread and secured in the population. This principle of adaptation through variation and selection can be applied not only to evolving population but also to the learning of an individual organism.

In their interactions with an environment organisms repeatedly encounter problems. Adaptive learning is required to solve them. Thus, to start learning, *a problem should be detected first*. This detection is only possible when an individual has certain expectations about upcoming situation. Then the *mismatch* between *current* and *anticipated* states of environment indicates existence of the problem.

Recognition of the problem initiates the process of learning. According to variation and selection principle the first phase of adaptive learning is generation of tentative solutions. An initial behavior that failed to deliver expected result should be modified by varying parameters of actions. If new alternative does well then it is selected to be fixed in memory accompanied by association with features of environment that are specific to the problem situation. On the other hand, if generated solution does not succeed then creation of further variants continues until anticipated outcome received.

The natural selection acts on variation in population. The key difference of individual learning from evolution is that in the former an individual cannot evaluate several different variants of behavior simultaneously. During learning, selection acts not on the variation in the population of behaviors but on the sequence of varying behaviors.

Thus, the basic idea of adaptive learning through variation and selection can be summarized as: "*When the problem is recognized produce variations of the behavior until adaptation is achieved.*"

Important Scientific Research and Open Questions

The variation and selection approach to learning was conceptually developed in the framework of *evolutionary epistemology* (Popper 1984; Campbell 1974). The famous formula of Karl Popper (1902–1994) describing the growth of knowledge is

$$P_1 \rightarrow TT \rightarrow EE \rightarrow P_2,$$

where P_1 stands for the *initial problem*, *TT* are *tentative theories* or solutions proposed to solve it, *EE* is a process of *error elimination*, and P_2 is a new problem. Extended formula for the sequential generation of solutions takes the following form:

$$P_1 \rightarrow TT_1 \rightarrow EE_1 \rightarrow TT_2 \rightarrow EE_2 \cdots \rightarrow TT_n \rightarrow \textit{success},$$

where n is a number of attempts which an individual has performed until solution was obtained. Popper noted that the key property of the process is causal independence of variation on selection because the former precedes the latter, i.e., in this sense variation is "blind."

An important contribution of the evolutionary epistemology is a concept of "*vicarious selector*" (Campbell 1974). Vicarious selectors serve as internal representations of external factors of natural selection, thus allowing transfer of evolutionary values to the level of learning. Vicarious selection "substitutes" natural selection during lifetime learning, making possible evaluation and preselection of behavioral solutions without execution of them in the environment. The hierarchy of vicarious selectors accumulates previous (even unsuccessful) experience and, as a consequence, addition of new adaptations takes the form of progressive growth on the top of existing competence.

Ideas of adaptation through variation and selection were also developed in early cybernetic theories (Ashby 1960). William Ross Ashby (1903–1972) had introduced so called *essential variables* (variables indicating viability of an organism) and considered them as a source of control for the blind variation. Research on behavior stability brought forward the important notion that adaptation in one behavioral subsystem should not disturb other subsystems. The conclusion is that subsystems for different behaviors should be *loosely connected*. Unfortunately, the issue of retention of previous experience was not recognized in the proposed scheme. Therefore, each new learning episode should start from scratch and this would lead to the repetition of previous errors and make learning less effective. Another shortcoming was that only predetermined fixed set of essential variables were allowed to control blind variations.

Physiological theory of selective retention of adaptive combinations of central and peripheral physiological elements was proposed by Petr Anokhin (1898–1974) under the name of Theory of Functional Systems (1935). This theory was further developed by Vyacheslav Shvyrkov (1939–1994) who suggested system-selection principle explaining behavioral specialization of neurons determined at the level of functional system as a whole.

In behavioral science, B.F. Skinner (1904–1990) advocated his theory of "*selection by consequences*" (Skinner 1981). Skinner considered selection by consequences as an explanatory scheme that is common for the three different levels, namely, the Darwinian evolution, learning, and social evolution. In the field of neuroscience, selectionist theories were developed by Jean-Pierre Changeux (Changeux and Dehaene 1989), and by Gerald Edelman (Edelman 1987). Both theories declare application of "*neural Darwinism*" to processes at all levels of brain organization from the synapse to the consciousness. The suggested mechanisms of variation are generation of excessive synaptic connections during development and variable activation of neural assemblies. In their basic form theories attribute selection to the input matching:

At a given stage of the evolution of the organism, some of these spontaneously generated pre-representations may not match any defined feature of the environment (or any item from long-term memory stores) and may thus be transiently meaningless. But, some of them will ultimately be selected in novel situations, thus becoming "meaning full." The achievement of such adequacy (fitness) with the environment (or with a given cognitive state) would then become the basic criterion for selection (Changeux and Dehaene 1989, p. 87).

But input matching only is not enough for creation of an adaptive behavioral act because a process of action selection should also be specified. This problem is usually considered in the paradigm of *reinforcement learning*. An association between perception and action is assumed to be modulated by a value system. Value system categorizes states of an environment in terms of their adaptive significance and controls competition between alternative actions by sanctioning increase of probability for effective and decrease for futile ones. Evolution of value system by natural selection assures effective evaluation of stimuli in terms of their expected contribution to the evolutionary success of an organism.

Though the behavioral principles of learning through variation and selection are mostly clear, an understanding of neurophysiological mechanisms is still to come. Some challenges and prospects for the current theory are summarized below.

- Recognition of the problem situation is required to initiate learning and perform selection. This recognition is impossible without preexisted memory. An organism starts to learn on the top of inherited or *primary repertoire* of functional neural systems formed during *ontogeny*. In *postnatal* learning, primary systems are enriched by the *secondary repertoire*. Natural selection acts upon the primary repertoire and the primary upon the secondary. That makes possible a transfer of adaptive value from the level of evolution to the level of learning. Interplay between these levels defines the following questions:

  - How do developmental programs result in the primary repertoire of distributed neuronal populations tuned for specific adaptive functions?
  - What are mechanisms for selection of novel neuronal groups by existing functional networks of cells?
  - How can tentative neuronal groups be evaluated and preselected without execution of actions to make learning less risky and more time effective?
- Variations of the present behavior to solve the problem require generation of tentative neuronal groups. This process is not random but canalized by the current repertoire of neuronal systems available for recombination and reuse.
  - How do novel neuronal groups recombine, integrate, and extend existing neuronal systems?
  - How can existing neuronal groups preserve their functions being incorporated in novel systems?

Cross-References

► Anticipatory Learning
► Adaptation and Unsupervised Learning
► Ontogeny of Memory and Learning
► Reinforcement Learning
► Role of Prior Knowledge in Learning Processes

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Adaptive Memory and Learning

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Synonyms

Evolution and memory; Memory adaptation

Definition

The concept of adaptive ► memory and ► learning has two defining assumptions: First, the capacity to preserve and recover information over time is adaptive, meaning that the systems that enable memory and learning are goal-directed and functionally designed. Rather than domain-general, operating the same regardless of input and domain, species' retention systems are "tuned" to solve particular problems (such as remembering the locations of food sources or predators). Second, as products of ► natural selection, these systems likely bear the specific imprint of nature's criterion – the enhancement of fitness (survival en route to differential reproduction). As a result, the ability to *learn* and *remember* will likely be influenced by the fitness relevance of the information and tasks involved.

Theoretical Background

Most of the adaptive tasks animals have to solve during their lifetime do not have a stable solution. Animals cannot know ahead of time where the most abundant food sources will be found or where predators or potential mates are likely to be encountered. In fact, many important features of the environment are unpredictable; consequently, animals benefit from mechanisms that allow them to fine-tune their behavior to the current (or recently experienced) parameters of an environment. An animal equipped with the capacity to preserve and recover information adaptively – that is, to learn and remember – can exploit the stable properties of the environment while keeping track of any environmental events that necessitate behavior change.

Because different species must meet different ecological demands and are affected by different environmental features, each species' learning abilities should be fine-tuned to those environmental characteristics with the greatest impact on their ► inclusive fitness. In other words, we should expect cross-species variation in the ability to learn about different environmental variables. This expectation has been confirmed by an enormous amount of data. Food-storing specialists such as Clark's nutcrackers or marsh tits that rely on *spatial memory* to retrieve hidden seeds are known to outperform closely related non-storing (or with less predisposition to store) species in laboratory-based spatial memory tasks. In the *Pavlovian conditioning* domain, the classic work of Garcia and Koelling (1966) demonstrates that rats easily avoid a flavor previously paired with illness as well as audiovisual stimuli previously paired with electric shock but seem unable to learn when the cues are swapped. Presumably, this pattern is due to prevailing conditions in the environments in which rats evolved – peripheral pain was most frequently caused by external agents with particular visual and/or auditory properties, not by a particular flavor; conversely, illness was most frequently caused by specifically flavored meals rather than by visual or auditory stimuli. This pattern of biased learning to promote success in species-specific fitness relevant problems has also been observed in *instrumental learning* preparations in which animals must perform a particular response to obtain a reward or avoid a negative consequence. Rats, for example, rapidly learn to avoid an impending electric shock when the required avoidance response is part of their repertoire of defensive reactions (e.g., running), but this ability declines as the required response becomes incompatible with their typical reactions to danger (e.g., rearing).

Whether nature's criterion – the enhancement of fitness – has left a similar mark on human cognitive functioning is more controversial (see Nairne 2010). Human memory researchers usually propose domain-general memory mechanisms, that is, researchers assume that our retention systems operate similarly across materials and domains and are unaffected by information content. For example, it is often claimed that successful retention is determined simply by the functional "match" between the conditions present at *encoding* and those existing at the point of *retrieval.* Processing information at time 1 establishes a memory record that, in turn, dictates what retrieval cues can effectively access that record at time 2 (Tulving and Thomson 1973). Encoding tasks that promote the generation of multiple retrieval cues through *elaboration*, or the linking of the target item to other information in memory, increase the chances that an effective (matching) retrieval cue will be encountered later. However, the process itself is domain-general. Retention is controlled by the presence of a diagnostic retrieval cue and it is the chance characteristics of the retrieval environment, rather than the content of the information per se, that determines when (or if) an effective cue will be present. There are no inherent memory "tunings," only taxonomies relating encoding and retrieval contexts.

From a fitness perspective, of course, not all occurrences are equally important. It is much more important to remember the location of food, the appearance of a predator, or the activities of a prospective mate than it is to remember events and activities that are unrelated to fitness. Indeed, the ability to relive past experiences through *episodic memory*, which may be a uniquely human characteristic, may be an evolved *adaptation* designed specifically to help us interact in the social world. Ancestrally, humans lived in small groups and needed the ability to develop a sense of personal identity and to differentiate among other members of the social group (e.g., track coalitional structure, identify cheaters, develop accurate personality assessments, track the activities of kin versus non-kin); the capacity to remember is a crucial ingredient of each of these tasks. One can also imagine memory playing a vital role in navigational abilities – everything from recognizing landmarks to remembering diagnostic weather patterns or relevant constellations (Nairne and Pandeirada 2008).

Empirically, there is strong evidence that human learning and memory systems may be selectively tuned to process and retain information that is relevant to fitness. For example, analogous to the cue-to-consequence work of Garcia and Koelling (1966), studies have consistently found that people easily associate fitness-relevant stimuli, such as snakes and spiders, to aversive events such as shock but not as easily to positive consequences (Öhman and Mineka 2001). Both children and adults report strong and vivid memories for highly emotional events, such as situations in which their lives were in danger. Fitness-relevant information, such as information about social interactions or heroic exploits, also tends to transmit easily and effectively from individual to individual and across cultures.

Additional evidence comes from the survival processing paradigm, a procedure in which people are asked to process information with respect to a survival situation prior to a surprise retention test (Nairne et al. 2007). In one case, people were asked to rate the relevance of random words to an imaginary grasslands scenario in which they were stranded without food and water and susceptible to predators. People later remembered words rated with respect to this scenario much better than a host of control conditions, such as forming a visual image of the words, relating the words to a personal experience, or intentionally trying to remember them. Such comparison conditions are widely recognized to enhance memory – in fact, these are the encoding manipulations typically championed in human memory textbooks – yet survival processing produced the best retention. From an evolutionary perspective, of course, this is the anticipated result. Natural selection sculpted our learning and memory systems based on nature's criterion – the enhancement of fitness – so the footprints of that criterion remain apparent in their operating characteristics. Our learning and memory systems evolved because they helped us retain things such as the location of food or the recent appearance of a predator.

Important Scientific Research and Open Questions

At the same time, it is extremely difficult to build a definitive case for evolved cognitive adaptations, that is, to place the locus of adaptive memory "tunings" in specialized structures that were sculpted by natural selection. There are no "fossilized" memory traces, and our knowledge about the ancestral environments in which our cognitive systems actually evolved is limited. Adaptive solutions to recurrent problems can arise indirectly, by relying on adaptations that evolved for different reasons (*exaptations*), or as a result of natural constraints in the environment (e.g., the physical laws of nature or genetic constraints). The proximate mechanisms that enable us to read and write, for example, did not evolve directly for those ends even though reading and writing are very adaptive abilities. Our cognitive systems were also not built from scratch – natural selection "tinkers," which means that changes usually emerge from existing structures. The design of these structures, in turn, introduces constraints that influence how the adaptive problems that drive *evolution* are ultimately solved. Thus, even if we could correctly identify the ancestral selection pressures that drove the development of adaptive memory, it would still be difficult to predict how nature solved the relevant adaptive problems.

However, it is possible to collect relevant data. For example, there is growing evidence that human cognitive systems may show ancestral priorities, that is, it may be easier to perceive and remember events that are congruent with the adaptive problems faced during the environment of evolutionary adaptedness. People are able to identify evolutionarily relevant stimuli, such as snakes and conspecifics, more easily and quickly than familiar stimuli that are fitness-relevant but rooted in modern environments (such as guns). Specific phobias are more apt to develop to ancestral stimuli (e.g., spiders) than to aversive stimuli experienced exclusively in modern environments (e.g., weapons). In the survival processing paradigm, people show better memory for information processed with respect to ancestral scenarios, ones that tap hunter-gatherer activities such as searching for edible plants, than fitness-relevant scenarios that describe modern fitness-relevant activities (such as locating a pharmacy to buy antibiotics). These data suggest that current learning and memory processes remain sensitive to the selection pressures that led to their development (Nairne 2010).

Regardless of where one looks in the physical body (e.g., heart, lungs, kidneys), one finds structures that reflect function – pumping or filtering blood, respiration, and so forth. These physical structures evolved subject to nature's criterion (fitness enhancement) and faithfully perform functions to reflect that end. The capacity to learn and remember evolved, so it is not surprising that our cognitive systems are not only adaptive but functionally designed as well.

Cross-References

▶ Adaptation and Learning
▶ Biological and Evolutionary Constraints of Learning
▶ Episodic Learning
▶ Evolution of Learning
▶ Fear Conditioning in Animals and Humans
▶ Functional Learning
▶ Learning and Evolutionary Game Theory
▶ Memory for "What," "Where," and "When" Information in Animals

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Adaptive Proactive Learning with Cost-Reliability Trade-off

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Synonyms

Cost complexity; Cost-noise trade-off; Learning theory; Optimization; Proactive learning; Submodular function

Definition

Proactive Learning is a generalized form of active learning where the learner must reach out to multiple oracles exhibiting different costs and reliabilities (label noise). One of its major goals is to capture the cost-noise trade-off in oracle selection. Sequential active learning exhibits coarse accuracy at the beginning and progressively refines prediction at later stages. The ability to learn oracle accuracies over time and select better oracles or oracle ensembles leads to potentially faster error reduction rate as a function of total cost, and thus improves its cost complexity. This potential can possibly be realized by a statistical model that adapts to a range of accuracies at different stages of active learning. In a more general scenario, the problem can be formulated as maximum submodular coverage subject to a budget envelope.

Theoretical Background

Proactive Learning with Persistent Oracles

Consider the binary classification task. Let $\mathcal{F}$ be the hypothesis class. Let $\mathcal{X}$ represent the data space, and $\mathcal{Y} = \pm 1$ represent the label space. The target function $f^* \in \mathcal{F}$. Let $I = \{1, 2, \cdots, n\}$. We consider the active learning problem with n persistent oracles whose noise is arbitrary. The cost for oracle j is $c_j > 0, j \in I$. We have the following assumptions on the oracle error rates.

Assumption 1. The error indicator $\mathbb{1}(O_i(X) \neq f^*(X))$ of individual oracles are independent, where $O_i(X)$ is the answer of oracle i for a given example X and $i = 1, \cdots, n$.

Given n oracles with varied noise rates and costs, the goal of a proactive learner is to choose an ensemble of oracles with minimum cost and whose error rate is no greater than $\frac{\epsilon}{2}$ as the labeling mechanism, and to output a classifier f whose generalization error $\mathbb{P}(f(\mathrm{X}) \neq f^*(\mathrm{X})) \leq \epsilon$ where $\mathrm{x} \in \mathcal{X}$, with high probability $1 - \delta$, while keeping the total query cost small. Note that the oracles we study in this work are persistent: they provide the same answer for a given example if asked multiple times. Furthermore, the situation with arbitrary noise forces one to sample the oracle space, since there is no theoretical guarantee that one can get better than $\frac{\epsilon}{2}$ error rate by querying the same oracle multiple times with different examples.

We propose a meta-procedure that takes any agnostic active learning algorithm **A** as subroutine. The agnostic algorithm **A** halts and outputs a classifier after making certain label requests. The meta-procedure lets **A** choose examples to query, and hands back to **A** the “true” label after calling the oracle selection routine and synchronize the answers from the selected oracles by (weighted) majority vote. Furthermore, we may choose an ensemble of oracles adaptively to accommodate a range of accuracy: different ensembles for different level of accuracy. Or we may pick the ensemble offline and to use it for all queries. Our later analysis shows that the former can produce a modest cost savings over the latter simpler method.

Combining Oracle Answers by Weighted Majority Vote

We combine the answers from the set of selected oracles S, by (Weighted) Majority Vote. Consider first a simple majority vote on the label of example X. Let Y be the true label, and Y_i be the answer by oracle i. Denote the majority vote error rate as er_{maj}, and the average error rate of n oracles as $\bar{\epsilon}_S = \sum_{i\in S} \frac{\epsilon_i}{|S|}$. Assumption 1 implies that $er_{\text{maj}}(S)$ should exponentially decrease as a function of the number of oracles. By Hoeffding inequality and Assumption 1, after querying a sample size of m,

$$\begin{aligned} er_{\text{maj}} &= \mathbb{R}\left(\frac{\sum_{i\in S} \mathbb{1}(Y_i \neq Y)}{|S|} \geq \frac{1}{2}\right) \\ &= \mathbb{P}\left(\frac{\sum_{i\in S} \mathbb{1}(Y_i \neq Y)}{|S|} - \bar{\epsilon} \geq \frac{1}{2} - \bar{\epsilon}\right) \\ &\leq \exp\left(-2|S|\left(\frac{1}{2} - \bar{\epsilon}\right)^2\right) \end{aligned} \quad (1)$$

Thus $er_{\text{maj}} < \frac{\epsilon}{2}$, sufficient if

$$\bar{\epsilon} < \frac{1}{2} - \sqrt{\frac{1}{2m} \ln \frac{2}{\epsilon}} \quad (2)$$

Let us extend the above analysis to Weighted Majority Vote. Denote the weighted majority vote error rate as er_{wmaj}. Denote w_i for $i \in S$ as the weights of a subset of oracles we choose.

$\bar{\epsilon}_S = \sum_{i\in S} \frac{\epsilon_i w_i}{|S|}$. We determine the weights by minimizing er_{wmaj}. By Hoeffding inequality,

$$\begin{aligned} er_{\text{maj}} &= \mathbb{P}\left(\frac{\sum_{i\in S} w_i \mathbb{1}(Y_i \neq Y)}{|S|} \geq \frac{\sum_{i=1}^{n} w_i}{2|S|}\right) \\ &= \mathbb{P}\left(\frac{\sum_{i\in S} w_i \mathbb{1}(Y_i \neq Y)}{|S|} - \bar{\epsilon}_S \geq \frac{\sum_{i=1}^{n} w_i}{2|S|} - \bar{\epsilon}_S\right) \\ &\leq \exp\left(-\frac{2|S|^2\left(\frac{\sum_{i=1}^{n} w_i}{2|S|} - \bar{\epsilon}_S\right)^2}{\sum_{i\in S} w_i^2}\right) \\ &\leq \exp\left(-\frac{2|S|^2\left(\frac{\sum_{i\in S} w_i}{2|S|} - \frac{\sum_{i\in S} \epsilon_i w_i}{|S|}\right)^2}{\sum_{i\in S} w_i^2}\right) \\ &= \exp\left(-\frac{2\left(\frac{\sum_{i\in S} w_i\left(\frac{1}{2} - \epsilon_i\right)}{|S|}\right)^2}{\sum_{i\in S} w_i^2}\right) \end{aligned} \quad (3)$$

To minimize this bound on the error rate, we set the partial derivative of Eq. 3 to be zero

$$\frac{\partial\left(\frac{\left(\sum_{i\in S} w_i(1/2 - \epsilon_i)\right)^2}{\sum_{i\in S} w_i^2}\right)}{\partial w_i} = 0$$

and get

$$w_i = (1/2 - \epsilon_i) \frac{\sum_{i\in S} w_i^2}{\sum_{i\in S} (1/2 - \epsilon_i) w_i} \quad (4)$$

If error rate ε_i or its estimation is known, we can calculate w_is by Eq. 4. If ε_i is unknown, we simply use majority vote. We also notice that when $\epsilon_i = 1/2$, $w_i = 0$. Equation 4 assigns zero weights to those oracles whose noise rate amounts to random guess. However, for ε_i=0 (a perfect oracle), Eq. 4 does not give an especially large w_i, due to the relaxation of the original er_{wmaj} by Hoeffding inequality. To this end, we denote **OrSelRoutine** (ε) as any oracle selection procedure that chooses a min-cost subset of oracles $S \subseteq I$, such that with weights w_i for $i \in S$ calculated as in Eq. 4, $er_{\text{wmaj}} \leq \frac{\epsilon}{2}$. In the later sections, we will provide efficient optimization procedures to this task.

Oracle Selection Adaptive to Active Learning

If there is any hope that switching oracles during active learning can improve the cost complexity, then the following model should realize that potential.

Assumption 2. The availability of oracles. ∃ function g: $\epsilon \mapsto c$, mapping from a required accuracy to the cost per example, such that $\forall \epsilon$, ∃ oracle whose cost is $g(\varepsilon)$, and error rate is ε.

According to Assumption 2, for a given accuracy, there is at least an oracle with a certain available noise rate. The earlier stage of active learning needs a relatively coarse accuracy, however, higher accuracies should be reached in later stages. This can be modeled by a sequential level of accuracy.

$$\epsilon_1 = 1/2, \epsilon_2 = 1/4, \epsilon_3 = 1/8, \cdots, \epsilon_t = (1/2)^t, \cdots$$

Intuitively, having options to select the oracles may let active learning have a faster error reduction rate in terms of the cost. The idea of adaptive labeling mechanism construction is as follows: given the accuracy level ε_t of active learning, we choose an ensemble of M_t oracles to form labeling mechanism to accommodate ε_t. The lower the ε_t, the larger the M_t. Suppose m_t is the sample complexity of A given ε_t. We have the following algorithm for proactive learning with adaptive oracle selection.

Proactive Learner with Adaptive Oracle Selection (denoted as **AdaProAL**)

Input an agnostic active learning algorithm **A**

0. Initialize $t = 1$
1. **do**
2. $\epsilon_t \leftarrow (1/2)^t$
3. (S_t and w_j^t for $j \in S_t$)=OrSelRoutine (ε_t)
4. j=0
5. **do**
6. Let **A** choose a query point X from the unlabeled data
7. $Y = \mathrm{sgn}(\sum_{j\in S_t} w_j^t f_j(X))$
8. $j = j + 1$
9. Return Y to **A**
10. **until** $j = m_t$
11. $t = t + 1$
12. **until A** halts

Alternatively, the nonadaptive approach constructs the labeling mechanism ahead of time and uses that chosen mechanism all the time while running the active learning algorithm.

Agnostic Proactive Learning with Nonadaptive Oracle Selection

Input an agnostic active learning algorithm **A**

0. (S and w_j for $j \in S$)=OrSelRoutine ($\frac{\epsilon}{2}$)
1. Initialize $t = 0$
2. **do**
3. $t = t + 1$
4. Let **A** choose a query point X_t from unlabeled data
5. Let $y = \mathrm{sgn}(\sum_{j\in S} w_j f_j(X_t))$
6. Return y into **A**
7. **until A** halts

Denote θ as the disagreement coefficient (Hanneke 2007) and d as VC-dimension (Vapnik 1998). The upper bound of sample complexity in achieving a given level of accuracy $O(\theta\epsilon_t)$ is

$$\tilde{O}\left(\theta^2\left(d + \log\left(\frac{1}{\delta}\right)\right)\right)$$

according to a step of the proof in Hanneke (2007), if we choose the $\mathbf{A^2}$ algorithm given in Balcan et al. (2006) as the active learning algorithm **A**.

Thus the cost complexity of the nonadaptive approach is

$$\tilde{O}\left(\theta^2\left(d + \log\left(\frac{1}{\delta}\right)\right)\right) g\left(\frac{\epsilon}{2}\right) \log\left(\frac{\theta}{\epsilon}\right)$$

whereas the cost complexity of AdaProAL is

$$\tilde{O}\left(\theta^2\left(d + \log\left(\frac{1}{\delta}\right)\right)\right) \sum_{i=1}^{\left\lceil \log\left(\frac{32\theta}{\epsilon}\right)\right\rceil} g\left(2^{-i}\right)$$

Note $\mathbf{A^2}$ achieves the accuracy $16\theta 2^{-i}$ by making θd^2 queries. We want the noise rate of the last oracle to be $< \varepsilon$; thus we let

$$16\theta 2^{-i} = \epsilon/2$$

Therefore, $i = \log\left(\frac{32\theta}{\epsilon}\right)$.

Proactive Learning with Cost-Reliability Assumption

The cost-reliability trade-off assumption that more reliable oracles cost more than noisy ones might be formalized as

Assumption 3. $\exists\, \beta > 0, \gamma > 0$ s.t. for $i \in I$,

$$c_i \epsilon_i^{\gamma} \leq \beta \tag{5}$$

Large cost c_i leads to a small error rate ε_i. Large error rate ε_i drives the cost down. Our algorithm is (α, β) dependent. It will be interesting to explore algorithms that adapts to the value of α and β. When $\gamma < 1$, a decrease of ε_i has to be much faster than the increase of the cost c_i, as ϵ_i^{γ} is sublinear; whereas with $\gamma > 1$, the increase of ε_i forces a faster reduction on cost c_i.

A trivial labeling mechanism is to pick a single oracle whose cost $\geq \beta\left(\frac{2}{\epsilon}\right)^{\gamma}$. Condition (5) will force its error rate to be $< \frac{\epsilon}{2}$. However, the hope is that an ensemble of cheap oracles can have just as good accuracy as the expensive one at lower cost. Based on Assumption 3, we will provide an algorithm that requires zero query to construct a label mechanism whose error rate $< \frac{\epsilon}{2}$, if the upper bound in (5) is tight.

The Algorithm and Complexity Analysis

Given the error rate $\frac{\epsilon}{2}$ set up by the adversary, we can choose a cost c and an ensemble of M oracles with roughly this cost (or within a factor of 2 difference) by Assumption 2. The goal is to minimize the total cost of the chosen ensemble, subject to Inequality 2 and Assumption 3. We formulate this task as the following optimization problem:

$$\min \quad cM$$
$$\text{s.t.} \quad \left(\frac{\beta}{c}\right)^{1/\gamma} = \frac{1}{2} - \sqrt{\frac{1}{2M}\ln\frac{2}{\epsilon}}$$

Since

$$M = \frac{\ln(2/\epsilon)}{2\left(\frac{1}{2} - \left(\frac{\beta}{c}\right)1/\gamma\right)^2}$$

we set

$$\frac{\partial(cM)}{\partial c} = \frac{\partial\left(\frac{c\ln(2/\epsilon)}{2\left(\frac{1}{2}-\left(\frac{\beta}{c}\right)1/\gamma\right)^2}\right)}{\partial c} = 0$$

Thus

$$c^* = \beta 2^\gamma \left(1 + \frac{2}{\gamma}\right)\gamma \tag{6}$$

$$M^* = \lceil 2\ln\left(\frac{2}{\epsilon}\right)\left(1 + \frac{\gamma}{2}\right)^2 \rceil \tag{7}$$

We notice that c^* has nothing to do with ε, and is fixed once γ and β are set up. M^* is inversely related to ε: the higher level of accuracy the active learning algorithm requires, the more oracles will be needed to accommodate such an accuracy. We combine the answers from the M^* selected oracle by a simple majority vote (weighted vote by estimating oracle accuracy may yield even better results).

Oracle Selection Routine with Assumption 3 $\left(\frac{\epsilon}{2}\right)$ (denoted as OrSelRoutineA3)

1. Calculate M^* by (7)
2. Calculate c^* by (6)
3. $S = \{j : j \in I \wedge c_j \approx c^*\}$ with size M^*
4. Output S

Algorithm 1

Choose the $\mathbf{A^2}$ algorithm given in Balcan et al. (2006) as the algorithm A

0. Initialize $t = 0$
1. **do**
2. $t = t + 1$
3. Let **A** choose a query point X_t from unlabeled data
4. S_t=OrSelRoutineA3 $\left(\frac{\epsilon_t}{2}\right)$
5. Let $y = \text{sgn}\left(\sum_{j\in S_t} f_j(X_t)\right)$
6. Return y into **A**
7. **until A** halts

Theorem 1. *The total cost complexity of Algorithm 1 is*

$$\tilde{O}\left(\theta^2\left(d + \log\left(\frac{1}{\delta}\right)\right)\right)c^*M^*$$

Adaptive Oracle Selection Saves a Constant Factor

To illustrate the range of saving one can get by using the adaptive oracle selection procedure compared to the nonadaptive version, we suppose $\tilde{O}\left(\theta^2\left(d + \log_2\left(\frac{1}{\delta}\right)\right)\right)$ as previously mentioned is a constant b, independent of t. For instance, under threshold classifier, the disagreement coefficient θ=2 and VC-dim d=1; thus $\tilde{O}\left(\theta^2\left(d + \log_2\left(\frac{1}{\delta}\right)\right)\right)$ is a constant. Define M_t^* as the number of oracles selected to accommodate ε_t. For adaptive oracle selection, Algorithm 1 has $g(\epsilon) = cM(\epsilon)$. By Eq. 7, the cost complexity of using the adaptive procedure is

$$bc^* \sum_{t=1}^{\lceil \log_2\left(\frac{16\theta}{\epsilon}\right)\rceil} M_t^*\left(\frac{\epsilon_t}{2}\right) = bc^* \sum_{t=1}^{\lceil \log_2\left(\frac{16\theta}{\epsilon}\right)\rceil} \lceil 2\,In\left(\frac{1}{\epsilon_t}\right)\left(1+\frac{\gamma}{2}\right)^2\rceil \tag{8}$$

where

$$\sum_{t=1}^{\lceil \log_2\left(\frac{16\theta}{\epsilon}\right)\rceil} In\left(\frac{1}{\epsilon_t}\right) = \left(\frac{\log\left(\frac{16\theta e}{\epsilon}\right)}{2}\right) \approx \frac{\log_2^2\left(\frac{16\theta e}{\epsilon}\right)}{4e^2} \tag{9}$$

The total sample complexity of the active learning is $b\log_2\left(\frac{1}{\epsilon}\right)$.

The cost complexity for the nonadaptive approach is

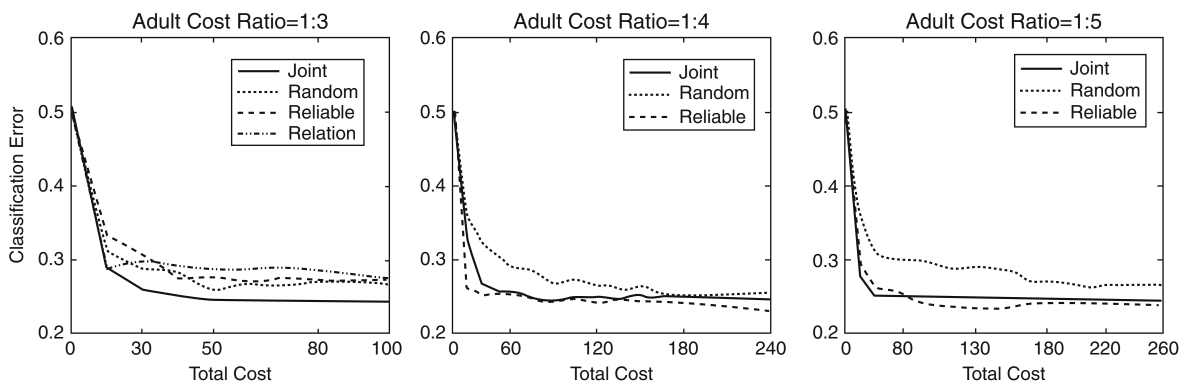
$$bc^*M^*\left(\frac{\epsilon}{2}\right)\log_2\left(\frac{1}{\epsilon}\right) = bc^*\left[2\,In\left(\frac{2}{\epsilon}\right) + \left(1+\frac{\gamma}{2}\right)^2\right]\log_2\left(\frac{1}{\epsilon}\right) \tag{10}$$

Comparing (9) and (10), for small θ, we have

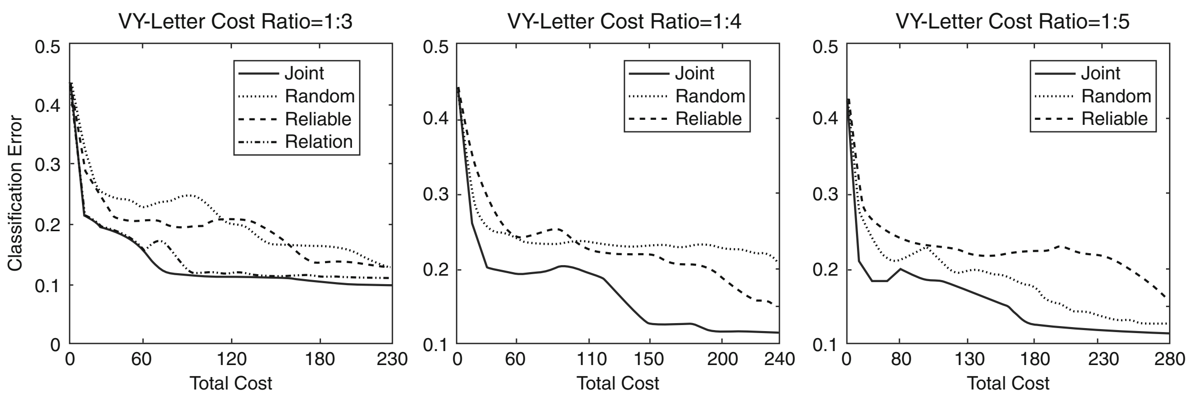
$$\frac{\log_2^2\left(\frac{16\theta e}{\epsilon}\right)}{4e^2} < k\log_2^2\left(\frac{1}{\epsilon}\right)$$

with $k > 1$. Thus the adaptive oracle selection procedure saves the cost complexity by a constant factor compared with the nonadaptive version, under the above specified scenario.

Empirical evidence from Donmez and Carbonell (2008) is consistent with the above example: picking oracles adaptively can reduce the cost complexity by a constant factor versus always using the better and expensive oracle or always using the cheaper, less reliable one. Figures 1 and 2 display the trends of classification error as a function of the total cost on the Adult dataset and the VY-Letter dataset, respectively. It studies a proactive learning scenario where there are two oracles: one is cheap but noisy, the other expensive but reliable. Each plot in Fig. 1 indicates a different cost ratio between the two oracles (same for Fig. 2). Experiments on the two datasets show that, when the classification accuracy is low, the proactive learner tends to pick the low-cost oracle; however, it tends to select the high-cost oracle once the error rate has been significantly reduced. At the later stages, the curve of the proactive learner goes roughly in parallel with that of the baseline, meaning their speed of error rate reduction is roughly the same. If we draw a horizontal line on the plot, the amount of total cost in achieving certain error rate by the proactive learner is roughly half of that by the baseline. Thus one roughly saves a factor of 2 by using the adaptive oracle selection. For these two datasets, the constant factor can be smaller or larger depending on the difficulty of the classification task.



Adaptive Proactive Learning with Cost-Reliability Trade-off. Fig. 1 Performance comparison on the Adult dataset. The cost ratio is indicated above each plot



Adaptive Proactive Learning with Cost-Reliability Trade-off. Fig. 2 Performance comparison on the VY-Letter dataset. The cost ratio is indicated above each plot

This entry provides the theoretical framework for proactive learning, and our analysis is quite consistent with the above-mentioned empirical results.

Maximum Submodular Coverage Subject to a Budget: A More General Scenario

If we do not make any explicit assumption on cost-reliability trade-off, that is, cost and accuracy are not in strictly monotonic inverse relation, the proactive learning problem is actually finding a subset of oracles with small enough majority vote error rate, given a budget B. It can be formulated as the following optimization problem:

$$\max_{S \in I} \left\{ f(S) : \sum_{i \in S} c_i \leq B \right\} \tag{11}$$

where the majority vote accuracy f: $S \mapsto \mathcal{R}$ with $S \subseteq I$ is defined as:

$$f(S) = E\mathbb{1}\left(\left(\frac{\sum_{i \in S} w_i(Y_i \neq Y)}{\sum_{i \in S} w_i}\right) < 1/2\right) \tag{12}$$

$$= \frac{1}{|\mathcal{Z}|} \sum_{(X, Y \in \mathcal{Z})} \mathbb{1}\left(\left(\frac{\sum_{i \in S} w_i \mathbb{1}(Y_i \neq Y)}{\sum_{i \in S} w_i}\right) < 1/2\right) \tag{13}$$

where Y is the true label and Y_i is the answer by ith oracle. f has the following properties: First, f is nondecreasing, a polynomial computable set function. Second, f is monotonic, since $\forall S \subseteq T$, we have $f(S) \leq f(T)$. Third, f is submodular: it increases more by adding elements to a small set, than by adding to a super set. $\forall S,\ T \in I$, we have $f(S) + f(T) \leq f(S \cup T) + f(S \cap T)$. The role submodularity plays for set functions is similar to that of concavity for ordinary functions.

Problem (11) is the problem of Maximum Submodular Coverage Subject to a Budget. Sviridenko (2004)describes a greedy algorithm for this type of problem as an $(1 - e^{-1})$ approximation algorithm for maximizing a nondecreasing submodular set function subject to a knapsack constraint. The quality of greedy solutions is strongly related to submodularity of the set function. When the submodularity property holds (as in our case), the number of computations necessary to get a greedy solution can be significantly reduced. The following greedy approximation algorithm **bMaxSubCover** efficiently solves Problem (11).

bMaxSubCover (B)

0. $I = \{1, 2, \cdots, n\}$
1. Phase 1: $S_1 = \arg\max_{|S|=1,2} f(S)$
2. Phase 2: for every $U \subseteq I$ s.t. $|U| = 3$
3. Initialize $S^0 = U,\ k = 0$
4. **do**
5. $\forall e_j \in I/S^k$, compute $\Delta^k(e_j) = \frac{f(S^k + e_j) - f(S^k)}{c_i}$
6. $e_{j0} = \underset{(e_j \in I/S^k) \wedge \left(c_i \leq B - \sum_{e_j \in S^k} c_j\right)}{\text{argmax}} \Delta^k(e_j)$
7. $S_K \leftarrow S_k \cup \{e_{j0}\}$
8. **while**(e_{j0} exists)
9. $S_2 \leftarrow S^k$ as local optimal obtained by Phase 2
10. If $f(S_1) \geq f(S_2)$ output S_1, otherwise output S_2

The algorithm has α performance guarantee $(0 < \alpha < 1)$, if it always outputs a solution of value that is not smaller than α times the value of the optimal solution. The following performance guarantee of **bMaxSubCover** is due to Sviridenko (2004).

Theorem 2. *The worst-case performance guarantee of the above greedy algorithm bMaxSubCoverfor solving Problem (11) is $(1 - e^{-1}) \approx 0.632$. In another word, assume S is the subset output by bMaxSubCover(B), the following holds:*

$$f(S) \leq (1 - e^{-1}) f(S^*)$$

where S^* is the solution found by the exact approach.

Without knowing the smallest amount to spend in letting $f(S) > 1 - \frac{\epsilon}{2}$, a double-and-guess on the budget B can help decide the minimum budget.

Subroutine1 (ε_i for $i = 1, \cdots, n$)

0. Initialize $B = 1$
1. **do**
2. $S \leftarrow$bMaxSubCover(B, ε_i for $i = 1, \cdots, n$)
3. $B \leftarrow 2B$
4. **while** $(f(S) < 1 - \frac{\epsilon}{2})$
5. Output S and B.

Important Scientific Research and Open Questions

This paper provides the theoretical framework for proactive learning. We propose a meta-procedure for the active learning problem with multiple persistent oracles under arbitrary noise. Having options to select oracles may let active learning have a faster error reduction rate as a function of the total cost; we thus choose subsets of oracles adaptive to a range of accuracies. The nonadaptive approach is to construct the labeling mechanism ahead of time and use that all the time while running the active learning algorithm. Analysis in some specified scenarios shows the adaptive oracle selection procedure saves the cost complexity by a constant factor compared with the nonadaptive version, and our analysis is quite consistent with empirical results from Donmez and Carbonell (2008). We further combine the answers from the set of selected oracles by Weighted Majority Vote.

Under the assumption that more reliable oracles cost more than noisy ones, we provide an algorithm that costs zero query to construct a minimum-cost label mechanism whose error rate $< \frac{\epsilon}{2}$. Without assuming that cost and accuracy are not in strictly monotonic inverse relation, we formulate the problem as maximum submodular coverage subject to a budget that can be solved by a greedy algorithm with $1 - e^{-1}$ worst-case performance guarantee.

Cross-References

- ▶ Active Learning
- ▶ Learning Algorithms
- ▶ Statistical Learning in Perception
- ▶ Statistical Learning Theory and Induction

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Adaptive Robotics

▶ Robot Learning Via Human–Robot Interaction: The Future of Computer Programming

Adaptive Specializations in Learning

▶ Biological or Evolutionary Constraints on Learning

Adaptive Support

▶ Scaffolding

Adaptive Systems

▶ Anticipatory Learning Mechanisms

Adaptive Testing

▶ Adaptive Evaluation Systems

Adaptivity

▶ Flexibility in Problem Solving: Analysis and Improvement

ADD

▶ Attention Deficit Hyperactivity Disorder

Additive Language

▶ Learning to Write in a Second Language

Adjunct Questions

▶ Learning from Questions

Adjunct Questions: Effects on Learning

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Synonyms

Supplementary questions; Supportive questions

Definition

Adjunct questions are questions which are inserted into text with the intention of drawing attention to important textual material. Adjunct questions are known to serve several functions, including both forward and backward effects. The forward effect alerts the reader what to pay attention to in the passage. The backward effect requires the reader to go back and reread sections and to be made aware of what is more significant in the passage. Research has indicated that adjunct questions enhance comprehension by increasing the learner's attention to specific text information and, when used skillfully, guiding learners in organizing and interpreting text material.

Theoretical Background

A large body of research on adjunct questions has made apparent that through questioning student acquisition of content and learning can be improved. Early studies in adjunct questioning indicated that questions facilitate learner selection so that by answering questions, learners focus their attention on specific concepts in the instructional materials. Subsequent adjunct question research demonstrated that the type of question asked directly influences both the level of cognitive processing and the type of information learned.

One of the major theoretical foundations on which much of the research on adjunct questioning is based is levels of processing (Craik and Lockhart 1972), which suggests that information can be processed at varying levels of depth. Such levels of depth are located on a continuum where when one processes information shallowly, one processes the information at a surface level, whereas, when one processes information deeply, one fully analyzes the information. It is important to note that levels of processing are located on a continuum; one processes text information relative to other information. Research in cognitive processing of information indicates that the level at which one processes information is related to the extent to which one remembers information; thus, the more a person analyzes text material, the more one is able to remember the text.

Important Scientific Research and Open Questions

Much of the study of adjunct questions has focused on the level of the questions and their effects on learning. Specifically, adjunct questioning research has focused on two types of questions: verbatim or factual questions that ask learners to repeat or recognize information from text (Andre 1979) and higher-order questions that require learners to manipulate text information (Winne 1979). Early studies suggested that there were two types of effects from factual postquestions: the specific backward effect and the general backward effect. The specific backward effect is due to the review of material that is actually questioned and improved performance is evident on such questions, and the general backward effect is due to text material that is found near to the text that is actually questioned and improved performance is evident on related materials. Whereas factual postquestions have backward effects, factual prequestions have forward effects. Research indicates that prequestions may result in learners limiting their reading experience to a search for the correct answers; thus, limiting their ability to recall of specific text information.

Research related to the use of higher-order questions as adjunct questions (i.e., inferential, comprehension, application questions) has repeatedly aided students in performance on recall and recognition tasks. Hamaker's (1986) review of adjunct questions makes clear that because higher-order processing likely induces integration and elaboration, higher-order adjunct questions will require the learner to produce new information that they can then use in answer subsequent test questions. Thus, performance on related questions may be positively impacted. However, it is not clear whether higher-order adjunct questions positively impact performance on factual test questions. Current research on elaborative questions and elaborative processing may be useful in addressing this question.

One way of understanding why deep processing should lead to better memory is that deep processing requires elaboration such that that text can be associated with a greater number of other things allowing for more pathways for retrieving the text information. Some research suggests that for questions to be beneficial, they must require learners to transform the material (i.e., integrate across text or elicit and integrate prior knowledge) rather than to simply attend to specific concepts.

Text Design

The hundreds of adjunct question investigations that have been conducted provide suggestions regarding text design. It is generally accepted, for example, that benefits for adjunct questions are greatest with repeated, rather than new, items (Anderson and Biddle 1975). Other important considerations include placement of the questions, access to instructional text, and number of questions.

Hamaker (1986) described four sequential arrangements of experimental text and adjunct questions: massed prequestions, inserted prequestions, inserted postquestions, and massed postquestions. Inserted questions are inserted in the text at various places, while massed questions are presented together, either at the beginning or at the end of the text. Prequestions are presented prior to reading while postquestions are presented after reading. Prequestions are generally accepted to have forward effects while postquestions are generally accepted to facilitate backward effects.

Forward effects occur when learners are cued to attend to information in the text. There is some speculation that because prequestions direct learners' attention to specific text content, they may limit the reading task to a search task in which the learner searches for answers in the text but may not construct a strong representation or even comprehend the text. Backward effects occur when the learner reviews the material related to the questioned material. Backward effects are expected to improve performance on both repeated test questions and related test questions.

Another important consideration for those using adjunct questions in text design is how frequently questions are presented. Research suggests that when given meaningful-learning questions, students generally perform better on total recall than when an equal number of questions were provided more frequently. These findings support claims that a question's usefulness is increased when it is located closer to the text to which it refers. Position of question, however, also plays an important role in decisions regarding the frequency of questions. For example, learning increases as amount of text between questions decreases when learners are answering postquestions; however, when answering prequestions, learning increases as the amount of text between questions increases. Frequency of questions requires careful consideration when designing instruction that will implement various question strategies.

Effects of lookbacks, or allowing participants to refer back to the text when answering massed or inserted postquestions, are also important to consider. Incidental learning is often limited when lookbacks are discouraged (Andre 1979). Yet at the same time, when learners are encouraged to look back, they may be less likely to study the entire text (Hamaker 1986).

Cross-References

► Learning from Questions
► Learning from Text
► Reading and Learning
► Socratic Questioning

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Adjustability

► Flexibility in Problem Solving: Analysis and Improvement

Adjustment

► Adaptability and Learning

Adler, Alfred (1870–1937)

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Life Dates

Alfred Adler was born in a suburb of Vienna on February 7, 1870, the second son and second child of seven siblings. His father was a middle-class Jewish grain merchant and his mother was a housewife. They had the choice of living in a mostly Jewish section of the city but chose to reside during most of Adler's youth in neighborhoods that were primarily non-Jewish. Thus as Adler grew up he was largely spared the brunt of anti-Semitic activity that pervaded that period. His family did not stand out by religion or social status and Adler made that a positive aspect of his theory and life. Belonging, being a part of others, and equal to others, were posited by Adler as critical elements of a healthy outlook and lifestyle, and of social interest which he described as belonging in thought, feeling, and behavior. His sociability and openness in his personal and professional life were reflected in his emphasis on respect and community in his theory.

As a young child, Adler had rickets; his movements became restricted and he suffered spasms in his vocal cords. He contracted pneumonia at about the age of 4 and heard the doctor tell his parents that he might not survive. He took all of these constraints as challenges and incorporated this attitude into his theory as an emphasis on "overcoming." Later his movement abilities returned; he became interested in music and developed a strong singing voice. He resolved to become a physician for the avowed purpose of combating death.

He saw the importance of finding one's place in the family as this influenced personality development. This aspect of his theory was no doubt in part the result of his competing in all possible ways with Sigmund, his older brother. He included analysis of birth order and family constellation as diagnostic tools in the therapy methods he proposed. With other children he was said to get on well, was active and popular. His school achievement was average and he graduated at the customary time from the University of Vienna Medical School in 1895.

He briefly trained to be, and had a short stint practicing, as an ophthalmologist. He subsequently opened a general medical practice with an office in a lower-class section of Vienna near the Prater, a large amusement park and circus. His patients included restaurant workers and waiters, circus acrobats and artists. He saw in their ailments and weaknesses compensations and overcompensations for their organ inferiorities that resulted in unusual strengths and skills.

Through Adler's student days, and beyond, the country was caught up in political upheaval, discussion, and unrest. He was not passionately interested in racial and religious differences or nationalist arguments. He attended political meetings without taking an active role. He held political convictions and sought to be involved with the currents that were sweeping the country and because of his friends' involvements and encouragement.

He spent time at these meetings with a dynamic Russian student who was far more deeply involved, Raissa Timofeyewna Epstein. She was an avid communist which Adler was not. But his views overlapped with various socialist positions and they had much in common if not identical positions.

In 1897, Adler married Raissa Epstein and they remained together until he died in 1937. A year after they married their first child, Valentine, was born, followed by a second daughter, Alexandra, born in 1901; their son Kurt in 1905 and their last child, daughter Nellie, in 1909.

In 1902, Sigmund Freud invited Adler and three others to his home for the first of regular weekly discussions of work, philosophies, and problems of neurosis. These meetings proved to be the genesis of the Vienna Psychoanalytic Society of which Adler became president in 1910.

In 1915, as World War I took its toll on human misery, Adler was drafted to serve as a physician in the Austro-Hungarian army. He served in Vienna and in a Polish province of Austria. Confronted with the enormity of the suffering of war casualties, both physical and psychological, he concluded, “one should not be content to cure mental illnesses, but one should make every effort to prevent them.” He saw social interest, community feeling, as the standard of an individual’s mental health. This was accompanied by his conviction that the benefits of social interest should run through society in education, parenting, organizations, and community.

After the war, he became more involved with politics through the Socialist-Democratic Party with particular emphasis on educational activities and educational reform. He received permission to establish his first child guidance clinic in Vienna in 1922. He welcomed parents, teachers, and visitors in the audience at open forum counseling sessions. By the end of the 1920s, 32 clinics were being conducted in Austria under his direction by school and parent–teacher associations and there were additional clinics in Germany.

Adler became well known with many followers and persons interested in his theory and its applications. He gave regular lectures at an adult education center and also lectured as a member of the faculty at the Pedagogical Institute, the Vienna teacher training college. Adler’s name was put forward for a faculty appointment at the University of Vienna but Freud used his tenure and status as a Professor in the University of Vienna Medical School to stop the approval of his application.

Starting in the 1920s, Adler spent more and more time teaching in different formats with a major emphasis on prevention of mental illness, ill health, and maladjustment. He continued to counsel and to attend to his clinics and to lecture but his evenings were increasingly occupied with discussions held at his home with supporters, enthusiasts, and adherents. From a weekly discussion at home, these grew to almost nightly informal conversational sessions at the Café Siller where lively conversations went on until the late hours.

In 1926, he purchased a substantial home with large grounds in Salmannsdorf, a suburb of Vienna. Here he hosted many distinguished Austrian and foreign colleagues and students.

In the same year, he began to spend more time in the United States. He met and counseled people in New York and traveled across the country lecturing to a wide variety of audiences. His academic lectures drew large crowds at Harvard and Brown as did his public lectures in Cincinnati and Milwaukee and at several schools in California. His lecture for teachers at the Opera House in Chicago was sold out and 2,500 applications to attend had to be turned down.

During these later years, he took daily lessons in English so he could confidently lecture in that language. He also, at 60, learned to drive a car. The pace he set for himself in his personal and professional life was remarkable.

In 1929, Adler was appointed a visiting professor at Columbia University and further established his migration to the United States when he was appointed to the first chair of Medical Psychology in the United States at Long Island University Medical College in 1932. Although he was, as it were, based in the United States he published on both sides of the Atlantic and oversaw his clinics, albeit loosely and at a distance.

When the Austrofascists overthrew the Austrian Republic in 1934 they almost immediately abolished school reform with related programs. Adler’s clinics were closed; the educational reforms they practiced philosophically contradicted the Fascists viewpoint. Adler’s Jewish heritage may also have played a role (even though he had converted to Christianity long before).

His wife, Raissa, and their oldest daughter, Valentine, had remained in Europe until this time when so many who were able fled the Nazis. Raissa moved to be with Adler in New York. Valentine, whose political views were closer to her mother’s, went to the Soviet Union. She was not heard from again. He made great efforts and every contact he had including Albert Einstein to locate her, but to no avail.

Through the 1930s, Adler worked at a frenetic pace. In the spring of 1937 he embarked on a tour of Europe, lecturing and meeting friends and colleagues. He was scheduled to lecture in Aberdeen on May 28. In the days prior to this lecture, he mentioned that he was still upset not knowing his daughter Valentine’s whereabouts and condition. He wrote that his heart was breaking. Before he was due to lecture that evening he took a walk in the neighborhood of his hotel and he collapsed from a heart attack. He died in the ambulance taking him to the hospital.

Theoretical Background

Alfred Adler originated Individual Psychology, a theory of personality and psychopathology, an approach to psychotherapy, and methods for self-help. His theory also embraces parent education, and education including teacher training. Moreover, Adler explored and encouraged the application of his theory to the fullest range of social issues. Many of the basic tenets of the theory can be seen as emanating from his early life experiences and setting.

In line with his early interest in the social democratic movement and his practice with working class patients, his earliest writings inquired into public health issues. His first professional publication, in 1898, was "Health Book for the Tailor Trade" which showed the relation between the economic condition of a trade and its disease, and the dangers for public health of a low standard of living. The approach in this book forecast the social science, sociological, and holistic underpinning of his future work.

In 1902, Sigmund Freud invited Adler and three others to his home for the first of regular weekly discussions of work, philosophies, and problems of neurosis. These meetings proved to be the genesis of the Vienna Psychoanalytic Society of which Adler became president in 1910.

Those who attended these meetings presented and discussed their own papers and evolving ideas. Freud's and Adler's ideas increasingly diverged over the years and Freud became increasingly impatient with Adler's independent positions and critiques. Adler could not accept Freud's metapsychology, the mechanistic concepts of libido and repression. He sought to understand neurosis in psychological and cultural terms. In this vein, his 1907 publication "Study of Organ Inferiority and its Psychical Compensation" moved in a holistic direction. With his 1910 paper on inferiority feelings and masculine protest as overcompensation, Adler dropped "drive" as the operating concept and replaced it with "value." The concept of masculine protest was followed by striving for power and then striving for superiority as primary goals, teleological motivators. Then, holistically, these constructs were incorporated and developed into the notions of life plan, and then lifestyle to represent the unified individual striving toward a self-created goal or goals.

Adler had reached a point of comprehensiveness in the evolution of his theory by 1911 when he resigned from Freud's psychoanalytic society and the editorship of its journal. About half of the members left with Adler as he established first the Society for Free Psychoanalytic Research, that was soon renamed the Society of Individual Psychology.

The schism between Adler and Freud was academic, theoretical, and practical. Adler's theory preached democratic, cooperative, and egalitarian values and ways of living. In therapy and in the organization of the Society Adler followed his own advice. He was open to opinions other than his own and to involving interested people without regard to their credentials.

Freud disagreed with opening the society to persons of differing opinions, people without the "highest" credentials, and conducting therapy with the therapist and the client at the same level facing each other. Thereafter Freud and Adler maintained a distant, antagonistic, and rancorous relationship. Freud took numerous opportunities to disparage Adler and impede his success. He referred to Adler as if he were a former student of his, an ungrateful and unworthy disciple. Adler took umbrage with this incorrect and unjust characterization, and countered it in conversations for many years. He considered that they had been colleagues.

Adler's theory was almost fully explained and clarified in "The Neurotic Constitution" published in 1912, which was considered by many to be Adler's most important book. His last major construct, the focus on social interest draws together his theory with a positive mental health orientation for the individual and a positive view of the healthy and utopian human community. This construct was not introduced until 1918.

Adler published articles, pamphlets, and books throughout his professional life. His most popular book, "*Understanding Human Nature*," was published in 1927. This book, like several other publications, was based on lectures that were taken down and transcribed by supporters and followers. Although this was valuable, in that these materials might not otherwise have been published, particularly his views on feminism and "the woman question," the quality of the written material was not consistent.

To assure the spread of Individual Psychology and its validation Adler was active in establishing journals and professional societies and organizing international Congresses. He founded the Zeitschrift fur Indivdual psychologie, the first Adlerian periodical, in 1914, but it ceased publication with World War I. After the war, Individual Psychology groups in Vienna and elsewhere in Germany with supporters in various other countries formed the International Society of Individual Psychology. Journals were printed in succession in Europe and the United States until Adler's death. Some were then revived and new ones initiated after World War II.

The Individual Psychology News and the Bulletin was brought out in 1940 by Rudolf Dreikurs in Chicago and it became the American Journal of Individual Psychology in 1952 with the founding of the American Society of Individual Psychology. Heinz Ansbacher became editor in 1958 and renamed it the Journal of Individual Psychology: This pleased Adlerians in other countries and additional journals proliferated across the national Adlerian societies in Europe and Asia.

The first Congress of the International Society of Individual Psychology was held in Munich in 1922, with others held though to 1930 when over 1,000 people attended the 5th International Congress in Berlin. The 6th Congress was held in 1954 in Zurich at which time the International Association of Individual Psychology was formally proclaimed. The Association holds meetings every 3 years. The 25th Congress commemorating the hundredth anniversary of Adler founding the Society of Individual Psychology is scheduled to be held in Vienna in 2011.

Contribution to the Field of Learning

Alfred Adler is not considered a learning theorist or a specialist or expert in the field of learning. And yet learning is central to the unique, self-consistent, socially oriented individual Adler describes who creates a lifestyle striving for a goal of success with the potential for social interest.

In brief, in Adler's model, the individual creates an understanding of how he or she can belong in the social world, of his or her place in the world, and acts to move toward that goal. That movement toward a goal (or goals) is based on the individual's conception of self, conception of the world, and conclusion about what he or she has to do or be to fit into that world. Aspects of the environment, educational influences, are accepted, and recognized and understood, as they seem, within the individual's lifestyle framework, to hold the potential for movement toward a lifestyle goal, for movement toward success. The individual's phenomenological world thereby dictates the individual's interests and values.

In this model, an individual may learn and achieve for personal reasons the individual does not consciously understand and unrelated to generally accepted, socially accepted explanations. For instance, a child who wants attention may strive to be valedictorian or a school's outstanding mischief. A child who strives to be right may do well in math but not in art where there is no absolute right. A child who wants to be liked may become teacher's pet or the classroom clown. The possibilities are endless for learning, adaptations and adjustments as are individual's unique constructions.

People can learn to see things in new and different ways and thus alter their behavior without altering their lifestyle. In Adlerian theory, lifestyle only changes with trauma and through therapy. Adler focused on the interest, activity, spontaneity, and creativity of the learner as the ultimately crucial factor in the process.

Adler's contributions to this process, beyond therapy, can be seen in such of his suggestions for group procedures in the classroom, applying logical and natural consequences in school and family discipline, *Dreikurs*'s four mistaken goals of children's problem behaviors, and Adlerian approaches to school and counseling psychology.

Cross-References

► Analytical Psychology and Learning
► Freud, Sigmund
► Psychoanalytic Theory of Learning

Further Readings

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Administrative Capacity

► Absorptive Capacity and Organizational Learning

Adolescent Learners' Characteristics

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Synonyms

Skill development during adolescence; Social and cognitive underpinnings of adolescents' learning

Definition

Adolescent learners' characteristics comprise the various attributes that shape the way individuals make meaning of their world. These attributes include specific skills, such as hypothetical-deductive reasoning and metacognition, which are tied to an individual's stage of cognitive development. They also include individuals' subjective views of the learning enterprise, for instance, their levels of motivation and mastery goals. All of these attributes are shaped in important ways by the social environment in which the learning experience occurs.

Theoretical Background

The characteristics of adolescent learners are shaped by the cognitive advances and distinct social experiences that accompany this stage of development. With respect to cognition, Jean Piaget (1897–1980), arguably the most influential developmental psychologist of the twentieth century, described adolescence as the period during which individuals' cognitive abilities fully mature. According to Piaget (1955), the transition from late childhood to adolescence is marked by the attainment of formal operational thought, the hallmark of which is abstract reasoning. Because their thoughts are no longer constrained to their concrete reality, adolescents can consider possibilities beyond their direct experiences. This ability to reason abstractly, in conjunction with expanded information-processing and memory capacities, makes it possible for adolescents to grapple with sophisticated intellectual problems.

The attainment of formal operational thought is associated with a host of new skills that distinguish adolescent learners from their younger counterparts. In contrast to the concrete operational thinkers that precede them, abstract thinkers are able to engage in complex proportionality reasoning, including analysis of probability and physical systems. They can also think in a hypothetical-deductive manner, which involves generating testable hypotheses, controlling variables to isolate the cause, and extracting generalizable theoretical laws from empirical evidence. Historical perspective matures as well during adolescence, as individuals develop a greater appreciation for the way in which present and past events shape the future. Finally, metacognition – the ability to think about one's thinking – emerges with formal operational thought. Learners who engage in metacognitive thought are able to monitor their learning and, as a result, assume greater responsibility for their progress.

With abstract thought also come new ideas about knowledge and knowledge acquisition. In contrast to younger children, who view knowledge acquisition as a straightforward process of accumulating objective facts, adolescents tend to adopt a more relativistic stance. Aware of the subjectivity of personal experience, adolescents may begin to doubt that true knowledge can be acquired. Some adolescents may respond by abandoning the pursuit of knowledge altogether, while others may turn to dogmatic belief systems for relief from their anxiety-provoking doubt.

Since Piaget formulated his theory of cognitive development more than half a century ago, there have been notable advances in the field of neuroscience that contribute to our understanding of adolescent learners' characteristics. We now know that the frontal cortex changes dramatically during adolescence. It is this part of the brain that controls higher-level cognitive thought processes such as planning, metacognition, and multitasking. Interestingly, though, researchers have found that not all higher-level cognitive abilities increase as individuals move from childhood to adolescence (Blakemore 2007). For instance, tasks that involve working memory and decision-making actually dip at puberty before increasing again from age 13 or 14 to age 16 or 17. Researchers believe this dip can be explained by the fact that the onset of puberty prompts a sudden increase in the number of synapses in the frontal cortex, which disrupts functioning in this part of the brain. As these synapses are pruned and reorganized during the course of adolescence, cognitive functioning starts to increase again.

Other contemporary research into adolescent cognition finds a greater variation in adolescents' cognitive abilities and learning characteristics than Piaget originally postulated. For instance, Fischer's (1980) skill theory extends Piaget's work by articulating several levels of abstract thought. According to Fischer, single abstractions are the first to develop around the ages of 10–12 years. Individuals at this first level of abstract thought can coordinate various concrete examples to define an abstract concept such as love or justice. From about 14 to 16 years, individuals move to the next level of abstract thought, called abstract mappings, defined as the ability to compare two abstractions along one dimension. Abstract systems develop toward the end of adolescence, approximately 19–21 years. Individuals at this level can now use two or more dimensions to compare abstractions. Fischer claims that, for any given individual, these levels of abstract thought may develop at varying paces across different domains such as linguistic and mathematical reasoning. Thus, skill theory accounts for cognitive variation both across the span of adolescence as well as within individual adolescents.

Like other neo-Piagetian theorists, Fischer also describes the important role that social and contextual factors play in an individual's development. A consideration of such factors may help to explain why, despite the cognitive advances that take place during adolescence, the transition from elementary school to middle and high school is typically accompanied by an increase in dropout rates, school misconduct, and truancy, as well as a decline in grades and loss of interest in school. Eccles and her colleagues attribute these negative developments to a mismatch between adolescents' developmental needs and the social conditions they experience in school (Eccles et al. 1993). They observe that adolescent learners thrive in school environments that acknowledge and support their growing desire for autonomy, peer interaction, and abstract cognitive thinking, as well as the increasing salience of identity-related issues and romantic relationships. Unfortunately, the researchers find that the transition from elementary to middle school is typically marked by a greater emphasis on teacher control and discipline, student competition and social comparison, and a parallel decline in opportunities for decision-making and self-management. There is even evidence that schoolwork is less cognitively challenging in middle school than in elementary school. According to Eccles and her colleagues, this stage–environment mismatch contributes to the negative aspects of adolescent learners' characteristics, including school misconduct and low motivation levels.

Other contextual contributors to negative learning outcomes in adolescence are group-specific. For instance, researchers have found that both female students and African American students perform worse on mathematics tests if they are first exposed to negative stereotypes about their group's mathematics abilities. The theoretical underpinnings of these findings postulate that exposure to negative stereotypes about one's group arouses anxiety in the individual learner, which in turn diminishes the learner's cognitive capacity during the test-taking situation. This work on "stereotype threat" (see Steele 1997) suggests that students' cognitive abilities are impacted by the social environment in which they find themselves.

Important Scientific Research and Open Questions

In recent years, the proliferation of digital media technologies has altered the landscape of many learning environments. It is therefore important to consider how these new technologies may be impacting adolescent learners' characteristics. Today's American youth are regular users – both in and out of school – of cell phones, personal computers, portable media players, and video game consoles, many of which are Internet-enabled. The ubiquity, portability, affordability, and intuitive functionality of these devices have contributed to a precipitous increase in youths' media consumption, which often consists of using multiple media devices simultaneously. Consider the adolescent who sits down at the desk in his or her bedroom to complete a homework assignment. As this adolescent surfs the web to find references for a school project, he or she is listening to music on an iPod, carrying on multiple conversations with friends via text messaging, and keeping track of the latest news from his or her 251 Facebook friends. Scholars have begun to examine the impact of such an environment on the learning process. While some scholars suggest that today's youth have adapted to today's media-rich landscape by becoming expert multitaskers, others have found evidence to support the claim that the human brain is ill-equipped to engage in multitasking and that juggling multiple tasks simultaneously diminishes the attention individuals pay to any one task. As this line of inquiry moves forward, we will gain a more comprehensive view of the relationship between adolescents' multitasking practices and their learning processes. The emerging field of digital media and learning will likely also provide insight into the impact of incorporating digital media technologies like video games and cell phones into instructional practice. It remains to be seen whether and how such technologies influence adolescents' skill development and subjective experiences of school.

Cross-References

► Cognitive Skill Acquisition
► Development and Learning (Overview)
► Individual Differences in Learning
► Learning in the Social Context
► Social Cognitive Learning

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Adolescent Literacy

► Content-Area Learning

Adult Development

► Adult Teaching and Learning

Adult Education

► Adult Teaching and Learning

Adult Leaning

► Adult Learning/Andragogy

Adult Learners' Characteristics

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Synonyms

Adult learning; Learning across the life span

Definition

Adult learners' characteristics constitute the habits of mind that affect the way individuals approach the learning process. These habits of mind are shaped by both internal cognitive processes and external social contexts. Learning in adulthood is distinguished by its self-directed and critically reflective nature, as well as its rootedness in everyday experiences and the social roles associated with those experiences.

Theoretical Background

Decades of research in the behavioral and social sciences confirm what philosophers, novelists, and other observers of mankind have always known – learning does not stop with the conclusion of formal education; it is, rather, a lifelong process. We now know that, instead of ending in adolescence, as developmental psychologist Jean Piaget (1897–1980) postulated, cognitive development continues well into adulthood. This broader view of development comes as welcome news to those scholars who contend that the complexities, ambiguities, and contradictions inherent in modern life demand increasingly sophisticated responses from adults (Kegan 1994).

Eduard Lindeman (1885–1953) stands as a central and pioneering figure associated with the field of adult learning and education. Lindeman (1926) identified four characteristics of adult learners that shape the way they approach learning. According to Lindeman, adults (1) require their learning to be personally relevant; (2) seek to apply their learning to real-life situations; (3) desire to engage in the learning process in a self-directing manner; and (4) display individual differences in learning, including differences in style and pace, which increase with age. These characteristics all underscore the informal and contextual nature of learning in adulthood. Instead of the classroom, social roles provide the context of learning. That is, adults learn by drawing on and making sense of their experiences as worker, parent, spouse, and citizen. Their learning is situated in their personal biography and the broader sociocultural context in which they live.

Malcolm Knowles (1913–1997) studied under Lindeman and expanded on his ideas, particularly Lindeman's description of the self-directed nature of adult learning. Knowles (1980) described how self-direction permeates the entire trajectory of a given learning experience in adulthood, from diagnosing one's learning needs and articulating reasonable learning goals, to finding appropriate supports and, finally, evaluating learning outcomes. An important aspect of self-directed learning is the ownership that adults take of their learning, which infuses it with a sense of purpose. For this reason, the self-directed adult learner is a particularly motivated learner. Mezirow (1991) further expanded upon the concept of self-directed learning by articulating the important role of critical reflection. According to Mezirow, critical reflection entails examining one's taken-for-granted assumptions and considering how they shape, and perhaps distort, the way one views and makes sense of the world. Adults who succeed in assuming this stance are more likely to engage in what Mezirow calls "transformative learning."

The idea of a self-directed learner is somewhat in tension with another adult learner characteristic: the desire to learn in dialog with others. Scholars of adult learning contend that adults learn best within a "community of practice" defined as "a group of people who engage in a shared activity and who wish to learn what other members know" (Merriam and Clark 2006, p. 43). Given the variety of social contexts that make up their lives, adults typically participate in multiple communities of practice simultaneously. Whether at work, home, or at play, adults learn from the people with whom they share their common experiences. In addition to communities of practice, the concept of "situated cognition" also contributes to our understanding of adult learning as an inherently social enterprise. Situated cognition refers to every aspect of the social environment that shapes the learning process, including people, tools, and context (Merriam and Clark 2006). Within this framework, learning is considered most likely to occur when it feels authentic to the learner. Thus, apprenticeships, internships, and simulations are considered ideal contexts for adult learners.

Kegan's (1994) Subject–Object Theory provides insight into how adult learners navigate the tension between connection and independence in their learning. According to Kegan's stage theory of adult development, a key cognitive achievement of adulthood is the transition from the "socialized mind," which is dominant during adolescence, to the "self-authoring mind." Kegan explains that connection and context are still critical for self-authoring individuals; however, these adults are more autonomously oriented toward their contexts and the people within them. Within this view, social context might be regarded as providing the supportive foundation for learning, whereas self-direction determines what is ultimately built upon that foundation. Some adults are able to reach an even higher level of cognitive development, which Kegan calls the "self-transforming mind." Self-transforming adults have achieved distance from their own ideology, making it possible for them to entertain competing ideologies simultaneously and find connections among them.

Important Scientific Research and Open Questions

An important area of research that bears on adult learners' characteristics concerns the effects of aging on the learning process. Research on aging reveals age-related declines in the prefrontal cortex, which impacts a number of cognitive processes, such as working memory, processing speed, and executive functioning. While these declines do not necessarily prevent learning, they may change how learning occurs toward the end of the life cycle. The "Selective Optimization with Compensation" (SOC) model developed by Baltes and Baltes (1990) provides insight into the ways in which the cognitive declines associated with aging may affect adults' approach to learning. The SOC model comprises three processes: selection, optimization, and compensation. Selection refers to the decision to engage in fewer learning activities in light of one's diminished cognitive capacities. The second process, optimization, describes the proclivity of older adult learners to engage in learning activities that allow them to use and strengthen their remaining cognitive abilities. Lastly, older adults who make use of the process of compensation are able to seek and employ new learning strategies in order to compensate for impairments in their cognitive functioning. Future research is needed to investigate how theoretical frameworks like the SOC model might be used to support learning among older adults, particularly those adults with various forms of dementia such as Alzheimer's.

Cross-References

► Adult Learning/Andragogy
► Adult Learning Styles
► Adult Learning Theory
► Adult Teaching and Learning

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Adult Learning

► Adult Learners' Characteristics

Adult Learning Styles

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Synonyms

Behavior styles; Perceptual modalities; Teaching styles

Definition

Learning styles classify different ways people learn and how they approach information. Learning styles differentiate the way each learner begins to concentrate on, process, absorb, and retain new and difficult information.

If a person feels he or she can not learn something important – even after they use a method that a friend, parent, colleague, or a teacher suggested – they might have a different learning style than that person and their approach might now be the best approach to pursue. Each of us learn and process information in our own special way, though we all share some learning patterns, preferences, and approaches. Knowing our own style can also help us realize that other people may approach the same situation in a way that is different from our own.

Learners of all ages may think they are dim, dumb, lazy, or crazy because they cannot understand materials the way the others do. When these learners can match the way they approach information with the way they learn, they see dramatic improvements in understanding, meaning making, self-image, and for students: grades.

To reveal each person's natural tendencies and styles, it is important to use a comprehensive learning style assessment that identifies each individual's strengths and preferences across the full spectrum of physiological, sociological, psychological, emotional, and environmental elements.

Learning style assessments provide an opportunity to learn how people are likely to respond under different circumstances and how to approach information in a way that best addresses particular needs.

Learning styles can be defined as the way each person begins to:

- Concentrate on new and difficult information
- Process this information
- Internalize and retain this information
- Use this information

Theoretical Background

Perceptual Modalities

One of the most useful and widely used approaches to assessing people's learning styles examines how we take in information through our senses. Researchers call these sorts of assessments "perceptual modality assessments." They look at how we see, hear, feel, and move through the world. Those perceptions deeply affect our ability to learn. Whether we tend to rely more or less on one sense than another has a tremendous influence on how we interpret new experiences and succeed in whatever we work with each day.

The Conner Learning Styles Assessment focuses on people's visual, auditory, kinesthetic, and tactile preferences.

Building Excellence by R. Dunn and S. Rundle identifies the following:

- Perceptual Domain: auditory, visual word, visual picture, tactual and/or kinesthetic, verbal
- Psychological Domain: analytic/global, impulsive/reflective
- Environmental Domain: sound, light, temperature, seating design
- Physiological Domain: time of day, intake, mobility
- Emotional Domain: motivation, task persistence, conformity, structure
- Sociological Domain: alone, pairs, small group, large group, authority, variety

Multiple Intelligences

Howard Gardner asserts there are at least seven modalities (referred to as intelligences) that can be used to describe your individual style. His work encourages everyone to think about learning in new and creative ways. This work suggests people can be:

- Verbal-linguistic: sensitive to the meaning and order of words
- Musical: sensitive to pitch, melody, rhythm, and tone
- Logical-mathematical: able to handle chains of reasoning and recognize patterns and order
- Spatial: perceive the world accurately and try to re-create or transform aspects of that world
- Bodily kinesthetic: able to use the body skillfully and handle objects adroitly
- Interpersonal: understand people and relationships
- Intrapersonal: possess access to one's emotional life as a means to understand oneself and others

Mind Styles

According to Anthony Gregorc, there are four basic learning styles. Gregorc's Mind Styles model categorizes learners as Concrete Sequential (CS), Abstract Sequential (AS) Abstract Random (AR), and Concrete Random (CR).

- Concrete Sequential (CS) learners are hardworking, conventional, accurate, stable, dependable, consistent, factual, and organized.
- Abstract Sequential (AS) learners are analytic, objective, knowledgeable, thorough, structured, logical, deliberate, and systematic.
- Abstract Random (AR) learners are sensitive, compassionate, perceptive, imaginative, idealistic, sentimental, spontaneous, and flexible.
- Concrete Random (CR) learners are quick, intuitive, curious, realistic, creative, innovative, instinctive, and adventurous.

Learning Styles Indicator

David Kolb's Learning Style Model classifies learners as having a preference for (1) concrete experience or abstract conceptualization (how they take information in) and (2) active experimentation or reflective observation (how they internalize information).

- Type 1 (concrete, reflective). A characteristic question of this learning type is "Why?" Type 1 learners respond well to explanations of how course material relates to their experience, their interests, and their future careers. To be effective with Type 1 students, the instructor should function as a motivator.
- Type 2 (abstract, reflective). A characteristic question of this learning type is "What?" Type 2 learners respond to information presented in an organized, logical fashion and benefit if they have time for reflection. To be effective, the instructor should function as an expert.
- Type 3 (abstract, active). A characteristic question of this learning type is "How?" Type 3 learners respond to having opportunities to work actively on well-defined tasks and to learn by trial and error in an environment that allows them to fail safely. To be effective, the instructor should function as a coach, providing guided practice and feedback.

- Type 4 (concrete, active). A characteristic question of this learning type is "What if?" Type 4 learners like applying course material in new situations to solve real problems. To be effective, the instructor should stay out of the way, maximizing opportunities for the students to discover things for themselves.

Myers–Briggs

The Myers–Briggs Type Indicator, based on the work of Carl Jung, identifies 16 personality styles based on:

How you relate to the world (extravert or introvert)

- Extraverts try things out, focus on the world around
- Introverts think things through, focus on the inner world of ideas

How you take in information (sensing or intuiting)

- Sensors (practical, detail-oriented focus on facts and procedures)
- Intuitors (imaginative, concept-oriented focus on meanings and possibilities)

How you make decisions (thinking or feeling)

- Thinkers are skeptical, tend to make decisions based on logic and rules
- Feelers are appreciative, tend to make decisions based on personal and humanistic considerations

How you manage your life (judging or perceiving).

- Judgers set and follow agendas, seek closure even with incomplete data
- Perceivers adapt to changing circumstances, resist closure to obtain more data

For example, one learner may be an ESTJ (extravert, sensor, thinker, perceiver) and another may be an INFJ (introvert, intuitor, feeler, judger).

There are other ways to organize learning style models. These fall into general categories such as information processing, personality patterns, and social interaction.

Information processing distinguishes between the way people sense, think, solve problems, and remember information. Individuals have a preferred, consistent, distinct way of perceiving, organizing, and retaining information. Kolb's Learning Styles inventory, Gregorc's Mind Styles Model, and Keefe's Human Information-Processing Model.

Personality patterns focus on attention, emotion, and values. Understanding these differences allows you to predict the way you will react and feel about different situations. The Myers–Briggs Type Indicator and the Keirsey Temperament Sorter are two of the most well-known personality pattern assessments. A lesser-known assessment is Dellinger's Psycho-Geometrics.

Social interaction looks at likely attitudes, habits, and strategies learners will take toward their work and how they engage with their peers when they learn. Some learners are independent, dependent, collaborative, competitive, participant, and avoidant. Reichmann and Grasha, Honey and Mumford, and Baxter-Magolda have developed assessments.

Important Scientific Research and Open Questions

Learning style is a concept used worldwide. For over 30 years, the International Learning Styles Network (ILSN) has been helping both children and adults reach their full learning potential. In 1996, Professor Rita Dunn began replacing the original assessments with updated online versions that catered to both analytic and global learners and include both text and graphic images. The venerable research upon which the Dunn and Dunn Model was built continues as the assessments are improved.

In recent years, opponents of learning styles have criticized its use, primarily in schools, where students are being stereotyped based on the results of their assessments. They argue that learning preferences cannot be generalized and doing so limits, rather than enhances, learning. Objections can often be addressed by ensuring that the results of these assessments is used primarily for learners themselves to better advocate for themselves in formal education environments. If an instructor lectures without providing any visual cues, the learner could request a photo or illustration. If a learner can focus most effectively in a certain environment, he or she can create that space for themselves. This puts the onus on the learner.

Cross-References

► Adaptation to Learning Styles
► Attitudes and Learning Styles
► Cross-cultural Learning Styles
► Jungian Learning Styles
► Kolb's Learning Styles

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▶ Learning Style(s)
▶ Multiple Intelligences and Learning Styles
▶ Styles of Learning and Thinking

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International Learning Styles Network (ILSN) is comprised of 25 International Centers in 11 countries that provide additional training, direction and support for the use of the Dunn & Dunn Model in over 100 countries worldwide. http://www.learningstyles.net

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Adult Learning Theory

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Synonyms

Andragogy; Lifelong learning

Definition

Learning is the transformative process of taking in information which, when internalized and mixed with what we have experienced, changes what we know and builds on what we can do. It is based on input, process, and reflection. It is what changes us. Learning is what makes us more vibrant participants in a world seeking fresh perspectives, novel insights, and first-hand experiences. When shared, what we have learned mixes with what others have learned then ripples out, transforming organizations, enterprises, ecosystems, and the society around us.

Learning can be defined formally as the act, process, or experience of gaining knowledge or skills that fosters the transformation. In contrast, memory can define the capacity of storing, retrieving, and acting on that knowledge. Learning helps us move from novices to experts and allows us to gain new knowledge and abilities.

Theoretical Background

The field of adult learning encompasses changes in how adults learn compared to how they learned when they were younger, their memory, intelligence, and cognition in context and amid life experience.

It acknowledges that learning strengthens the brain by building new pathways and increases connections that adults can rely on when they want to learn more. Definitions that are more complex add words such as comprehension and mastery through experience or study.

Physiologically, learning is the formation of cell assemblies and phase sequences. Children learn by building these assemblies and sequences. Adults spend more time making new arrangements than forming new sequences. Our experience and background allow us to learn new concepts.

At the neurological level, any established knowledge (from experience and background) appears to be made up of exceedingly intricate arrangements of cell materials, electrical charges, and chemical elements. Learning requires energy; relearning and unlearning requires even more. We must access higher brain functions to generate the much-needed energy and unbind the old.

Learning, from the most fundamental to complex, is (1) any increase in knowledge, (2) memorizing information, (3) acquiring knowledge for practical use, (4) abstracting meaning from what we do, and (5) a process that allows us to understand.

People can learn from the moment of birth. Learning can and should be a lifelong process. Learning should not be defined by what happened early in life, only at school. We constantly make sense of our experiences and consistently search for meaning. In essence, we continue to learn.

Though humans like the familiar and are often uncomfortable with change, the brain searches for and responds to novelty. "Ah-ha!" you may think. "That's why I hated freshman English. No novelty!"

Rote learning frustrates us because the brain resists meaningless stimuli. When we invoke the brain's natural capacity to integrate information, however, we can assimilate boundless amounts. This may also explain why sometimes a tough class, one you never thought you would get through, was one of your all-time favorites.

Western society once believed adults did not learn. Even today, if you ask a group why adults cannot learn, it may surprise you how many begin answering the question without challenging the premise. Unfortunately, many adults deny themselves what should be one of the most enriching parts of life because they assume they cannot learn.

We can learn from everything the mind perceives (at any age). Our brains build and strengthen neural pathways no matter where we are, no matter what the subject or the context.

In today's business environment, finding better ways to learn will propel organizations forward. Strong minds fuel strong organizations. We must capitalize on our natural styles and then build systems to satisfy needs. Only through an individual learning process can we re-create our environments and ourselves.

Important Scientific Research and Open Questions

The field of adult learning was pioneered by Thorndike, Bregman, Tilton, and Woodyard in their 1928 book, *Adult Learning*. It was the first systematic investigation of adult learning. They looked at memory and learning tasks of 14- and 50-year-olds, considering how they did compared to younger learners. The tests, however, made a direct comparison between the learning of younger and older people, without considering differences in adults approach, connecting what they are learning to what they already know, and this lead to the conclusion (later disproven by many) that adults do not learn as effectively as younger people. Many of these studies have shown that declines occur in some groups and at some times, but not with others. Typically, adults score better on some aspects of intelligence as they age, and worse in others, resulting in fairly stable composite measure of intelligence until very old age.

Malcom S. Knowles was one of the first to propose that adult learners shared specific characteristics that supported their ability to learn through life. He identified the following distinctions:

Adults are autonomous and self-directed. They want to be free to direct themselves – even if that means asking for assistance from others.

Adults have accumulated a foundation of life experiences and knowledge that may include work-related activities, family responsibilities, and previous education. They need to connect learning to their knowledge based on experience.

Adults are goal-oriented. When seeking to learn something new, they usually know what goal they want to attain.

Adults are relevancy oriented. They must see a reason for learning something. Learning has to be applicable to their work or other responsibilities to be of value to them.

Adults are practical, focusing on the aspects of a lesson most useful to them in their work. They may not be interested in knowledge for its own sake. Instructors must tell participants explicitly how the lesson will be useful to them on the job.

As do all learners, adults need to be shown respect. Instructors must acknowledge the wealth of experiences that adult participants bring to the classroom. These adults should be treated as equals in experience and knowledge and allowed to voice their opinions freely when they are in a class.

Since Knowles pioneering work, many still question if adults learn differently than children. His proposition that children preferred to learn from teachers, and adults learned best by being self-directed, seems biased by a culture heavily reliant on school rather than a clear examination of children's capacity to learn. It might be more accurate to conclude that the only certain difference is that children have fewer experiences and preestablished beliefs than adults and thus have less to relate.

Cross-References

- ▶ Adult Learner Characteristics
- ▶ Adult Learning/Andragogy
- ▶ Adult Teaching and Learning
- ▶ Humanistic Theory of Learning: Maslow
- ▶ Jack Mezirow on Transformative Learning
- ▶ Lifelong and Worklife Learning

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Adult Learning/Andragogy

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Synonyms

Adult leaning; Facilitated learning

Definition

Although Malcolm Shepherd Knowles (1913–1997) has been linked most closely with the word andragogy, the term had a long history before he became associated with it. In 1833, Alexander Kapp, a German grammar teacher used it to describe Plato's educational theory and later, in 1921, social scientist, Eugen Rosenstock stated that "adult education required special teachers, special methods, and a special philosophy" (Knowles et al. 1998, p. 59) and used the term on several occasions. Swiss psychologist, Heinrich Hanselmann used the word in his book *Andragogy: Nature, Possibilities and Boundaries of Adult Education* published in 1951, while in 1957, Franz Pogeler, a German teacher published *Introduction to Andragogy: Basic Issues in Adult Education* (Knowles et al. 1998, p. 59). A number of European educators also mentioned andragogy in their work, among them Dusan Savicevic, a Yugoslavian adult educator, who discussed the concept during a presentation in the USA in 1967. Malcolm Knowles heard it at that presentation and in 1968 first used the term in an article in *Adult Leadership*. He then began promoting it as an important set of assumptions about the learning needs of individuals, first for adult educators and later as a concept to be applied at any level of education where they are applicable and can help students learn.

Originally defined by Knowles as "the art and science of helping adults learn" (Knowles 1980, p. 43), andragogy delineates assumptions that describe considerations necessary to develop effective learning for adults. Knowles four original concepts include:

The *Learner's Self-concept* discusses how adults move from dependence upon their instructor to a more mature, self-directed learning personality (Knowles 1980, pp. 43–44).

The *Role of the Learner's Experience* emphasizes that adults have a wealth of experience from the many aspects of their lives and want to use and be given credit for those experiences in any learning situation (Knowles 1980, pp. 43–44).

The *Student's Readiness to Learn* focuses on whether the student recognizes a need or reason to learn something. They may want to improve their life, work, or social situation and will therefore seek instruction in order to improve their circumstances (Knowles 1980, pp. 43–44).

The *Student's Orientation to Learning* emphasizes the learner's need to realize how they can use the knowledge they will gain. They will be more eager to follow through on lessons if they understand how what they learn can make their lives better tomorrow (Knowles 1980, pp. 43–44).

A fifth assumption, *Students' Motivation to Learn* was added in 1984. Knowles felt that although students may have external motivation to learn such as work requirements, the most powerful incentives tend to be internal, those that promote an individual's growth and development or help them to reach personal goals (Knowles et al. 1998, p. 68).

Later, Knowles' writing discussed an additional concept, *The Adult's Need to Know* why they should learn something (Knowles et al. 1998, p. 64).

Although originally contrasted with pedagogy and aimed completely at adults, the concept has grown to describe a continuum that moves from pedagogy to andragogy and applies to younger students as well as their adult counterparts allowing instructors to have more flexibility in implementing assumptions depending on the situation.

Theoretical Background

Andragogy was originally contrasted with pedagogy. Dusan Savicevic explains that "the traditional research paradigm was predominately oriented toward studying the phenomenon of learning of children and young people" but "the main subject of andragogy is studying the learning and education of adults" (Savicevic 2008, p. 361). Knowles' initial explanations of the concept also contrasted andragogy with pedagogy, the art and science of teaching children. As years went on teachers in elementary and secondary schools as well as colleagues told Knowles that they were applying the concepts from andragogy to those who were younger. As a result Knowles came to think of andragogy as "another model of assumptions about learners to be used alongside the pedagogical model" (Knowles 1980, p. 43). He felt that the two formed the two ends of a spectrum and gave educators alternative models to work with, a second "tool kit" as some might describe it, when working with any learner. As Knowles explained, "whenever a pedagogical assumption is a realistic one, then pedagogical strategies are appropriate, regardless the age of the learner and vice versa" (Knowles 1980, p. 43). Today, andragogy is recognized as a set of assumptions that are primarily associated with adult learning but are also well within the repertoire of those who teach younger students. From an adult educator's perspective, it is assumed that some adult learners may need a more structured pedagogical approach, particularly as they begin their first educational interaction after years of being trained in elementary and secondary schools. The goal of the instructor is to move the student to a more flexible, student-focused learning environment, indicative of the principles of andragogy. Some subjects, such as those that are more technical may also require more pedagogical methods even for adults. In contrast, some younger students may come with a wealth of knowledge or experience in a particular area leading the instructor to use strategies that are more likely to be associated with andragogy than pedagogy. In all, there are situations where instructors will feel that andragogy fits well while in others they may need to provide more pedagogical type experiences for their students.

The use of andragogical principles in a learning environment takes the focus off the instructor and makes them a facilitator of student learning. It is necessary for the teacher to move a student whose concept of learning is more structured to a self-directed model through choices of activities and specific support as the student moves away from dependency to a more independent self-concept of learning. Instructors must also acknowledge the student's experience whether with life issues or on the job, and allow the student to use their knowledge to contribute to the instruction, to move to another plane of learning or understand differences in their experiences versus the current focus of learning.

The teacher must also seek to understand why a student has chosen to undertake instruction. What has made them ready to learn this particular topic at this time in their life and how can the instructor use this situation to move the student forward both as a learner and in learning the topic studied? As the teacher develops lessons and experiences it is important that they can focus on what Knowles calls the student's "full life potential" (1980, p. 44). The faculty member should be aware of the students' orientation to learning so that what is learned today can be applied tomorrow to a student's life experience. Using problem-centered activities can directly link learning to real-life situations. These life-centered or task-centered activities can help the facilitative instructor guide students into what may be the first thing a student must understand, why they should know what they are undertaking to learn. As students develop an appreciation of their need to know a topic they can then relate more affectively to how it will make their life better tomorrow. In addition, students will begin to develop a bigger motivation to learn the concepts taught if they find that the learning experience will meet higher internal goals that they are pursuing such as job satisfaction, quality of life or, as they develop further in the path of other andragogical principles; a better self-concept that makes them more independent. According to Knowles, these higher level internal motivations will be more effective for adults than external motivations.

Important Scientific Research and Open Questions

Many people refer to the theory of andragogy but others argue that it is not a theory. In his 1980 work, Knowles said that andragogy was a “model of assumptions.” Merriam and Caffarella (1999) cite Hartree and Brookfield as among others who question whether andragogy can be considered a full-blown theory. Some educators posit that the assumptions have not been tested empirically or are simply the result of observation by its proponents. According to Merriam, in his autobiography Knowles himself commented that andragogy is “a model of assumptions about learning or a conceptual framework that serves as a basis for emergent theory” (1999, p. 271).

Questions about andragogy’s status as a theory have led to one stream of current research that focuses on finding ways to measure the impact of the implementation of andragogical principals on student learning. Work by authors such as Holton et al. (2009) explores the effects of the implementation of instructional strategies based on andragogy and seeks to quantitatively substantiate the claims of Knowles and others that andragogy positively enhances student learning.

A second line of research focuses on the role of andragogy in online learning design. Donavant (2009) and others are exploring the impact of andragogical principles as they are applied to the use of current technology and online learning.

Finally, with the internationalization of today’s world, Dusan Savicevic and others continue to examine andragogy and to seek an understanding of how its tenants are used and interpreted internationally. While Knowles built a body of work that gained respect worldwide, Savicevic has also continued to write and further elucidate the role of andragogy in adult learning, particularly in Europe, stating that it continues to be “necessary to reconsider on a scientific basis and to study the elements of learning distinctive for adult learning and education” (2008, p. 364).

Cross-References

- ▶ Adult Learner Characteristics
- ▶ Adult Learning Styles
- ▶ Adult Teaching and Learning

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Adult Literacy

Is concerned with those adults who are experiencing problems with basic literacy, numeracy, or with wider communication skills.

Adult Teaching and Learning

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Synonyms

Adult development; Adult education; Experiential learning; Lifelong learning

Definition

Adult teaching and learning refers to our understanding of how adults learn, the context of their learning, and the teaching practices deemed most suitable for adults.

Theoretical Background

The contemporary interest in the distinctiveness of adult teaching and learning has its origins in the adult education movement. As a movement, adult education is presented in various contexts as holding the key to democratization, internationalization, the good society, and personal and economic well-being. It includes university extension courses, workers' education, labor education, literacy and numeracy, migrant education, indigenous education, continuing education, and community education. Even though the majority of adult learning nowadays is not identified with adult education (e.g., adults learning in the workplace or adults studying at university), the legacy of the adult education movement is apparent in the important ideas and practices it has fostered. Such ideas have to do with relationships between teachers and taught; the recognition of learning; links between informal, nonformal, and formal learning; engagement and participation in learning; learning from experience and reflection; new understandings of our capacity to learn across the life span; workplace and professional learning; and learning for individual, organizational, and social change.

In this context there are four themes which have pervaded the adult teaching and learning literature: the autonomy and self-direction of adult learners, the distinctiveness of the adult teacher–learner relationship, the primacy of learning through experience, and the necessity of learning through collaborative community engagement.

"Self-directed" and "autonomous learning" constitute foundation concepts in the literature on adult teaching and learning. The terms are constantly used in journals, monographs, and texts, and have featured in a number of national and international policy documents. It evokes associations with a cluster of terms such as "learner-centeredness," "independent learning," "self-teaching," "autonomy," "freedom," and "needs-meeting," all of which are enthusiastically embraced within the ethos of adult and lifelong learning. Self-directed learning as a practical and theoretical concept is still strongly linked to the work of Knowles and his model of the lifelong learner (Knowles 1984). The term "self-direction" in learning has come to mean four distinct phenomena: personal autonomy, the willingness and capacity to manage one's own learning, an environment allowing some level of control by the learner, and the pursuit of learning independently of any formal course or institutional support. The emphasis on autonomy in particular is linked with the development of the capacity to think rationally, reflect, analyze evidence, and make judgments; to know oneself and to be free to form and express one's own opinions; and finally to be able to act in the world. The development of these capacities is informed, firstly, by what we know about adult intellectual and personal development (Tennant and Pogson 1995), and, secondly, by the literature on the role education plays in promoting significant personal and social change (Freire 1974; Mezirow 2003; Brookfield 2004).

Because teachers and adult learners are adult peers, there is a widely held view that the relationship between teachers and adult learners should be participative and democratic and characterized by openness, mutual respect, and equality. The question of how to realize this ideal adult teacher–learning relationship is a focus of much of the literature on adult teaching and learning. This question is typically analyzed from three different perspectives: the political, philosophical, and psychological. The political perspective concerns the ideal distribution of power between teachers and learners and among learners. In this connection Freire's writings have been very influential, particularly his advocacy of what he calls "problem posing" education as opposed to "banking education," whereby the teacher assumes all the authority. The former is firmly centered on the learners who determine the goals, and, together with the facilitator, the direction of class sessions. The philosophical perspective refers to how the relationship serves the aims of the educational activity. In many instances the relationship may be partially determined by the nature of the learning, for example, where the content demands significant expertise of the teacher – but the task is always to distribute power as evenly as the circumstances allow. The psychological perspective has to do with how the teacher and learners relate at an interpersonal level – in particular, how the expectations and perceptions of learners are reconciled with the expectations and perceptions of the teacher.

The importance and centrality of learning from and through experience is widely accepted as a hallmark of adult teaching and learning. This is so for a number of reasons; for example, it is argued that adults have a more "street wise" practical approach to learning, and experiential methods allow them to capitalize on their practical experience. Secondly, adults typically scrutinize ideas and knowledge in terms of accumulated life experiences and not solely in terms of conceptual clarity, internal consistency, fit with experimental observation, and other academic criteria. Thirdly, adults demand a strong link between what they are learning and some application in family, community, or workplace settings, and experiential learning methods help to address this demand. Focusing on the learner's experience is an integral part of a tradition which places the learner at the center of the education process. The justification for learning based on experience can also be found in the psychological literature. Cognitive psychology stresses the interactive nature of the relationship between learning and experience. Learning is an active process in the sense that learners are continually trying to understand and make sense of their experiences. In effect, learners reconstruct their experiences to match more closely their existing rules and categories for understanding the world. These rules and categories may also change to accommodate new experiences. From another perspective, the psychodynamic psychologies draw attention to the emotionally laden nature of the relationship between experience and learning. In this regard the work of humanistic psychology has had a substantial impact on adult teaching and learning. In particular their emphasis on personal freedom, choice, and the validity of subjective experience can be seen in the importance adult educators attach to the concept of "self" in learning.

The idea of learning through collaborative community engagement to achieve liberation from psychological repression or social and political oppression is a recurring theme in adult teaching and learning. It is most commonly identified with the concepts of "conscientization" (Freire 1974) and "transformative learning" (Mezirow and Associates 2000), but it is also a feature of some contemporary conceptions of critical pedagogy, action research, models of the learning process, and techniques of facilitation. Freire (1974) adopts the term "conscientization" to describe the process whereby people come to understand that their view of the world and their place in it (their consciousness) is shaped by social and historical forces which work against their own interests. "Conscientization" leads to a critical awareness of the self as a subject who can reflect and act upon the world in order to transform it. Many commentators have noted the dominance of the concept of transformative learning in the adult education literature (Taylor 2007); in doing so they invariably acknowledge the centrality of Mezirow's (2000) ideas in shaping debate and research in the area. Given that fundamental personal change is a feature of contemporary life, it is not surprising that educators have an ongoing interest in how to effect such change. Different educators, of course, have different interests, and transformative learning has been variously critiqued, adapted, and adopted across widely different contexts and widely different theoretical perspectives. Despite the varieties of applications and adaptations of transformative learning, a common feature is a "disorientation" of some kind, variously described as disruption of one's "world view," "frame of reference," "meaning perspective," or "taken-for-granted assumptions." In Mezirow's formulation, the process of transformative learning commences with a "disorienting dilemma" which leads to a self-examination with others (in mutual dialogue), a critical assessment of internalized assumptions, and finally to a "perspective transformation" or new "meaning perspective" which are more inclusive, discriminating, and reflective. Much of the theoretical debate and empirical findings since have been concerned with identifying and elaborating on the triggers, the processes, and the outcomes of transformative learning.

Important Scientific Research and Open Questions

Our understanding of adult teaching and learning is continually informed by a wide range of research in the social sciences and humanities. The disciplines of psychology and sociology have been strong influences, particularly in conceptualizing adulthood as both an ontogenetic and social category. Issues of culture, selfhood, identity, and difference are continually being explored in adult teaching and learning alongside more psychological approaches having to do with motivation, group processes, learning styles, and adult development. The research targeted directly at adult teaching and learning tends to be more context specific as educational researchers recognize the overwhelming influence of context in understanding the dynamics of particular programs.

Cross-References

► Adult Learning/Andragogy
► Collaborative Learning
► Experiential Learning
► Self-Regulated Learning
► Transformational Learning

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Advance Organizer

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Synonyms

Anchoring framework; Conceptual framework

Definition

Advance organizers are pedagogic devices that bridge the gap between what learners already know and what learners need to know (Ausubel 1968, 2000). They were first formally introduced by Ausubel in 1960 to test the hypothesis that learning of unfamiliar verbal material can be facilitated by the advance introduction of relevant subsuming concepts. Ausubel (1968) defined advance organizers as "appropriately relevant and inclusive introductory materials [...] introduced in advance of learning [...] and presented at a higher level of abstraction, generality, and inclusiveness" (Ausubel 1968, p. 148). Thus, according to Ausubel, advance organizers should be more abstract or general than the following learning material. Therefore, the Ausubelean advance organizers are different from initially presented more concrete instructional aids such as overviews and previews, as the Ausubelean organizers provide more abstract, inclusive, and general subsumers than the more detailed learning material they precede.

However, in a more general conceptualization, the requirement of advance organizers being more abstract than the material they precede was abandoned (Corkill 1992; Mayer 1979). In this more general sense, advance organizers can be defined as relevant introductory materials presented during the initial phase of instruction. Their main function is similar to the function specified by Ausubel: to provide ideational scaffolding for the stable integration and retention of the learning material provided. The scaffolding includes the activation of relevant prior knowledge, but also the activation of cognitive and metacognitive processes that enable meaningful learning. Examples of advance organizers include introductory paragraphs, examples, concept maps, videos, and classroom discussions of the main themes in familiar terms.

Theoretical Background

Ausubel's view on the role of prior knowledge is summarized by the introductory statement to his book on educational psychology: "If I had to reduce all of educational psychology to just one principle, I would say this: The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly," (Ausubel 1968). Advance organizers are based on the idea that new information is linked to relevant, preexisting cognitive structures and that both the newly acquired and the preexisting structures are modified in the process. This interactional process forms the core of Ausubel's assimilation theory (Ausubel 2000). The assimilation of new information includes relating same-level concepts (combinatorial learning), generalization processes creating new subsumers (superordinate learning), and anchoring a new idea below a higher-level anchoring idea (subsumption), with the new idea being either a new example of the original higher-level concept, or an extension, modification, or qualification of an existing higher-level anchoring idea. This is linked to Bartlett's (1932) view of cognitive functioning. Bartlett, the "forerunner of cognitive psychology" (Mayer 1979), conceptualized a schema as an organizing and orienting attitude or affect. He theorized that a schema results from the abstraction and articulation of past experience and influences the interpretation of incoming data. This is closely related to Ausubel's concept of an anchoring idea. However, in the Ausubelean sense the interpretative process is cognitive rather than attitudinal in nature (for related information, see ▶ Anticipatory Schema in this encyclopedia). Therefore, advance organizers provide opportunities for learners to start from a schema to connect new information to existing concepts. When incoming information contradicts existing information as, for example, in refutational texts, prior knowledge structures may be refined, differentiated, or adapted.

Two different strands of research on advance organizers can be outlined. The first strand centers on the Ausubelean subsumption hypothesis that learning and retention of unfamiliar but potentially meaningful material can be facilitated by the advance presentation of relevant more abstract, general, and inclusive concepts. Ausubel attributed positive effects on (1) the selective mobilization of relevant higher order structures to establish a subsuming focus for the new learning material and thus increase the tasks meaningfulness and (2) the facilitation of an "optimal anchorage" below relevant and subsuming concepts. Ausubel distinguished between expository and comparative advance organizers: Expository advance organizers provide an overview of the to-be studied concepts and should be used for relatively unfamiliar material. They serve the purpose of providing relevant proximate subsumers that form a basis for superordinate connections with the new learning material. Comparative advance organizers can be used if learners possess prior knowledge of a related topic. For example, if the to-be presented learning material is about major concepts of information processing in human memory, a comparative advance organizer could be about the main concepts of memory in computers (assuming the respective learners have prior knowledge about memory components in computers) and later explicitly compare and contrast similarities and differences.

The second strand rests on the more general conceptualization of advance organizers including concrete examples and discussions of the main themes in familiar terms (e.g., Mayer 1979) and thus does not limit advance organizers to more abstract, general, and inclusive concepts. Building on the idea that learning involves relating new, potentially meaningful material to existing knowledge, Mayer predicted the following conditions when and how advance organizers should unfold their potential: The advance organizer should provide or locate a meaningful context and encourage learners to use that context during learning. This can only be beneficial if the material is potentially meaningful but rather unfamiliar for the learner so he/she does not automatically relate the to-be learned information to prior knowledge. If the learners relate the new content to the appropriate prior knowledge automatically, the advance organizer would be superfluous redundant. Concerning possible assessments of learning, tests should measure knowledge integration, transfer, or long-term retention rather than memorization.

Important Scientific Research and Open Questions

Research on advance organizers yielded mixed results. Some researchers have suggested that the use of advance organizers has either limited or no effects on understanding and recall. For example, Barnes and Clawson (1975) used a "voting technique" to review 32 studies in favor versus against facilitative effects of advance organizers. Finding more statistically nonsignificant than statistically significant and facilitative effects, they concluded that organizers, as reviewed, do not facilitate learning. From a methodological point of view, Luiten et al. (1980) correctly pointed out that voting techniques do not take into account positive effects that failed to reach significance and thus are biased against favorable findings. Proposing the more sophisticated meta-analysis method and analyzing 135 studies about advance organizers, he concluded that the average advance organizer has a small, but facilitative effect on immediate and delayed measures of knowledge acquisition in different content areas, grade, and ability levels. From a theoretical point of view, Mayer (1979) analyzed 44 studies on advance organizers and considered whether the material was lacking a basic assimilative context or/and whether the advance organizer was likely to provide an assimilative context. Refuting the conclusion of the Barnes and Clawson (1975) review, Mayer explained the absence of beneficial effects with the absence of specific conditions that have to be met so advance organizers can live up to their potential. Explanations included too short durations of advance organizer presentation, advance organizers that seemed not enough related to the to-be learned material, procedures that included tutors that provided individual remediation and thus possible anchors, and learning material that consisted mainly of facts. He also pointed out that many advance organizer studies that compared a group with an advance organizer to a control group that received either a control passage or nothing failed to control the information equivalency requirement and thus left the nature of the effect unclear. Studies that included advance organizers and similar organizers after studying the learning material (postorganizers) indicated that the effect is rather at encoding than at retrieval. Studies that included a variation in the familiarity or organization of the learning material indicated that advance organizers were more beneficial for poorly organized and rather unfamiliar (e.g., technical) material. In addition, advance organizers had stronger effects on conceptual posttest questions and on transfer than on recall. Studies also indicated interactions with learner characteristics, favoring the use of advance organizers for low-knowledge and low-ability students. However, other reviews do not support the latter conclusion, for example the review from Luiten et al. (1980) indicated that high-ability participants had an average effect size almost twice that of low-ability participants. One possible explanation is that many studies failed to consider carefully the range of learning material and posttest item difficulties. For example, if the posttest items are too easy for many high-knowledge or high-ability learners, no differences can be found between those learning with an advance organizer and those learning without one. Reviewing 30 experiments about advance organizers written in paragraph form, Corkill (1992, p. 61) similarly concluded that "statements suggesting that the efficacy of advance organizers has yet to be determined seem inappropriate." Above and beyond, Corkill pointed out that we cannot assume that subjects attend to an advance organizer just because one is available, thus emphasizing that additional guidance or specific tasks may be necessary for some groups of learners. Examples of such tasks are paraphrasing or writing about how the advance organizer relates to prior knowledge. This relates to the general point that a deep processing of the advance organizer is necessary to facilitate beneficial effects. Corkill also presented evidence that concrete advance organizers can outperform abstract advance organizers in a direct comparison. Extending the advance organizer versus postorganizer debate, Corkill indicated that presenting or paraphrasing an advance organizer prior to reading and having access to the organizer at recall may further facilitate long-term retention.

Concluding, empirical evidence supports the theoretical consideration that providing an anchoring framework in general facilitates learning. However, the large amount of statistically nonsignificant results reported by Barnes and Clawson (1975) points to the fact that it is not easy to reach positive effects on learning. Thus, interactions between the advance organizer, the learning material, and learner characteristics have to be considered. For example, advance organizers cannot be useful if the to-be learned content is mainly a collection of disconnected facts without a unifying organization, or if learners do not need or use the advance organizer to connect new information with relevant prior knowledge.

Open questions include whether differently structured advance organizers, including similar concepts, lead to different learning outcomes (for related empirical studies see ► Concept Maps in this encyclopedia). Related, it remains an open question whether advance organizers only work through the selective mobilization of selected concepts that are most likely part of the learner's prior knowledge or whether advance organizers may also elicit specific processes that lead to a deeper processing of the material provided. In addition, there has been ample research on text-based organizers introducing simple, paragraph-long texts, but a lack of research on more global text-adjuncts (e.g., concept maps) that are most likely especially useful for complex hypermedia material. Last, it remains an open question how long the initial phase of learning should be in prototypical settings.

Cross-References

► Assimilation Theory of Learning
► Ausubel, David P.
► Concept Maps
► Elaboration
► Schema Theory

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Advanced Distributed Learning

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Synonyms

Corporate eLearning; Distributed learning model

Definition

Although Advanced Distributed Learning (ADL) is often associated with a United States Department of Defense (DoD) initiative, it is also a wide-ranging, scientific, and technical objective that is not tied to any agency or organization. In the broadest sense, its intent is to provide universal access to high-quality education, training, and performance/decision aiding available on-demand, anytime and anywhere. This objective has stimulated numerous research and development efforts. Because the objective can only be practicably achieved through the use of technology, ADL keys on applications of the continuing, rapid development of computer technology, communications, and networking.

Theoretical Background

The words "Advanced," "Distributed," and "Learning" each covers a range of capabilities.

"Learning" in ADL is used as a catchall designator for education, training, and performance aiding. Education and training both seek to provide individuals with new, relatively long-lasting abilities. By contrast, performance aiding provides relatively short-term assistance for making decisions and solving problems. A fundamental assumption in ADL is that education, training, and performance aiding can and should be generated from the same underlying knowledge base and delivered on the same computer platform.

"Distributed" draws on an analogy with distributed computer networks in which every node is capable of delivering key services needed to achieve a common goal. "Distributed" signifies learning that can be provided in classrooms with a teacher present, in the field linking together widely dispersed teachers and students, and standing alone with no teacher present other than the computer platform and its software. In the ADL sense, "Distributed" is not just another word for distance instruction.

"Advanced" in ADL implies affordable, interactive, and adaptive learning. ADL relies on computer technology for affordable, scalable delivery. An army of highly trained tutors, mentors, and advisors could accomplish delivery of ADL services, but it would not be affordable. Costs would rise linearly with every user. By contrast, once a capability is captured by computer technology, it scales up readily – it can be delivered to a very large number of users with relatively small incremental costs.

Researchers have emphasized the lack of individual interactivity in classrooms, its importance in learning, and its ready availability through the use of computer technology (e.g., Fletcher et al. 2007; Graesser et al. 2011). A goal of ADL is to make widely available the intense, immersive interactivity that characterizes effective technology-based instruction and that has proven its value in enhancing learner achievement and motivation.

ADL objectives further emphasize adaptive learning. If learning is not tailored to the needs of individual learners, it will be of limited utility and effectiveness. It has long been recognized that tailoring instruction to the needs, abilities, goals, interests, and even values of each student is critical for its effectiveness. Individualization was early characterized as an educational imperative and an economic impossibility (Scriven 1975).

A key argument for using learning technology is that it can deliver advice and instruction that is not only interactive and individualized, but also affordable. Although often neglected, individualization is as critical in performance and decision aiding as it is in instruction. If advice is not tailored so that individual problem solvers can understand it, it will be of little use.

ADL is contributing to what may be a third major revolution in education, training, and performance aiding. The first of these revolutions arose from the development of writing, which made the content of learning accessible without requiring direct access to a sage, mentor, or subject matter expert. The second revolution arose from the development of moveable type and mass-produced books, which, in time, made the content of learning not just accessible but affordable.

Finally, computer technology is making most, if not the whole, of human learning universally accessible and affordable, but it is also doing the same for the adaptive interactions of effective learning environments. It is evolving to a future, envisioned by researchers in the 1960s (e.g., Uttal 1962) and pursued into the present (e.g., Graesser et al. in press), in which education, training, and performance aiding do not take place solely through prefabricated lessons but are primarily accomplished in the form of guided, natural language conversations. Learners and the computer in this future will engage in dialogues not unlike those used for the first 100,000 years or so of human existence.

Although not widely found, computer dialogues of this sort have been available since the 1970s (e.g., Brown et al. 1982). This capability may provide an Aristotle for every Alexander, and a Mark Hopkins for the rest of us. In addition to restoring guided dialogues as the primary mode for human learning, a common thread through all three revolutions is the ADL objective of making learning accessible, on demand, anytime and anywhere.

More specifically, ADL envisions a future in which users (learners and problem solvers) have full access to the global information infrastructure. This view keys on three main components: (1) a global information infrastructure fully populated by sharable instructional objects; (2) servers that locate and then assemble the appropriate instructional objects into relevant learning materials; and (3) devices that serve as personal learning associates by delivering these materials to individuals and teams (Fletcher et al. 2007).

This objective is a fairly straightforward extrapolation from such present capabilities as portable, increasingly accessible computing, the global information infrastructure (currently manifest in the World Wide Web with its multifarious search engines), modular object-oriented software architectures, Web 2.0 technologies, and natural language processing. Given current technological developments this future seems inevitable. The emergence of wikis, blogs, instant messaging, and chat rooms adds another capability that enables geographically dispersed students to collect information and collaborate in a collegial fashion to solve problems, form opinions, and discuss all matters great and small. Lessons, simulations, and tests can still be downloaded, but instructional, one-on-one dialogues between students and individual instructors, mentors, or experts, computer and human, are becoming increasingly likely. All this activity suggests that we are racing into an anytime-anywhere distributed learning future.

The ADL vision is that a device delivering these capabilities will be portable, small enough to be carried in a shirt pocket or worn as a personal accessory or even as clothing. At present PDAs, laptops, mobile telephones on steroids, and other computing capabilities are beginning to serve as reliable sources of these learning capabilities, presaging their further development.

Some of the progress needed to achieve ADL objectives will be independent of ADL activities. For instance, the market-driven race to imbue computer technology with natural language understanding should ensure development of affordable, mobile, conversation-capable computing. Moore's Law, which anticipates a doubling of computing power, with shrinking size and cost, every 18 months, will continue in effect for at least the next 10 years and probably longer. It should ensure availability of the devices needed for ADL.

Conversely, some efforts specifically intended to achieve ADL objectives have utility beyond ADL. For instance, if objects are going to be collected from the global information infrastructure for use by different individuals using different computer platforms, they will need to operate in whatever computer platform and environment they find themselves. Objects drawn from the global infrastructure must be portable (able to operate across many computer platforms), durable (despite modifications in underlying systems software), reusable (operating within different application programs), and accessible (locatable by all who seek them). Specifications for achieving the first three of these objectives have been made by the DoD ADL initiative with its Sharable Content Objects Reference Model (SCORM). The DoD ADL initiative also joined with the Corporation for National Research Initiatives to develop the Content Object Repository Registration/Resolution Architecture (CORDRA), a system of registries for objects that make them globally visible while ensuring control by their developers over access to them (Fletcher et al. 2007). SCORM and CORDRA have application for the management of any digital objects – well beyond the instructional objects they focus on.

Important Scientific Research and Open Questions

A critical element in this scheme is the server, which will collect and assemble material on demand and in real time. This material will be tailored to the needs, capabilities, intentions, and learning state of each individual or group of individuals. Today, much of the work of the server may be accomplished by "middleware" in the form of learning management systems (LMSs). Within ADL, the term LMS implies a server-based environment that provides the intelligence for delivering appropriate, individualized learning content to students. LMSs are expected to determine what material to deliver, when, and to track student progress. However, the role of LMSs continues to evolve. In the future, they may be "fat" or "thin," performing many or very few of these activities. Their proper role remains an empirical issue.

Research in technology-based instruction that began in the 1960s will continue to evolve the models of learners, subject matter, and instructional strategies needed to develop the techniques needed to individualize instruction and realize this instructional imperative – affordably. One key capability needed to achieve the ADL objective is to integrate these models with the on-demand assembly of instructional objects to produce relevant and effective learning materials. Development of this capability is the current, most pressing challenge for ADL researchers.

Another serious challenge for ADL does not involve research on learning as much as management of change. As described by Fletcher et al. (2007), the overall developmental capabilities, of which the ADL objective is just one component, will effect major changes in the roles and functions of our existing instructional institutions and the way we staff, organize, administer, and even fund them. What should the roles and responsibilities of these institutions be when learning becomes ubiquitously available on demand? Technology and research for learning are proceeding apace. They present substantive but solvable challenges that are being met with steady, discernable progress. The administrative issues also need and deserve serious attention from all those concerned with learning. They are currently receiving less attention, but they may prove to be the most difficult and intractable challenges for ADL and its objectives.

Cross-References

- ► Adaptive Blended Learning Environments
- ► Advanced Learning Technologies
- ► Classification of Learning Objects
- ► Distance Learning
- ► Distributed Learning Environments
- ► Technology-Based Learning

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Advanced e-Learning Technologies

► Remote Laboratory Experiments in Virtual Immersive Learning Environments

Advanced Learning Technologies

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Synonyms

Artificial intelligence in education; Intelligent tutoring systems; Learning environments; Technology enhanced learning

Definition

Advanced Learning Technologies (ALTs) are artifacts (*technologies*) that enable, support, or enhance human *learning*, emerging from the most recent *advances* available in both areas. There are nowadays two real challenges to be faced when trying to outline in detail this definition of ALTs as a meaningful, full-fledged state of the art of the key concepts for future use, not just an historical overview of socio-technical approaches. The main technical challenge is due to the unprecedented speed of innovation that we notice in Information and Communication Technologies: ICTs; in particular: the Web. The educational challenge is a consequence of the technical one. An account of educational uses of technologies has to consider the impact of ICT innovation onto unexpected changes in human practices in any domain, modifying substantially the classical human learning cycle that since the nineteenth century was mainly considered to be managed within formal teaching institutions such as the schools. Therefore, our interpretation of *advanced* will be in the sense of *dynamic, experimental, to be implemented and evaluated* in order to limit the risk that what we describe today as advanced will be considered obsolete in a few months. This vision of ALTs, however, does not underestimate the interest for a reasoned analysis of past experiences. On the one side this analysis will guide us to avoid well-known pitfalls, on the other it will teach us lessons not only about how to exploit the potential learning effects of *current* advanced technologies – the applicative approach – but also how to envision, elicit, estimate, evaluate the potential promising effects of *new* technologies and settings to be studied and developed within human learning scenarios – the experimental approach – the last, enabling scientific progress both in Informatics and in Psychology of human learning.

Theoretical Background

Advanced Learning Technologies may be described and classified according to different criteria, such as their historical development (from the PLATO – TICCIT investments in the 1960s in the US, to current wikis, semantic web and social networks) or their links with disciplinary works (Informatics, Psychology, Pedagogy, etc.). Each and all these classifications are widely available already (► ITS: Intelligent Tutoring Systems or ► AI in Ed: Artificial Intelligence in Education or IEEE ICALT: International Conference on Advanced Learning Technologies). What seems to us interesting here is to present a couple of *new* criteria that may offer a frame of reference for the years to come. Classification criteria should be now different because we are facing a totally different world that is globally connected through the Web where the role of ICTs becomes primary for science, education, and any socio-economic domain. In this sense, most of the remarks in this article are intertwined with the ones in the Web Science one. The core observation is that on the current Web, humans are both consumers and producers of Information and of Services, i.e., they have a bidirectional access to the Web. Differently said, the modern Web consists of some billions of machines *and* of connected people. In this context, previous definitions are challenged; for instance the classical distinction between technologies and humans (artificial and human autonomous agents) needs to be revisited.

Reflecting on each word on turn: let us start with *Technologies***.** It is to be debated if current Information and Communication Technologies (ICTs) are just technologies in the traditional term (artificial tools, artifacts that facilitate the human for the achievement of his/her goals) or rather, represent the modeling substrate of current and future reality. For instance: social networks are just tools or – by including the millions of humans connected – are they a new natural phenomenon, as it is envisaged in the Web Science view? In the latter hypothesis: where is the equilibrium between a vision such that humans exploit technologies for their superior needs and the dual one: technologies influence humans in their behavior, an issue that may be classified under the topic of coadaptation? Are these technologies applications of previously defined principles and design rules or rather do they emerge as the evolution of a kind of natural selection process among thousands of options available?

In this reflection, the contributions of Eileen Scanlon and Tim O'Shea (2007) and Marc Eisenstadt (2007) are a splendid synthesis of the last 40 years of research, developments, and practical implementations; successes and failures, directions to go and pitfalls to avoid. The main conclusions are that *we now have new topologies for learning which have no direct analogues in past educational practice* (Scanlon and O'Shea 2007) . . . and *the essence of the problem is that new-tech disguising old ideas is almost certainly doomed to failure. Learning Management Systems and Learning Objects, for example, despite the noble intentions of many protagonists, can in fact conceal neobehaviourist drill-and-practice thinking* (Eisenstadt 2007).

The subsequent word to be examined is *advanced.* This is rather self-explaining; however, the meaning of the word concerns more likely the exploratory nature of the infrastructures, tools, and practical implementations that one wishes to consider for enabling, supporting, or enhancing human learning. The issue is not so superficial, knowing that often people do not consider that the introduction of technologies in human life, particularly in Education or Learning, implies a profound modification of the human behavior. In principle, radical changes are regarded with suspect by the key actors. In our case, students (learners) are usually ready to accept, while teachers and administrators resist to the introduction of changes as most professionals often do with respect to innovation (other historical examples being technologies for health or for the legal professions). Therefore, *advanced* suggests a life cycle of innovation that cares for an experimental part: similar to a spiral (software development) approach based on trial and error as opposed to the waterfall one, in order to *motivate and convince* the actors of their own interest to adopt changes in their practice. No major change in the work practice will ever occur if it is not preceded by an experimentation that puts the actors and their motivation and awareness at the center of the implementation itself. Some authors even reverse the argumentation by proposing to exploit the proactivity of humans in open participatory learning infrastructures – *serendipitous mashups foster creative integration* (Eisenstadt 2007). Anyway, the classical concepts of ICT products optimizing the acquisition of knowledge and skills by interactive training are challenged by more modern concepts of peer-to-peer services adapting to the partner's needs and collaborating in social networks in order to facilitate learning. More often as before, those modern socio-technical scenarios enable human learning that otherwise would be impossible to conceive, so that the administrator's right question becomes more *what would happen if we do not use technologies for learning* as the traditional question: *why should we use them*?

Thirdly, we are interested in *learning technologies* in the sense of human learning. However, we know very little about human learning. The relation teaching-learning (effects of teaching) is not always clear (see, e.g., *the no significant difference phenomenon* Web site: http://www.nosignificantdifference.org/). We are facing a kind of dichotomy between a natural process (human learning) and the practice supposed to facilitate it (teaching). The opposition is similar to the one of biology versus medicine: practicing medicine is not worth unless the patient is healed. Similarly, the only interest of teaching is in its effects: that learners indeed learn. Medicine is an art while biology is a natural science; we will never better our practices in medicine unless we better understand the underlying biological phenomena concerned. For those reasons, it is important to admit that technologies for teaching do not necessarily imply better or different learning. A vision of human learning may have a substantial influence on the priorities to attribute to the development of technologies for learning, the most radical difference being the one between behaviorism, constructivism and social constructivism which are treated extensively elsewhere in this encyclopedia.

Important Scientific Research and Open Questions

The most important scientific research question concerns which discipline profits from the success of the interdisciplinary projects in ALTs. These profit from disciplinary competences of humans, and may produce advances in each discipline but in quite different proportions according to the choices made in the goals, plans etc., adopted for the research process. In making progress in ALT, does one produce advances in understanding learning, thus improving as a side-effect teaching practices, or rather the technologies experimentally developed in educational or learning scenarios are significant for progress in Informatics? One of the most interesting paradigm shifts in current Web Technologies and Web Science is that new usage-centered business processes do require to introduce interoperability among machines and people but reuse old technologies. Another is that social software success is hardly to be forecasted and may not be stable, will rather be dynamic, evolving, and volatile. So it is the case for the learning effect of informal learning situations such as those offered by the Web. The acceptance is also variable with the age: digital natives behave differently as digital immigrants independently from their role of students, teachers, or administrators. Within this totally new framework, the real open question concerns what are the established principles that we may assume as valid and how to progress.

For instance, in the Bioinformatics of genome it is well known that the main effect is a progress in understanding the genome; minor effects though exists in the availability of efficient algorithms for generic purposes (advances in Informatics). The opposite case considers the business domain (human learning in our case) as a *scenario* for the elicitation of new ideas (not as an application domain): an example being the seminal work done by Alan Kay around the Dynabook as well as Smalltalk in the early 1970s. Fundamental advances in Informatics research (the personal computer, the first real object oriented programming language, the window interface, the integrated environment including the language and the interface, etc.) emerged from observations about the needs of children (the dynamic book; the small talk for small children) with an enormous impact in the 40 following years. Similarly, the PLATO system conceived in the 1960s by Don Bitzer and Paul Tenczar for military and educational purposes was a precursor of many currently used generic interactive technologies: the PLASMA flat 512 $\times$ 512 dot graphic display with images superimposed projected from a microfiche of color slides; an operating system with a kind of virtualization of student's variables, enabling in the 1970s the remote access of up to 1,000 simultaneous users, the TERM-TALK option for chatting, the interactive TUTOR programming language that later became TENCORE for PCs, etc. On the opposite side, TICCIT was an early example of pure exploitation of the television for distance education with no real ambitions of advances in technologies.

In the case of ALTs, the most important advances concerned with modeling human learning have been obtained as a consequence of the need to tune (or adapt) interactions to individual learners. As Artificial Intelligence has demonstrated, modeling complex natural phenomena implies understanding them better. In the case of learner modeling, it means understanding better human learning. The domain of learner modeling, opened by the foundational work of John Self (1974) has been at the core of years of quite profound research of generic impact for human–computer interaction, where models have represented human competence, human skills and, more recently, human emotions and personality traits. Adaptable interfaces are now among the top priorities of any modern ICT application.

However, the fundamental question on ALTs still remains, after more than 50 years of research and practice. The question is if ALTs are concerned with a more efficient production of teaching material by using technologies, as it was the case for the CAI (Computer-Assisted Instruction or its synonyms) that basically attempt to mimic the schoolteacher in transmitting content and examining the acquisition of the subject matter, or rather are called for stimulating learning by dialogue and interaction in any area (learning environments), such as it is the case for (serious) games, social networks, communities where learning may occur as a side effect of social interaction. In order to have once more a direct answer, one may refer to the arguments of one of the pioneers: John Seely Brown. Related to this question, the distinction is sometimes made between formal and informal learning. In the first case, today's focus is ontologies (the intensional representation of concepts and relations for reasoning, problem solving, and search), instructional design and experiments on the learning effects due to teaching strategies. In the second case the issues are interaction design, dialogue management and the evaluation of the success by other parameters such as motivation, implication in social networks, and professional impact of the actors. It is certain that both approaches are synergic to one another.

While Artificial Intelligence may pervade each of the approaches, it does it in very different ways. In order to understand how pioneers paved the way for radical changes in the research and practice on ALTs, we refer to the inspiring paper of Jaime Carbonnell (1970): the notion of mixed initiative dialogue has introduced a shift in the conception of classical, previous educational software (such as the one produced on PLATO) by requiring the *automated tutor* to understand the learner's question, needs, and statement. While in the beginning this was supposed to require just some natural language software able to recognize *WH- questions*, later the approach opened the research agenda on user models and, in general, on dialogues including models of the pragmatics of conversations such as those typical of modern Agent Communication Languages (performatives, speech acts).

As a conclusion, ALTs are at the core of questions and answers that have challenged informaticians since the 1960s. ALTs have historically been prototypical for most innovations in interaction models and technologies as well as, nowadays, in interactive, multi-centric, heterogeneous, asynchronously communicating service-oriented business (learning) processes (Cerri et al. 2005; Ritrovato et al. 2005). In its essence, the question concerns how to *design interactions* suitable to have effects on a human partner in conversations where the meaning of design is far from the rigid definition of classical workflow and more in the sense of exploiting open interactions for enhancing learning. This scientific question fits well with very modern issues (service-oriented computing: semantics, processes, agents). A service is different from a product in the sense that it is produced on the fly when required by the consumer (dynamic) and its effectiveness is measured by the consumer's satisfaction, not just by its intrinsic performances. This recent paradigm shift in Informatics fits better with the above mentioned concepts of conversations among autonomous agents (such as teachers, learners, or other actors in the community of practice) where the dimension of heterogeneity of knowledge, competence, skills and motivation, the distribution of resources and interests, the asynchronous communication channels and patterns, the coexistence of artificial and human agents in the collaborative efforts, the ubiquity of bidirectional access worldwide ought to be considered components of a Web Science scenario where learning occurs everywhere at any time rather than classical ICT products in a traditional classroom equipped with some computers.

Cross-References

- ► Interactive Learning Services
- ► Learning as a Side Effect
- ► Social Network Analysis and the Learning Sciences
- ► Web Science

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Advanced Resource Classrooms

► High Performance Learning Spaces

Adventure Learning

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Definition

Adventure learning is an approach used to design online and hybrid education that provides students with opportunities to investigate and experience authentic topics within collaborative learning environments. Adventure learning environments and opportunities can take one of two forms:

1. A team of individuals goes on an exploratory expedition of a topic of interest. The expedition is adventure-based and occurs outdoors, at a location that allows meaningful investigation of the topic of interest. For example, to explore a community's flora, a team could kayak the length of a local river to investigate local plants. The team can then share media from the trail, along with findings and observations on an online learning environment. At the same time, instructors and learners study the topic via an inquiry-based curriculum and through the online learning environment. The learners interact with the explorers and with other experts who provide input and insight on the learners' investigations. The data from the trail and the opportunities for collaboration/interaction are synchronized with the learning activities that occur in the classroom.
2. Teams of instructors and learners go on an exploratory expedition of a topic of interest. The expedition is adventure-based and occurs outdoors, at a location that allows meaningful investigation of the topic of interest. For example, to investigate social inequality, the team may visit a city's downtown area to collect authentic data (e.g., photographs). The team's observations, data, and findings are then shared on an online learning environment. The topic is studied with the support of an inquiry-based curriculum and with the support of other individuals who may contribute knowledge on the topic. For instance, experts may be invited to a videoconference to answer student questions. At the same time, instructors and learners in other classrooms can study the same topic and collaborate with others on the same online learning environment. These classrooms can (a) conduct their own local exploration of the issue, share their findings/observations, and use the findings/data/observations from other classes, or (b) use the authentic findings/data/observations provided by other classes.

The design of adventure learning environments is grounded on the following principles (c.f. Doering 2006; The Learning Technologies Collaborative 2010):

- A researched curriculum that is inquiry-based
- Opportunities for collaboration and interaction between learners, instructors, and experts
- Use of the Internet to facilitate the learning experience, including the delivery of the curriculum, delivery of the media, and interaction between the individuals partaking in the experience
- Timely delivery of media and text from the field to enhance the curriculum
- Synchronized learning opportunities
- The provision of pedagogical guidelines to guide curricular and online learning environment use for the instructor to effectively implement an adventure learning project
- Adventure-based education to elicit excitement as a result of the risk, danger, uncertainty, and hazard inherent in the adventure
- Authentic narrative. The learning experience is based on an authentic story/narrative that (a) unifies the expedition, curriculum, student activities, media, and learning experience under a common purpose and theme, and (b) serves to encourage creativity and enjoyable learning experiences
- Identification of a location and issue to explore (including investigation of the contextual factors surrounding the location and issue)

Theoretical Background

Adventure learning is rooted in the socio-constructivist school of thought. In this perspective, individuals learn in social settings, through their interactions, collaboration, and negotiation of meaning and understanding with each other. Within this theory, learning becomes a negotiated process, and the roles of learners and instructors shift. Specifically, learners are seen as being active and legitimate participants, with the ability to make valuable contributions to the learning process. Over time, as learners gain greater and more diverse knowledge and understanding, they also become able to assist and scaffold their peers. In turn, instructors are seen as guides, facilitators, supporters, aggregators, and connectors.

Adventure learning embraces this concept of learning within a technology-rich context. In adventure learning environments, learners collaboratively investigate real-world issues and negotiate solutions to posed problems, contribute their knowledge and understanding of the studied issues, and support each other in this process. Instructors and other experts scaffold student inquiry and assist learners in their investigation of the topic.

Finally, adventure learning is further informed by four theoretical constructs, summarized below, but also cross-referenced within this volume (see section "Cross-References"):

- *Experiential learning*. In adventure learning projects, learners are involved in the experience through observation of and participation in the expedition, reflection, engagement with real data (e.g., videos posted on the online learning environment), and analysis. These activities help learners create knowledge from their experience.
- *Inquiry-based learning*. Adventure learning curricula and experiences are grounded in inquiry where learners seek answers to their own questions, formulate hypotheses, design investigations to test their hypotheses, and evaluate the results of their investigations. Evaluation in adventure learning projects occurs within collaborative settings where learners, instructors, and other experts discuss and reflect on findings.
- *Authentic learning*. Adventure learning experiences focus on a diverse set of authentic (or real-world) processes, data, and experiences. These range from engagement with real-world issues that are complex (e.g., studying socio-scientific issues of global concern such as environmental degradation), to using real-world data (e.g., snow samples). Within these investigations, learners enact practices that are also authentic and include interacting and collaborating with others, engaging with multiple perspectives, and reaching diverse solutions to problems that do not encompass single solutions.
- *Open-ended learning environments*. Adventure learning environments are instances of open-ended learning environments. These are online environments that support individual learner participation, flexibility, and control. Open-ended learning environments are student-centered in that they do not impose a uniform and specific learning sequence, and do not focus on specific content/goals (Hannafin et al. 1994).

Important Scientific Research and Open Questions

Adventure learning is a relatively new development in the field, as the first report delineating the approach described above appeared in 2006 (Doering 2006). Since then, researchers have sought to operationalize the adventure learning construct (e.g., The Learning Technologies Collaborative 2010), while also synthesizing empirical research on the topic so as to push the field forward (Veletsianos and Kleanthous 2009). It is important to note that since adventure learning is an approach for the design of online and hybrid education, research on the topic is conducted within the context of ecologically valid learning environments designed for specific purposes. Results from these investigations have indicated that the approach has fostered student interest, motivation, and engagement (e.g., Doering and Veletsianos 2008a), has been flexible enough to enable multifaceted adoption within classrooms (Doering and Veletsianos 2008a), and has enabled learners to engage in inquiry-based practices that have been memorable and captivating (e.g., learners in a study conducted by Doering and Veletsianos 2008b, reported that they discussed their learning with their parents and parents asked teachers to continue using the adventure learning projects in their teaching). These results have also been observed in a long-term study of the approach (Veletsianos and Doering 2010). The long-term investigation of the approach (ibid) also noted that the social and participatory nature of the learning experience enabled students to develop a sense of community, while the unfolding narrative of the approach assisted in mediating learning and engagement.

While the adventure learning (AL) approach provides much promise for the design and development of powerful learning environments and experiences, there is also much scope for scholarly contributions to enhance the AL construct. The following areas may yield important insights into the adventure learning approach and need to be addressed by future research:

- To what extent is the adventure learning model applicable to higher education, out-of-school settings, and diverse content areas? Most research to date has been conducted within the context of socio-scientific investigations in K-12 schools. Research on environments and implementations outside of K-12 may yield valuable insight with regards to the effectiveness, complexities, and adaptability of the approach in diverse settings.

- How can individual instructors effectively design and develop their own adventure learning projects, how can they be supported, and what are the outcomes of such projects? To date, most of the research/design contributions on the topic are concerned with adventure learning environments developed by experts and used by teachers. What happens when teachers become designers of adventure learning projects?
- What are the learning outcomes of adventure learning projects? While the effectiveness of the approach has been demonstrated in terms of student interest, excitement, and engagement, and teachers have reported that they find the adventure learning approach beneficial for student learning, current literature lacks empirical results on learning outcomes.
- What does learner participation and interaction look like in adventure learning environments? Prior research has highlighted the collaborative nature of adventure learning projects, but no research reports have been published on the nature and extend of learner participation in these online learning environments.

Cross-References

▶ Authenticity in Learning Activities, and Settings
▶ Experiential Learning Theory
▶ Informal Learning
▶ Inquiry Learning
▶ Online Learning
▶ Open Learning Environments
▶ Socio-constructivist Models of Learning
▶ Technology-Enhanced Learning Environments

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Adversarial Growth

▶ Posttraumatic Growth

Aesthetic Experience

▶ Science, Art, and Learning Experiences

Aesthetic Imagination

▶ Imaginative Learning

Aesthetic Learning

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Synonyms

Development of judgment; Learning a taste; Sensori-emotional learning; Transformation of aesthetic experiences

Definition

The term *aesthetic* was derived by the German philosopher Alexander Gottlieb Baumgarten (1714–1762) from the Greek word "αίσθητά" (aístheta) meaning *perception*, which he used in the sense *things perceived* as opposed to *things known*. The current use of the term originates from Baumgarten's countryman and colleague Immanuel Kant's (1724–1804) adaptation in his *Critique of Judgment* of aesthetics as concerning *judgments of taste*, about our experiences of the *beautiful* and *ugly* and what is *agreeable* or *disagreeable*. Hence, aesthetic learning is to be understood as the learning of certain ways of experiencing and distinguishing things in the world that can be summarized in aesthetic judgments of taste. Aesthetic learning in this inclusive sense does not concern merely the realm of art, but the transformation of aesthetic experiences and taste generally in life.

Theoretical Background

As already noted by Kant, an *aesthetic judgment* says something both about our inner feelings and about an outer object or an event. In communication between people aesthetic judgments are used constantly. We, for instance, talk about such central aspects of our life as our daily work, food, clothes and friends in terms of taste and whether we like them or not. Language abounds with various aesthetic words describing our feelings for different qualities of objects and events. Such aesthetic judgments are not only made through spoken and written language, but also through gestures, facial expressions and sounds like sighs and laughter.

Two major schools can be distinguished regarding the meaning of aesthetic judgments and experiences that have bearing theoretically on how aesthetic learning is construed. They can be summarized as representational and situated ► approaches to learning. These two theoretical frameworks differ regarding their basic assumptions about the function of an aesthetic judgment as part of language and about what constitutes learning. As a backdrop, a short description is given here of the representational school, but the emphasis is on the socioculturally oriented situated school of learning, where the *term aesthetic* learning is actually adopted.

The *representational approach* to learning sees an aesthetic judgment as either a conceptual representation of the inner emotional or motivational states of an individual or as conceptual representation of certain outer qualities of form. Learning amounts to getting reality right through correct representations of the world. Learning is genuinely cognitive and aesthetic learning, accordingly, is also purely cognitive, or else it is not learning. Accordingly, the affective domain is not changed by learning. It is an inner reward or arousal system with already set distinctions in terms of emotions and motivational states. Learning that something is, for example, beautiful or agreeable either means learning what kind of object someone intends by the word (because it is true that a person intends this object) or learning what kind of emotional reward or punishment that comes with the object with a concomitant motivational state assigned toward the object. According to such a perspective, the role of aesthetics in learning is to create a positive motivation to learn certain things.

Adherents to the ► situated learning approach argue that aesthetic judgments and aesthetic experiences can only be made sense of as part of an activity. An early representative of this approach is the Austrian-British philosopher Ludwig Wittgenstein (1889–1951), who noted in his *Lectures on Aesthetics* that in understanding aesthetic judgments we should not focus on the aesthetic words themselves and what they represent, but on the whole situation in which they are used. He argued that we learn to use aesthetic judgments in the same way as any other words of our language, i.e., as part of certain activities. Especially the American philosopher John Dewey's work *Art as Experience* has been influential within this school of research. He argued that to understand the function of aesthetic experience we need to study how it is continuous with the normal processes of living (Shusterman 2000). He intended the processes as wholes, integrating language, outer events, and inner reactions as activities of lived life. Learning is not about getting correct representations of the world, but as that of acquiring habits for coping with life. Generally, also sociological approaches as those of Pierre Bourdieu (1979/1984) and historical stances as the emotionology of Peter Stearns and Carol Stearns (1985) have been influential in establishing the cultural dependence of aesthetic learning. Aesthetic judgments have important social and communicative components, and are not merely designating readymade private emotions or motivational states in relation to certain objects. Although not denying biological and physical ► constraints of learning, taste and aesthetic experience are studied as culturally embedded and how they need to be learnt in action as part of specific situations.

Important Scientific Research and Open Questions

Research has demonstrated the close association of aesthetic judgments and experiences with evaluations and the learning of how certain objects and events are conducive to purpose (Wickman 2006). *Purpose* in this sense should be understood in a holistic way, as answering a question about what people are doing. Aesthetic judgments are used to designate certain qualities distinguished and evaluating to what degree they are anticipated to be conducive to purpose, and also in summing up to what degree they actually did further the purpose. In this regard aesthetic learning is about learning how to make distinctions concerning what should be included and excluded in an activity. Through the learning of such distinctions and judgments, aesthetic learning has a bridging function for cognitive as well as normative learning.

Aesthetic learning has both a creative side, dependent on imagination, fiction, and intuition, and a socially subordinating side, fostering certain predetermined ways of distinguishing and aesthetically experiencing, which is dependent on copying (Schön 1991). This is the case in art as well as seemingly more cognitive practices like science. Many types of activities are already culturally well-established as traditional and customary ways of distinguishing and proceeding. Aesthetic learning here means learning to make these distinctions and experiencing the social moments of fulfillment according to cultural norms in aesthetic terms, through language and emotionally. At the same time learning to take part and master new activities are not fully predictable, and vague aesthetic anticipations and judgments about how certain distinctions and discriminations further purpose necessarily mean that learning also has a risk and encompasses negative aesthetic experiences. In learning to proceed successfully, one needs also to learn what should be excluded or avoided, something which typically is experienced in negative aesthetic terms. Aesthetic learning in this way means learning certain rules and norms for action and so necessarily is closely connected to getting bodily and sensory involved in situations, no matter how intellectual the activity may seem.

Aesthetic learning often entails learning to distinguish certain qualities or objects aesthetically in different ways depending on the situation and the purpose. Certain things can be experienced in negative ways in one activity and in positive ways in another. When an aesthetically negative way of judging a certain object hinders a certain activity people can be seen to adapt by learning (1) how to avoid the activity as a whole; (2) how to deal with the specific object to avoid it, but still be able to continue with the activity; or (3) to get used to the object (Wickman 2006). Such observations have been made in science in relation to feelings of disgust and in art in understanding new genres. Getting used to the object may entail that an individual actively changes the context of experiencing the object. Play seems to be a way that children adopt in getting used to certain objects. Often getting used to means finding ways of overcoming anticipated negative aesthetic experiences and learning that they eventually will not happen and that an unanticipated sense of fulfillment will instead be the case. In artistic work, shifting between the role of producer and onlooker is important in learning how to proceed with an artwork.

Aesthetic learning involves coming to understand the kinds of activities that one can aesthetically be part of and hence entails also a transformation of oneself in relation to others, i.e., our identity. Although we know about the short-term learning processes, we need to know more about how they ad up, through our upbringing and through education to what Bourdieu (1979/1984) called our *habitus*, i.e., the specific taste that we share with people of similar background and occupation as ourselves. How such learning occurs is of importance to structure learning situations in education that build up an interest to continue learning. Related to such learning is also the empathy side of aesthetic learning, how we come to understand and value other people's taste, not only of those with whom we share a cultural background, but also with those that have radically different backgrounds and taste depending on, for example, class, ethnicity, gender, or sexual inclination. Answers to such questions are vitally important in our increasingly multicultural societies.

Cross-References

- ▶ Affective Dimensions of Learning
- ▶ Cross-Cultural Factors in Learning and Motivation
- ▶ Interests and Learning
- ▶ Learning in Practice (Heidegger and Schön)

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Affect

- ▶ Affective and Emotional Dispositions of/for Learning
- ▶ Creativity, Problem Solving, and Feeling
- ▶ Mood and Learning

Affect and Memory

- ▶ Emotional Memory

Affect Dynamics

- ▶ Monitoring Affective Trajectories During Complex Learning

Affect Regulation

- ▶ Extraversion, Social Interaction, and Affect Repair

Affect Sequencing

- ▶ Monitoring Affective Trajectories During Complex Learning

Affect Transitions

- ▶ Monitoring Affective Trajectories During Complex Learning

Affective and Cognitive Learning in the Online Classroom

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Synonyms

Distance education; Education; Knowledge; Learning; Virtual classroom

Definition

Affective and cognitive learning are two of the three domains of educational activity (the third being psychomotor learning) identified by Benjamin Bloom in the seminal *Taxonomy of Educational Objectives* published in 1956. The affective domain refers to emotional and attitudinal engagement with the subject matter while the cognitive domain refers to knowledge and intellectual skills related to the material. These domains have a long history of use within traditional classroom instruction and have also been applied to the online classroom. The online classroom refers to the virtual learning environment in which students and instructors separated by distance and/or time engage in planned instruction. Like their physical counterparts, online classrooms vary widely, although they often include areas for announcements, course materials, discussion forums, assignments, and gradebooks.

Theoretical Background

Beginning with the 1948 Convention of the American Psychological Association, a group of educators led by educational psychologist Benjamin S. Bloom worked to develop a classification scheme of educational outcomes. The hope was that such a classification would help educators to "begin to understand more completely the relation between the learning experiences provided by these various [instructional] programs and the changes which take place in their students" (Bloom 1956, p. 10). The result was a taxonomy of educational domains including cognitive, affective, and psychomotor.

The initial publication resulting from this effort was *Taxonomy of Educational Objectives. Handbook 1: Cognitive Domain* (Bloom 1956). Although the overall taxonomy was defined in this text, the primary focus was on the cognitive domain, which dealt with "recall or recognition of knowledge and the development of intellectual abilities and skills" (p. 7). The cognitive domain involves knowledge, comprehension, application, analysis, synthesis, and evaluation. This hierarchy is often referred to by the shorthand Bloom's Taxonomy and has been regularly employed in instructional design and development since its publication.

Although identified in the original *Taxonomy*, the affective domain did not receive its own companion volume until 8 years later with the publication of *Taxonomy of Educational Objectives. Handbook 2: Affective Domain* (Krathwohl et al. 1964). The affective domain relates more to the emotional aspects of learning including feelings, values, appreciation, enthusiasms, motivations, and attitudes. The focus is more on the development of attitudes and behavior rather than on the intellectual abilities associated with the cognitive domain.

Cognitive and affective learning have been important considerations with the emergence of online learning. Distance or online learning is planned learning that occurs where the students are geographically (and often chronologically) separated from the instructor and often from each other as well. Distance education existed long before the Internet and is not dependent on any particular technology or media, although online learning (and thus the online classroom) is the dominant modality in the early twenty-first century.

The first question that many ask when considering distance education is "But is it as effective as face-to-face education?" The answer is "yes," although the results are more nuanced than such an answer would suggest. A meta-analysis of 232 comparative distance/traditional instruction studies found that there was no average difference in academic achievement, there was significant variability (Bernard et al. 2004). The authors found that "a substantial number of [distance education] applications provide better achievement results, are viewed more positively, and have higher retention rates than their classroom counterparts. On the other hand, a substantial number of [distance education] applications are far worse than classroom instruction" (p. 406). So while the average achievement findings confirm that the delivery medium is not the determining factor in educational effectiveness, the wide variability indicates that there are noticeable differences on a course-by-course basis.

Such findings have resulted in an increased focus on the dynamics associated with the virtual classroom. Rather than merely looking at grades or other traditional measures of academic performance, researchers have looked more deeply at the psychosocial dynamics within the online learning environment and their relation to affective and cognitive learning. The Community of Inquiry framework (Garrison and Arbaugh 2007) is an increasingly popular model within online course design. The Community of Inquiry model considers overlapping degrees of presence, namely cognitive presence, social presence, and teaching presence within the online classroom.

Russo and Benson (2005) examined the relationship between perceptions of presence and affective and cognitive learning in the online environment. They found that perceptions of instructor presence were positive correlated with affective learning and satisfaction. Cognitive learning, as measured by course performance and self-grading, was related to perceptions of the students' own presence in the class. Such findings are consistent with online learning research where increased levels of presence are found to promote increased self-reports of affective and cognitive learning within the online classroom. However, there is a need for more empirical research to better understand the relationship between these dynamics and learning outcomes (Garrison and Arbaugh 2007).

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Important Scientific Research and Open Questions

Although initial inquires into the effectiveness of online learning examined grades and other measures of academic performance, recent efforts have considered multiple dimensions such as affective and cognitive learning. However, there is a significant difficulty associated with how to operationalize the variables and promote cross-disciplinary research.

Course grades have been the most common measure of cognitive learning; however, grades can be problematic because they have a restricted range (which limits their use in correlation studies) and do not necessarily measure the presence of new learning in a course. There are a number of self-report instruments used to measure cognitive and affective learning, although they vary from single-item to 20-item instruments that are not consistent in their design. A recent instrument by Rovai et al. (2009) presents a nine-item self-report scale which measures cognitive, affective, and psychomotor learning; however, as with existing instruments, it depends on the self-reporting of the student to determine the degree to which these domains are engaged.

The online learning field would benefit greatly from an increased focus on quantitative studies examining the degree to which cognitive and affective learning occurs within the virtual classroom, the instructional design and psychosocial dynamics that affect those domains, and the practices that can promote the achievement of learning objectives within these domains. As online learning continues to grow outside of the university setting, there should also be an increased focus on the psychomotor domain. In these regards, the online learning field is akin to education in general at the time that Bloom and his colleagues developed the taxonomy of educational objectives. New models have been developed (e.g., Community of Inquiry) and old ones have been applied (e.g., Bloom's Taxonomy) but there is a need for empirical research to validate and elucidate the varied activities within the online classroom and the ways in which online instruction can be improved.

Cross-References

► Affective Dimensions of Learning
► Bloom's Taxonomy of Learning Objectives
► Cognitive Learning
► Cognitive Learning Strategies for Digital Media
► Cognitive Models of Learning
► Distance Learning
► eLearning and Digital Learning
► Learning by Design
► Online Learning
► Virtual Reality Learning Environments

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Affective and Emotional Dispositions of/for Learning

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Synonyms

Affect; Emotion; Feeling; Flow; Mood; Well-being

Definition

Affect refers to the experience of feeling or emotion. Affect plays a crucial role in the process of an organism's interaction with stimuli. Affect indicates an instinctual reaction to stimuli before a typical cognitive process starts. Affective reactions can occur without extensive perceptual and cognitive encoding, and can be made sooner and with greater confidence than cognitive judgments (Zajonc 2000).

Emotions are basic psychological systems regulating the individual's adaptation to personal and environmental demands. They are closely related to cognitive, behavioral, motivational, and physiological processes, and therefore they are also important for learning and achievement.

Emotions may be defined as a system of interacting processes including subjective feelings, cognitive appraisals, physiological factors, expressive behavior and characteristics, as well as motivational tendencies. Component models help to characterize and define emotions. Emotions are multidimensional constructs which have an affective (subjectively experienced feeling), a cognitive (thoughts, achievement goals, and expectations), an expressive (mimics, gestics), a motivational (actional tendencies), and a physiological component (e.g., heart rate) (Scherer et al. 2001). Further classification criteria include the concepts of valence, activation, intensity, duration, and frequency. Furthermore, emotions are experienced in specific situations (state-component), and they are biographically developed and enduring (trait-component).

Emotions are limited-in-time feelings. In contrast to mood and other emotion-related constructs, emotions may be described very clearly (e.g., as enjoyment, anger), and they are generally caused by a specific event (e.g., a good mark, a conflict with another person). Mood and emotion are often applied as synonymies because they both may be characterized by affective experience, specific physiological arousal, cognition, and mimics and gestics. But mood is typically of longer duration, less intensively, and not explicitly object-related like emotion. In contrast to emotion, mood may be classified in positive, neutral, or negative dimensions. Further constructs similar to emotion are well-being, flow, and stress.

Well-being is a specific concept that combines emotional and cognitive aspects, and it can be defined as an indicator of a learning environment (Diener 2000). Well-being may develop over a short or a longer period and vary with respect to intensity. Well-being in school is a feeling where positive emotions and cognitions dominate over negative emotions and cognitions toward school, teachers, and classmates, and the whole school context. It may not directly enhance student achievement but enables students to move toward their academic and social goals and a qualitatively good school life.

One of the important affective constructs supporting sustained participation and engagement is the experience of flow. Flow was described by Csikszentmihalyi (1990) as a holistic feeling while being absorbed in an action. The experience of flow depends on demands and individual's abilities, and it occurs if demands and abilities stay in a balanced relation to each other. In comparison to emotion, flow is a more cognitive construct, and a process which is relevant for learning and performance.

Finally, stress may be characterized as a state of highest readiness of a person in an achievement situation. Stress is experienced when demands exceed individual's abilities, or if they are called in question. The rise, effects, and regulation of stress and anxiety show many similarities (Hembree 1988).

Theoretical Background

In the field of educational psychology, emotions, feelings, well-being, and affect or mood, and school enjoyment or learning enjoyment are important topics in the last 20 years. Definitions are not used consistently and different research domains and empirical studies on the structure of emotions have led to various classifications. These classifications are related to specific research fields, for example, in learning and achievement environment, the workplace, as well as in leisure time. Therefore, theoretical classifications of emotions are determined to a large extent by the specific contexts in which they are developed.

Theories concerning the classification and origins of emotions mainly followed the central paradigms in psychology and related scientific fields in biology and sociology. Mainly psychobiological approaches, psychoanalytical, cognitive theories, and integrative approaches highlight emotions, their development, and their relevance for human life in general and especially for learning and achievement. Biologically oriented approaches relate to Darwin's work. It is assumed that somatic processes, facial, vocal, and expressive aspects are characteristic for emotions, and their function in regulating social communication. Ekman (1972), inspired by Darwin's approach, takes emotional expressions to be important parts of "affect programs" – complex responses found in all cultures and human populations. Intercultural studies show that six basic emotions may be differentiated: happiness, surprise, anxiety, anger, sadness, and disgust. Psychoanalytic theories in orientation to Sigmund Freud understand emotions as closely related to satisfaction or dissatisfaction of drives. Freud described emotions as functions of the "Ego" that serve as signal for behavioral and cognitive processes. Cognitive theories assume that emotions are induced by cognitive appraisals. One important theory is the attributional theory explaining emotions as a result of causal attributions in learning and achievement. Expectancy theories assume that emotions in future are induced by event- and coping-related expectancies (Pekrun). Social learning approaches emphasize the influence of social interaction and cultural environment, and thereby the development of individual specificity of emotions (Bandura). In general, social influence on emotions is mediated by cognitive processes through observing and interpreting the behavior of significant other persons, like parents, peers, or teachers. Finally, integrative approaches to emotions complement, instead of contradict, each other.

Emotions may initiate, terminate, or disrupt information processing and result in selective information processing, or they may organize recall (Pekrun et al. 2002). Thus, emotional processes have an evaluational relation to learning, instruction, and achievement. Pekrun's conceptual model of emotions specifically experienced in an academic and achievement context represents a classification schema that takes the traditional criteria of valence (positive vs negative) and activation (activating vs deactivating) into account, and classifies academic emotions in orientation to these criteria. It is assumed that discrete academic emotions have specific effects on learning and achievement. The model distinguishes between emotions that are positive-activating (enjoyment, pride, hope), positive-deactivating (relief, relaxation), negative-activating (anxiety, anger, shame/guilt), and negative-deactivating (boredom, hopelessness, disappointment). It may be expected that positive-activating emotions do have a positive influence on learning and achievement, and negative-deactivating emotions would have a negative impact. But it remains unclear how emotions influence learning and achievement. A simple positive effect of positive emotions or a simple negative effect of negative emotions may not be assumed. However, negative deactivating emotions may be detrimental for learning and achievement.

Test anxiety, for example seems to occur primarily during elementary school. Some studies document a sharp increase in mean frequency and intensity from grade 1 to 4, resulting in a high prevalence in late childhood. This development trend is congruent to the decrease of average academic self-concept and the decrease of enjoyment in learning.

To understand why emotions play an important role for learning and achievement, appraisal theories offer a framework to understand and to explain causes of emotions (Smith and Lazarus 1993). One and the same situation is experienced in different ways, depending on the person's interpretation of the situation. In orientation to appraisal theories, and especially for the context of learning and achievement, Pekrun developed the control–value approach. This approach points out that subjective control of the learning and achievement situation, as well as the subjective value of learning process and achievement are crucial for the interpretation and emotional experience. Students experience different situations in instruction and value these situations depending on previous experiences, the social context, their personal goals, their interests, and other personality factors (Pekrun et al. 2002). For test anxiety, the relevance of missing possibility of control is very well analyzed (Hembree 1988). Furthermore, it has been described that different aspects of instruction may cause anxiety, for example, unstructured learning material, lack of feedback, and lack of transparency in achievement demands. For students' test anxiety, negative correlations to academic achievement were reported in numerous studies. Furthermore, test anxiety has been shown to correlate with parent, peer, and teacher behavior, such as punishment after failure and competition in classroom. The influence of the social context and the learning environment on learning and achievement emotions was emphasized by Pekrun et al. (2002). Instruction, value system, concession of autonomy, expectancies, and learning and achievement goals, but also achievement feedback, and consequences do have an influence on students' emotions.

Attributions and self-concept are related to emotions, as well. Internal attributions of success, e.g., having adequate abilities, were related to positive achievement-related emotions. A negative self-concept and negative expectancies of achievement played a role in creating feelings of anxiety or hopelessness (Hembree 1988). Emotions also have an effect on learning and achievement, mediated by attention, self-regulation, and motivation (Pekrun et al. 2002), thus directing the person toward or away from learning matters in learning situations. Positive emotions also facilitate self-regulation in learning. Students' perceived self-regulation correlated significantly positive with positive emotions, whereas perceived external regulation correlated with negative emotions. The experience of competence and autonomy in learning has been stressed out as important for self-regulation and the experience of self-determination. Furthermore, information processing and learning strategies are influenced by emotions. Positive emotions, such as enjoyment and pride are correlated to deeper and integrated processes of information and understanding, and thereby to elaboration. Negative emotions are related to rigid information processing on the surface level, and correlate stronger with memorization.

Important Scientific Research and Open Questions

Generally, research on learning and instruction has recognized that emotional dispositions and emotional experiences are crucial conditions for information processing, cognition, motivation, and social interaction. Numerous studies have described which emotions are experienced in learning situations, and how they interact with cognition, learning strategies, motivation, achievement, and the learning environment. Up to now, this is well documented and analyzed for "anxiety." Especially it should be clarified how emotions influence cognitive processes. Results of mood research point out that negative or positive emotion does not simply have a contrary effect on learning. Rather it has to be differentiated with respect to demands, tasks, and context. Effects of emotions are specific, and they may enhance or hinder learning processes.

But still some questions remain open. First, further detailed analysis is needed to understand differences between emotions in specific learning and achievement situations. Also causes and consequences of many emotional experiences are still unclear. School and learning are associated by most of the students with more negative experiences and feelings. And it seems that school itself contributes to this estimation by performance pressure, and learning environments that do not consider individual needs. Therefore, it is an important issue for school, and for research in this context to focus on reduction of boredom, anxiety, frustration, and to enhance enjoyment, satisfaction, and pride. Consequently, a theoretically and systematically oriented development of instructional approaches and interventions is needed. Generally, in the education system changes are needed. Modifications that focus more on the influence of individual needs and affective aspects in students' learning might be reached by creating a student- and competence-centered learning culture, developing adequate ways of assessment, and organizing schools as life-oriented environments.

Cross-References

► Achievement Deficits of Students with Emotional and Behavioral Disabilities
► Achievement Motivation and Learning
► Affective Dimensions of Learning
► Attention and Implicit Learning
► Attitudes To(wards) Learning
► Autonomous Learning
► Aversive Motivation and Learning
► Avoidance Learning
► Climate of Learning
► Coping with Stress
► Creativity, Problem Solving and Feeling
► Effects of Anxiety on Affective Learning
► Emotional Intelligence and Learning
► Emotional Regulation
► Emotions: Functions and Effects on Learning
► Feeling-Based Learning/Feelings and Learning
► Flow Experience and Learning
► Joyful Learning
► Learned Aggression in Humans
► Learned Helplessness
► Learning by Feeling

► Learning to Feel
► Mood and Learning
► Motivation and Learning: Modern Theories
► Motivation Enhancement
► Motivation to Learn
► Needs of/for Learning
► Neuropsychology of Emotion
► Personality and Learning
► Relaxation and Learning
► Resilience and Learning
► Risks of Learning and Failure
► School Climate and Learning
► Self efficacy and Learning
► Self-Determination of Learning
► Socio-Emotional Aspects of Learning
► Stress and Learning
► Surprise and Anticipation in Learning
► Volition for Learning
► Well-Being

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Affective Conditioning

► Evaluative Conditioning

Affective Dimensions of Learning

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Synonyms

Emotional aspects in learning; Emotional dimensions of learning; Emotional factors in learning

Definition

Affective Dimensions of Learning represents one of the three dimensions of learning identified by Illeris (2002). It is a complex concept that refers to dimensions for affective learning. According to Martin and Reigeluth, there exist six dimensions for affective learning: emotional, social, esthetic, moral, spiritual, and motivational (Martin and Reigeluth 1999). In the literature, the terms *Emotional Dimensions of Learning* and *Affective Dimensions of Learning* are often used to designate the relationship between emotions and learning (e.g., fears associated with formalized learning).

Although there is no consensus about the meaning of the term *emotion*, there is an agreement that emotional states are considered complex processes that change in time and are affected by several factors. An emotion represents a mental state, such as happiness or fear, that arises spontaneously rather than through conscious effort and is often accompanied by physiological changes. The majority of emotional theories concur that appraisals are necessary causes of emotions; however, there are divergent theories like James-Lange's theory which claims that emotion could arise due to physiological changes. This theory has been criticized by several recent researchers who think completely the opposite (Critchley et al. 2005). According to the appraisal theory, emotions arise from mental evaluation of events or situations depending on a person's goals (Ortony et al. 1988).

Theoretical Background

Some researchers in neurosciences and psychology (e.g. Damasio 1994; Isen 2000) have proved that emotions are widely related to diverse cognitive processes such as attention, long-term memorizing, problem solving, decision making, etc. In fact, some studies have found that human beings tend to code more information if the tone of the material corresponds to their emotional states (Isen 2000). For example if the learner is happy, he would encode more information when the material was also emotionally positive. Similarly, it has been demonstrated under various circumstances that human beings have a tendency to retrieve, from memory, information which is coherent to their current emotional states (Isen 2000). For example, if the learner is happy he would recall more easily happy material.

In addition, positive emotions are fundamental in learning processes; they play an important role to improve creativity and flexibility in problem solving and to enhance performance on the task at hand. They also may increase intrinsic motivation. However, negative emotions such as anxiety can give rise to disorders of attention, slow decision latency, and deficit in inductive reasoning. They also have two types of effects: impairment effect related to reduced performance and bias effect related to prioritization of treating stimuli which have negative impact or valence (Matthews and Wells 1999).

Mayer and Salovey defined emotional intelligence as: "*ability to perceive accurately, appraise and express emotions; the ability to access and/or generate feelings when they facilitate thought; the ability to understand emotional knowledge; and the ability to regulate emotions to promote emotional and intellectual growth*" (Mayer and Salovey 1997). According to this definition, emotional intelligence is very important in learning environments. In the classroom, the teacher who has emotional intelligence abilities would maintain attention and learners' interest by making jokes, for example, when he feels that his students are bored, he attempts to manage their emotional state in order to keep a good atmosphere for learning.

Because of the importance of emotional dimensions in learning and thought processes, several techniques for measuring emotion have been developed:

Self-Report Techniques

This technique includes adjective checklists and a questionnaire-type scale. The adjective checklists consist of a series of adjectives describing the individual's current emotion, for instance, bored, joyful, and sad. The challenge posed by this technique is choosing words that describe the current situation. The questionnaire-type scale represents a set of questions related to emotional states. For example, to measure anxiety, the participants are asked to indicate their current feelings on a 4-point scale.

Facial Expressions

Emotional expressions have received great attention from both psychologists and computer science researchers interested in developing systems that detect emotions. Paul Ekman is among the first researchers who studied the expression of emotions. He created, along with his colleague Friesen, a system called FACS (*Facial Action Coding System*), which measures facial muscle movements (Ekman and Friesen 1978). All subsequent research in the field is based on this pioneer work. In computer science, researchers have used various approaches to model the mechanism involved in the automatic detection of facial expressions. This mechanism consists of extracting and classifying facial characteristics. The extraction can be applied to the face entirely (considered like a whole), or locally, while focusing on the most expressive parts of the face, which depend on the facial expression itself.

Prosody Speech

The detection of emotion through voice analysis has not received as much attention from researchers as the detection of emotions using facial expressions. The first voice-related work studied the contents of each word. Recently, researchers started investigating the prosodic and acoustic aspects, e.g., analyzing message features like intonation, duration, power, and articulation. Petrushin, for example, developed a system, geared toward call center applications, that uses voice to detect emotion in real time using neural networks. His system can classify two emotions (calm and agitated) with 77% accuracy rate (Petrushin 1999).

Physiological Changes

Another technique for detecting emotion consists of tracking physiological changes, for example, blood pressure, heart rate, skin conductance, muscle tension, etc. This technique is efficient when studying arousal, but is not as useful in detecting a specific emotion because it is very difficult to establish a relationship between physiological changes and specific emotions. On the one hand, some different emotions can have the same physiological changes. On the other hand, so many factors could trigger physiological changes that it would be difficult to link them to a given emotion.

In spite of the various approaches proposed to measure emotion, this task continues to be challenging in real scenarios. Human beings could have the same feelings but express them differently. This is why some researchers have combined different techniques to improve the automatic recognition of emotions. However, such methods for emotion detection present two limitations: (1) the use of sophisticated technology in a learning context can interfere with learning as noted by Picard who found that people may feel uncomfortable in the presence of video, cameras, or physical sensors and that their presence may interfere with emotion recognition; and (2) it requires significant effort and financial resources. Thus, some researchers thought about considering the potential causes of emotions in the detection process.

Potential Causes of Emotions

Some psychology theories attempt to determine the origin of emotion by studying the relationship between cognition and emotion. Appraisal theories of emotion, in particular, consider that cognition is the core element in producing emotion (Ortony et al. 1988). They argue that emotion arises as a result of a cognitive evaluation of events or objects according to a person's goals and concerns. For example, let us take the case of a student who has just received an email indicating that he had passed a course. An emotion will occur following this situation according to his cognitive evaluation. If the event is important for the student's goals (to have the diploma), he may, for example, express joy. This evaluation is done according to some criteria or variables as defined in the appraisal models. For instance, in the OCC model, emotions are regarded as valenced reactions (positive or negative) to environment perceptions. The environment in this model is composed of agents, events, and actions. Thus, emotions arise as a consequence of

1. Whether the event is desirable or not (satisfaction/dissatisfaction)
2. Approval or disapproval of the agent's actions (approval/disapproval)
3. Love or rejection of some object's aspects (love/rejection)

In the OCC model, the authors define three criteria of evaluation:

1. Goals which represent the criterion employed to evaluate events
2. Standards which represent the criterion employed to evaluate the agent's actions
3. Attitudes which represent the criterion employed to evaluate aspects of object

All these criteria are used to indicate 22 emotion types.

OCC model was the basis for most computational systems modeling emotion because of its effectiveness in simplifying the emotional states' representation. In addition, it offers clear and distinct evaluation criteria (goals, preferences, and moral standards). This model provides a reliable representation of the virtual agents' emotions, but it is too general for modeling the user's emotion. Indeed, each individual exhibits different emotions following the same event. These reactions, according to Hess, depend not only on events, but also on several other factors such as sex, personality, current emotion, etc. Thus, emotions change over time in response to an emotional event and according to individual traits.

Important Scientific Research and Open Questions

Most existing learner models focus only on the learner's knowledge about the domain. However, the learner model should describe both cognitive and emotional information about the learner. Emotional model should inform us about the emotional and the motivational state of the learner. It would focus on identifying the learner's emotional state in order to choose the right teaching strategy used by the tutor. In addition, during learning activities, we should pay attention to various factors that could trigger negative emotions. The tutor's role is then to intervene at the appropriate moment to alleviate the effects of these factors as far as possible and to adapt tutorial actions in order to stimulate positive emotions and achieve instructional goals. Initially, adapting tutorial actions in learning environment was mainly based on the learner's intellectual skills. Then, given the importance of emotions in cognitive processes and learning, selecting tutorial actions takes into account not only the cognitive state but also the emotional one which becomes an essential component of the learner's model (e.g., Chaffar et al. 2009; Conati 2002).

The concept of *Emotional Dimensions of Learning* is sometimes so general that it raises and leaves many important questions:

- What emotions are relevant to learning?
- What emotions are good for learning?
- What are the best techniques to detect the learner's emotional state?
- What are the best methods for inducing good emotions for learning?

Cross-References

▶ Emotional Learning
▶ Emotion-Based Learning
▶ Learning by Feeling
▶ Learning to Feel
▶ Stress and Learning

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Affective Learning

▶ Emotional Learning
▶ Evaluative Conditioning
▶ Superlearning

Affective Priming and Learning

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Synonyms

Evaluative priming

Definition

At a procedural level, affective or evaluative priming refers to a reaction time procedure. It is a variant of the classical (associative) priming tasks in which the effects of related or unrelated prime stimuli are observed for responses to target stimuli. A classic example of an associative priming effect is the finding that one responds faster to the target word "doctor" if it is preceded by the prime word "nurse" than when it is preceded by "roof." In affective priming tasks, primes and targets are evaluatively related or unrelated rather than associatively. In these studies, a typical finding is the observation of statistically shorter response latencies for affectively congruent trials (positive–positive, negative–negative) as compared to affectively incongruent trials (positive–negative, negative–positive) (e.g., Fazio et al. 1986). In these studies, the asynchrony between the onset of the prime and the onset of the target is so brief (e.g., 250 ms) that these effects are to be attributed to fast-acting automatic processing.

More recently, the affective priming task is used as an indirect measure of stimulus valence (attitudes). Rather than demonstrating that valenced stimuli automatically activate their affective meaning from memory, the procedure is now used to assess the "unknown" valence of prime stimuli (e.g., "if the prime facilitates responses to positive targets and inhibits responses to negative targets, this would indicate that the prime is positive"). As such, affective priming tasks have been employed in human conditioning research to assess (changes in) the evaluative meaning of the conditioned stimuli.

Theoretical Background

Classical conditioning typically refers to a procedure in which two or more stimuli are presented. Due to this "learning experience," changes in responding are observed. For example, in fear conditioning preparations, an originally neutral stimulus (e.g., a tone) contingently precedes the presentation of an aversive stimulus (e.g., an electric shock). As a result of these presentations, changes in responding to the neutral (conditioned) stimulus (CS) can be observed, such as increases in self-reported fear or increased levels of skin conductance responding (SCR) in the presence of the CS. In addition, because the CS is a valid predictor of the aversive unconditioned stimulus (US), participants will start to *expect* the aversive stimulus (unconditioned stimulus) on the basis of the CS. These behavioral changes have traditionally been the focus of Pavlovian fear conditioning studies.

Based on extensive work on evaluative conditioning, it is now known that classical conditioning procedures may also engender a completely different type of outcome. More specifically, it has been demonstrated that CSs can acquire the evaluative meaning of the stimulus (US) with which they have been associated. Originally, neutral stimuli that were contingently presented – or even merely co-occurred – with a clearly positive (or negative) US are subsequently experienced as more positive (or negative) (Hofmann et al. 2010). This outcome has attracted much scientific attention, because empirical work suggests that changes in evaluative responding follow different learning rules than other outcomes (e.g., US-expectancy, fear). The best example, perhaps, is the differential sensitivity to extinction which refers to the repeated unreinforced presentation of the CS after acquisition. During acquisition, an organism may be confronted with a series of trials in which a tone CS is contingently followed by an electric shock. Subsequent extinction would then consist of repeated presentations of the CS, which is now no longer followed by the shock. This procedure is known to significantly impact conditioned responding to the CS. With increasing numbers of CS-only trials, US-expectancy and fear responding will dissipate.

With respect to evaluative learning, a crucial finding has been that this type of learning is less impacted by extinction. One explanation for this finding relates to the "informational value" of the CS-only trials. As a result of these trials, the organism can learn that the CS is no longer a valid predictor for the US. This knowledge is then translated in reduced US-expectancy and fear. In contrast, with respect to the evaluative meaning of the CS, information about the statistical contingency between CS and US is assumed to be less relevant. An example might illustrate this point. Assume that you encounter a certain new perfume (CS) in the context of someone you really like (US). Over time, this scent may acquire a positive valence. Encountering this perfume, however, later on, in the absence of the loved one (extinction procedure) does not bring upon corrective information about the odor. It does not "destroy" previous knowledge.

Important Scientific Research and Open Questions

The study of (changes in) evaluative meaning as a result of classical conditioning has attracted a lot of attention during the last 30 years (see Hofmann et al. 2010). In animal studies, these evaluative changes have traditionally been studied using behavioral preference tests. In humans, on the other hand, verbal rating scales are typically employed. Because ratings are easily influenced by social desirability (or other response strategies), indirect measurement procedures like the affective priming task are provided a valuable alternative.

An extensive series of studies in humans has demonstrated that evaluative changes that are produced by an evaluative conditioning procedure are reflected in affective priming measures (for an overview, see Hermans et al. 2003). For instance, in a study by

Hermans et al. (2005), pictures of different brands of yoghurts (CSs) were contingently presented with a positive or negative odor (US). Rating data showed that this acquisition procedure resulted in a reliable evaluative learning effect. This could be corroborated by the results of the priming task in which the yoghurt CSs were used as primes. Participants responded faster to positive target words and made fewer errors when they were preceded by a yoghurt CS that had been associated with a positive odor, as compared to a CS that had been associated with a negative odor. A reversed pattern was present for negative targets. Similar affective priming effects have been observed for a variety of stimuli (including visual and gustatory), and using different variations of the acquisition procedure (e.g., fear conditioning preparation).

In a study by Vansteenwegen et al. (2006), a fear conditioning preparation was used. Participants were presented with two pictures of a human face, one of which was contingently followed by an electrocutaneous stimulus (CS+), while the other was not (CS–). After eight acquisition trials, a lengthy extinction phase followed which consisted of 24 unreinforced presentations of both CSs. Evaluative changes as a result of acquisition and extinction were assessed by means of an affective priming task that was scheduled immediately after acquisition and extinction. As a measure of US-expectancy, skin conductance responses were obtained throughout the experiment. The authors observed that whereas fast extinction was obtained for expectancy learning, as measured by the SCR, the affective priming task clearly showed resistance to extinction of evaluative learning. Because a differentiation between the two types of learning was demonstrated in one and the same paradigm using an extended extinction procedure, and because indirect measures were used for both types of learning, this demonstration was considered as strong evidence for resistance to extinction of evaluative conditioning (Vansteenwegen et al. 2006, p. 75). Without going into further details about the validity of the distinction between evaluative learning and expectancy learning, these data clearly indicate the usefulness and sensitivity of the affective priming task for measuring conditioned valence.

There are a number of open questions for future research on affective priming for acquired valance. The most important probably pertains to the psychometric properties of this procedure (e.g., reliability). Research on this issue is scarce, but several labs are conducting relevant research at this moment. A second issue pertains to the development of variants of the affective priming procedure (and related measures such as the Implicit Association Test) for studying acquired valence. The priming measure as described here has a disadvantage in that it cannot be used as an online measure (like is the case for SCR). In the example of the study by Vansteenwegen et al. (2006), skin conductance responding was measured on a trial-by-trial basis, whereas affective priming was only scheduled *after* acquisition and *after* extinction. This could be an important methodological difference. Because of this limitation, more recently, an online version of the affective priming task was developed that allows tracking changes in valence on a more trial-by-trial basis (Kerkhof et al. 2009). Another limitation of the priming procedure could be that valence is always assessed in a relative way (e.g., CS + as compared to CS−). Future research could aim at developing variants that allow the assessment of stimulus valence without the use of neutral comparison stimuli.

Cross-References

- ► Conditioning and Anxiety
- ► Evaluative Conditioning
- ► Expectancy Learning and Evaluative Learning
- ► Fear Conditioning in Animals and Humans
- ► Pavlovian Conditioning

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Affective Responses

▶ Emotions in Cognitive Conflicts

Affective Schema

▶ Emotional Schema

Affective Value

The affective properties of a stimulus, characterized by a degree of hedonicity (or valence) and physiological arousal (or activity).

Affordance and Second Language Learning

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Synonyms

Meaning potentials; Mediated signs; Mediation; Potential opportunities; Relevance

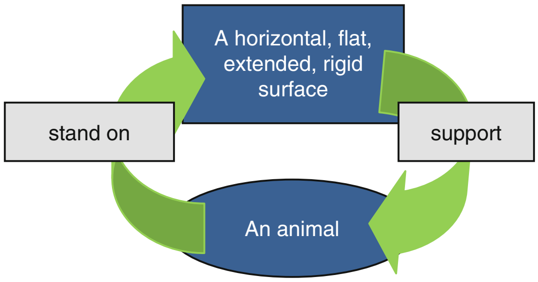
Definition

Gibson (1979, p.127) has noted the term affordance as "what (the environment) offers the animal, what it provides or furnishes, either for good or ill." However, Singleton and Aronin (2007) note that real affordances are those possibilities that are to be perceived and recognized. Affordances can be expressed as "verb-able." For example, a rock near the river affords "sit-able" or apple on the branch affords "eat-able." Kono (2009) refers to affordances as the potentials of the environment. He notes that it can be expressed as the circular functional process between an animal and surrounding environment. This idea can be expressed as follows (Fig. 1):

So affordance is the property of the environment that is determined by the relation to an individual or an animal. The term "relation" means that affordance is relative to an observer. For example "a stone" in the above figure affords standing but relative to the size of animal.

Theoretical Background

In this chapter, the term *affordance* will be explicated through different perspectives, and then it will be tied to the notion of language and language learning. Language is still a complex phenomenon in nature. The notion of language and language acquisition is grounded in the theory of language acquisition (linguistics) that is in turn the reflection of the philosophy of learning (psychology). Many theories, models, and frameworks have come into existence to propose the wizardry of language acquisition, but each one stands in one particular angle. If these views about the process of language acquisition in different angles become convergent, it leads to the *ecology of language learning*. Affordance is placed within the *ecological perspective of learning* and is assumed to be one of its mainsprings. Brown (1993) defines ecology of language acquisition in a way that the "seeds of predisposition" and "roots of



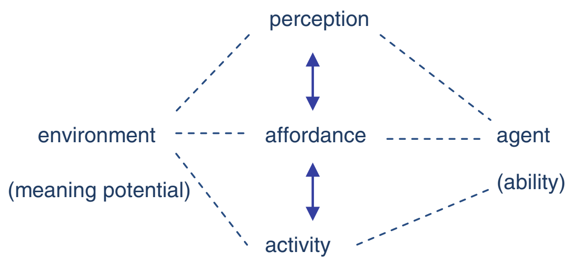
Affordance and Second Language Learning. Fig. 1 A surface affords support (Kono 2009, p. 359) competence" in the "climate of context" through "germination strategies" produce "fruit of performance." Nonetheless, the course of language acquisition is too complex and many factors such as the caregivers, the way of interaction with the child, the beliefs about child language learning, and the kind of child activities all codetermine and affect this process (Leather and van Dam 2003). Moreover, the kind of society in which the child is being reared, the kind of *scaffolding* that adults provide for the child, elicitation methods as well as participation of the child in the communicative event are all culture-bound.

Affordance

The idea of affordance dates back to 1954 when Gibson in his theory of visual perception argued that the concepts of motion can be understood relationally. Before that time, perceptual psychologists, as Greeno (1994) discusses in his article, had talked about perception when an observer was stationary. To Gibson, this status of stationary disregards some crucial factors embedded in the perception. Perception is different from the stimulus–response theory as some perceptual psychologists believed. J. J. Gibson and E. J. Gibson argued that in ► perceptual learning the observer does not produce an associated response to a stimulus, but rather perceives differentiating qualities of stimuli in the environment. In other words, in perceptual learning, as Greeno (1994) argues, the focus is on the process of "*differentiation*." In 1979, Gibson proposed the theory of affordance as the perceived opportunities for action provided for the observer by an environment. To him affordances refer to the opportunities for action or interaction that are offered to an individual in a context in which language is one part of it. This theory affected many fields such as learning and communication. Ecological study of language as van Lier (1998) proposed concerns for the way of relating the individual to the environment through language or other sign systems (*semiotics*). In semiotics, a sign is neither an object nor thought, but a relationship or mediated affordance between the individual and the social, physical world.

Van Lier (2004) has diagrammed the role of affordance in our life (Fig. 2).

The notion of affordance was first supposed to be direct and relevant, but was later expanded to be indirect and mediated (Reed 1988; Shotter and Newson

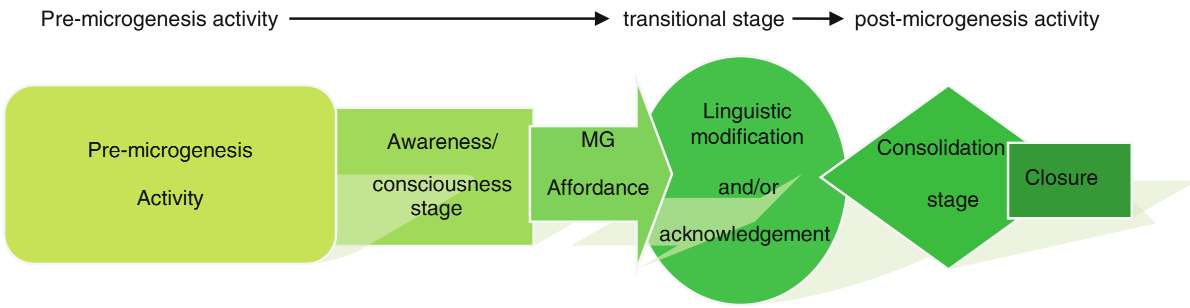


Affordance and Second Language Learning. Fig. 2
Affordance in context (Van Lier 2004, p. 96)

1982; Forrester 1999). Affordances have been categorized as *natural*, *social/cultural affordances*, *cognitive affordances*, and *actualized affordances* and ► *potential affordances* (Reed 1988; van Lier 2004; Heft 2007a, b). Forrester talks about the conversational affordances in terms of intonation patterns, back channels, and turn-taking signals, and assumes this kind of affordance is directly available to the learner. In sum, the three features of affordance according to van Lier (2004) are as follows: relationship between a person and a linguistic expression – available to the active interlocutor to pick up if relevant – used for further action and which leads to a higher level of interaction.

Affordance and Language Learning

van Lier (2004) argues that affordance is the first level of language awareness with which the learner can establish a direct relationship with a property in the environment. The notions of language, language learner, and language learning will take a different perspective if we bring the theory of affordance to the fore. From this perspective, language is not a range of accumulated objects or signs in the environment to be taken into the mind of the learner for processing (input) nor is it retrieved from memory (output); rather it is a relationship between the learner and the context, and so the language learner should actively establish such a relationship with the environment. Language learning will ultimately occur through active participation out of which affordances and learning opportunities will arise. In the collaborative learning of Vygotsky, many opportunities will be created for learners to develop the use and understanding of target language. The two concepts of "creating opportunities" and "developing the use and understanding of the target language" have been reiterated as "affordance" and



Affordance and Second Language Learning. Fig. 3 Microgenesis phases (Gánem-Gutiérrez 2008, p. 129)

"learning," respectively in the literature. It is, therefore, obvious that there is a link between affordance and learning. Gánem-Guitérrez (2008) refers to *microgenesis affordance* to elaborate the process of language development. In this pattern, activity leads to affordance. Pre-microgenesis activity includes organizational talk and awareness/consciousness stage (represented below) (Fig. 3).

Organizational talk entails learners' speech or reading aloud while preparing the task. In the awareness stage that occurs in the social plane, the learner realizes that there is a gap between his or her knowledge of L2 and that of the native speaker. Subsequently, this social or inter-psychological plane leads via microgenesis affordance to the intra-psychological plane whereby the learner modifies the language verbally and the knowledge will be finally internalized. Microgenesis affordance includes the kinds of assistance (e.g., reply, paraphrase, co-construction, corrective feedback) provided to the learner by the experts or the characteristics of linguistic environment that help the learner to modify his or her L2 knowledge. In this regard, multilinguals can perceive the environment and relevant affordances much better than monolinguals since their linguistic knowledge helps them to develop awareness that has an influential effect on language learning.

Important Scientific Research and Open Questions

Zukow-Goldring and Arbib (2007) take the two concepts of affordance and effectivities as complementary to talk about abilities to perceive opportunities for action in the environment and also the repertoire of what the body can do. They note that affordances and effectivities present at birth can be developed when the learner is engaging in the activities or through trial and error. Therefore, it is an alluring question how these affordances can be learned and developed. Affordance is the relationship between learner's abilities and the environment on the one hand and the perception and activity on the other hand. The emerging result is "*meaning*." It is also said that the affordances in the environment should be relevant to the organism, but the question is what features of the environment are relevant. This question can be answered in two ways: in one sense, some affordances are naturally relevant as flowers to the bee or the rock near the river for a person to sit on; whereas in the case of other cultural or manufactured objects, it is the intended use of them that signifies the relevance. Moreover, there exists the notion of "mediation" in the sense that there are some tools in the environment that mediate activity. In the case of first language learning, these tools can be gestures, points, joint attention, and in higher level of language learning the tools encompass words, gestures, bodily expressions or semiotic resources (McCafferty 2002), and private speech (Vygotsky). Carr (2000) notes that technological affordance needs to have the three features of transparency, challenge, and accessibility to be understood and used by the learners.

Conclusion

In the case of language learning, it is tricky to learn the language that is in the environment and transmitted to the learner; on the contrary, the learner must pick it up while being involved in meaningful activities. Furthermore, we cannot pick the necessary parts of language up if we do not have enough attention. So perception, action, attention, and consciousness totally form the theory of relevance. Perception should be recognized in language learning classes where the teacher takes the learner's attention in the form of noticing, focusing, and consciousness. The first level of attention-getting is affordance or direct perception. In fact, without providing the affordance in language learning classes, the students are unable to move to the higher levels of perception that are action, cognition, and interaction. I referred somewhere (Ziglari 2008) that the objects or features of the environment which are more frequent and regular afford the individuals to perceive and act upon them. In other words, the frequency and regularity offer potential actions to the organism. Learning is not fixed and can be modified as the learners experience different settings and become aware of different affordances. In the theory of affordance, the concepts of language, learning, educational context, and curriculum should be reiterated as follows:

Learning will be emanated from the learners' activity and is located in a meaningful and affordable situation and through their joint interaction it becomes explorative and experiential. Moreover, perception is an indistinguishable part of affordance. Without perceptual capabilities, no learner can benefit from the learning opportunities provided to them. With reference to language context, the theory of affordance will lead to *project-based*, *activity-based*, *contextualized*, *experiential*, and *developmental curriculum*, to name the words of van Lier 1998. The result of such methodology will lead to *autonomous* and *creative learning* in which the students learn language collaboratively. So it can be concluded that language is not acquired innately; rather language is part of a whole ecology of learning system.

In sum, language knowledge and the ability to perceive environmental affordances are reciprocal: the more knowledge of language within one individual, the more affordances will be perceived. Moreover, the more affordances provided to the learner, the faster the rate of language learning. It is, therefore, up to the teachers to deploy affordances, whether environmental, linguistic, or communicative, in the language classrooms. More interestingly, citing McArthur and Baron (1983), Kono notes that the theory of affordance can change the definition of meaning. Meaning is not fixed in one's mind, but it is constructed by the relation of an object to individual. If one changes his or her interpretation of this relation, the mental representation of that concept and, subsequently, the meaning will be changed. This can have an effect on the theory of communication. Moreover, I would like to point out that meaning does not come from the words and their syntactic relations. Many aspects of linguistic environment such as voice quality, gesture, and facial expression allusively provoke meaning construction. Moreover, the behavior of an individual is not stable any longer, and can be influenced by his or her cognition and perception of the affordances as well. By deliberately changing the environmental affordances, the perception and action of the individuals can be controlled.

Cross-References

► Affordances
► Attention, Memory, and Meditation
► Ecology of Learning
► Mediated Learning and Cognitive Modifiability
► Perceptions of the Learning Context and Learning Outcomes

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Affordance

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Synonyms

Action possibility; Afforded action; Affording; Functional affordance; Perceived affordance

Definition

1. (n.) An *affordance* is an action possibility formed by the relationship between an agent and its environment (Gibson 1977, 1979). For any combination of agent or environment, any given affordance either exists or does not exist. There is no middle ground. The most inclusive definition of affordances considers only the physical possibility of an action occurring. An agent does not need to be aware of the afforded action, such as the affordance of opening a secret door. This definition is rooted in perceptual psychology and its primary source is *The Ecological Approach to Visual Perception* by Gibson (1979).
2. (n.) An *affordance* may refer to a *perceived affordance*. Perceived affordances are a subset of affordances. A *perceived affordance* uses a more restrictive definition that requires an agent to be aware of the affordance, either through direct perception or experience. A perceived affordance is a possible action to an agent (Norman 1988). Unlike the traditional definition, a perceived affordance is primarily a relationship between an agent's cognition and the environment. This definition is commonly used within the human–computer interaction (HCI) community.
3. (n.) *Affordance* may refer to how appealing an action possibility is to an agent, as in "this switch has affordance." While the other definitions are dichotomous, this definition implies a magnitude (continuum) of affordance. This usage combines the ease of perceiving and/or perceived ease of performing a possible action. Since this usage refers to one or both of these qualities, this form is unclear from a theoretical standpoint.

Theoretical Background

The affordance is a theoretical construct that represents the potential for an action to occur between an agent and an environment. This "potential for action" is an existential relationship between an agent and an environment. In many cases, this relationship is simplified by considering only a part of an agent's environment as offering an affordance. An example of an affordance is the potential to open a door using a doorknob. "Opening by doorknob" affordance exists between an agent with hands and a door having a functional doorknob. No affordance exists if an agent lacks hands (and similar abilities) capable of opening the door or if the doorknob is broken. This oversimplifies an agent's environment; pulling a door open uses support from one's feet, for example. However, many affordances may be considered dyadic relationships between an agent and an object and these are the most commonly studied.

Originally, affordances were developed for studying perception. This is because when an agent perceives the world, it becomes aware of the ability to do certain actions – even if those actions are not occurring or might never occur. There is a need for this term because the potential for an action to occur is quite different than an action occurring and warrants its own construct. For example, a person learning that a closed door is "opening" is different than that it is "openable." The concept of the "affordance" succinctly describes the relationship that an agent has perceived, which is that a potential action exists.

Theoretical Underpinnings

The Gestalt school first published concepts similar to the affordance. Jon Von Uexküll described the "functional coloring" of objects in his discussion of how organisms might perceive the world in terms of its action possibilities (Von Uexküll 1920). Later work by Koffka describes the perceived meaning of objects in similar terms, effectively describing perceived affordances (Koffka 1935). These initial constructs were limited because they tended to describe affordances as requiring perception and were dyadic between an agent and an object. Perceptual psychologist James Gibson introduced the term *affordance* in "The Theory of Affordances" (Gibson 1977). This definition, which was clarified in his later book *The Ecological Approach to Visual Perception* (Gibson 1979), defined an affordance as a relationship between an agent and its environment. This is broader than an agent–object relationship, since multiple parts of an environment might be important to performing a given action (e.g., banging two rocks together). This extension allowed affordances to be stated independently of any particular agent or environment, making it a central construct in Gibson's work on direct perception and evolutionary perception.

Affordances were a central piece of Gibson's later work on direct perception (Gibson 1979). Direct perception theories posit that organsisms perceive the environment directly in terms of the actions it affords. For comparison, indirect perception theories typically propose that an agent must first develop an internal representation of the world based upon physical properties of the environment (Rock 1997). By stating perception in terms of affordances, Gibson's theory explained how an agent's perceptual capabilities can be tuned to guide an agent's behavior without requiring conscious analysis of an "inner world."

The concept of affordances helps examine ecological perception, which accounts for perception in an evolutionary and agent-based context. In this view, the role of perception is to enable beneficial action. Gibson stated that agent's competitive advantages will be determined by their ability to perceive beneficial affordances they have available (Gibson 1979). From an evolutionary standpoint, organisms will survive because their perception helps them to act when presented with stimuli. Gibson described how an agent could have an affordance to perform some action (such as eating bananas) and how its perceptual capabilities detect these affordances through invariant characteristics (i.e., yellow coloring). Gibson questioned: if an organism could detect actions using its senses (direct perception), then what is the benefit of a mental model that duplicates the sensory information into a new set of nonaction constructs (indirect perception)? This supported Gibson's theory of direct perception, though it did not rule out the possibility of indirect perception as a complementary process.

Recent Theoretical Work

Theoretical work on affordances has been slowed by confusion about affordances and overloading of the term "affordance" (McGrenere and Ho 2000). The main alternative definition was introduced in *The Psychology of Everyday Things* by Donald Norman (1988). Norman's usage of affordances brought Gibson's theory to the design of user interfaces within the human–computer interaction (HCI) community. The text provided a theoretical basis for implementing user interfaces with perceptually salient affordances. Norman's usage in this text refers to perceived affordances, ones that an agent knows, and how these make certain actions salient. Unfortunately, Norman's terminology made affordances seem like a perceptual construct rather than an objective relationship. Norman later clarified his usage to be closer to the Gibson definition, but the alternative meaning had already gained widespread acceptance in this new community. Affordance can also indicate a property of an object, which refers to a concept more akin to salience or utility, a third meaning. By this definition, a button could be said to "have affordance" in the same way it might "draw attention" or "have utility." This definition does not provide a meaningful construct for analysis and its inconsistent usage causes great confusion. While the definition of affordances has primarily found a consensus, these alternate definitions still cause confusion in some disciplines.

Formalizations have been a factor in building consensus about the definition of affordances. Affordances have since been formalized mathematically by a number of formulations, including the Stoffregen (2003), Chemero (2003), and Steedman (2002) formulations. These formalizations define affordances symbolically, in mathematical language. This makes them more amenable for experiment design and for computational implementation. Different formalizations utilize assumptions that make them alternatively useful for perception, planning, or concise representation.

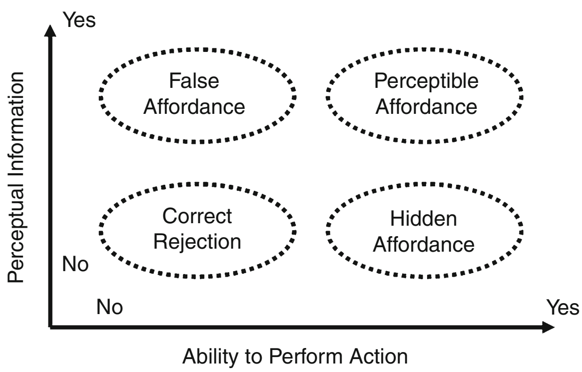
Researchers have extended affordance theory beyond the classical view of affordances. Gibson's seminal work distinguished between perceived affordances and the more general definition of affordances. As affordances became a major topic in literature, additional classifications for affordances were created (Gaver 1991). Figure 1 shows the relationships between affordances and an agent's perceptual information. The x-axis determines if an affordance exists, while the y-axis determines if an affordance perceptually seems to exist. Figure 2 gives examples that fit these categories, for the possibility that a handed creature could open a door.

Important Scientific Research and Open Questions

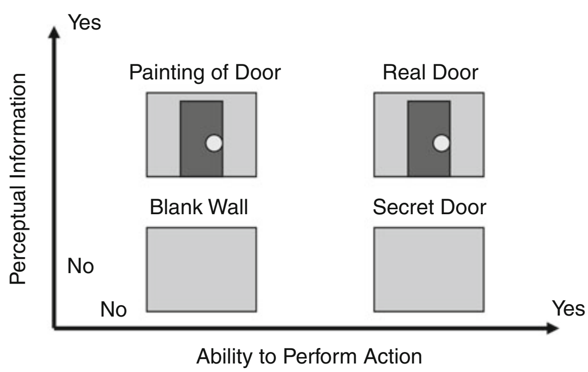
The study of affordances advances research in the behavioral science domain as well as the applied science domain. In the behavioral sciences, affordances are used to study perceptual psychology, learning, and imitation. Perceptual psychology uses affordances within the realm of direct perception research. Gibson's work on direct perception laid the groundwork for a new branch of perception theory. This branch of perceptual theory does not consider the main component of perception to be the passive absorption of the environment. Instead, perception's main role is to guide action in a direct manner. Ongoing research attempts to build ontologies of affordances (e.g., Sanders 1997) and to explore how organisms detect affordances (Gibson and Pick 2000).

Researchers build on this by studying how affordances are learned. Eleanor Gibson's work on affordance learning considers the primary learning process to be differentiation (Gibson and Pick 2000). Differentiation is a process where new affordances are learned by generating a distinction between one of its existing affordances with a new, more specific affordance – causing a more general action to be split into multiple, more specific actions. Affordance discovery experiments expose infants and children to novel tasks under different conditions and examine how they learn. Researchers also study imitation and social learning of affordances. Animal imitation research studies if a particular animal is capable of affordance learning, such as Klein and Zentall (2003).

Applied science uses affordances in the fields of human–computer interaction, robotics, and agent-based simulation. Human–computer interaction uses affordances to determine general principles of interface design that are optimized to allow the function of a tool to be obvious from its appearance (Norman 1988). Robotics researchers use affordance-based learning for situated robotics, such as autonomous vehicles or robot arms. Some of these robots can discover actions from its environment, either through exploration or imitation (Chemero and Turvey 2007). Agent-based simulation uses simulated humans who interact with the environment through its affordances (Silverman



Affordance. Fig. 1 Categories of potential affordances



Affordance. Fig. 2 Potential "Openable" affordances et al. 2006). In this paradigm, agents and their environment are designed separately, with affordances defining the possible activities between them. Affordances also contribute to systems research. John Holland's work on complex adaptive systems contained in *Hidden Order* (Holland 1996) presents a mechanism for adaptation based upon affordances and the schema theorem, a proof based on the genetic algorithm.

While affordances have been a useful concept within theoretical, empirical, and applied disciplines, they have fundamental open questions. These questions are connected to the meaning of abstractions, the origins of knowledge, dualism, and the mind–body problem (Gibson and Pick 2000). Others are primarily of a semantic nature, such as those addressed by Michaels (2003). A key question is how information about affordances is perceived and encoded (Gibson and Pick 2000). This relates to the origins of knowledge and the nature of memory.

Other unresolved issues with affordances relate to their underlying constructs, such as the definition of an action. Actions exist as part of patterns of continuous behavior. This causes a classification problem of what should be considered an action. The determination that an action is "possible" is an even thornier issue, one that underlies the disagreements between the Gibson and Norman definitions. Figure 3 shows different scopes of possibility, which are shown from the most inclusive to the most specific. In the most inclusive definition, an affordance is any action that could physically occur during the interaction of an agent and its environment, even unintentionally. Gibson's view requires the potential for intentionality when an agent acts on an affordance, implying that an agent must be either predisposed to certain behavior or change its disposition regarding to a behavior. However, the concept of potential intentionality is somewhat abstract and hard to define in real terms. The Norman definition restricts affordances further, limiting them to potential actions which are readily perceived within the environment. This requires an affordance to be either perceived (known) or perceptible (readily known from its appearance). Finally, a fully specified and deterministic view posits that the only possible action is the one that is going to occur. These are but a few debates ongoing about affordance theory, which will have implications for the meaning and practical uses of the concept.

Scope of Possibility	Associated Definition
1. Physically Possible	-
2. Purposefully Possible	J. Gibson, 1979
3. Perceptible	Norman, 1988
4. Perceived	-
5. Deterministic	-

Affordance. Fig. 3 Definitions of the possibility of an action

Cross-References

- ► Action Schemas
- ► Affordances in AI
- ► Cognitive Modeling with Simulated Agents and Robots
- ► Human–Computer Interaction and Learning
- ► Modeling and Simulation
- ► Visual Perception Learning

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Affordance-Based Agents

► Affordances in AI

Affordance-Based Design

► Affordances in AI

Affordances in AI

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Synonyms

Affordance-based agents; Affordance-based design

Definition

Affordances in AI (artificial intelligence) refer to a design methodology for creating artificial intelligence systems that are designed to perceive their environment in terms of its affordances (Sahin et al. 2007). Affordances in AI are adapted from affordances introduced in *The Ecological Approach to Visual Perception* by Gibson (1979). Design methodologies in the applied sciences use affordances to represent potential actions that exist as a relationship between an agent and its environment. This approach to artificial intelligence is designed for autonomous agents, making it suitable for robotics and simulation.

Theoretical Background

Affordances are a concept rooted in the field of perceptual psychology, as part of Gibson's seminal work on ecological perception (Gibson 1979). An affordance is an action possibility formed by the relationship between an agent and its environment. For example, the affordance of "throwing" exists when the grasping and pushing capabilities of an agent are well matched to the size and weight of an object. This capacity for throwing is not a property of either the agent or the object, but is instead a relationship between them. This relationship-oriented view of the potential for action has a growing following in the applied sciences, as it presents advantages for functionality and design over traditional AI techniques.

The first major usage of affordances within the applied sciences was in the human–computer interaction community as a result of the Norman (1988) book, *The Psychology of Everyday Things*. Design techniques emerged within the interface community, attempting to make the affordances of a user interface obvious to its intended users in the form of a tool indicating its function. The intent was that the look and feel of the application would help communicate information about its affordances. While affordances had made an inroad into the computer science community, Norman's usage of the concept was constrained compared to Gibson's definition and not well suited for artificial intelligence purposes.

Usage of affordances into the artificial intelligence community started with the intent to build better autonomous agents. Traditional AI approaches have had problems dealing with complex, dynamic environments (Maes 1993). There were two primary issues. Firstly, agents designed for one environment tended to be poorly designed for any other environment. This was the result of an agent being the sole focus of knowledge engineering. Since an agent's available actions were designed as intrinsic properties of an agent, the agent itself would have to be designed around its environment. Affordances provide a pattern to decouple actions and agents by making actions available through affordances.

A second issue with traditional AI in complex and dynamic environments was that traditional approaches were processing information from the environment with little concern as to its ultimate purpose: action. Computer vision approaches exemplify this problem.

Even if an agent has perfect segmentation and feature recognition capabilities, this new form of information may be hard to translate into appropriate actions. Simply put, knowing the objective properties of the environment still leaves the agent with the problem of figuring out what to do with that information. In a static environment with little data collection cost, this approach may work quite well. However, if the environment is constantly changing and there is a large amount of information, an agent could waste major resources collecting essentially useless and quickly outdated information without being any more informed about its relevant actions. By focusing agent perception around the detection of affordances, less importance is placed on processing sensory information simply for the sake of a well-defined "mental image" of its environment that may have little utility for navigating that environment (Gibson 1979). In this way, the affordance-based paradigm can lead designers to a system that reacts quickly and effectively within its environment. This advantage primarily benefits AI developers for embedded applications. While robotics research has been most interested in this aspect, it is also relevant to web agents such as automated shoppers or Web site interface testers.

As with most design decisions, each advantage comes at a cost. While affordances can be used to make agents reusable across multiple environments, the conditions that determine the existence of an affordance can become increasingly complex as a function of the environment. For example, the affordance "can throw" must be represented more elaborately if mass and an agent's strength are considered. While a more traditional representation allows agents to define their possible actions in their own terms, the affordance paradigm establishes global rules for the availability of an action. This could be a drawback in some systems. Similarly, for a fixed environment where detailed maps of all information are needed to perform an action, affordance-based AI will provide little advantage over traditional systems. For example, if an agent's "actions" consist of segmenting and labeling images, then traditional machine vision techniques could be a better fit.

There are a variety of ways of implementing affordances in artificial intelligence, which are based on different mathematical formalizations of the affordance concept. Sahin et al. (2007) gives an

$$W_{pq} = (X_p, Z_q)$$
$$h = f(p, q)$$
$$h \in W_{pq}; \quad h \notin X_p; \quad h \notin Z_q$$

Affordances in AI. Fig. 1 Stoffregen's formalization (Adapted from Stoffregen (2003))

overview of the prevalent formalizations. Stoffregen's formalization will be presented as an example formulation in Fig. 1, to help explain how affordances are implemented in a computational context (Stoffregen 2003). Figure 1 shows this formulation. In this formulation, W_{pq} is a system including an agent Z_q and part of the environment X_p. p are some traits of the environment and q are properties of the agent, respectively. h represents the potential affordance, which exists due to the relationship between the properties p and q (f represents that it is a relationship between these). Under this formalization, the affordance is said to exist if the system W_{pq} contains the affordance h but neither of the subsystems X_p or Z_q contain this affordance. This formulation ensures that the affordance emerges due to the relationship between agent and environment, rather than a property of either alone.

A common approach to implementing affordances is by defining affordances in terms of relationships between properties of an agent and properties of the environment. In other words, a programmer will define the relationship f in terms of the attributes of the agent (q) and the environment (p). For example, the affordance "can traverse" could exist if the agent had wheels and the ground was rigid and flat. Any combination of agent and landscape that fits the affordance's conditions would be able to take that action. Likewise, the "can traverse" affordance could be enabled for an agent with flippers and a watery environment. It can be readily seen that affordances provide a straightforward way for defining where different actions exist. Especially when allowing for nesting of affordances, affordances defined in terms of other affordances, this can be a powerful tool for abstracting the potential for action.

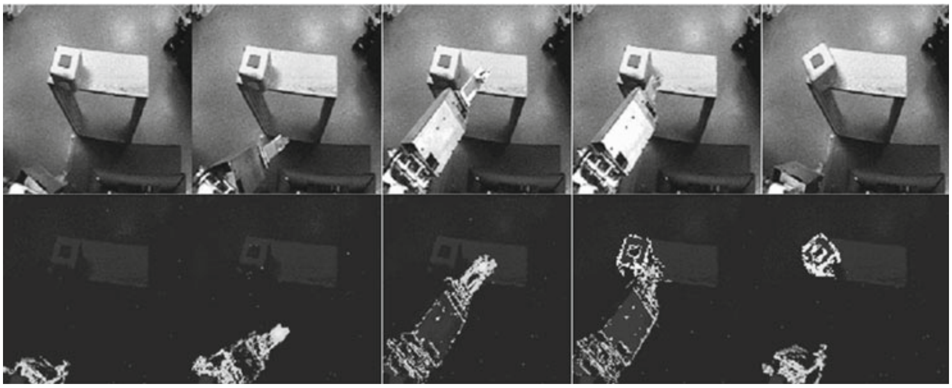
Affordances can then come full circle and be used for perception, in an artificial intelligence context. The simplest approach is to design an environment where an agent directly perceives affordances. For a person working in modeling and simulation, it is possible to design the affordance relationships in terms of the qualities of the agents and elements of the environment. This allows an agent to directly see the affordances available to them at any given time, if they are allowed to evaluate the existential conditions for the given action. Cognitive architectures such as PMFServ use affordances as fundamental elements of perception that can be observed within the environment (Silverman et al. 2007). For embedded autonomous agents, the situation is more complicated. The environment for an agent can be mapped into properties, emulating the affordance-only perception situation. Alternatively, an agent can be built to learn invariant properties through experience or imitation. These different techniques provide a basis for applied research in AI.

Important Scientific Research and Open Questions

The use of affordances within AI and adaptive agents has been growing over the decade. The increase in usage is evident in the development of new formalizations in order to accommodate new uses. An early formalization by Turvey (1992) presented a first pass at representing affordances. However, efforts to implement affordance-based adaptation did not truly catch on until almost 10 years later. Three formalizations were presented by Steedman (2002), Stoffregen (2003), and Chemero (2003) in close succession. Additional representations have been developed since then, including Chemero and Turvey (2007) and Sahin et al. (2007). These formalizations suit different needs. The Steedman version, for example, is built for planning and computational logic. The Stoffregen and Chemero formalizations focus on issues of perception and existence rather than inference. Research developing formal representations helps drive the use of affordances in AI at the theoretical level.

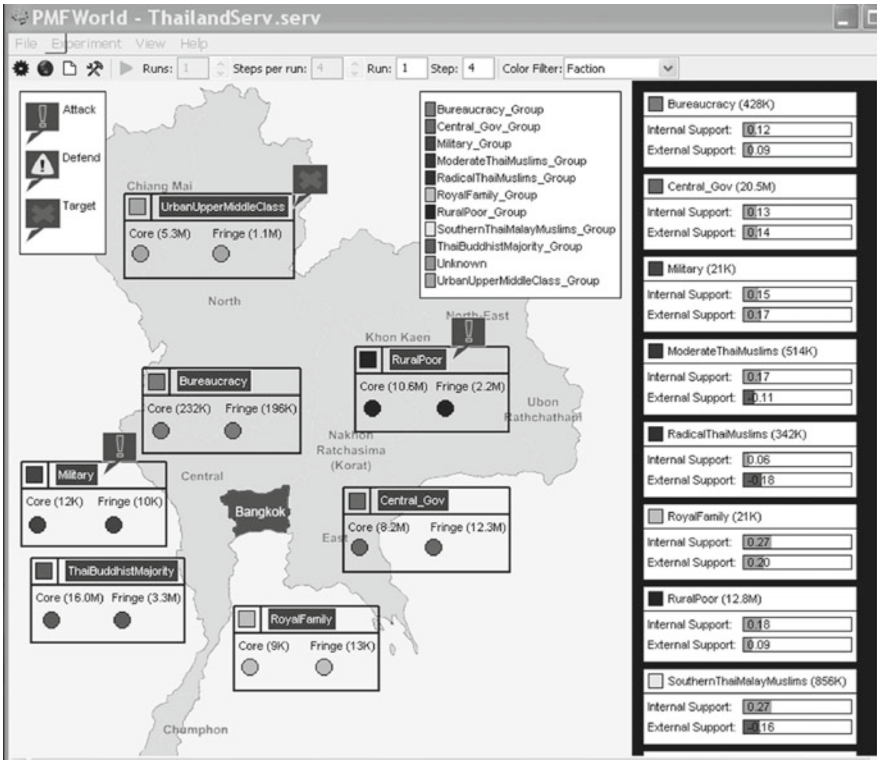
The formalizations of affordances enable applied uses of affordances. Robotics research currently uses affordances to help deal with the problem of autonomous robots in complex environments. One research topic is to have a situated agent learn about actions in its environment. This approach is based on the theoretical work by Gibson (1979) and also the later work on learning of affordances by Gibson and Pick (2000). One implementation of this is to have a goal-directed agent which gets feedback from outcomes in its environment through unsupervised or supervised learning, a design similar to empirical affordance learning research done with children. A common paradigm is that a stationary robot has certain available movements for interacting with objects within its environment such as Cog, shown in Fig. 2 (Fitzpatrick and Metta 2003). The robot will be presented with different objects and allowed to manipulate the objects to learn invariant properties that help infer if an affordance is present. Research also has demonstrated the ability of robots to learn affordances from other robots, enabling basic imitation and social learning (Montesano et al. 2008).

Affordances have also gained a foothold in the agent-based modeling and design community. Software-based agents are also autonomous, but they are embodied within a stylized environment, application, or even the internet. Affordance-based design has been applied to web agents, such as would be used within a semantic web. Economic applications, such as a comparative



Affordances in AI. Fig. 2 Cog, A Robot used to learn affordances (Source: Fitzpatrick and Metta (2003)) shopping or price bidding, are one of the goals of such research. Agents in virtual environments, such as games, can also be based on affordances in order to assist agent navigation or context-based adaptation.

Agent-based simulation has been using affordances to help build cognitive agents for some time. Affordance theory provides a plausible cognitive process for perception in humans, the ecological theory of



CountrySim country stability simulation

Non-Kin Village Simulation

Affordances in AI. Fig. 3 PMFServ affordance-based agent applications perception. This makes affordance theory a desirable choice for cognitive modelers seeking a biologically plausible model for perception. PMFServ, a project started in 1998, is a cognitive architecture built up from descriptive models of cognition from the social sciences and an early adopter of affordance-based perception (Silverman et al. 2007). Affordance theory allows PMFServ agents' cognitive models to perceive actions within the environment, rather than endowing agents with a particular set of actions. This paradigm allows agents to learn and adapt to new contexts and also facilitates reuse of agents, actions, and environments. Simulations using PMFServ agents, shown in Fig. 3, have modeled country stability, insurgent cells, and even an Iraqi village known as the Non-Kinetic Village, upon which a cultural training game runs. These agents are designed for adaptation, decision-making, and emotional concerns. Alternatively, affordances have also been used by finer-grained agents that simulate spatial problems such as path-finding (Raubal 2001). Each of these areas has significant opportunities for further exploration, as affordance-based AI is still maturing as a field-drawing off of formalizations developed within the last decade.

Cross-References

► Affordances
► Artificial Intelligence
► Cognitive Modeling with Simulated Agents and Robots
► Modeling and Simulation
► Robot Learning

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Afforded Action

► Affordance

Affording

► Affordance

After School Tutorial Programs

► Learning and Development After School

Agency

► Biographical Learning

Agent-Based Computational Economics

► Learning Agent and Agent-Based Modeling

Agent-Based Modeling

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Synonyms

Agent-based simulation; Artificial societies; Individual-based modeling

Definition

Agent-based modeling is a computational method that enables researchers to create, analyze, and experiment with models composed of autonomous and heterogeneous agents that interact within an environment in order to identify the mechanisms that bring about some macroscopic phenomenon of interest.

Theoretical Background

There is an increasing interest in agent-based modeling (ABM) as a modeling approach in the social sciences because it enables researchers to build *computational* models where individual entities and their cognition and interactions are directly represented. In comparison to alternative modeling techniques, such as variable-based approaches using structural equations or system-based approaches using differential equations, ABM allows modelers to simulate the *emergence* of macroscopic or system regularities over time, such as ant colonies, flock of birds, norms of cooperation, traffic jams, or languages, from local interactions of autonomous and heterogeneous agents (Gilbert 2008). The emergent properties of an agent-based model are then the result of "bottom-up" processes, the outcome of agent interactions, rather than "top-down" direction. In fact, the absence of any form of top-down control is the hallmark of ABM, since the cognitive processes, behaviors, and interactions at the agent-level bring about the observed regularities in the system- or macro-level. For this reason, ABM is most appropriate for studying processes that lack central coordination, including the emergence of macroscopic patterns that, once established, impose order from the top down.

Agent-based models involve two main components. Firstly, these models entail the definition of a population of *agents*. The agents are the computational representation of some specific social actors – individual people or animals, organizations such as firms, or bodies such as nation-states – capable of interacting, that is, they can pass informational messages to each other and act on the basis of what they learn from these messages. Thus, each agent in the model is an autonomous entity. The artificial population can include heterogeneous agents, which is useful when the researcher wants to build a model of a certain phenomenon with different agents' capabilities, roles, perspectives, or stocks of knowledge. Secondly, ABM involves the definition of some *environment*. The environment is the virtual world in which the agents act. It may be an entirely neutral medium with little or no effect on the agents, as in some agent-based models based on game theory, where the environment has no meaning. In other models, the environment may be as carefully designed as the agents themselves, as in some ecological or anthropological agent-based models where the environment represents complex geographical space that affects the agents' behavior.

One of the main objectives of ABM is to falsify, by experimental means, the hypothesized *mechanisms* that bring about the macroscopic phenomenon the researcher is interested in explaining. Following the definition provided by Hedström (2005), a mechanism describes a constellation of *entities* (i.e., agents) and *activities* (i.e., actions) that are organized such that they regularly bring about a particular type of outcome. We explain an observed macroscopic phenomenon by referring to the mechanisms by which the phenomenon is regularly brought about. In ABM, these mechanisms are translated as the model *microspecifications*, that is to say, the set of behavioral and simple rules that specify how the agents locally behave and react to their environment (which includes, of course, other agents). Once the population of agents and the environment is defined, the researcher can implement the microspecifications and run the computer simulation in order to evaluate whether these rules bring about the macro-phenomenon of interest, over the simulated time. When the model can generate the type of outcome to be explained, then the researcher has provided a *computational demonstration* that a given microspecification (or mechanism) is in fact sufficient to generate the macrostructure of interest. This demonstration, called *generative sufficiency* (Epstein 1999), provides a candidate mechanism-based explanation of the macro-phenomenon. The agent-based modeler can then use relevant data and statistics to gauge the generative sufficiency of a given microspecification by testing the agreement between "real-world" and the generated macrostructures in the computer simulation. On the other hand, when the model cannot generate the outcome to be explained, the microspecification is not a candidate explanation of the phenomenon and the researcher has demonstrated the hypothesized mechanism to be false. Therefore, agent-based models can be used to perform highly abstract *thought experiments* that explore plausible mechanisms that may underlie observed patterns.

Finally, it can be said that the interest in ABM reflects a growing interest in *complex adaptive systems* by social scientists, that is to say, the possibility that human societies may be described as highly complex, path-dependent, nonlinear, and self-organizing systems (Macy and Willer 2002). The emphasis on processes and on the relations between entities that bring about macroscopic regularities, both of which can be examined by ABM, accounts for the developing link between this theoretical perspective and ABM research.

Important Scientific Research and Open Questions

Agent-based models have become a standard tool in most branches of the social sciences, ecology, biology, linguistics, anthropology, and economics. The scientific researches that are briefly described in the rest of the section have been chosen to illustrate the diversity of the problem areas where ABM has been used productively as well as issues where there is as yet not full agreement.

One of the most famous ABMs was proposed by Thomas Schelling (1971). His model aimed to explain observed racial segregation in American cities. Although this is an abstract model, it has influenced recent work on understanding the persistence of segregation in urban centers. The striking finding of this study, as explained by Schelling, is that even quite low degrees of racial prejudice could yield the strongly segregated patterns typical of US cities in the 1970s.

Another inspiring application of ABM is due to Epstein and Axtell (1996). Their model, named "Sugarscape," replicates market behavior. Agents are located on a grid and trade with neighbors. There are just two commodities: sugar and spice. All agents consume both these, but at different rates. Each agent has its own welfare function, relating its relative preference for sugar or spice to the amount it has "in stock" and the amount it needs. The expected market-clearing price emerges from the many bilateral trades. An analysis of such a model allowed them to state that the quantity of trade is less than that predicted by neoclassical theory, since agents are only able to trade with their neighbors.

There are a number of studies that apply agent-based models to investigate opinion dynamics and customer behavior. These models are mostly concerned with understanding the influence of friends, families, and other social factors on the development of political opinions and on shaping customers' taste; for instance, explaining the spread of extremist opinions within a population or identifying factors, not related to the quality of a product, that might affect consumer behaviors.

Several scholars have applied agent-based models to investigate cooperation, reciprocity, and long-term strategies. These authors understand cooperation as the emergence and maintenance of persistent relations among actors within a shared environment. Their aim is to design mechanisms that yield cooperative behaviors. One aspect of this work is the investigation of the role played by the creation and destruction of links between firms, such as supply chains and small firms clustered in industrial districts. ABM approaches have been successfully used to test the performance of different network structures with respect to innovation, knowledge, financial links, and other firm features.

Whether to conceive agent-based modeling as a mode of *building theory* or as an attempt for *imitation* is one of the current debates on ABM. Computer programs, like scientific theories, have semantic significance; each line of code stands for other things for the user of those programs and theories. However, theories do not possess the causal capability of computer programs, which act on those machines where they are loaded, compiled, and executed. Therefore, according to this perspective, computer programs allow a researcher to refine and adjust the theory by observing and measuring the causal features that this brings about. Contrarily, several scholars understand ABM as tool for imitation. They maintain that the knowledge produced by means of ABM is valid only if it reproduces some feature known by experience. Hence, this line of thinking suggests that the adequacy of imitation rather than any derivation from theoretical principles is the only successful criterion to build a sound agent-based model.

Cross-References

- ► Artificial Intelligence
- ► Cognitive Modeling with Multiagent Systems
- ► Computer Simulation Model
- ► Learning Agents and Agent-Based Modeling
- ► Modeling and Simulation

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Agent-Based Simulation

► Agent-Based Modeling

Agents

In artificial intelligence (AI), an agent is an autonomous entity, which acts upon an environment and directs its activities toward achieving some specified intentions. Intelligent agents are able to learn and apply knowledge to achieve their goals. Russell and Norvig (2003) distinguish five classes of agents in dependence on their intelligence and capability: Simple reflex agents, model-based reflex agents, goal-based agents, utility-based agents, and learning agents.

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Age-Related Differences in Achievement Goal Differentiation

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Synonyms

Achievement goal orientations; Learning and performance goals; Mastery and performance goals; Task- and ego-involvement

Definition

Students engage in achievement strivings for a variety of reasons and with diverse purposes. Achievement goals refer to these reasons, goals, and purposes underlying individuals' achievement-related behaviors. Achievement goals often function as a primary motivator driving students' cognition, affect, and actions in specific learning situations. For young children, the goal of improving their competence is the most important such reason when they demonstrate achievement behaviors. Because young children have strong mastery motivation and are not attuned to social comparison information just yet, the goal of validating their competence is less meaningful than that of acquiring new knowledge and developing new skills. In comparison, achievement behaviors of older students are often guided by other types of goals as well, including the goals of demonstrating their superiority or concealing their inferiority relative to others. Similar to most other belief systems, achievement goals tend to be more clearly differentiated as children grow older.

Theoretical Background

Many theorists working in the area of motivation research in the late 1970s and early 1980s have independently come up with similar conceptualizations that explain fundamental differences in the nature of individuals' achievement strivings (e.g., Ames and Archer 1988; Dweck and Leggett 1988; Nicholls 1984). Dweck and colleagues, for example, observed that children responded to failures in markedly different ways, with some children showing a particularly debilitating pattern of emotional and behavioral responses. These different reactions followed failure feedback that emphasized ability as having either fixed or malleable characteristics. When the children attributed their failure to lack of ability and also believed that their ability is more or less fixed, they demonstrated the most maladaptive and helpless pattern. More specifically, they avoided challenge, slackened effort prematurely with a hint of potential failure, and used ineffective strategies when facing obstacles.

This led Dweck to suggest that children subscribe different theories of intelligence and these theories in turn guide children to attach different meanings to their achievement behaviors and confront achievement situations with different purposes (Dweck and Leggett 1988). According to Dweck, children who subscribe an "incremental" theory of intelligence pursue a learning goal, whereas those who subscribe an "entity" theory of intelligence pursue a performance goal. Dweck thus distinguished between two contrasting purposes and named them a learning goal and a performance goal, respectively, whereas Nicholls (1984) contrasted task-involvement and ego-involvement to capture similar differences in the quality of children's achievement strivings. Ames and colleagues (Ames and Archer 1988) also proposed a distinction between a mastery and a performance goal that are associated with different patterns of cognition, affect, and motivation in specific learning situations.

Although these new concepts were called by slightly different names, all of them shared important commonalities. They were all competence-based goals and represented subjective meanings and purposes attached to one's endeavor in the given achievement situation. Depending on the types of reasons or purposes of achievement-related behaviors, there existed noticeable differences in the ways students defined success, approached and carried out academic tasks and activities, and responded to failure.

Achievement goals should be distinguished from typical goals, aims, or objectives that individuals pursue in achievement settings. Whereas the target or outcome goals represent "what" individuals try to accomplish, achievement goals represent "why" they try to accomplish those specific goals, aims, or objectives. Therefore, individuals who strive to attain the same objective may do so with different purposes in mind. Achievement goals offer more accurate explanations and predictions for individuals' responses to achievement situations than do target goals and hence have quickly become one of the most actively pursued topics in the classroom motivation research (Pintrich 2003).

Researchers generally agree that there are three major types of achievement goals students may pursue in academic situations. A mastery goal is rooted in belief that ability is malleable and improves with new learning. Students adopting a mastery goal thus engage in learning activities for the purpose of developing their competence. They define success as a progress, task mastery, and gaining understanding, and view occasional failures as part of natural learning processes that do not necessarily indicate low ability. In contrast, belief that ability is fixed and something that one either possesses or does not possess leads individuals to adopt a performance goal. Students pursuing a performance goal define success as normative superiority and view failures as indicative of low ability.

A performance goal is further divided into a performance-approach and a performance-avoidance goal (Elliot and Harackiewicz 1996), depending on whether one's goal is to validate their superior competence or conceal their incompetence, respectively. Students with a performance-approach goal seek opportunities to outperform others, achieve easy success, and when coupled with high competence, occasionally choose difficult tasks that could document their relative excellence. Those with a performance-avoidance goal, on the contrary, try to achieve for the purpose of avoiding the negative possibility of performing poorly compared to others and being judged by others as lacking ability. These students avoid challenge, use self-defeating strategies, and suffer from feelings of low competence.

When Bong (2009) assessed achievement goals of more than 1,000 elementary and middle school students in Korea, important age-related differences were observed in both the strength of correlation among the achievement goals and the degree of endorsement of each achievement goal across the age group. Achievement goals of younger children were more strongly correlated with each other than those of older students. Children in Grades 1–4 in elementary school also reported that they pursued a mastery goal more strongly than they did other achievement goals. In contrast, older students in Grades 5–9 endorsed a performance-approach goal as the most important reason for their achievement behaviors.

Important Scientific Research and Open Questions

More recently, Elliot and colleagues (e.g., Elliot and McGregor 2001) proposed a 2 × 2 framework that distinguishes achievement goals by goal definition (i.e., mastery vs performance) and goal valence (i.e., approach vs avoidance). Accordingly, they argued that a mastery goal could also be differentiated into a mastery-approach and a mastery-avoidance goal. Whereas a mastery-approach goal refers to the desire to learn new things and improve one's ability, a mastery-avoidance goal represents the desire to avoid the aversive prospect of not learning as much as possible and getting worse at things one used to perform well. A mastery-avoidance goal is said to be most relevant for individuals with a strong perfectionist orientation, the elderly, and those who begin to focus on maintaining their level of performance after having reached their peak in a particular domain. The literature is not conclusive at this point regarding the psychological reality of this goal. More investigations are needed to test validity of this framework, especially among younger populations.

Another area that has been under constant debate is the role of a performance-approach goal. A performance-approach goal demonstrated positive relationships with many adaptive outcomes, most notably performance indexes. Motivation theorists are divided over the implications of this finding. Some advocate the benefit of adopting a performance-approach goal, which often yields tangible gains such as improved test scores (e.g., Harackiewicz et al. 2002). Others point to the harmful emotional consequences associated with a performance-approach goal upon failure and warn educators to discourage students from adopting such a goal (e.g., Midgley et al. 2001). These researchers argue that the seeming advantage of a performance-approach goal is short-lived and will disappear quickly when students start experiencing difficulties and repeated failures. Longitudinal research over multiple years will be able to shed light on the true nature of a performance-approach goal.

Cross-References

▶ Academic Motivation
▶ Achievement Motivation and Learning
▶ Attribution Theory of Motivation
▶ Motivation and Learning: Modern Theories
▶ Motivational Variables in Learning
▶ School Motivation

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Age-Related Verbal Memory Decline

▶ Verbal Learning and Aging

Aging Effects on Motor Learning

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Synonyms

Skill acquisition in the elderly

Definition

Motor learning, also referred to as skill acquisition, has been described as the processes associated with practice or experience that lead to a relatively permanent change in one's capability for responding. Older adults show impairments in skill acquisition when compared to their younger counterparts; that is, they learn at a slower rate and typically do not attain the same performance level as young adults, despite extended task practice. Recent work has identified many of the factors underlying age deficits in motor learning, paving the way for new rehabilitative interventions.

Theoretical Background

The study of motor learning has a rich history, spanning more than 100 years. Recent technological advancements in neuroimaging have provided researchers with the ability to map time-varying networks of brain activity to theories regarding changes in motor behavior. A greater understanding of the cognitive and neural underpinnings of skill acquisition in young adults has led to an enhanced understanding of the mechanisms of age-related learning deficits.

Motor learning researchers have typically classified learning into two distinct categories: sensorimotor adaptation and sequence learning. Sensorimotor adaptation involves the modification of one's movements to compensate for changes in sensory inputs or motor output characteristics. Motor sequence learning involves the progressive association between isolated elements of movement, eventually allowing for rapid sequence execution. These two types of skill learning are thought to rely on distinct underlying neural substrates and cognitive strategies at different stages of the learning process (cf. Doyon et al. 2003).

The early stage of motor learning is associated with engagement of the dorsolateral prefrontal and parietal cortices, and is susceptible to interference from secondary cognitive tasks. We have recently shown that, while young adults engage spatial working memory during the early stage of sensorimotor adaptation, age-related deficits in adaptation are associated with a failure to engage spatial working memory processes (Anguera et al. 2011). An extensive literature demonstrates that older adults rely more on cognitive resources for the control of simple actions than young adults; in terms of motor learning, however, it appears that older adults are less likely to engage the relevant cognitive processes (cf. Anguera et al. 2011; Bo et al. 2009).

In terms of motor sequence learning, we have recently reported that older adults exhibit a slower rate of learning and form shorter chunk lengths associating individual movement elements (Bo et al. 2009). In addition, older adults exhibit an overall reduction in both working memory capacity and sequence chunking patterns, indicating that working memory impairments partially explain age-related deficits in motor sequence learning. In combination, these two examples document that age-related cognitive deficits affect motor learning ability.

Important Scientific Research and Open Questions

We have demonstrated an important role for spatial working memory in the two major types of motor skill learning. Moreover, age-related spatial working memory deficits contribute to declines in skill acquisition. However, it is likely that other cognitive and sensorimotor physiological processes also play a role (cf. Seidler et al. 2010). An important future direction will be to measure and take into account both peripheral and central neurophysiological changes that occur with senescence to better understand how each contributes to deficits in motor learning. Moreover, approaches to improve motor learning performance in older adults, such as working memory training or the provision of alternate strategies, are potential avenues that could facilitate meaningful interventions that would improve one's quality of life.

The use of brain imaging techniques to study changes in brain structure and function with age has contributed greatly to our understanding of performance declines with age. Such work suggests that older adults recruit compensatory brain networks to maintain cognitive task performance. While some studies report evidence of compensatory recruitment for motor control as well, there is no evidence that older adults exhibit over-activation of brain regions when learning new motor skills. In fact, our recent findings have demonstrated that older adults show a failure to effectively engage essential cognitive processes during the early learning period (Anguera et al. 2011). Clearly, additional brain imaging studies need to be performed to provide a deeper understanding of the neural mechanisms of motor learning in aging.

The older adult population in the USA in 2030 has been projected to be nearly twice as large as it was in 2000. This dramatic shift in population demographics will result in an increased need for programs and interventions that not only improve activities of daily living, but also spur a faster recovery for individuals afflicted with an injury or neurological insult. Novel rehabilitative strategies based on motor learning principles have shown to be effective. For example, individuals affected by stroke that underwent mental motor training have reported better functionality in their upper extremities and greater gains in activities of daily living than those seen with standard physiotherapy (Page et al. 2009). Broader-based interventions have led to improvements in both cognitive and motor function in older adults (Williamson et al. 2009). Such approaches, based on current mechanistic understandings of motor learning and brain plasticity, may extend independent living and quality of life.

Cross-References

- ► Implicit Sequence Learning
- ► Procedural Learning
- ► Sensorimotor Adaptation
- ► Sequence Learning

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Agreeableness

One of the big five personality factors. Individuals scoring high on this dimension are empathetic, friendly, generous, and helpful.

AIME - Amount of Invested Mental Effort

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Synonyms

Amount of invested mental effort; Attention; Concentration; Mental effort; Mental workload; Use of cognitive capacity

Definition

AIME is an acronym that stands for "amount of invested mental effort." First proposed by Gabriel Salomon in

1983, he defines the construct of AIME as "the number of non-automatic elaborations (► Elaboration) applied to a unit of material" (Salomon 1983, p. 42). In cognitive theories of learning, elaboration involves connecting new information with related information, often stored as prior knowledge. When new information is mentally connected to related information, it can be stored in terms of a more inclusive concept in the learner's mental schemata. The increased contact with the learner's mental schemata that results from the conscious, non-automatic generation of elaborations, or mental effort, is presumed to facilitate the retention and retrieval of the new material. In contrast to automatic processing, which is fast and effortless, non-automatic processing is deliberate, conscious, and very much under the control of the individual. Because AIME is assumed to be a voluntary process that is under the control of the individual, and as such is available for introspection, it is measured through self-report questionnaires.

AIME has been studied in relation to learner's preconceptions of a medium of presentation, such as television, video, and print. In a series of studies, Salomon (Salomon 1983, 1984; Salomon and Leigh 1984) consistently found that students reported investing more effort in processing a text-based lesson than in processing a lesson presented through the oral and representational symbol systems employed by television. Furthermore, these studies noted a significant positive correlation between the amount of mental effort students reported and their achievement scores. These findings initiated a series of similar research studies investigating the extent to which preconceptions of the processing requirements of a medium may influence the amount of mental effort expended in learning from a medium, especially television and video, that continued through the mid-1990s.

Cross-References

► Children's Learning from TV
► Mental Effort
► Schema(s)

References

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Alertness and Learning of Individuals with PIMD

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Synonyms

Attention; Behavior state; Concentration; Engagement; On-task behavior; Responsiveness

Definition

Although individuals with profound intellectual and multiple disabilities (PIMD) form a heterogeneous target group, with every individual experiencing a different combination of possibilities and disabilities, a number of characteristics are similar for the entire group. Individuals with PIMD all suffer from severe or profound intellectual and motor disabilities, mostly caused by damage to the central nervous system. Additionally, sensory disabilities and secondary impairments such as seizure disorders, pulmonary infections, and skeletal deformations are common. As a consequence, individuals in the target group reach a maximal developmental age of 24 months and most of them are confined to a wheelchair. Language in any form, for example, speech, signing, or use of symbols, will be limited or nonexistent. Because of the complexity and severity of their disabilities, their daily support needs are qualified as pervasive (Nakken and Vlaskamp 2007).

In the care of individuals with PIMD, alertness has been described as "being open for or focused on the environment." Descriptions in the behavioral sciences can be distinguished as being of two types. On the one hand, authors refer to alertness as the internal state of an individual which becomes manifest and observable in the individual's behavior; on the other, alertness is described as the level of an individual's interaction and engagement with the environment. The main difference in the descriptions here is that of focus: either on the individual or on interaction with the environment.

Theoretical Background

In general, "being alert" is one of the most important preconditions for learning and development. Activities to promote learning and development need to be started at the "best moment." Only if individuals are open to the environment, can the stimuli that are presented enter the consciousness of the individual.

This is also true for individuals with PIMD. As they are dependent on others for almost all daily activities and experiences, it is very important for parents and direct support persons (DSPs) to choose the "best moment" to stimulate these children. However, DSPs regularly face a number of problems concerning that "best moment." Individuals with PIMD use preverbal communication involving signals such as reflex responses, sounds, facial expressions, and bodily movements. Because only subtle signals show whether they are alert or not, such signals are difficult to interpret for DSPs. Sometimes these signals are so subtle that they even go unnoticed. The communicative repertoire is not only limited, but may include idiosyncratic ways of communicating. Not only can the same signal have a different meaning for different individuals, but the same signal shown by the same individual in different situations can also mean something else (Vlaskamp 2005). Additionally, the severity and complexity of the disabilities can have an impact on the alertness expressions of an individual with PIMD. If a person is blind, for example, he/she might not use their eyes or head to show his/her focus on an object, or if a person suffers from cerebral palsy, he/she might not be able to point or grasp. Quick and irregular changes in alertness levels are another complicating aspect. Individuals with PIMD often show short periods of "being alert" alternating with periods of "being drowsy" (Mudford et al. 1997). Since these periods sometimes only last for a few seconds, it is even more important to see and use them.

A first step in choosing the individual's "best moment" is to register the individual alertness expressions carefully. Alertness is mostly described on three different levels: (1) being alert and actively focused on the environment; (2) being awake, but focused on oneself and not in contact with the environment; and (3) being asleep, without any focus or contact. Moreover, the position of stereotypical behavior within these observation schemes has been discussed. On the one hand, stereotypical behavior has been described as a separate alertness level; on the other, researchers state that stereotypical behavior can occur on all levels. Another point of view is that stereotypical behavior is a form of communication or coping rather than being related to alertness levels (Munde et al. 2009).

In a second step, and based on the individual description of alertness expressions, DSPs can choose the "best moment" during the day for a person with PIMD. To do so, DSPs can register alertness levels along with the influencing effects of internal and external factors at that moment. Internal factors such as being ill or being tired have to be taken into account when observing alertness. These may cause the individual to react differently to the environment than in a "normal" situation. Additionally, external factors such as tactile stimulation or additional, possibly irritating stimulation from the direct environment can be manipulated to determine the impact of those factors on the different alertness levels. Consequently, the two following points can be considered as most important: (1) staff training to make DSPs aware of alertness expressions along with observing individuals with PIMD can offer a first step in increasing the alertness level of their clients; and (2) in order to influence alertness in individuals with PIMD, individual differences in preferences for and reactions to stimuli always need to be taken into account. In general, external factors are expected to have more impact on alertness than internal factors.

Important Scientific Research and Open Questions

In 1993, Guess and his colleagues were the first to describe alertness in this target group (Guess et al. 1993). Subsequently, their differentiation of nine observable alertness levels has been used as a standard scheme, with modifications by other researchers over the years. Although these observation schemes resemble each other, a number of questions concerning alertness observations still need to be answered. One point of discussion is that of scoring frequency. Because of the quick and irregular changes, continuous observation would provide the maximum of information. This is, however, time-consuming and almost impossible to realize in clinical practice. Conducting observations based on videotapes can help to solve these problems. Observers can stop the tapes to note alertness levels and look at the video pictures for a second time in order to register environmental conditions. But again, this is not always a possibility for DSPs and very time-consuming as well. Another discussion point is who can reliably conduct the observations. Several studies show that alertness in individuals with PIMD can be observed reliably by proxies as well as by external observers. Consequently, neither the observations of the proxies alone nor those of external observers alone should be judged as being the most reliable; both should be seen as complementary.

Note that previous studies are mostly based on behavioral observations, because DSPs are able to register the behavior itself, the meaning of the behavior, and the context information at the same time. In contrast, neurological and physiological measurements of alertness are difficult to carry out and even more difficult to interpret for this target group. Thus, observations seem to be the most suitable method for determining alertness levels in individuals in the target group. However, despite the valuable information that observations provide, the subjectivity of observations remains an issue. Determining alertness levels using neurological and physiological measurements may, therefore, reveal interesting additional information. Carrying out such measurements for individuals with PIMD remains another challenge for future research.

A subsequent step following measurements of alertness should be to influence and improve alertness levels in individuals with PIMD. However, methods that are possible for this have not been clearly described. Although researchers and DSPs agree that external factors in general can have an impact on alertness levels, there are different assumptions about the effect that different methods have. Most obviously, treatment activities and stimulation can be applied, whereas tactile and vestibular stimuli seem to have the greatest impact. Presenting stimuli in a one-to-one interaction and reducing stimuli in the environment can, therefore, help to promote alertness. Additionally, individual differences in preferences and reactions remain the most important point of interest. When DSPs give a person with PIMD the opportunity to choose the activity himself/herself or present already known preferred stimuli, higher alertness levels are most likely to occur. In the future, further research with larger groups needs to be conducted, because all the above-mentioned assumptions have until now only been found in case studies or based on personal experiences.

Cross-References

► Achievement Deficits of Students with Emotional and Behavioral Disabilities
► Affective and Emotional Dispositions of/for Learning
► Attention and Implicit Learning
► Behavior Systems and Learning

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Algorithm Quasi-Optimal

► AQ Learning

Algorithmic Learning Theory

► Mathematical Linguistics and Learning Theory

Aligning the Curriculum to Promote Learning

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Synonyms

Constructive alignment

Definition

Alignment as used in curriculum theory refers to a deliberate and intrinsic connection between aspects of the curriculum and assessment methods, and ideally including teaching methods, institutional policies, and climate. Teaching and learning then take place in an integrated *system*, in which all components interact with and support each other. In this article, alignment is addressed primarily in the postsecondary context.

Theoretical Background

The concept of alignment in curriculum has been around for many years. Aligning assessment tasks to what it is intended students should learn, and grading student on how well they reach preset standards, as in ► criterion-referenced assessment (CRA), is an example of one form of alignment. An example of nonaligned assessment is when students are graded not on what they have learned as such, but on how they compare with each other, as in norm-referenced assessment (NRA). As for the broader curriculum, Tyler (1949) talked about integration between aims, teaching, and assessment, and later, English (1975) argued for a "tight relationship" between the tested curriculum, the taught curriculum, and the written curriculum if optimal test results are to be achieved. Cohen (1987), focusing on the effects of CRA on learning, called such alignment the "magic bullet" in increasing student performance. Because students learn what they perceive they will be tested on, an aligned test means that the students will be focusing on what it is intended that they should be learning.

► Outcomes-based education (OBE) makes the link between what-is-to-be-learned and the criteria of assessment rather more explicit than it is in CRA itself, because what-is-to-be-learned in OBE is not a content topic as such, but how the teacher would intend the students' behavior to change as a result of their learning a topic or group of topics. The assessment is in terms of how well the students achieve those intended learning outcomes; the assessment and the outcome require the same activity. Many universities claim to address ► graduate attributes or university learning goals, such as lifelong learning, critical thinking and the like, which are themselves learning outcomes and thus lend themselves to be addressed by OBE. The traditional curriculum on the other hand is topic-based, which makes alignment between the topics in the tested curriculum, in the written curriculum and in the taught curriculum harder to achieve as this requires alignment on several fronts. A further difficulty with topic-based assessment is that it is mediated by the students' "understanding" of the topic, a vague term that needs to be firmly pinned down, but often is not.

According to ► constructivist learning theory, students construct knowledge through their own activities, and these activities too need to be aligned to the intended learning outcomes. As Shuell (1986, p. 429) says:

> If students are to learn desired outcomes in a reasonably effective manner, then the teacher's fundamental task is to get students to engage in learning activities that are likely to result in their achieving those outcomes. . . . what the student does is actually more important in determining what is learned than what the teacher does.

This important statement introduces the notion that the teacher, in addition to aligning assessment to the intended learning outcomes, needs also to engage student's learning activities in a way that is likely to achieve the intended learning outcomes.

Constructive alignment (Biggs and Tang 2007) is a design for teaching that operationalizes these points. In constructive alignment (CA), we need to:

1. Describe the *intended learning outcomes* (ILOs) in the form of a *verb* that denotes how the content or topics are to be dealt with and in what context.
2. Create a learning environment using *teaching/learning activities* (TLAs) that address that verb and therefore are likely to bring about the intended outcome.

3. Use *assessment tasks* (ATs) that also contain that verb, together with rubrics that enable one to judge how well students' performances meet the criteria.
4. Transform these judgments into standard grades.

The verb in the ILO becomes the common link by which alignment can be achieved between the ILO, the teaching/learning activities, and the assessment tasks. Some ILOs would require low-level verbs such as "describe," "enumerate," "list"; others middle level, such as "explain," "analyze," "apply to familiar domains," "solve standard problems," while at an advanced level, appropriate verbs would include "hypothesize," "reflect," "apply to unseen domains or problems." The teaching/learning activities and assessment tasks for that ILO would then address that same verb. For example, an ILO in educational psychology might read: "solve a disciplinary problem in the classroom by applying expectancy-value theory." The TLA might be a case study of a particular classroom situation requiring the students to apply the theory and solve the problem, while the assessment would be in terms of how well the problem was solved. Grading is best achieved using rubrics by which the quality of the solution as a whole may be judged. Typically in a semester length course, there would be no more than five or six ILOs, with some ILOs addressing several topics.

Traditionally in university teaching, both the pedagogy and the assessment have been held constant, the lecture and tutorial being the default in many subjects and the invigilated examination the default assessment method. These methods of teaching and assessment do not align at all well with high-level ILOs especially. Large classes and limited resources may make it difficult to build the same verb into the teaching/learning activities and assessment tasks, in which case the teaching and the assessment should be as *congruent* as possible with the intended learning outcome. In implementing constructive alignment, it is useful to use ► action research, by keeping a data base on the quality of student learning and adjusting aspects of alignment in repeated cycles, in order to achieve ► quality enhancement in teaching.

Preliminary studies suggest that a constructively aligned system is effective in promoting learning, particularly in achieving higher order outcomes, because all the components in the system are designed to reinforce each other in supporting learning, while students themselves are clearer not only in *what* they are to learn and to what standard, but on *how* they might best go about learning it. Accordingly, in many systems worldwide, ► quality assurance of teaching assumes that alignment is a good indicator of a quality teaching environment.

Important Scientific Research and Open Questions

Constructive alignment is a design for teaching rather than a theory as such, so that research and development, and evaluation studies under different conditions and contexts, are the kinds of studies that are most needed at this stage. Several studies of individual courses have been reported, but large-scale meta-analyses are needed so that the effect sizes of constructively aligned courses can be compared with traditional teaching, and with each other. For example, it is possible that constructive alignment may be more effective in professional courses than in the basic arts and sciences, as the outcomes in the former are more easily definable in terms of what graduates are suppose to be able to do, but this has yet to be established.

Cross-References

► Action Research on Learning
► Alignment of Learning, Teaching and Assessment
► Constructivism and Learning
► Curriculum and Learning
► Schema(s)

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Alignment of Learning, Teaching, and Assessment

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Synonyms

Academic process; Curriculum; Individualized education plan (IEP); Instructional outcomes; Instructional planning; Lesson plan; Mental model; Teacher work sample method (TWSM); Unit plan; Ways of thinking and practicing

Definition

Alignment of learning, teaching, and assessment is a process where each of the critical elements (learning objectives, assessment of learning, and anticipated knowledge, skills, and/or dispositions) of instruction interact and support learning outcomes. It is also a process of taking instructional ideas from a personal mental model and transforming those ideas through an instructional design process into a functional unit for teaching and learning.

Theoretical Background

The idea of alignment of learning, teaching, and assessment is foundational to formal education and has gained importance with the growth of the instructional standards-based movement in modern educational settings. Alignment of the various processes of teaching with the outcomes of learning has a beginning as far back as the 1600s in Europe with the "normal schools" to train teachers. The purpose of normal schools was to support teaching of content through establishment of teaching standards (norms) that included how to present instruction to encourage learning. This process has become known as "pedagogy." The word *pedagogy* comes from late sixteenth century from French *pédagogie*, from Greek *paidagōgia* "*office of a pedagogue*," from *paidagōgos*. Pedagogy is the study of the methods and activities of teaching and has become a foundational process for learning how to teach. Pedagogies (instructional methods) although containing basic information on teaching, also contain specific methods for teaching a type of content. For example, the pedagogy for teaching mathematics will vary from the pedagogy for teaching economics.

There are many different types of models used to align learning, teaching, and assessment. Commonly used models include unit plans, individualized education plans (IEP), and the teacher work sample methodology (TWSM).

The unit plan is considered to be the foundational model for alignment of the various elements of instruction. A unit plan is comprised of several chunks of instruction (individual lessons) that are organized in a logical sequence to teach a general concept. The unit planning process breaks the general concept into smaller chunks of instruction containing knowledge, skills, and/or dispositions to be taught. These chunks of instruction are each critical pieces of the larger concept and are arranged in a logical sequence for learning (lessons). The assessment of the effectiveness of the teaching process occurs during the lessons and often culminates in a unit test for all concepts learned in the unit. There are many different instructional methods for teaching a unit or lesson such as discovery learning, inquiry, critical thinking, problem-based learning, direct instruction, drill and practice, and lecture. The chosen instructional method usually reflects the underlying philosophical approach toward learning held by the instructor.

The individualized education plan (IEP) is most commonly associated with instructional planning for students with unique needs beyond the anticipated skills level of average achievement students. The IEP usually involves a group of stakeholders (teacher, parent, remediation specialist, medical specialist, etc.) who determine what will be taught to the student and to a specific level of achievement. The IEP is more detailed than a unit plan because it is specific to one individual learner. Assessment of the learner's progress with their IEPs is also defined by that plan. In the USA, the IEP process is mandated by the Individuals with Disabilities Education Act (IDEA), originally enacted in 1975 and updated in 2004.

The teacher work sample method (TWSM) is primarily used to prepare pre-licensure teachers. The TWSM is an instructional design model for teaching how to align instructional methods, assessment, and anticipated learning outcomes. This model is widely used in preservice teacher education programs. The methodology was developed by Western Oregon University (Girod 2002). The TWSM approach for clearly defining and articulating learning outcomes with the assessment was found to be effective in highly structured environments such as those provided by teacher preparation programs but was less effective in actual school environments because of the differences in performance tasks due to the idiosyncratic nature of teacher practices (Girod et al. 2006).

Although there are a variety of defined models for alignment of the various components of instruction, there are some common underlying principles of design. These include: (1) identifying what is to be learned, (2) determining the important chunks to be taught and in what order the knowledge, skills, and/or dispositions will be taught, (3) alignment of assessment with the chunks of instruction in order to determine if learning occurred, and (4) evaluation of the overall effectiveness of the process of instruction.

The first element of designing instruction always begins with clearly identifying what is to be learned (instructional outcomes or objectives). This may be determined by reviewing existing educational guidelines for learning levels (grades) for types of content (curriculum) or by using formal instructional design evaluation (task analysis) of a problem to determine if there is a lack of learning, lack of tools, or a lack of motivation. Once the type of lack or educational guideline is determined then the instructional outcomes can be formally stated. This statement is in terms of what will be learned, in what conditions of learning, and how it will be assessed and at what degree of proficiency.

Once the instructional outcomes are decided, the second task of design is begun. The learning process is organized into smaller chunks of instruction. The chunks are the defined knowledge, skills, and/or dispositions critical to learning. These instructional chunks are frequently combined. For example, a lesson may be taught on how to outline (knowledge) and include affective reasons (dispositions) as to why outlines are good ways to express what is known with the anticipated expectation that the student will both know how to create outlines but also want to use outlines in the future to help organize his/her thoughts. It is generally at this stage of preparing the learning process that previously identified instructional outcomes are aligned with assessment methods. The importance of assessing learning outcomes with questions or methods that actually determine if learning occurred is the critical part of this step. For example, if you are assessing reading competence then the question or method should assess only reading competence not a different skill such as the ability to write an outline.

Another important reason for breaking the concept into smaller pieces is to create doable instructional chunks for teaching and for learning during a lesson. The organization is critical to what is learned, how it is taught, where it is taught, and what instructional support materials are used to support learning and teaching. After the instructional chunks are created and logically organized, the points in time of assessment can be determined for each instructional chunk. Refer to Gagne et al.'s (1981) Nine Events of Instruction for a highly researched model for organizing learning events.

The third task is assessment of learning outcomes during instructional events. Assessment may be either formative or summative. Formative assessment is often an informal event such as verbally questioning students about what is being learned during instruction. The formative assessment process is considered to be important during the instructional events to help gauge if the desired learning is being achieved. If formative assessment indicates that learning is not occurring or is not accurate, then the instruction is either repeated or revised. Summative assessment is the formal event that determines if the instructional outcomes were achieved at the end of learning and at what level of success. Alignment of instruction with assessment is considered to be effective if the results of evaluation match the outcome statement and degree of success of the learning created during the first task of instructional design.

The types of assessment may include paper-pencil tests, oral examination, performance-based activities, or many other types of tests. Refer to the updated version of Bloom's Taxonomy for levels of knowledge and levels of proficiency. D. R. Krathwohl's Taxonomy of Affective Domains may be used as a guideline for assessing intended outcomes for dispositions.

The final step of aligning learning, teaching, and assessment is analysis of the completed process. This is the final analysis of the unit of instruction for degree of success in achieving the desired learning outcomes identified by the learning objectives. Teacher reflection on the final results of instruction is considered to be important and has become a part of the contemporary process of teaching pedagogy. The reflective process helps to identify areas of strength and weakness in the overall alignment of learning, teaching, and assessment and promotes revision of materials to improve instructional outcomes for the next cycle of teaching.

An effective model for the general instructional design process is the ADDIE model (analyze, design, develop, implement, evaluate). The choice of support materials for teaching and learning is a highly specialized part of the instructional design process and includes rules for choice of materials that best support the activity of learning. For an instructional design model that integrates materials and media into the lesson, refer to the ASSURE model (analyze; state objectives; select instructional methods, media, and materials; utilize media and materials; and evaluate and revise) developed by Heinich et al. (1993).

Important Scientific Research and Open Questions

All areas of alignment of learning, teaching, and assessment continue to be important areas of research. With the growth of distance learning environments, many researchers are pursuing research to determine if the alignment process of place-based instructional content and remotely or digitally offered instruction are similar or different. The instructional standards-based movement has also generated research to answer the questions of what is an appropriate sequence (alignment) of content to teach and how to appropriately assess learning outcomes for the content across broad ranges of learners and learning environments.

Cross-References

► Affective Dimensions of Learning
► Assessment in Learning
► Bloom's Taxonomy of Learning Objectives
► Everyday Learning, Instruction and Technology Designs
► Gagne, Robert M.
► Games-Based Learning
► Interactive Learning Environments
► Technology-Enhanced Learning Environments

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Alikeness

► Analogy/Analogies: Structure and Process

Allegory

► Intuition Pumps and Augmentation of Learning

All-Pervading Learning

► Ubiquitous Learning

Alternative/Commonsense Conceptions

► Preconceptions and Learning

Altruism and Health

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Synonyms

Compassion; Empathy; Generativity; Kindness; Social interest behaviors

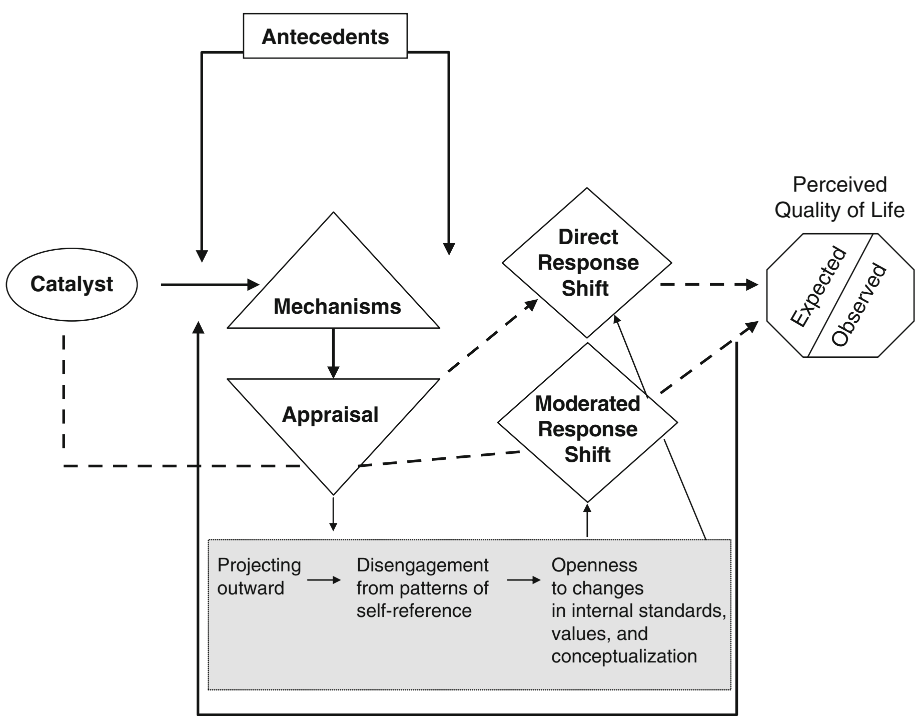
Definition

Altruism refers to behaviors or attitudes that are focused on helping others. This helping can be related to (1) emotional support behaviors, such as listening fully without trying to direct the other's actions; (2) general helping behaviors, such as small kindnesses that make others feel more comfortable or assist others in tangible ways (e.g., carrying books for someone, holding a door open); (3) having a helping orientation or worldview that values and prioritizes being helpful and kind to others; and (4) having a capacity to listen to or help others without feeling burdened by their needs or wishes.

Theoretical Background

The link between altruistic practice and health has been discussed from several theoretical perspectives. Erik Erikson's concept of generativity refers to the individual's concern for the welfare of future generations and for the world at large. In his developmental model, Erikson noted that generative concerns peak in middle adulthood, although they are assumed to be present at all stages of the life cycle. Rowe and Kahn's model of successful aging posits that social participation requires the mobilization of both cognitive faculties and physical functioning, which inhibit the deterioration of well-being in old age. Other theoretical models of the relationship between altruistic practice and health focus on the distraction inherent in altruistic activities. For example, these behaviors might alleviate boredom, and enhance well-being by providing a sense of being useful to others, and thus a sense of purpose and meaning in life. By counteracting negative emotions and reducing psychological stress, they are posited to enhance physical health. Several different terms have been used in the literature to describe the altruism construct, including helping behavior, altruistic activities, and generativity.

A promising theoretical model linking altruism and health builds on response shift theory, and integrates these other models into a model that focuses on the internal changes that might impact perceived quality of life or health (Fig. 1) (Schwartz et al. 2009). Response



Altruism and Health. Fig. 1 Response shift theory explains the link between altruism and health. It posits that altruistic practice causes the individual to project outward by focusing on others. By so doing, the individual disengages from patterns of self-reference, and emerges with a refreshed and more positive perspective on his/her own problems or challenges shift refers to the idea that when individuals experience changes in health state, they may change their internal standards, their values, or their conceptualization of a target construct, such as quality of life, health, and pain. Response shift theory (Sprangers and Schwartz 1999) explains discrepancies between expected and observed levels of perceived quality of life (far right on figure) in physically ill patient populations after health state changes (*catalysts* of response shift, far left on figure). These changes would directly (i.e., health state changes impair or enhance perceived quality of life) and indirectly impact perceived quality of life (i.e., response shifts moderate or mediate perceived quality of life via stable characteristics or behavioral mechanisms). Stable characteristics of the individual (*antecedents*), such as personality characteristics, would interact cognitive or behavioral *mechanisms* (e.g., altruistic practice, social support) to cope with these health changes, and result in *response shifts*. Figure 1 shows how altruistic practices are posited to lead to response shifts: altruistic practice causes the individual to project outward by focusing on others. By so doing, the individual disengages from patterns of self-reference. That is, by getting outside of oneself, one gets a hiatus from the burden of one's everyday problems and challenges, after which one has a different perspective and these problems or challenges do not seem too big or difficult or burdensome. This disengagement enhances perceived quality of life in the face of disability or pain. The resulting response shifts then lead to changes in reported quality of life.

Important Scientific Research and Open Questions

There is a growing and solid body of evidence that positive behavioral factors can play an important role in health, and in particular, the health benefits of altruism (Post 2007). Research on populations representing a broad range of age has documented that people who engage in altruistic activities are happier and healthier, and that these benefits extend as much as 50 years later. These activities might include volunteer work or spending time providing emotional support to others in their community. Even committing regular acts of kindness to strangers has been shown to increase subjective well-being. Altruistic activities have also been associated with enhanced physical functioning and lower morbidity rate, reduced mortality among bereaved elderly spouses, and better mental health in healthy adults (Schwartz et al. 2003).

Although there has been some suggestive research documenting a benefit of helping others in chronically ill people, most research on the health benefits of altruism has addressed healthy samples using observational research designs. It is possible that the altruism–health connection is a correlational illusion: one must be well enough – physically and mentally – to be able to help others. Thus, perhaps it is not that altruism causes wellness but rather that wellness is a necessary condition for altruism.

Future work should use data collected prospectively over a clinically meaningful period of time to allow causal inference. It might also include measures of higher levels of well-being (e.g., Ryff's measure of psychological well-being (Ryff 1989)), as past research has documented numerous benefits at a more existential level. Finally, it would be worthwhile to include a measure of appraisal processes (Rapkin and Schwartz 2004) so that the response shift theoretical model can be tested.

Cross-References

► Altruistic Behavior and Cognitive Specialization in Animal Communities
► Altruistic Learning
► Calibration
► Change of Values Through Learning
► Cognitive Self-Regulation
► Emotional Intelligence and Learning
► Emotional Regulation
► Flow Experience and Learning
► Learning the Affective Value of Others
► Observational Learning: The Sound of Silence
► Prosocial Learning

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Altruistic Behavior and Cognitive Specialization in Animal Communities

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Synonyms

Cooperation; Division of labor

Definition

In contemporary evolutionary biology, an organism is said to behave altruistically when its behavior benefits other organisms, at a cost to itself. The costs and benefits are measured in terms of reproductive fitness or expected number of offspring. So by behaving altruistically, an individual reduces the number of offspring it is likely to produce by itself, but increases the number that other individuals are likely to produce. Eusociality can be considered an extreme form of altruism in animal communities. This is the highest level of social organization in animals. To be considered eusocial, an animal society should meet the following criteria: reproductive altruism (which involves reproductive division of labor and cooperative alloparental brood care), overlap of adult generations, and permanent (lifelong) philopatry. Eusociality was firstly described in social insects, and later discovered in several other organisms including eusocial rodents (several rodent species of the African family Bathyergidae) and shrimps. The next level in the hierarchy of social organizations in animals is cooperative (communal) breeding. This level corresponds to "semisociality" in a classification system of social levels originally suggested by C. D. Michener (1969) and then developed by E. O.Wilson in his *Sociobiology: A New Synthesis* (1975). As distinct from eusociality which is based on irreversible determination of sterile and fertile casts, cooperative breeding is less rigorous. It refers to a breeding system in which individuals other than parents ("helpers") behave altruistically providing additional care for offspring. Many species possess more flexible types of social organization than eusociality and semisociality. However, some social systems are based on facultative division of labor and on temporal limits on breeding for some members of communities.

Altruistic behavior in animal communities is based, to a greater or lesser extent, on the division of roles between individuals depending on their behavioral, cognitive, and social specialization. Social specialization is connected with social roles and tasks performed by community members. Behavioral specialization can be expressed in differences in diets, techniques of getting food, selective reactions to certain stimuli, escaping predators, nestling, and so on. Relatively stable groups can exist in populations that differ by complexes of behavioral characteristics (Bolnick et al. 2003). Some specimens can possess complex behavioral repertoires which enable them to learn pretty fast and effectively within a specific domain. This ability can be called individual cognitive specialization. Cognitive specialization in animal communities is based on the inherited ability of some individuals to form associations between some stimuli easier than between other stimuli and thus more readily learn certain behaviors. Altruistic behavior in animals does not necessarily rely on intelligence and the ability to learn. However, the presence of "cognitive specialists" facilitates the tuning of integrative reactions of a whole animal community to unpredictable influences in its changeable environment.

Theoretical Background

Altruistic behavior of animals is still enigmatic for evolutionary biologists in many aspects. Charles Darwin famously developed a group-selection explanation for the apparent self-sacrificing behavior of neuter insects; however, he found this phenomenon difficult to explain within the frame of his theory of evolution by natural selection. Analysis of these problems became possible on the basis of ideas of gene dominance and fitness outlined by R. Fisher (1930). J. B. Haldane (1932) suggested that an individual's genes can be multiplied in a population even if that individual never reproduces, providing its actions favor the differential survival and reproduction of collateral relatives. In the 1960s and 1970s, two theories emerged which tried to explain evolution of altruistic behavior: *kin selection* (or *inclusive fitness*) theory, due to W. Hamilton (1964), and the theory of *reciprocal altruism*, due primarily to R. L. Trivers (1979) and J. Maynard Smith (1974). The theory of reciprocal altruism is an attempt to explain the evolution of altruism among non-kin. The basic idea is straightforward: it may benefit an animal to behave altruistically toward another, if there is an expectation of the favor being returned in the future: "If you scratch my back, I'll scratch yours" principle. Whereas "kin altruism" is based on animals' ability to recognize relatives and to adjust their behavior on the basis of kinship, reciprocal altruism requires certain cognitive prerequisites, and among them the ability to recognize community members and to keep in mind aftereffects of repeated interactions. A good example here is the finding by G. S. Wilkinson (1984) of blood sharing in vampire bats, which is based on partner fidelity among non-kin individuals. In primates, there is experimental evidence that reciprocal altruism relies on sophisticated cognitive abilities that make current behavior contingent upon a history of interaction and calculation of mutual rewards and punishes (deWaal 2000).

Both kin altruism and non-kin altruism in animal societies are based on the division of roles and thus on great individual variability that includes behavioral, cognitive, and social specialization. It is worth noting that in many eusocial species social specialization is based on the division of roles between members of morphologically distinct castes. For example, termites, social aphids, social shrimps, naked mole rats, and some ants produce special casts of soldiers. In contrast, cognitive specialization is based on intricate distinction between individuals reflected in their learning abilities rather than on morphological and physiological traits.

Important Scientific Research and Open Questions

There are several variants of division of social roles in animal communities, from division of labor in kin groups to a thin balance between altruism and "parasitism" within groups of genetically unrelated individuals. Task allocation in animal communities can impose restrictions on the display of intelligence by the members. For instance, eusocial rodents, termites, and ants condemned to digging or babysitting or suicide defending cannot forage, scout, or transfer pieces of information. Furthermore, subordinate members of cooperatively breeding communities sacrifice their energy and possibly cognitive skills to dominating individuals, serving as helpers or even as sterile workers.

Cognitive specialization in animal communities is based on the ability of some individuals to learn faster within specific domains. In eusocial animals, cognitive specialization between groups of sterile workers can serve for the maintenance of colony integrity. For example, in *Myrmica* ants, some members of a colony learn to catch difficult-to-handle prey much easier and earlier in the course of the ontogenetic development than others do. These individuals can serve as "etalons" for those members of communities that possess poorer skills and can learn from others by means of social learning (Reznikova and Panteleeva 2008). In several highly social ant species (such as red wood ants), a rare case of cognitive specialization between team members have been described (Ryabko and Reznikova 2009). There are stable teams within ants' colony each containing one scout and 4–8 foragers. Only scouts are able to solve complex problems and pass information to other team members. For instance, scouts memorize and transfer the information about a sequence of turns toward a goal; they also can perform simple arithmetic operations. Such feats of intelligence cannot be performed by the foragers. Cognitive specialization within ants' team very much increase effectiveness of solving problems while searching for food (Reznikova 2007). In ant species with low level of social organization, specialization does not predict individual efficiency. Surprisingly, little is known about cognitive specialization in other eusocial organisms, although there is some evidence of great differences in cognitive abilities between individuals in some eusocial species. For example, in honeybees, a few active foragers in a hive can solve problems demanding abstraction and classificatory abilities at a similar level with monkeys and dogs (Mazokhin-Porshnyakov 1969), and in naked mole rats, some colony members use tools while gnawing on substrates (Shuster and Sherman 1998).

In cooperatively breeding animals, members of a society sacrifice their specific behavioral and cognitive abilities to provide food and protection for the few reproductive community members and their offspring. Social groups can be made up of individuals who specialize in certain helping behaviors or those who perform a number of behaviors to differing degrees. For example, in a gregarious bird, noisy minor *Manorina melanocephala*, a considerable number of subordinates that were never seen to provision the young, help intensively with predator mobbing. Furthermore, bad provisioners contribute more to mobbing than good provisioners (Arnold et al. 2005). In meerkats, there is a high variation between helpers in provisioning rates as well as in their exploratory activity. Meerkats exhibit teaching of prey-handling skills and social learning of the use of new landmarks, so individual variability in learning capacities of helpers influences the prosperity of a group (Clutton-Brock 2002; Thornton and Malapert 2009). Both in cooperative breeders and in highly social species with more flexible breeding systems, behavioral and cognitive specialization is tightly connected with division of labor during joint actions. For example, cooperative hunting is based on clearly coordinated actions of individuals which are specialized on different tasks demanding different behavioral peculiarities and cognitive skills. Such division of labor includes “flush and ambush” strategies in Harris’ hawks, “driving and blocking” subtasks in chimpanzees, “center and wing” roles in lionesses, “driver and barriers” subtasks in bottlenose dolphins, and so on (see Gazda et al. 2005, for a review).

Future Research

In virtually all cooperative species, there are large individual differences in altruistic behavior, the causes and consequences of which remain poorly understood despite 30 years of research on the evolution of cooperation. To date, very few studies have used experiments to test the role of cognitive specialization in integrity of animal communities. The intriguing problem is how behavioral and cognitive flexibility interacts with inherited propensities of community members. As altruistic behavior in many species is based on social specialization and division of labor within communities, it is likely that cognitive specialization manifests itself only within distinct strategies. It is still an open question whether clearly distinct behavioral strategies used by community members are based on an evolutionary stable package of features or they are based on flexible decision making. For example, “professional specialization” in cooperatively hunting mammals, such as wolves, wild dogs, and lions, seems rather flexible. However, it is still enigmatic if there is room for intelligence, or cognitive specialization in these and many other situations is based on a high level of inherited predisposition. A hypothesis which explains how community members can learn efficiently complex forms of behavior, based on behavior fragments that they already have in their repertoire, was suggested by Reznikova and Panteleeva (2008). It could be adaptive for members of different species to have dormant “sketches” of complex behavioral patterns being implemented on several carriers and then distributed by means of social learning. The authors call this “distributed social learning” because fragments of useful behavioral programs are distributed among members of a population and remain cryptic until appropriate changes in the environment occur, such as climate changes or appearance of new abundant prey, or new predators, and so on. Indeed, it could be rather costly for animal brains to be equipped with complex stereotypes for all possible vital situations. Propagation of complex stereotypes, new for certain populations, is based on relatively simple forms of social learning which underlies species’ predisposition to learn certain behaviors and does not require feats of intelligence from animals. This hypothesis has been experimentally tested on ants, and there is much to be done for investigating how it can work in vertebrates. There remains an explanatory gap between the growing body of data on displaying cognitive specialization in highly social species and our understanding of possible relations between altruistic behavior and cognitive specialization.

Cross-References

► Abstract Concept Learning in Animals
► Animal Intelligence
► Cognitive Aspects of Deception
► Imitation: Definition, Evidence, and Mechanisms
► Learning Set Formation and Conceptualization
► Linguistic and Cognitive Capacities in Apes
► Social Learning in Animals
► Theory of Mind in Animals

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Altruistic Learning

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Synonyms

Cooperative learning

Definition

Altruistic learning describes the manner in which self-orientated decision-making systems learn about their social environment in a way that yields altruistic behavior. Based on neurobiological accounts of human decision-making, processes such as reinforcement learning and observational learning in game-theoretic social interactions lead to altruistic behavior, both as a result of computational efficiency and optimal inference in the face of uncertainty. Evolutionary pressure acts not over the object of learning ("what" is learned), but over the learning systems themselves ("how" things are learned), enabling the evolution of altruism in otherwise selfish individuals.

Theoretical Background

Many apparently pro-social and cooperative social interactions are self-beneficial, incurring immediate costs that are more than recovered in future exchanges, such interactions being typically formalized within Game Theory. However, extensive experimental evidence points to the fact that humans behave positively toward each other even in situations where there is no self-interested beneficial capacity. Arguments against altruistic interpretations of this type of observation include suggestions that individuals do not understand "the rules of the game," are prone to misbelieve they (or their kin) will interact with opponents again in the future, or falsely infer they are being secretly observed and accordingly act to preserve their reputation in the eyes of beholders (i.e., experimenters). However, these objections have wilted in the face of both experimental evidence (Fehr and Fischbacher 2003), and insights from the neuroscience of learning which suggest that the evolution of altruism might not be as unexpected as economists have traditionally thought (Seymour et al. 2009).

At the heart of arguments about altruism is the difficult question as to why evolution endows otherwise highly sophisticated brains to behave selflessly. This forces attention toward the decision-making systems that subserve economic and social behavior (Lee 2008), and raises a question as to whether they are structured in a way that yields altruism either inadvertently, or necessarily.

Humans have at least three distinct decision systems (Dayan 2008). Goal-directed ("cognitive") decision-making systems function by building an internal model of the environment and derive an explicit representation of outcome states and state-transitions that lead to a specific outcome. Habits, on the other hand, lack specific knowledge of outcome of a decision, being acquired through experience, and involve processes such as associative reinforcement. Lastly, innate ("hard-wired," or Pavlovian) decisions represent the expression of inherited behavioral response repertoires that reflect basic, reliable knowledge gleaned from evolutionary success.

Important Scientific Research and Open Questions

Decision neuroscience has addressed how these basic decision-making systems operate within social interactive environments. For example, many classic game-theoretic paradigms mandate that you choose whether to cooperate or defect, with your payoff depending on both your and the other's choice. A goal-directed, cognitive decision-making policy can consider multiple future scenarios, with an internal model of other people's intentions and planned actions ("Theory of Mind"). It can also infer that he or she also has a sophisticated enough goal-directed system, and hence realize via reciprocal inference that mutual cooperation is often worthwhile (Camerer et al. 2004). There is nothing truly altruistic about this, since you are both simply trying to maximize your own payoff in an environment that contains another intelligent agent. It does, however, require an ability to resist a short-term temptation to exploit mutual reciprocity for immediate benefit, which often exists in game-theoretic paradigms.

Habits operate by allowing recently experienced rewards to reinforce actions that are statistically predictive of good outcomes. If a positive outcome is reliably predicted by an action, then the value of that action is enhanced. In novel social interactions, the goal-directed system will initially dominate. In a stable environment as experience is accumulated, cooperative actions that reliably predict positive outcomes become habitized, saving the substantial computational cost associated with the complex internal modeling of hypothetical interactions. Furthermore, habits may generalize across similar "games." Habits are efficient, but since they do not explicitly represent outcomes, they trade this with the risk of occasionally acting suboptimally. This means that they are prone to acting cooperatively in situations when not doing so might have a greater selfish benefit, yielding true altruism.

A second potential mechanism of learning is by observation of others, and this is especially important when you lack information about the structure of a particular social interaction, and the particular characteristics of others you will interact with. As long as success in others is discernible, observational learning allows you to learn through reverse engineering the policies and intentions of others (Ng and Russell 2000), or simply by imitating their actions. In principle, even though the individual you observe might be cooperating for purely selfish reasons, it will usually not be possible to infer this with certainty, not least because the selfish benefits of cooperation are often long-term. Hence learning pro-cooperativity in this manner will generalize across both selfish and truly altruistic social interactions, as long as long term benefits outweigh any losses incurred through using this mechanism.

A critical feature of both mechanisms, and decision systems in general, is that they deal with learning processes optimized for dealing with the vast diversity and complexity of situations that arise in the real world. That is, they very rarely specify a particular action to take in a particular situation (as the innate system does), their evolutionary selection deriving from their utility as a general decision process. Hence, any economically suboptimal propensity to yield true altruism is dwarfed by other abilities to behave near-optimally across new, diverse, and uncertain situations. Indeed, that pro-social behavior is likely to be self-beneficial in the vast majority of evolutionary situations (since humans tend to live in small communities where reciprocity and reputation formation are strong) suggests that the innate decision-making system might actually "hard-wire" cooperativity in humans, although this has so far been difficult to determine experimentally.

Cross-References

- ► Altruism and Health
- ► Goal Theory/Goal Setting
- ► Learning the Affective Value of Others
- ► Reinforcement Learning

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Ambitions

► Goals and Goalsetting: Prevention and Treatment of Depression

Amnesia and Learning

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Synonyms

Learning and amnesia; Learning and loss of memory

Definition

Amnesia refers to a difficulty to remember information encountered before (retrograde amnesia) and/or after (anterograde amnesia) the event that caused it. Amnesia is often caused by neurological damage, in particular to the medial temporal lobes (MTL). Amnesia specifically affects recollection of personally experienced events (episodic memory) and facts (semantic memory). Other, non-declarative types of memories are relatively spared. For instance, individuals with amnesia can often learn new skills and habits, and show priming and simple conditioning effects. These spared forms of learning have in common that they are expressed as a gradual change in behavioral performance over repeated learning instances. Crucially, they don't require recollection of the learning instances themselves.

Theoretical Background

Amnesia is often caused by neurological damage, in particular to the hippocampus and wider medial temporal lobes (MTL), as well as the medial diencephalon. Causes of neurological amnesia include physical trauma (e.g., head injury, surgery), disease (e.g., Alzheimer's disease), infection (e.g., herpes simplex encephalitis), chronic drug and alcohol abuse, and reduced blood flow to the brain. The damage can be bilateral (implicating both sides of the brain), or unilateral (implicating either the left or right side of the brain). Unilateral damage results in amnesia for specific materials: left-sided damage affects mostly memory for verbal material, while right-sided damage especially affects memory for nonverbal material (e.g., faces and spatial maps). Neurological amnesia can result in both retrograde and anterograde amnesia. A similar, but transient form of amnesia can also be induced pharmacologically, by, e.g., the benzodiazepine diazepam or the anticholinergic drug hyoscine. Functional amnesia, a psychiatric disorder which can be caused by severely stressful life-events, is much rarer and only results in retrograde amnesia.

Amnesia involves the inability to recollect personally experienced events (episodic memory) and factual information (semantic memory, e.g., "Paris is the capital of France"). Both are forms of declarative memory and are what is commonly understood by "memory." In retrograde amnesia, there is a difficulty in remembering declarative information acquired before the onset of amnesia. Retrograde amnesia is often temporally graded, being more severe for information encountered in the recent than in the more distant past. Depending on the severity of the neurological damage, the memory loss may cover a period from a year to decades. This temporal gradation suggests that while the MTL and medial diencephalon play a crucial role in the consolidation of memory, they are not themselves the repositories of long-term memory.

Anterograde amnesia involves difficulties in learning new facts and events after the onset of amnesia; amnesic individuals show profound forgetfulness. In severe cases, this has been described as forgetting events almost as soon as they have happened. Amnesic individuals show impaired declarative learning whether memory is tested by free recall (e.g., recalling as many items as possible from a previously studied list), cued recall (e.g., presenting the first letter of the to-be-remembered item), or recognition (presenting items and asking whether they came from a previously studied list). Interestingly, anterograde amnesia seems specific to declarative memory. Other forms of memory are relatively spared. Amnesia does not affect short-term memory. For instance, individuals with amnesia are able to repeat short sequences of digits, as long as they can actively rehearse the sequence during the retention period. Intact short-term memory is crucial to most tasks and, for instance, allows one to have a normal conversation. Non-declarative memory is also typically spared in amnesia. In particular, amnesic individuals have been shown to be relatively unimpaired in the following forms of learning (Gabrieli 1998; Squire et al. 1993):

- *Motor and perceptual skill learning.* Unimpaired skill learning has been shown for a number of tasks, including mirror tracing, rotary pursuit (tracking a moving object), response sequence learning (matching responses to visual cues that occur in a fixed sequence), and reading mirror-reversed text.
- *Priming.* Priming involves the facilitation of a response through previous exposure to related material. Individuals with amnesia have been found to exhibit unimpaired levels of repetition priming, identifying stimuli more rapidly when they have been presented before, despite being not able to recollect the previously presented information.
- *Simple conditioning.* Certain forms of simple conditioning are also spared in amnesia. One example is eye-blink conditioning, where presentation of an auditory tone signals an air puff directed to the eyes. As long as the tone overlaps with the air puff, the tone itself starts to elicit an involuntary eye-blink. However, if there is a brief interval between the tone and the air puff, amnesic individuals show reduced learning of this conditioned response.
- *Probabilistic category learning.* These tasks involve predicting an outcome from a number of cues which are probabilistically related to the outcome. It has been found that amnesic individuals' prediction accuracy increases at a similar rate to controls (Knowlton et al. 1994; Speekenbrink et al. 2008), at least in the initial stages of learning.

The non-declarative forms of learning above have in common that they are directly expressed through performance rather than recollection. In principle, these tasks can be learned by gradual strengthening stimulus–response associations, without the need for conscious recollection of the experienced training episodes. Indeed, it has been found that amnesic patients can learn new semantic knowledge in such a way. For instance, it has been found that amnesic individuals can learn simple factual statements after many repetitions. A factor that may enhance such learning in amnesia is the reduction of interference from competing alternatives. Non-declarative memory typically involves emitting the strongest response from the available actions, so performance is increased by strengthening the correct response. When responses are freely chosen, individuals can inadvertently strengthen the incorrect response. This is prevented in "errorless" learning, where individuals are prevented from making incorrect responses during training, thus reducing interference from incorrect responses in later tests. Errorless learning has been shown to sometimes drastically improve declarative memory in amnesia (e.g., Wilson et al. 1994).

The finding that amnesic individuals are relatively unimpaired in non-declarative learning tasks has led to the claim that declarative and non-declarative memory are supported by neurologically and functionally independent memory systems (e.g., Squire et al. 1993). According to this view, declarative learning depends on the MTL and medial diencephalon, the areas affected in amnesia. Non-declarative learning depends on other brain structures, in particular the basal ganglia, and is not affected by amnesia.

Important Scientific Research and Open Questions

Early research on the effects of amnesia on learning comes from single-case studies. A famous and extensively studied patient is H.M., who, following a bilateral lobectomy (large parts of both sides of the MTL were removed), retained normal intellect but suffered severe anterograde amnesia (as well as graded retrograde amnesia). A problem with single-case studies is that the results can depend on the precise nature of the brain damage. This makes direct generalization to other individuals with amnesia problematic. Research with animals allows precise control over the neurological damage, but may not always directly apply to amnesic humans. The results of research comparing groups of amnesic patients to matched controls can give inconsistent results. Patient groups are usually relatively small and include patients with a wide variety of neurological profiles, which may partly explain inconsistent results between experiments.

While there is little disagreement that amnesia involves a profound loss of episodic memory, its impact on semantic memory is more controversial (Spiers et al. 2001). Semantic learning is spared in some amnesic individuals, despite severe episodic memory problems, and other amnesic individuals are able to learn semantic information after many repetitions.

While non-declarative learning is often found to be relatively unimpaired, there are studies that do show significant impairments. It is important to note that results on amnesia are typically comparative to unimpaired control individuals. Thus, unimpaired performance means that no difference could be detected between amnesic and control individuals. But, due to the relatively small sample sizes in patient studies, these null findings may be due to lack of statistical power. A more cautionary conclusion is that amnesia impairs performance on non-declarative tasks to a lesser extent than performance on declarative tasks. This implies that declarative and non-declarative memories are not necessarily independent, which has led to a debate whether memory consists of multiple systems, or is really a unitary system. A related issue concerns the implicit nature of non-declarative memory. Declarative memory is usually taken to be explicit, requiring direct access to conscious recollection. Non-declarative memory is taken to be implicit, acquired without awareness, and inaccessible to conscious recollection. The explicit/implicit distinction is often taken to be synonymous to the declarative/non-declarative distinction. Thus, amnesia is taken to involve impaired explicit, but unimpaired implicit learning. However, the idea that learning can occur in the complete absence of awareness is controversial. Moreover, amnesic patients can show conscious insight into what they have learned in non-declarative tasks (Speekenbrink et al. 2008).

Cross-References

- ► Explicit Learning
- ► Habit Learning in Animals
- ► Implicit Learning
- ► Memory Dynamics

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Amphetamine, Arousal, and Learning

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Synonyms

Monoaminergic drug; Neuroenhancement; Neuromodulation; Psychostimulants

Definition

Amphetamine (alpha-methylphenethylamine), first synthesized by the Romanian chemist Lazăr Edeleanu in 1887, is an indirect sympathomimetic psychostimulant drug, which centrally and peripherally stimulates the release of endogenous biogenic amines by binding to the monoamine transporters, thereby phasically increasing extracellular levels of norepinephrine, and to a smaller degree dopamine and serotonin. The most studied compound is its d-isomer, *dextroamphetamine*, which has a higher bioavailability and fewer systemic effects compared to the racemic mixture (containing levo- and dextroamphetamines in equal amounts). After oral administration of a typical dose of 0.25 mg/kg body weight in human adults, blood plasma levels reach their maximum after 30–120 min and decline after 5–6 h, due to the short plasma half-life (12–13 h). Behavioral drug effects (of therapeutic doses) are increased arousal, mood elevation, improved concentration, and suppressed appetite. The most common *central side effects* are insomnia and agitation; the most common *peripheral side effects* are hypertension and cardiac arrhythmias.

Theoretical Background

Learning involves changes in synaptic strengths induced by activity-dependent coincident firing of pre- and postsynaptic neurons (► Neurotransmission). Additionally, synaptic strength is affected by heterosynaptic modulatory input (► Neuromodulation). Over the past decade, there has been an enormous interest in drugs with the potential to boost "normal" learning as well as functional recovery after brain injury (► Neuroenhancement). Animal studies have shown that dextroamphetamine effectively increases general *brain excitability* and enhances the formation of new neural networks when administered together with intensive sensory stimulation/behavioral training. Studies of healthy human adults have demonstrated increased working memory functions, procedural and associative learning performances, and improved retention of verbal material after oral dextroamphetamine administration. The relationship between dextroamphetamine doses and learning efficiency, however, seems to follow a *U-shaped curve*, with maximum learning success at medium drug doses (Goldstein 2009). Furthermore, the optimal drug dose may differ between individuals depending on their specific set of genetic polymorphisms (e.g., catechol *O*-methyl transferase=COMT, brain-derived neurotrophic factor=BDNF; DRD2).

Learning enhancement by dextroamphetamine may be accomplished via four different molecular pathways. First, its effects on *noradrenergic neurotransmission* lead to more focused attention during learning processes. Secondly, an indirect contribution to enhanced learning and memory may be through a *neuromodulatory facilitation of NMDA-receptor-gated mechanisms* in memory-relevant brain structures like the hippocampus, leading to the induction of long-term potentiation and subsequently to more effective memory consolidation (Kandel 2001). Third, dextroamphetamine's effects on *dopamine transmission* can modify two different dopaminergic processes: Tonic dopamine levels, maintained by slow irregular cell firing, contribute to maintaining alertness during learning and working memory functions. Phasic dopamine release enhances learning via increasing intrinsic reward signals (Schultz 2007). Either of these two dopamine functions is enhanced by dextroamphetamine (Breitenstein et al. 2006). Fourth, dextroamphetamine also increases extracellular levels of *other monoamines like serotonin*, and may, therefore, affect learning by other mechanisms like elevated mood states.

Important Scientific Research and Open Questions

Current clinical indications for dextroamphetamine are *narcolepsy* (with the goal of increasing alertness) and *attention-deficit hyperactivity disorders* (by improving attention). Both animal work and several small clinical trials with *stroke* patients indicate that pharmacological interventions coupled with intense behavioral training can enhance recovery days to weeks poststroke (Barbay and Nudo 2009). Among the most effective drugs, when given at sufficiently high doses, with respect to both motor and language recovery after stroke in humans is dextroamphetamine. To date, there is a lack of randomized controlled clinical trials supporting "class 1" evidence for treatment efficacy in stroke patients (Martinsson et al. 2007). Reasons for the paucity of relevant studies may be safety concerns due to dextroamphetamine's cardiovascular side effects and its addiction potential. Furthermore, explanations for the inconsistency of amphetamine effects across studies may be offered by the different dosing and timing schemes. The long-term administration of amphetamine under routine clinical conditions may also yield detrimental effects due to its sleep-depriving effects, which may impair ► sleep-dependent memory consolidation and thus hamper the relearning of lost functions.

The as of yet unresolved question is how exactly amphetamine administration modulates learning. Future studies have to elucidate which of the four aforementioned molecular pathways presents the major mediating mechanism of amphetamine's learning enhancement to determine whether the effect is (a) a simple increase in arousal (which could also be achieved by administration of safer substances, like caffeine) or (b) a more direct neuromodulatory effect in memory/internal-reward-related brain structures. If learning enhancement could be achieved without (cardiovascular) arousal, alternate substances or procedures (like physical exercise) could be more safely applied, particularly in patients with critical cerebrovascular conditions, like hypertension and cardiac disease.

Cross-References

- ► Abilities to Learn: Cognitive Abilities
- ► Acceleration of Learning in Networks
- ► Arousal and Paired-Associate Learning
- ► Associative Learning
- ► Attention Deficit and Hyperactivity Disorder
- ► Dreaming as Consolidation of Memory and Learning
- ► Drug Conditioning
- ► Exercising and Learning
- ► Neuropsychology of Learning
- ► Superlearning

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Amygdala

A part of the limbic system, located in the medial temporal lobe of the brain. The amygdala is found just anterior to the hippocampus, and has been shown to be critical for the processing of emotional information and the formation of emotional memories.

Analogical Coherence/ Correspondence

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Synonyms

Multi-constraint theory of analogical thinking; Parallel constraint satisfaction theory of analogy; Retrieval or mapping

Definition

An analogy can be thought of as the existence of a type of similarity relationship between at least one source domain and one target domain that are not identical. It may also be thought of as the linguistic, imagistic, or other expression of such a relationship. Finally, analogy can refer to the cognitive processes involved in comparing the source and the target of an analogy, where that comparison may be made for different purposes. Correspondences are the mappings between the source and the target making up the analogy. Sometimes "correspondence" is used to refer to the mapping of a specific element in the source domain to the target; sometimes it refers to the overall comparison or set of mappings between domain and target. Herein, "correspondence" will be used in the former sense. The coherence or multi-constraint approach to analogy computes correspondences between source and target elements by using the constraints of similarity, structure, and purpose. Each of these constraints is soft; this is to say that they are assigned weights and need not be perfectly satisfied in every case. The interpretation of source and target that satisfies the most constraints, or is most coherent, is selected. The coherence approach allows for a graded notion of analogy – things can be more or less analogous. In the limiting or ideal case, there is an isomorphism between source and target elements in the analogical mapping.

Theoretical Background

The classical Greek term for analogy – αναλογία or *analogia* – is sometimes translated as "proportion" or even "ratio." It was not uncommon for thinkers like ► Aristotle to use mathematical examples such as 2 is to 4 as 4 is to 8 to explicate the notion of *analogia*. However, the concept was not restricted to mathematics. Toe is to foot as finger is to hand would also be considered an *analogia*. The key idea is that there is some sort of relation or pattern that is common to both the source and to the target. As Cameron Shelley (2003) makes clear, the classical notion of *analogia* is not restricted to a single relation (such as x is twice y, or x is an appendage of y) holding between a source and target. More complex patterns may be at issue. Moreover, classical theorists understood that analogies could be used not only to explain but also to argue or persuade. These classical views had a powerful influence on medieval thinkers, and work on analogy continues to the present day. Contemporary work on analogy retains some of the insights of classical theorists.

The structure mapping approach is currently the dominant paradigm for understanding analogy in psychology and cognitive science, and it preserves the classical emphasis on the importance of relational structure. The solar system is like the atom – this analogy draws on the sharing of a 2-place or relational predicate, x revolves around y, shared by the planets and the sun as well as by electrons and the nucleus of an atom. More complex relations are also possible: three-place relations (e.g., x is between y and z), four-place relations, and so on. It is also possible to assert relations about relations, or higher order relations. First order and higher order relations are often referred to as relational structure, and they figure centrally in the psychological/cognitive theory of analogy pioneered by Dedre Gentner (1983). (Not all similarities are relational: the sun and corn are similar because they share the attribute or monadic predicate "is yellow.") Analogical coherence approaches can be seen as a variation on the structure mapping approach. They compute correspondences between source and target by using relational structure as one source of constraints, but there are other sources as well. Before getting to that, a few words are in order about why constraints are needed.

Any two things may be said to have properties or relations of *some sort* in common. My beta fish and I are both alive; we are both millions of kilometers away from the sun; we both live in the Milky Way galaxy; the force of gravity acts on both of us, as does the electromagnetic force, and we could go on and on outlining the many trivial similarities that hold between my beta fish and me. But this does not shed much light on what makes two things analogous. If any sort of similarity will do, then anything can be said to be analogous to anything else. Some constraints would appear to be needed for a more informative notion of analogy.

As we have already seen, commonality of relational structure between the source and target is one of the constraints used by the coherence or multi-constraint approach to analogy. This approach also stresses the importance of a specific sort of similarity in understanding analogy. Sometimes referred to as semantic similarity, this constraint is about the network of relationships that hold in the concepts involved in a purported analogy. For example, concepts can be related to one another as superordinate or subordinate. If Lassie and Spot are dogs, then they are both subordinates of the concept *mammal*, which is a subordinate of the concept *animal*, which is a subordinate of *living thing*. *Fish* is not a subordinate of *mammal*, but it is a subordinate of *living thing*. Say John is a human being and Charley is a goldfish. Looking simply at the hierarchy we have just examined, it might make sense to say that Lassie and Spot are more similar to one another than to John since Spot and Lassie are dogs and John is not. It might also make sense to say that Lassie and Spot are more similar to John than they are to Charley given that Spot, Lassie, and John are all mammals and Charley is not. Of course, this is much too simple since there are many different relationships that can hold between concepts besides superordinate and subordinate. That said, the idea is that semantic similarities holding between concepts are operative as constraints on how analogies are constructed, retrieved from memory, or understood. Sometimes perceptual similarities are also built into this notion of *semantic* similarity.

Purpose is the third constraint postulated by the coherence approach. Some of the applications or purposes of analogy making include explaining, arguing, or persuading, forming new concepts, generating predictions, solving problems, and evoking an emotional response. Say that Lassie is a loyal dog and Spot is not, and that we are in a context where this is well known. Someone in this context who wants to disparage John for his lack of loyalty may well compare him to Spot for the purpose of evoking a negative, disapproving emotional reaction toward John. If Henry is a loyal man, the analogizer may find it more useful, for the purpose of disparaging John, to compare John with Spot than with Henry. While this sort of analogy goes against the superordinate and subordinate semantic similarities considered in the previous paragraph, there may well be enough other semantic similarities or structural correspondences to fulfill the purpose of the analogy. For other purposes, the purported analogy may not work at all.

In the coherence or multi-constraint approach to computationally modeling analogy, positive and negative weights are assigned to the different possible connections between source and target elements in a way that instantiates the aforementioned constraints, and a coherence optimization or constraint satisfaction algorithm is run to maximize the satisfaction of as many constraints as possible. Different sets of possible correspondences between the source and target essentially compete against one another for acceptance.

Important Scientific Research and Open Questions

The originators of the coherence approach to understanding analogy are Keith Holyoak and Paul Thagard. The basic idea of the three constraints at work was being formulated in the mid-1980s, and powerful connectionist implementations (see ► Connectionism) began to arrive by the late 1980s and early 1990s. (See Holyoak and Thagard [1995, Chap. 10] for a history of the early years of this approach.) They developed a computational implementation of the coherence approach for carrying out analogical mappings – the Analogical Constraint Mapping Engine (ACME). They also developed an implementation for retrieving analogues from memory – Analogue Retrieval by Constraint Satisfaction (ARCS). Holyoak and Hummel (2001) went on to develop a more biologically realistic implementation of the multi-constraint theory of analogy called LISA (Learning and Inference with Schemas and Analogies). Thagard and Shelley (2001) have incorporated the analogical coherence into HOTCO (hot coherence), a strategy for constructing artificial neural networks that model the analogical transfer of emotions (as well as other aspects of cognition). The range of possible applications of analogy is vast, including but not limited to: analogical modeling of language, analogical reasoning, analogical reasoning in animals, analogical reasoning of young children, and problem solving. From the early days of the coherence approach to analogy, it was understood that *schemas* would play an important role in the *analogical transfer* of information. It was thought that theory of analogy could make a contribution to our understanding of *concept learning* and *conceptual change* (and that work on these later areas could improve our understanding of analogy).

As Holyoak and Thagard (1995) point out, much work remains to be done. Analogies may be visual or imagistic, and while some work has been done on the subject, more remains to be done with visual and other sensory modalities. Some analogies may even be multimodal. For example, it might be argued that a scene in one movie is analogous to a scene in another movie, and the analogy may consist in the correspondence of elements pertaining to plot structure, visual images, and sounds. The definition of analogical coherence offered above is silent on the nature of the elements that correspond to one another in an analogy. While much of the work on analogy has focused on linguistic representations of concepts, not all work has this focus, and more work will likely be done that does not have this focus. For these reasons, the nature of the elements being mapped (linguistic/conceptual, imagistic, auditory, multimodal, or whatever) has been left open.

Finally, the limits and scope of analogical coherence need to be better understood. For example, Dirk Schlimm (2008) has provided a thought-provoking critique of the limits of the structure mapping approach in domains such as mathematics. The direct target of the critique is the work of Gentner and her collaborators, but the critique suggests limits for any approach making the mapping of structural relations central to understanding analogy (and this includes the multi-constraint approach). The point of the critique is not that there are no analogies in mathematics; rather, it is that mathematical analogies are best understood using an axiomatic approach to modeling.

Cross-References

- ► Analogical Model(s)
- ► Analogy/Analogies: Structure and Process
- ► Analogy-Based Learning
- ► Case-Based Learning
- ► Learning Metaphors
- ► Measures of Similarity
- ► Memory Structure
- ► Mental Models
- ► Model-Based Reasoning
- ► Model-Based Learning
- ► Similarity Learning

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Analogical Models

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Definition

► Analogical Models derive from a general theory for predicting behavior called Analogical Modeling (AM). Although most work in AM has been done in predicting language behavior, the theory is general enough so that it can be applied to almost any kind of problem involving classification or categorization according to a predefined set of outcomes. Predictions are directly based on a data set of exemplars. These exemplars give the outcome for various configurations of variables, which may be structured in different ways (such as strings or trees).

The most common method in AM has been to define the variables so that there is no inherent structure or relationships between the variables (that is, each variable is defined independently of all the other variables). In this case, the variables can be considered a vector of features. In the data set, each feature vector is assigned an outcome vector. The data set is used to predict the outcome vector for a test set of given contexts – that is, various feature vectors for which no outcome vector has been assigned (or if one has been assigned, it is ignored).

In AM, the resulting predictions are not based on any learning stage for which the data set has been analyzed in advance in order to discover various kinds of potential relationships between the feature vectors and their associated outcome vectors. Neural nets, decision trees, and statistical analyses that determine the significance of the features in predicting the outcomes all rely on first learning something about the data set and then using that information to make predictions. AM, on the other hand, directly uses the data set to make a prediction for each specific feature vector in the test set.

Theoretical Background

The basic theory of AM (Skousen 1989, 1992; Skousen et al. 2002) was developed during 1979–1987 and works from the hypothesis that in trying to predict the outcome (or behavior) for a vector of features, we consider all possible combinations of those features. Using a simple quadratic measure of uncertainty (not the traditional logarithmic one of information theory), we select those combinations of features that never permit any increase in the uncertainty. Those combinations that increase the uncertainty are referred to as heterogeneous and are eliminated from the analysis.

Another way to look at AM is to view each combination of features and its predicted outcome as a rule that maps from the feature combination to the outcome. The homogeneous combinations can be considered "true rules," the heterogeneous ones as "false rules." In other words, AM uses only the true rules; the false rules are ignored. Given that we have determined the true rules, the question then becomes: What are the chances of using a particular true rule to predict the outcome? The false rules, of course, are all assigned a probability of zero. Among the conceptual possibilities for assigning a probability to a true rule are the following: (1) each rule is equally probable; (2) the probability is proportional to the frequency of the rule in the data; (3) the probability is proportional to the square of the frequency of the rule. Over time, it has become clear that the third choice is the simplest and most natural since it directly uses the same quadratic measure of uncertainty that is already needed to determine which rules are true (that is, which feature combinations are homogeneous in behavior). Moreover, the third choice has provided the most accurate results in predicting language behavior, including the appropriate degree of fuzziness that occurs at the boundaries of linguistic behavior.

Important Scientific Research and Open Questions

AM has had considerable success in explaining actual language behavior and has commonly been referred to as ► Analogical Modeling of Language. The first work in AM began with Royal Skousen's description of the indefinite article in English and the past tense in Finnish (Skousen 1989), and this was followed by Bruce Derwing and Royal Skousen on the past tense in English (Derwing and Skousen 1994), David Eddington on various problems in Spanish morphology (Eddington 2004), and Harald Baayen and his colleagues in the Netherlands on various aspects of Dutch morphology (Ernestus and Baayen 2003). Steve Chandler has provided a thorough comparison of AM with connectionist models of language as well as with a number of competing instance-based models. Chandler has shown how AM, a single-route approach to language description (that is, AM has a single conceptual mechanism), can readily handle various experimental results that were earlier claimed to be possible only in dual-route approaches to language; moreover, Chandler has found evidence from various psycholinguistic results that only AM seems capable of explaining (see Chandler's article in Skousen et al. 2002).

One important aspect of AM is that the analysis is not restricted to just the important or crucial variables. We need to include so-called unimportant variables in order to make our predictions robust. The unimportant variables are crucial for predicting the fuzziness of actual language usage. Specifying unimportant variables also allows for cases where the preferred analogy is not a nearest neighbor to a particular given context, but is found in a gang of homogeneous behavior at some distance from the given context.

Another important aspect is that AM requires imperfect memory. In order to model the variability of language properly, it is necessary to assume that access to exemplars is probabilistic and works on a random basis.

A useful source for applying AM to various sorts of linguistic problems can be found in Skousen et al. 2002; an appendix by Deryle Lonsdale suggests ways of applying AM to nonlinguistic problems, such as analyzing congressional voting records and identifying toxic mushrooms.

One serious problem in applying AM has been the exponential explosion in running time and memory requirements. Adding one variable to an analysis basically doubles these requirements. More recently, Skousen has developed ► Quantum Analogical Modeling, a quantum mechanical approach to AM that provides a simultaneous method of determining which feature combinations are homogeneous in behavior, thus reducing the exponential explosion to a tractable algorithm in no more than quadratic time and space.

Cross-References

► Analogical Modeling of Language
► Quantum Analogical Modeling

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Analogical Modeling of Language

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Synonyms

Language modeling

Definition

There are today several theoretical approaches to modeling language which posit an analogical basis for linguistic behavior, including ► connectionist models and exemplar-based models. Although connectionist models do not retain individualized memories for instances of linguistic behavior, the exemplar-based models all have in common that they operate on a new instance of linguistic behavior by comparing it systematically to remembered examples of similar instances and then choosing from memory one or more of those previously experienced examples to serve as the basis for an analogical interpretation or prediction of behavior for the new instance. Those models differ crucially, however, in how they identify the examples from memory that are to serve as the basis for the analogical operation. This entry describes specifically how Royal Skousen's ► Analogical Model (AM) interprets and predicts linguistic behavior.

Theoretical Background

Throughout the history of Western thought about language, grammarians and linguists have almost all assumed, either explicitly or implicitly, that linguistic usage – that is, the production and comprehension of language – operated analogically. In 1966, however, Noam Chomsky argued that all such appeals to analogical processes are vacuous as a linguistic theory because they cannot account explicitly for the creative aspects of linguistic usage such as whether a speaker of American English might choose to express the nonce verb *grive* as *grove* in the past tense, presumably on analogy with familiar English verbs such as *drive* or *dive*, or as *grived*, on analogy with regular verbs such as *gripe* or *dive*. (In American English the verb *dive* typically takes the irregular past tense form *dove*.) Ironically, much subsequent research has demonstrated consistently that any adequate model of language must include some sort of analogical mechanism of just the sort that Chomsky rejected (e.g., Pinker 1999). To date, connectionist approaches have provided the most popular framework for incorporating analogy into linguistic models. Skousen's AM, however, offers an alternative rebuttal to Chomsky's criticism of analogical models in general, and it exhibits several theoretical and empirical advantages over the connectionist approaches. For example, it predicts explicitly, and accurately, that a speaker will produce *grived* as the past tense of *grive* (about three fourths of the time) and *grove* (about one fourth of the time). The crucial theoretical question has now become whether an analogical model such as AM is adequate to account for both the irregular behavior just noted and the regular behavior that generativists have cited to motivate their models of language. The research to date suggests strongly that it is.

Skousen developed AM primarily as a usage-based alternative to the rule-based competence grammars of ► generative linguistics and, to a lesser extent, to the connectionist models that were then attracting considerable attention either as alternatives to generative ► grammar or as supplements to them (the so-called ► dual mechanism models as described in Pinker 1999). Consequently, Skousen developed AM independently of parallel theoretical developments then underway in cognitive psychology (the *Generalized Context Model*, only later applied to language) and largely independently of work in computational linguistics in Europe (*memory-based learning*). Since AM is essentially an *exemplar-based* (or *instance-based*) model of categorization, it often is compared directly to both connectionist models of language behavior as well as to other exemplar-based approaches to modeling linguistic and cognitive behavior. Steve Chandler (2002, 2009) has provided a thorough comparison of AM with connectionist models of language as well as with competing exemplar-based models, and he has described various theoretical and empirical advantages that the AM appears to exhibit over those competing models. Most importantly, AM researchers have reported results from various psycholinguistic studies that only exemplar-based models seem capable of explaining and that only AM seems capable of explaining without additional theoretical assumptions (Chandler 2002, 2009).

Skousen's *Analogical Model* predicts the behavior of a linguistic form by first comparing it systematically, feature by feature, with similar forms that have been encountered before and are retained in one's long-term memory, the data set (in computer simulations, a corpus of examples exhibiting the linguistic behavior of interest). The model then compares the new form with all the verbs in memory that share any phonological features with it. Thus, a nonce verb such as *grive* (represented in the International Phonetic Alphabet as [graiv]) would be compared with all the verbs in memory that share the following phonological segments or subsets of segments with it: [grai_], [gr_v], [g_aiv], [_raiv], [g _ _ v], etc. Notice that some feature subsets (*supracontexts* in AM) such as [_ _ aiv] correspond to both the irregular verb *dive* with its past tense form *dove* (in American English) and to the regular verb *jive*. Once the set of forms from the data set sharing each supracontext has been identified, another procedure within the AM program then determines which of those supracontexts, if any, introduce additional uncertainty – in an information-theoretic sense – about what the possible outcomes might be. Those *heterogeneous* supracontexts, and their associated verbs, are eliminated from further consideration in the analogical process. The verbs associated with the remaining supracontexts, the homogeneous ones, become part of the *analogical set*, the set of candidate sources for an analogical inference. Finally, a *decision rule* selects one or more of the forms in the analogical set to become the basis for an analogical operation on the target item.

From its beginning, AM has shown considerable success in replicating within a single theoretical framework a variety of actual language behaviors, including categorical behaviors (such as voice onset time), competing regular and irregular behaviors (as in the English past tense), and idiosyncratic behaviors. Skousen's initial work dealt successfully with issues as diverse as English indefinite article form, Finnish past tense verb forms, and terms of address in Colloquial Egyptian Arabic (Skousen 1989). Subsequent work by others has extended the AM to an even more diverse set of linguistic issues in phonetics, phonology, and morphology, in an increasing variety of languages, and addressing an ever broader array of linguistic data sources, such as child language acquisition studies, studies of psycholinguistic representation and processing, and studies of sociolinguistic variation (see Chandler 2009 for a recent survey of AM research).

Impressively, as illustrated below, the application of AM to linguistic data – even to data thought to be already well-described and well-understood – has often revealed new details about linguistic behavior beyond those that originally motivated the study. For example, other exemplar-based models of language rely crucially on anticipating – through preliminary analysis of a data set – which variables appear to convey more information than others about a form and its predicted behavior. The AM includes no such assumptions or preliminary analyses and simply treats all of the remembered features, or variables, that the forms in the corpus (data set) exhibit as potentially of equal importance. The value of this assumption shows up readily in even so seemingly simple an issue as predicting the English indefinite article form, *a* or *an* for which including seemingly "unimportant" variables makes possible several unexpected yet robust predictions about indefinite article usage in English.

The conventional "rule" governing the English indefinite article form seems to base the choice exclusively on the initial sound of the next word. Knowing that the following sound, whether consonant or vowel, "determines" the article form (*a* before consonants, *an* before vowels), a linguist could specify only the syllabicity of the following sound and thus predict *a*/*an* without error. Basically, that solution would be specifying a single rule analysis for the indefinite article form. Yet in modeling the behavior of the indefinite article, AM specifies not only the first sound of the following word but also the subsequent sounds in that word, supposedly unimportant variables. But by adding these other variables, AM is able to predict several behavioral properties of the indefinite article that are not predicted by the traditional, rule-based account: (1) the one-way error tendency of adult speakers to replace *an* with *a* (but not *a* with *an*); (2) children's errors favoring the extension of *a*, but not *an*, such as *a upper*, *a alligator*, *a end*, *a engine*, *a egg*, and *a other one*; and (3) dialects for which *an* has been replaced by *a*, but not the other way around. In other words, the "unimportant" variables turn out to be crucial for predicting the fuzziness of actual language usage. Finally, another unexpected but important consequence is that AM can predict the indefinite article even when the first sound is obscured (i.e., when one cannot tell whether that sound is a consonant or a vowel). In such cases, the other variables are used to guess the syllabicity of the obscured sound or even the word itself, thus allowing for the prediction. In other words, AM allows for robustness of prediction. If we assume a symbolic rule system with only one rule (one based on the syllabicity of the first sound), then no prediction is possible when that sound is obscured.

Some early exemplar-based models sought to identify the "nearest neighbor," the example most closely resembling the target form, as the basis for an analogical extension. However, this approach is empirically wrong, and such models often predict incorrect results. Other exemplar-based models address this problem by adding a preliminary procedure which evaluates the predictive value of different features and then weights the features accordingly before running the analogical program. Unfortunately, since those weighted feature values do not transfer to different data sets or to different tasks, they have to be recalculated each time a data set is revised (e.g., new exemplars added) or applied to a new task. Again, however, when forms are represented more generally and include variables that a priori may seem "unimportant," the test for homogeneity leads AM to predict the preferred analogy even when it is not based on a nearest neighbor to the target form. Sometimes, the correct exemplars are found in a gang of homogeneously behaving examples that are not the ones that resemble the target form most closely. An important example of this occurs in predicting the past tense for the Finnish verb *sortaa* "to oppress." Standard rule analyses of Finnish as well as nearest-neighbor approaches to language prediction argue that the past tense for this verb should be *sorsi*, whereas in fact it is *sorti*. Yet when AM is applied to predicting the past tense in Finnish, it is able to predict the correct *sorti*, mainly because AM indirectly discovers that the o vowel is the "crucial" variable in predicting the past tense for this particular verb. In previous analyses (typically based on the historically determined "crucial" variables), the o vowel was ignored. But AM, by specifying both "important" and "unimportant" variables uniformly across the whole word, is able to predict this "exceptionally behaving" verb correctly.

Important Scientific Research and Open Questions

The field of linguistics is currently undergoing a major paradigmatic shift in theory as more and more linguists move away from the generative theory that has dominated linguistics for the past half century. Analogical modeling described here represents one of the most radical departures from the established theoretical paradigm yet proposed. Virtually all theories of language posit that the brain somehow develops a set of resident linguistic generalizations about one's language that then becomes the basis for speaking that language (that is, it becomes one's grammar for the language). AM posits that one's knowledge of a language – the ability to speak a given language – does not reside in a set of resident linguistic generalizations about the language. Instead it resides in a process that allows one to accumulate examples of linguistic usage and then use those examples to interpret or produce new instances of usage "on the fly" by identifying one or more of those previous experiences as the basis for operating on the instance analogically. To date, AM has been applied to only a relatively few types of linguistic usage. Nonetheless, it has proven not only capable of modeling linguistic behavior extremely accurately but as well as – and often better than – the alternative models of language can. Moreover, its applications have often led to unexpected, deeper insights into the nature of language behavior, such as those described above.

As a relatively new approach to the modeling of language, many of the details of applying AM to language have yet to be worked out fully. For example, there are outstanding questions regarding how to represent linguistic exemplars most appropriately. In particular, it is not yet clear how best to represent the hierarchical structure of more complex linguistic constructions, and it is not yet clear how to integrate the effects of variables from different linguistic domains such as the mutual contributions of phonological representations and semantic representations to predicting past tense forms. There are also unanswered questions regarding which of the decision rules available to AM might apply under different circumstances. See Skousen (2009) for further discussion of these and related issues.

Cross-References

► Connectionism

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Further Reading

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Analogical Problem-Solving

► Analogy-Based Learning

Analogical Reasoning

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Synonyms

Argument by analogy; Case-based reasoning; Metaphorical thinking

Definition

Analogical Reasoning and Its Uses

Analogical reasoning or argument by analogy can be defined as a specific way of thinking, based on the idea that because two or more things are similar in some respects, they are probably also similar in some further respect. Integrating various human-level reasoning mechanisms, arguing by analogical thinking, use analogies by transferring knowledge from one particular entity (the analogue or source) to another one (the target). Furthermore, it refers to the linguistic form, which corresponds to the process of relating the source and the target. As specific form of inference or reasoning, analogies draw conclusions by applying heuristics to propositions or observations as well as by interpolating logical steps or patterns. Analogies focus on relating specific particularities in two or more cases or things to form the basis for a conclusion involving an additional aspect rather than using standard deductive, inductive, or abductive argument forms.

Analogical reasoning is used, among others, in science, jurisprudence, and politics, but also in every-day practice as well as in learning and problem solving. Reasoning via analogies suggests significant relationships, helps to make connections between different concepts, and conveys knowledge from an understood domain to one that is less familiar or not directly or immediately observable. Moreover, analogical reasoning can provide the base for interpreting possible causal relations and facilitating innovation and creative learning of new conceptual knowledge and general principles via abstraction.

Relevance

Analogies and analogical reasoning have been considered a central part of human intelligence and cognition and cognitive abilities like memory access, adaptation, learning, and creativity (Gust et al. 2008). Understood as a proclivity to take what we perceive, to abstract it, and to find resemblances to prior experiences, the ability to make analogies is the very essence of human thought (Hofstadter and Sander 2010). Accordingly analogy-making pervades human thinking in the forms of categorizing, imagining, speaking, and guiding in unfamiliar or decision-making situations. Analogical reasoning provides a means of enhancing human capacity for creative yet disciplined thought and learning in a way that allows us to grasp and deal with the many-sided character of phenomena. The educational value of analogical reasoning is evident, not only by that they allow effective learning of a new domain by transferring knowledge from a known domain, but as it promotes noticing and abstracting principles across domains.

Practically speaking, analogical thinking is the basis of much of problem solving in the sense that many of these problems are solved based on previous examples. This involves abstracting details from a particular set of problems, comparing and resolving structural similarities, and extracting commonalities between previously distinct realms. Furthermore, analogical reasoning and particularly analogy counterarguments (Shelley 2004) are also relevant to critical thinking and argumentation.

Theoretical Background

The ancient theoretical reflection on analogy (*αναλογια*, i.e., proportionality) and analogical reasoning interpreted comparison, metaphor, and images as shared abstraction, and then used them as arguments.

Throughout history there have been many links between models and multiple analogies in science and philosophy (Shelley 2003). Analogical thinking is ubiquitous in all cognitive activities and has been identified as being at the core of cognition because it plays a role in elementary and componential information processes as a base for intelligent behavior (Holyoak et al. 2001).

There have been several theories proposed to explain analogical reasoning. One of the most well-known is the structure mapping theory (Gentner 1983). According to this theory, the use of analogy depends on an aligned mapping of elements from a source to target. The mapping takes place not only between objects, but also between relations of objects and between relations of relations. This shows the significance of analogy as being more than similarity in that analogical reasoning involves shared structural relations, relational commonalities, and associated sub-processes. Based on background knowledge retrieved from memory for sources that are similar to the target, individuals determine whether there is a good match between what is retrieved and the target when reasoning analogically.

Relating and comparing two analogies foster learning and can lead to new inferences, reveal meaningful differences, or form abstractions. To avoid pitfalls, analogical mapping requires ensuring that the base domain is understood well, that the correspondences are clear, and that differences and potentially incorrect inferences are clearly flagged. However, analogical comparison has also been shown to improve learning even when both examples are not initially well understood (Kurtz et al. 2001).

The multi-constraint theory of Holyoak and Thagard (1995) outlines those factors that govern and limit the use of constructed analogies. Specifically, these are related to the match in structure, meaning, and purpose between the source and the target. According to this theory, analogies can be considered coherent to the extent that it satisfies the following constraints:

- Structural consistency: each mapping is a one-to-one correspondence.
- Semantic similarity: corresponding concepts are similar in meaning.
- Pragmatic effectiveness: the analogy provides information relevant to the issue in question.

Factors that influence the success of an explanatory analogy also include systematicity (conveying an interconnected system of relations), base specificity, (degree to which the structure of the base domain is clearly understood), transparency (ease with which the correspondences can be seen), and scope (reach of applicability).

Analogical Reasoning Through Metaphorical Thinking

Analogical processes can take many linguistic forms like exemplification, comparisons, similes, allegories, or parables, and in particular (conceptual) metaphors. Referring to the Greek origin *metaphorikos* – from the Greek roots *meta*, (beyond, across) and *pherein* (carrying over, or bearing) – metaphors can be used to mark key factors and make analogues more obvious. They are ways in which terms that originally apply to one domain are projected onto another domain in order to structure experience and create meaning. Metaphors can be seen as part of developing a symbolic understanding and vehicle for meaningful structuring of and communication about the world. As part of analogical reasoning, metaphorical thinking is a basic mode of symbolism, a creative form that is effectuated through using and crossing of images for bridging between worlds. Liberating imagination, the use of metaphors can provide a way of seeing a thing as if it were something else, thereby enable bridging between abstract constructs and concrete things or between the familiar to the unknown. According to Lakoff and Johnson's (1980, 1999) *embodied realism*, our abstract conceptualization and reasoning, including our thought and symbolic expressions and interactions, are tied intimately to our embodiment and to the pervasive characteristics of our experience. Accordingly, the use of metaphors in analogical reasoning translates an experienced reality into a perceptible object that has emotive import as well as discursive content. In this way, the use of metaphors in analogical reasoning has and mediates meanings that transcend traditional inference models (e.g., deduction, induction, abduction). Processing a form of emotional and imaginative rationality, the use of metaphors in analogical reasoning allows criticizing and bridging the gap between the objectivist and subjectivist interpretations (Lakoff and Johnson 1980).

Important Scientific Research and Open Questions

One important field of future research concerns relating analogical thinking to noncognitive dimensions like embodied, sensual, emotional, or esthetic processes. For overcoming a purely propositional interpretation of analogical reasoning, it will be important to inquire into the implication of the fact that the analogical reasoning process is essentially embodied. One important question would be how embodied perceptual tendencies or felt senses enable or constrain the ability to choose and recognize an appropriate analogous comparison or solution. Furthermore, it would be revealing to further investigate the status of imagination and how imaginary processes and effects operate in the domains of analogical reasoning. With regard to levels, in addition to an individual-based perspective, it becomes important considering systematically what and how collective dimension and co-creative practices constitute or impact analogical reasoning and its sharing. In this context, linking forms of schematic analogical reasoning and learning with individual feelings and collective emotions or moods provide a promising new area for future research.

Whether competence in analogical reasoning progress is a content-free manner, or if and how it is highly dependent on specific domains is contested. As analogical reasoning cannot be properly understood in a vacuum, it needs to be situated and further explored in the context of wider issues, including the theory and practice of development.

Moreover, it is vital to widen and deepen the scope for the application of conventional approaches to analogical reasoning by promoting analogical diversity, not analytical closure. For this the significance of analogies and tropes – that privilege dissimilarity or discordant similarity, like anomaly, paradox, or irony, which are operating from within a cognitive discomfort zone – need to be acknowledged. As such divergent forms of analogical reasoning permit the coexistence of multiple perspectives, they not only promote plurivocality but also provide the basis of generative, transformative, and frame-breaking insights and knowledge generation and may help to create a new theory (Oswick et al. 2002).

As there are always dissimilarities between an analogy and its target domain, there are doubts that a faithful mapping of the structural aspects happens. Rather it is assumed that analogical inference making transcends similarities at hand (Cornelissen 2006). Thus, using an analogy is itself a more creative act through which features of importance are constituted and not simply transferred. This understanding allows seeing that meaning-structures emerge from blending the source and the target as well as its relations while recognizing their irreducibility that they are irreducible to each other. By reassembling elements from existing knowledge bases in a novel fashion analogizing can be interpreted as an inventive and artful practice.

Furthermore, as analogies do not necessarily lead to a distinct or conclusive meaning structure, and interpretations potentially change each time the analogy is revisited, they remain ambiguous and help shape related knowledge domains not only in certain ways, but also at certain points in time. The relevance of an analogical source for a target domain shifts over time, not necessarily rendering old comparisons or domain interactions obsolete, but allowing for new and different relationships.

With regard to more complex interpretation, there is also the need for further research on the constitution and dynamics of *compound analogue*, which are comprising of many different metaphors and interwoven features.

Cross-References

► Analogical Coherence/Correspondence
► Analogical Learning
► Analogical Model(s)
► Analogical Modeling (of Language)
► Analogical Reasoning in Young Children
► Analogous Learning/Analogy-Based Learning
► Analogy-Based Learning
► Mental Model
► Metaphorical Models of Learning

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Analogical Reasoning by Young Children

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Synonyms

Relational reasoning

Definition

The first definition of analogy came from Aristotle. He defined an analogy as "an equality of proportions . . . involving at least 4 terms . . . when the second is related to the first as the fourth is to the third" (Aristotle, *Metaphysics*). This type of "classical" analogy is still used in intelligence testing, and is called the item analogy. Its terms and their relations are signified as A:B::C:D. A typical instantiation might be *cat:kitten::horse:foal.* This key criterion of an equality of relations is also captured by the "relational similarity constraint" applied to problem analogies. In problem analogies, one structure or domain is used to make an analogy to another, as in Rutherford's use of the structure and relations of elements in the solar system to explain the structure and relations of elements in the hydrogen atom.

Theoretical Background

Most psychological research on the development of reasoning by analogy was based on a set of assumptions formulated by Piaget (Piaget et al. 1977). Piaget argued that there were two levels of reasoning involved in successful analogizing, reasoning about "lower-order" relations and reasoning about "higher-order" relations. For example, in the item analogy *cat:kitten::horse:foal*, the relations between *cat* and *kitten* and between *horse* and *foal* were considered to be lower-order or first-order relations. These are the relations that link term A with term B and term C with term D. There are a number of possible lower-order relations, such as "nurtures," "gives birth to," and "looks like." The higher-order relation in this analogy was considered to be something like "offspring." Piaget argued that developmentally, lower-order relations were easier to reason about than higher-order relations, being ontologically simpler.

In a series of experiments, Piaget found evidence that supported these theoretical assumptions. In seminal studies, Piaget and his colleagues asked children aged from 5 years to adolescence to sort sets of pictures. The pictures first had to be paired on the basis of the lower-order relations. Examples of intended pairings are *bird:feather*, *ship:rudder*, *dog:dog hair*, and *bicycle: handlebars*. The pairs then had to be sorted into analogies. For example, an intended analogy was *bicycle: handlebars::ship:rudder*. Younger children tended to pair the pictures idiosyncratically, not even recognizing the lower-order relations. For example, one child paired the *bird* with the *ship*, explaining that you see both at the lake. Piaget argued that during this *preoperational* reasoning, even class-type relations were not stable. Children aged 7 years and above, who were thought to be in the more mature *concrete operational* stage of reasoning, could pair the pictures correctly. They could also find analogies by trial and error. However, if the experimenter changed an analogy to violate the relational similarity constraint (e.g., suggesting the analogy *ship:rudder::bicycle:pump*), these children would agree with the countersuggestion. Piaget argued that analogical reasoning was still immature, as children were only able to reason *successively* about the lower-order relations. The ability to reason about similarities between these lower-order relations appeared only to develop in adolescence, during Piagetian *formal operations*. Only formal operational children were able to resist successfully the countersuggestions of the experimenter. However, it can be asked whether the younger children tested were familiar with some of the key relations, such as *steering mechanism*, required to solve the analogies. Further, in each of Piaget's analogies, it can be argued that the higher-order relation is actually "relational identity." In the analogy *ship:rudder::bicycle:handlebars*, the lower-order relation is *steering mechanism*. The analogy is a good one because the pairing of relations obeys the relational similarity constraint.

The information-processing approach to cognition also concluded that analogy was late developing. Information-processing accounts were pioneered by Sternberg, who tested children with verbal item analogies (e.g., *narrow:wide::question: answer*). His data suggested that children were reasoning by association in analogy tasks (Sternberg and Nigro 1980). The children (7–9 years) appeared to be reasoning consecutively about associations between the terms in the analogy, without recognizing higher-order relational structure. When the D term in an analogy was highly associated with the C term (as in *question:answer*), then children were faster and more successful. However, as the experimental format depended on the child listening to a series of possible answer options before responding, younger children may have relied upon word association because of high memory load.

Early studies of children's ability to solve problems by analogy also found apparent late-developing competence. Here, children were typically told about a problem, problem A, and how to solve it. They were then given a similar problem, problem B. The test of analogy was whether they would realize that by making an analogy from problem A, they could solve problem B. In one classic study (Holyoak et al. 1984), children were told about a magic genie who had to transfer his precious jewels from his bottle to a new home in another bottle. He rolled up his magic carpet and carefully rolled the jewels through it to solve his problem. Children were then given a new problem involving transferring some small balls on a table in front of them to another bowl which was out of reach. They had to solve the problem without moving from their chairs. The experimenters expected the children to roll up a sheet of paper that was lying on the table, and roll the balls through it into the bowl. However, only 30% of children aged 4–6 years thought of this solution.

Finally, a popular theory in the 1980s about children's analogizing was that there was a "relational shift" in children's ability to use analogies. Gentner and her colleagues (e.g., Gentner and Toupin 1986) argued that younger children relied on perceptual similarity in analogy tasks, whereas older children used conceptual similarity. Hence, younger children were not affected by relational structure. For example, when explaining why a cloud is like a sponge, a younger child (5 years) might say "because both are round and fluffy." An older child (9 years) might say that "both store water and later give it back to you." Gentner suggested that when perceptual relations and conceptual relations are aligned, younger children will reason successfully in analogy tasks. However, when they conflict, younger children will use a matching strategy based on perceptual similarity ("mere appearance matching").

Important Scientific Research and Open Questions

More recent research into reasoning by analogy by young children has questioned all of these early assumptions. It is now believed that even very young children can reason by analogy, as long as the analogy is in a familiar domain. The key is relational familiarity. Even 3-year-olds can use the relational similarity constraint, and can resist perceptual or associative distractors when relations are familiar.

For example, Goswami and Brown (1989, 1990) devised a series of multiple-choice item analogies based on pictures. In their tasks, the child had to select the D term to complete an analogy from a series of possible D terms that were simultaneously available. Some of the wrong answers were "mere appearance" distractors or associative distractors. In Goswami and Brown (1989), analogies were based on causal relations. Causal relations were chosen because children understand simple causal relations like *cutting*, *wetting*, and *melting* by at least the age of 3–4 years. The causal relations were instantiated in familiar entities, such as *chocolate is to melted chocolate as snowman is to?*, and *playdoh is to cut playdoh as apple is to?*. Different possible solutions included the wrong object undergoing the correct causal transformation, a perceptual similarity or "mere appearance" match, and the correct object undergoing the incorrect causal transformation. Knowledge of the causal relations required to solve the analogies was measured in a control condition. Goswami and Brown found that both analogical success and causal relational knowledge increased with age in children aged from 3 to 6 years. The 3-year-olds solved 52% of the analogies and 52% of the control sequences, the 4-year-olds solved 89% of the analogies and 80% of the control sequences, and the 6-year-olds solved 99% of the analogies and 100% of the control sequences. There was also a significant *conditional* relationship between performance in the analogy condition and performance in the control condition. This was interpreted as evidence that successful analogical reasoning depended on relational familiarity.

Similar competence by young children was shown in problem analogy paradigms by Brown and her colleagues. Brown and Kane (1988) designed some animal defense mechanism analogies for 3-year-olds, and compared analogical transfer on the first pair of problems with transfer after the children had experienced three different analogies. These biological analogies were based on camouflage by color change, camouflage by shape change, and camouflage by mimicry of a more dangerous animal. For example, for shape change, the children were told about the walking stick insect, which can resemble a twig or leaf, and the pipe fish, which can resemble a reed. The measure of analogical reasoning was performance on the final analogy pair. Children were asked "How could the hawkmoth caterpillar stop the big bird that wants to eat him?" In this context of multiple analogies (which Brown called the A_1A_2, B_1B_2, C_1C_2, or "learning to learn" paradigm), 70–80% of the 3-year-olds showed reasoning by analogy with the final problem pair (i.e., unaided solution of C_2). In contrast, successful solution of the first analogy pair (i.e., solution of A_2) was 25%.

Overall, more recent research has shown that even very young children can reason by analogy, in both item analogy and problem analogy formats. However, it is critical for successful reasoning that they are familiar with the relations on which the analogies are based.

Important Open Questions

The most pressing question in current research is how to explain the age differences that can still be found in certain analogical reasoning paradigms. General cognitive factors such as the ability to hold and integrate relations in working memory and the ability to inhibit competing irrelevant distractors look likely to play an important role (Richland et al. 2006). Another important question is how to build developmental connectionist models of reasoning by analogy. A recent connectionist simulation of the development of analogical reasoning demonstrated that analogical completion can be an emergent property of the way that relational information is represented in a (neural) network that learns perceptual instances (Leech et al. 2008). The connectionist model was given repeated experience of perceptual instances such as "apple," "cut apple," and "knife," and from these learned how to complete the causal relation analogies used by Goswami and Brown (1989). Further, the model did not show a "relational shift" during development. Converging evidence (Bulloch and Opfer 2009) demonstrated that the "relational shift" is actually an epiphenomenon of children's developing sensitivity to the predictive accuracy of different types of similarity. They asked children aged 3–5 years to generalize novel information in two types of problems, *offspring* problems and *prey* problems. Relational matches increased with age in the offspring condition, and perceptual matches increased with age in the prey condition. Bulloch and Opfer argued that even young children can be cognitively flexible, as long as they have sufficient understanding of the knowledge base that is relevant to the experiment.

Cross-References

- ► Analogy/Analogies – Structure and Process
- ► Analogy-based Learning
- ► Analogical Reasoning
- ► Default Reasoning
- ► Inferential Learning and Reasoning
- ► Schema-based Reasoning

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Analogical Reasoning in Animals

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Synonyms

Reasoning by analogy; Relational matching by animals; Similarity-based problem solving by animals

Definition

Unlike other examples of similarity-based reasoning that depend on physical likeness (e.g., one can recognize even novel instances of a chair because of its similarity to prototypical chairs), analogical reasoning is problem solving based on relational or functional similarities, such that knowledge from a familiar domain is applied to a novel problem that is not overtly alike. Thus, reasoning by analogy is judgment of relations-between-relations (Thompson and Oden 2000). The mapping of knowledge from one domain to another is central to the assumption in formal analogical reasoning that relational concepts are held constant from one domain to the other. The challenge then for the study of analogical reasoning by nonhuman animals (henceforth "animals") is to infer whether responding reflects this mapping of relations between concepts, rather for instance than generalization of learning on the basis of the physical similarity of stimuli. Practically as well as definitionally then, demonstrations of analogical reasoning by animals tend to require the application of perceived similarities between problems or stimulus sets that are physically quite dissimilar.

Theoretical Background

Rattermann and Gentner (1998) described a relational shift whereby human children accomplish analogy only when terms of object (physical) similarity can be put aside in favor of relational similarity. Although human infants spontaneously detect *sameness* and *difference*, as evidenced for example by habituation and dishabituation paradigms, the conceptual mapping of those relations emerges much later in development. Because several errors in analogical reasoning by 4- and 5-year-old children were due to a focus on object-based similarity (i.e., attempted matching due to similar physical features rather than deeper relational mappings), Rattermann and Gentner (1998) concluded that surface similarities drive reasoning skills until a point at which knowledge of the objects or situations therein is mastered, giving way to the search for possibilities beyond that which is already known. This relational shift from object properties to common relational structures is itself a shift in attention enabled by more generalized object expertise. Because the shift is dependent upon the amount and kind of knowledge an organism possesses in each specific domain, the point at which animals "become analogical" varies by context.

Thomas (1980) placed analogical reasoning abilities at the endpoint of an increasingly complex 8-level ordinal scale of a learning-intelligence hierarchy. According to this perspective Levels 1–5 include basic stimulus–stimulus and stimulus–response learning including habituation (Level 1), classical conditioning (Level 2), operant conditioning (Level 3), chaining (Level 4), and discrimination learning (Level 5). Levels 6–8 outline a continuum of conceptual abilities from the ability to make class distinctions based on physical similarities, a competency present in many nonhuman animals. At Level 6 is class concept learning (like transposition). Levels 7 and 8 (conditional and biconditional concepts, respectively) include the kinds of learning that rely *not* on physical or functional similarities, but on relations-between-relations that form the necessary foundation for analogical reasoning.

Important Scientific Research and Open Questions

Is the capacity for analogical reasoning uniquely human? From Wolfgang Köhler's pioneering studies of ► transposition learning by chickens to recent findings that nonhuman primates can learn and use symbols that represent numerical quantities and referential meanings (see Rumbaugh and Washburn 2003), there have been numerous demonstrations that a wide variety of animals can learn generalizable, rule-like relations. The question of which animals, if any, can apply ► relational learning to analogical reasoning has not produced so clear an answer. Premack (1976) reported that a chimpanzee (*Pan troglodytes*) named Sarah, after extensive training with plastic tokens for the words "same" and "different," was capable of completing and creating analogies. In one study, she was provided with three terms of an analogy: two identical or nonidentical geometric chips to the left of her symbol for same, and one geometric chip positioned to the right of the same symbol. Sarah was then required to find the correct right-side companion chip to complete the analogy. If the chips on the left were identical, she would find the chip from a set of alternatives that was identical to the single chip in the right-side position. Likewise, if the left-side chips were nonidentical, she chose the nonidentically related companion for the right-side chip, matching the relation instantiated in the left-side pair. In subsequent studies, Sarah was also able to create analogies without benefit of a sample relation, and could form analogies on the basis of function as well as appearance.

Is symbol training required for analogical reasoning? Premack (1976) and Thompson and Oden (2000) suggested that Sarah's symbols for *same* and *different* played a critical role in these demonstrations, providing her with a concrete means of encoding conceptual-relational information that is otherwise abstract. Given knowledge of these labels, the task of matching then became one of covert symbol matching – mapping one mental representation of a label to the other. At least in the case of abstract relations, acquisition of conceptual knowledge necessary for analogical reasoning is dependent upon these specific language-like skills – a finding that is generally consistent with the human-developmental trajectories of analogical reasoning and language acquisition.

Conversely, there is a growing literature showing that animals without language training, predominantly non-ape species, fail on a simple test of analogical reasoning (see Flemming, Beran, and Washburn 2007 for a review). In many of these studies, the animals responded in a ► computer-task paradigm by manipulating a joystick in response to computer-graphic stimuli. For example, given a sample of two identical stimuli (AA), the animals are unable reliably to select two other stimuli that are identical to one another (BB) rather than a pair of nonmatching stimuli (CD). This test is termed the *relational matching-to-sample paradigm* (in contrast to the identity matching-to-sample experimental paradigm), because the correct response requires selection on the basis of relation rather than physical identity. For example, they can recognize stimuli like EF as being different, but they cannot match this relation by selecting two other different stimuli (GH); rather, they are equally likely to choose stimuli (II) that fail to complete the analogy. That is, monkey species seem predisposed to respond to such problems on the basis of physical rather than relational similarity, leading to the claim that so-called *analogical apes* can be distinguished from so-called *paleological monkeys* (Thompson and Oden 2000). Only with additional methodological conditions to encourage a focus on global stimulus features and extensive training can monkeys show even limited evidence of relational matching-to-sample.

Are monkeys "paleological" as opposed to "analogical apes" and humans? Investigations of analogical reasoning via simple cognitive mechanisms in birds and non-ape primate species often lead researchers to a common conclusion that the behavior of their animals reflects, at the very least, a precursor to formal analogical reasoning. Wasserman and colleagues (e.g., Cook and Wasserman 2007; Fagot, Wasserman and Young 2001) presented multiple icon arrays in a relational matching-to-sample paradigm to pigeons, baboons, and humans. Using the same 16-icon identical/nonidentical stimulus arrays for both sample and choices, Cook and Wasserman (2007) demonstrated successful matching of *same* and *different* arrays. With a reduction in ► the amount of perceptual variability of stimulus arrays in relational matching-to-sample, as in discrimination tasks, chance performance was observed in pigeons. Much like their discriminative behavior with the relational concepts, pigeons relied on contrasts of perceptual variability for the matching of these arrays suggesting more limited abstract conceptual abilities in birds.

Recent evidence suggests that although a predisposition to attend locally to stimulus features rather than globally to relations exists, the so-called paleological monkey can pass a relational matching-to-sample task given conceptually guiding scaffolding or altogether different relations (i.e., not *identity/nonidentity*, but rather *above/below* spatial relations). Fagot and Parron (2010) demonstrated relational matching in baboons (*Papio papio*) under conditions in which the separation between elements in pairs of stimuli was gradually increased across training. This gradual spatial separation encouraged the often difficult but necessary shift in attention from local (physical features) to global (relation) stimulus processing. Although monkeys tend not to focus their attention on structural similarities as is required for relational matching and analogical reasoning, they nonetheless possess similar rudimentary capabilities to map knowledge from one domain to another. Other researchers (e.g., Kennedy and Fragaszy 2008) found that capuchin monkeys (*Cebus apella*) showed analogical reasoning in a search task involving hidden food under cups of various sizes.

Cross-References

► Abstract Concept Learning in Animals
► Analogical Reasoning
► Analogical Reasoning by Young Children
► Conditioning
► Matching-to-Sample Experimental Paradigm

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Analogy Therapy

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Synonyms

Metaphor therapy; Narrative therapy; Stories in psychotherapy

Definition

The word *analogy* comes from the Greek "analogia," meaning "in proportion." An analogy is a comparison between one thing and another to show how they are alike – usually in order to explain or clarify. For example, a person's health may be compared to *the sea*, in that the ebb and flow of the tides echoes the balance between health and illness. *Metaphor* is a related term (from the Greek *meta* – sharing something in common – and *pherien* – to carry or change). A metaphor uses a familiar object or idea to describe something to which it does not literally apply ("A is B"). For example, "He is under the weather" or "The journey of life."

Psychotherapy can be defined as any psychological treatment that uses the relationship between therapist and client to produce changes in thoughts, feelings, and behavior. There are many different talking treatments, but they all share certain fundamental principles. These include establishing a confiding relationship, providing a rationale that explains how a therapy works, and allowing individuals to acquire insight alongside the learning of new behavior.

A therapist's effectiveness depends upon their deliberate use of language. Analogy therapy combines symbolic or indirect communication with the intention to heal (Blenkiron 2005). Important tools of figurative expression include the story, anecdote, analogy, metaphor, simile, allusion, image, joke, and quotation. Although these concepts overlap, key words that may help to distinguish between them include "like" (similes), "is/are" (metaphors) and "as in/as if" (analogies). For example, "My brain is *like* a computer" is a simile but "My brain *is* a computer" is a metaphor. A more detailed comparison becomes an analogy: "As in a computer, my brain has a large amount of memory. It needs an experienced operator to make the software work and to add new data". Even longer themed descriptions of imaginary or past events are known as stories.

Theoretical Background

Across history, religion, philosophy, science, and the arts, narrative has played an essential role in how we understand ourselves and the wider world. Metaphor is the language of change and modern psychotherapies have change as their central goal. Research from neuropsychology (Cahill et al. 1994) shows that individuals remember verbal information best when it is

- Interesting
- Organized into sensible chunks
- Expressed through slang or humor
- Linked to mental images
- Stimulating to all the senses (sight, sound, smell, and touch)
- Emotionally arousing
- Triggered later by cues from everyday life

Evidence indicates that narrative and metaphor are efficient ways in which to communicate important therapeutic messages. For example, Martin, Paivio, and Labardie (1990) demonstrated that a person's recall of therapy is linked to their use of metaphors and images during therapy sessions. A review of the research literature (Blenkiron 2010) confirms that introducing stories and analogies into therapy can result in a range of clinical benefits:

- An improved client–therapist relationship
- Greater retrieval of early memories
- Heightened personal impact (evoked emotions and interpretations)
- Better integration of logical and emotional responses ("heart" versus "head")
- Quicker learning of new concepts
- Clearer targets and goals
- Improved global psychological health

Narrative is a helpful learning tool for therapists as much as their clients. Aesop's Fable of *The Sun and the Wind* reminds clinicians that encouragement through guided discovery is a more powerful tool for change than direct persuasion or argument. Indeed, many psychological models are really no more than metaphors that serve to link theory with practical understanding. For example, an individual with a spider phobia does not need to hear the jargon of behavior therapy and operant conditioning in order to understand that avoiding spiders will lead to short-term relief but maintain the problem in the longer term. Therapists might help clients to grasp this concept – the self-perpetuating cycle of avoidance – by comparing it to "scratching an itchy rash," "borrowing on credit cards," or "giving in to the school bully."

A particular strength of analogy therapy lies in its inherent flexibility and wide range of clinical applications. Metaphor can be used in order to

- Clarify meaning and understanding
- Communicate flexibly (and express the inexpressible)
- Gain a new view or insight ("Is the glass half empty or half full?")
- Increase rapport between therapist and client
- Bypass emotional defenses
- Develop specific skills and outcomes (e.g., learn to ignore a self-critical "devil's voice")
- Inspire and motivate (e.g., Dick Whittington's success against the odds)

The main schools of psychotherapy have incorporated metaphor pragmatically into their clinical practice. For example, considerable research evidence supports the effectiveness of cognitive behavior therapy (CBT). Story and analogy allow individuals to use CBT principles to modify their thinking and behavior in everyday situations. Consider the example of John, who becomes upset when he notices his friend Bill walking past him in the street without saying "hello." However, Bill is not deliberately ignoring John; he is simply late for an appointment and is not wearing his spectacles. By encouraging John to weigh up the evidence for and against a thought such as "Bill doesn't like me" being true ("like a jury in a court of law"), he can generate alternative and more helpful explanations for this situation. This anecdote helps to convey an important concept in CBT: emotional distress is caused not by what happens, but by the way in which it is interpreted (Beck 1976).

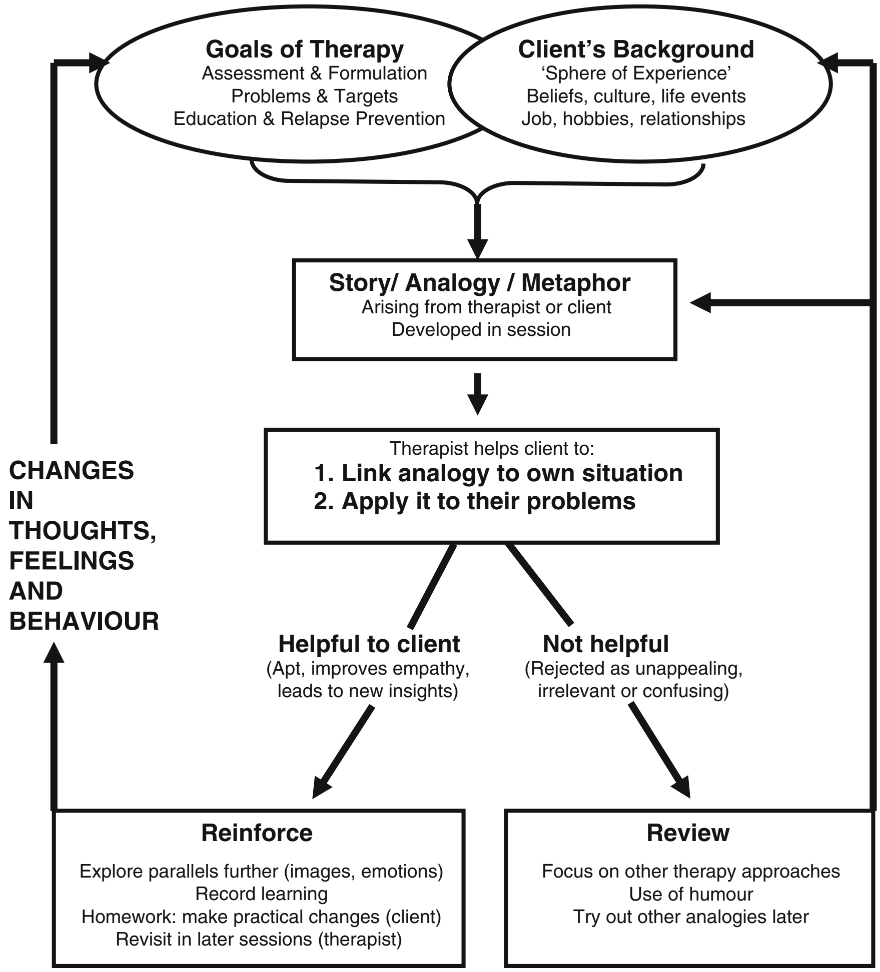
Psychodynamic therapy focuses on discovery: the "why" rather than the "what" of a person's problems. It translates experience into coherent stories that make sense and act as guides for future action. As stories interweave, "the light dawns," "the ice breaks," and "the penny drops." Sigmond Freud (1856–1939) used metaphor to "access the unconscious." He regarded dreams as the way we communicate with ourselves through metaphors. For example, a dream about winning a race might represent successful promotion at work. Carl Jung (1875–1961) highlighted the importance of myths, fables, and proverbs handed down the generations. Jung described "metaphorical prototypes" known as archetypes. These are universal human symbols, such as the hero, that are commonly portrayed in fantasies and fairy tales across all cultures. Milton Erickson (1901–1980) made insightful points with anecdotes. For example, if we placed a wooden plank on the ground, each of us could walk on it. But if it were raised 200 ft into the air, who could then walk on it? He also demonstrated use of different ways of ending a therapeutic story such as having no ending (cliff hanger that encourages an individual to work it out), the surprise ending (to stimulate thought), and the tragic ending (for someone who resists advice or change).

Counseling is practiced widely in primary healthcare systems. Analogy can enhance generic skills (empathy, warmth, and genuineness) by increasing understanding (for example, describing anxiety as a normal "flight or fight" survival response). It can also validate emotional suffering – trying to function with clinical depression is "like running with a broken leg." Narrative therapy involves listening to a person's difficulties and then helping that person to retell their "story." A man learned to understand his anger as his wish to be viewed as a "real man." Family and systemic therapists use analogy to improve communication and restore the balance. They treat problems by changing how the whole "system" works rather than focusing on one particular individual. For example, when one family said that they were "falling apart," their therapist asked them to consider what they would actually do if they were living in a crumbling house. This helped them to work together, generate ways of repairing the "faulty foundations" and build new "concrete" goals into a firmer family structure.

Important Scientific Research and Open Questions

A working psychological model of analogy therapy combines the goals of therapy with a client's prior knowledge and experience (see figure). The aim is to create something meaningful and useful. However, clinicians should be aware of the potential limitations as well as the benefits. Unhelpful metaphors may restrict and condition. For example, saying "I can only deal with my problems by putting them in a box" could hinder longer-term change. In addition, the use of "stock" analogies may be culture specific and not applicable to every client group. Whether a metaphor is effective will depend on its personal meaning for the client, and so a shared understanding of its meaning is desirable. However, dissecting a story too much can remove its spontaneity and appeal. Finally, a therapist's job is not to think up fanciful analogies without a clear purpose. William of Occam (a thirteenth-century Franciscan scholar) cautioned against offering an unnecessarily complicated explanation when a simple one would do. This principle of cutting away superfluous facts is known today as "*Occam's Razor.*" A good anecdote should be a passport to effective communication rather than a substitute.

Biological research is emerging to suggest that there may be a "metaphor center" in the human brain. The left angular gyrus lies at the crossroads of the frontal, temporal, and parietal areas. It is much bigger in humans than primates, and was especially large in the brain of Albert Einstein – the celebrated mathematical genius who reported thinking more in pictures than words (Witelson et al. 1999). Patients who suffer damage to the left angular gyrus have great difficulty understanding proverb, metaphor, and analogy. For example, they interpret the phrase "all that glitters is



Analogy Therapy. Fig. 1 Analogy Therapy: A Generic Model (Blenkiron, 2010, Adapted with permission, Wiley-Blackwell)

not gold" in a literal way ("Well, you know a shiny piece of metal doesn't mean its gold, it could be copper").

More good quality studies are needed into the use of analogy and narrative as therapy tools. Doing research in this area is challenging. Evidence-based care deals with populations, but clinicians deal with individuals. Moreover, qualitative research involves joining together many personal anecdotes with the detail removed. Yet several unanswered questions remain. In what situations are analogies and stories more useful than other therapeutic techniques? Are standardized ("manual-based") metaphors any more or less effective than personalized metaphors developed in the therapy session to suit a particular individual? Is the *what* (content) of less importance than the *how* (manner of exploring a common language)? Does training in analogical interventions lead to a better outcome in specific types of mental disorder such as depression, panic attacks, or obsessive-compulsive disorder? However, this uncertainty is no different to many other areas of psychotherapy research where the "active ingredients" are not fully understood.

Cross-References

► Analogical Model(s)
► Analogy/Analogies: Structure and Process
► Cognitive-Behavior Family Therapy
► Cognitive Models of Learning
► Learning Metaphors
► Socratic Questioning

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Analogy/Analogies: Structure and Process

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Synonyms

Alikeness; Correspondence; Homology; Likeness; Simile; Structural equivalence

Definition

It has been noticed that in many disciplines the development of a novel theory or perspective depends on applying an analogy drawn from a different domain of knowledge. Thinking by analogy is based on the transfer of ideas from one domain or situation (the source) to another domain or situation (the target). This process induces to apply some of the information or principles from the first domain to the second one. This extension leads one to view the second situation from a different perspective or to interpret it in a new way that allows for the discovery of new meanings (Gentner et al. 2001).

Thinking by analogy is considered to be a central component of human cognition and it has been argued that analogy is an important aspect of cognitive ability and the hallmark of intelligence.

Theoretical Background

Thinking by analogy can be divided into the following three phases: representation, retrieval, and application. In the first phase, a source situation is encoded within the mind. The second phase involves searching for, selecting, and accessing a relevant encoded source situation. The third phase then involves mapping the source representation onto the target situation; during this phase the source representation may be adapted and modified in various ways.

It was maintained that thinking by analogy involves the abstraction of a schema from the source domain and its mapping onto the target domain. More precisely, an analysis of the process of analogical reasoning predicts that during the presentation of the source people would derive a general schema of the situation. When faced with the target, they would apply the schema to such a situation (Holyoak and Thagard 1996).

This is a view which is supported by a considerable amount of empirical data. Firstly, the quality of the schema that people derive from the source is positively correlated with the strength of the transfer from the source to the target. Such a transfer sometimes occurs only when people have represented the source in an abstract format. Furthermore, experimental manipulations designed to encourage the formation of generalized schemata increase the rates of transfer from the source to the target.

According to an alternative interpretation, thinking by analogy is based on the summation of activation resulting from multiple features shared by the source and the target. If the sum of activation exceeds some threshold, the representation is retrieved and it can be used for further processing, such as an explicit source-target mapping (Anderson 1993). Retrieval by summation of activation can provide a general mechanism for flexible access to information in the memory that is related to a novel input.

Important Scientific Research and Open Questions

Thinking by analogy can be investigated by presenting a pair of pictures involving a causal relation – for instance, an egg (first picture) that is broken (second picture); respondents are asked to complete a second pair of items in which the first (e.g., a lightbulb) is given and the second must be chosen from a set of alternatives only one of which (a broken lightbulb) involves the same causal relation as the first pair. This kind of analogy is called proportional analogy (A : B = C : ?).

Alternatively, spatial analogy tasks can be employed: for example, children can be asked to indicate on a picture representing a tree or a mountain the points relative to the head, the shoulders, the legs, and so on, of the tree or the mountain, respectively (Goswami 1992). In this task the correct answer is achieved by transferring the human body schema onto the target object (the tree or the mountain) so as to identify the analogous counterparts of some body parts.

A third way to investigate thinking by analogy consists in telling a story and then asking respondents to map the narrative schema embedded in such a story onto a novel set of characters so to produce a new, but similar, tale.

Finally, in analogical problem-solving tasks a target problem to be solved is presented (Keane 1988). Such a problem is preceded by a source problem describing a situation structurally similar to the target, which has been previously solved by means of a set of strategies which can be applied also to the target problem.

It should be noted that association tasks, asking individuals to list objects and situations similar to a given one or to look for similarities between pairs of given objects or situations, can also be used to assess thinking-by-analogy skills.

Much interest has also been focused on the effects produced by different degrees or kinds of source-target correspondences – for instance equivalence versus similarity, superficial versus structural similarity, dissociated versus synthesized similarity, similar versus nonsimilar story lines and object correspondences, literal versus remote analogies, latent versus manifest analogies, or different kinds of superficial similarity and of procedural features. However, despite the wide range of topics investigated, a certain number of unsolved questions still remain.

One of the main questions is the following: does an adequate degree of activation of source information really enable the transfer from the source to the target? Results from experiments on source access showed that activation is not the critical process. The mere activation of the mental representation of the source is ineffective unless an individual realizes the source-target connection. This awareness does not seem to derive from a summation mechanism but it seems to be produced by some sort of insight (Anolli et al. 2001).

Cross-References

▶ Analogical Coherence/Correspondence
▶ Analogical Modeling of Language
▶ Analogical Reasoning of Young Children
▶ Analogy-Based Learning
▶ Analogy Therapy
▶ Heuristics and Problem Solving
▶ Measures of Similarity
▶ Mental Model(s)
▶ Schema(s)
▶ Schema-Based Reasoning

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Analogy-Based Learning

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Synonyms

Analogical problem-solving; Analogical reasoning; Learning by examples

Definition

When we have to face a new situation, we may retrieve knowledge that we have acquired previously about a different situation which is similar to the present one. This occurs since we realize that the new situation is structurally (namely, at an abstract level) isomorphic to that we have experienced in the past, even though the superficial features of the two situations are quite different. Students can take benefit from such a process when they have to comprehend a new concept: if the new concept is structurally similar to a familiar or previously learned concept, the understanding of the former can be facilitated by the latter since the familiar concept highlights, in a way that is easy to be understood, the essential characteristics of the new concept (Gentner 1997). In this sense, the analogy provides learners with an anticipatory schema.

Another possibility is that the familiar concept or procedure is embedded in a worked example which students master, so that they can easily identify the same concept in the new case and apply the familiar procedure to it.

When the task to be carried out is a problem and the aim is to foster students to generalize what they have understood in solving such a problem and to assimilate the strategies they have followed to solve the problem so that they can apply them in the future to other kinds of situations, the educational procedure is sometimes called case-based learning.

Theoretical Background

It is worth noting that learning by analogy is not only a way to prompt the understanding of hard concepts, but it is a skill which merits to be trained per se. In fact, one of the goals of school instruction is to develop the ability to transfer knowledge from one domain to another, by stressing the similarities existing between them, in order to cope successfully with novel situations.

Initially students can be taught to find analogies within a given domain. A good way to do so is to hint learners at reminding objects, situations, or concepts that show similarities with the issue at hand. For instance, in history lessons, after the presentation of a new topic – e.g., the Roman civilization – students might be asked to look for as many analogies as possible between ancient Greeks and Romans. When pupils cannot find further analogies, teacher begins to work on the analogies that have been produced. He/she starts from the analogy mentioned by most students, for example "Both Greeks and Romans used ships." Which new similarities can be drawn from this analogy? Why did Greeks use ships? To trade, by the other things. Thus, it can be hypothesized that Romans, like Greeks, had coasting trade. The work goes on in this manner. The aim is to "spread out" all the potential resources of the analogy in order to lead students to discover nontrivial correspondences between different ancient populations. The final result should be that understanding of both Roman and previous civilizations is enlarged and a wider historical view is reached. Further, students are stimulated to be more open-minded. Activities based on the search for analogies may be carried out also to find similarities between customs and habits of ancient people and of contemporary people. This should help learners to link cultural notions to everyday-life experience.

Another way to foster learning by analogy is the following. Teacher can consider a literary analogy, for instance, "The old age is the evening of the life." It can be rewritten into a proportional analogy: "old age: life = evening: day." Now the task is to try to change the first element of the second couple of the analogy. Students might find that the best answer is "old age: life = sunset: day." The next step is to modify the second element: "old age: life = sunset: sun." The work goes on by looking for a good substitute of the first element again: "old age: life = moon: sun." After a certain number of steps, the "chain" of variations proposed by students leads to realize that the original concept of "old age" has been enriched because it has been linked to different elements, each eliciting interesting connotations. Another possibility is to give students only the first part of the original analogy: "The old age is the . . . of the . . ." and to ask for many different completions ("The old age is the quiet of the storm," "The old age is the rest of the labor," "The old age is the falling asleep of the nature.") Also in this case new connotations can emerge and a deeper understanding of old age is achieved.

Important Scientific Research and Open Questions

Can the ability to learn by analogy be taught? Some techniques – such as synectics – have been devised to train to produce creative analogies in order to solve professional problems and also some computer-based instructional systems have been designed to enhance analogy-based learning. However, only programs to train specific subcomponents of learning by analogy have been experimentally tested (Alexander et al. 1998).

Learning by analogy is a multidimensional ability whose components have different developmental trends because of the involvement of different general mental functions (e.g., abstract intelligence, linguistic competence, divergent thinking). Because there is not a unique mechanism underlying learning by analogy, a range of different skills must be trained (Richland and McDonough 2009).

If students are trained to pay attention to analogies, reflecting about them, and re-elaborating them, fluidity and flexibility in thinking improve. Learners become more able to identify common aspects in different realities and to transfer ideas from a domain to another. This helps to think divergently and to solve novel problems. In other words, a general mental "mobility" leads to see familiar things with new eyes and to face new challenging situations by applying schemata drawn from past experience (Clemens 2008).

Cross-References

- ▶ Analogical Modeling of Language
- ▶ Analogy/Analogies
- ▶ Anticipatory Schema
- ▶ Retention and Transfer
- ▶ Role of Prior Knowledge in Learning Processes

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Analogy-Based Modeling

▶ Dynamic Modeling and Analogies

Analysis of Learning Data

▶ Educational Data Mining

Analytic Learning

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Synonyms

Analytical learning; Derivational analogy; Explanation-based learning; Knowledge-based learning; Sequential learning

Definition

The word *analytic* comes from the Greek word "ἀναλυτικός" (*analytikos*), which means having the ability to analyze and divide the whole into its components or elements. *Analytic Learning* is an analytical approach to learning that uses prior knowledge as a base from which concepts can be described, hypotheses can be developed, and concepts can be rationally generalized by analyzing the components and the structure of the concepts. Analytic learning allows the learner to process information, break it into its component parts, and generate hypotheses by using critical and logical thinking skills.

Theoretical Background

Cognitive style refers to the ways individuals think, perceive, remember, and use information. Assessing the cognitive style of the learners and matching one's cognitive style with the best appropriate instruction are important in the field of education. Since the mid-1940s, several models of cognitive styles have emerged (Riding 2001). Riding (2001) grouped cognitive style into two fundamental dimensions: *wholist-analytic* and *verbal-imagery*. The *wholist-analytic* dimension reflects how individuals organize and structure information and identifies whether an individual tends to organize information into wholes or parts. The *verbal-imagery* dimension describes individuals' mode of information representation in memory during thinking and identifies whether an individual is inclined to represent information during thinking verbally or in mental pictures.

Analytic learning and explanation-based learning (EBL) are used as synonyms (e.g., Mitchell 1997; Thrun 1995). In the fields of artificial intelligence and computer science, *analytical learning or explanation-based learning* is a form of machine learning which concerns the design and development of algorithms in mathematics, computer science, or related sciences. Thrun (1995) indicates that machine learning can be divided into two major categories: *inductive learning* and *analytical learning* and defines two types of learning as below:

- Inductive learning techniques, like decision tree learning . . .artificial neural network learning, generalize sets of training examples via a built-in, domain-independent inductive bias. [Inductive learners] typically can learn functions from scratch, based purely on observation. Analytical approaches to learning, like explanation-based learning, . . . generalize training examples based on domain-specific knowledge. [Analytic learners] employ a built-in theory of the domain of the target function for analyzing and generalizing individual training examples . . . Analytical learning techniques learn from much less training data, relying instead on the learner's internal domain theory. They hence require the availability of an appropriate domain theory. (Thrun 1995, p. 302)

Thrun (1995) presents empirical results obtained for applying the explanation-based neural network learning algorithm to problems of indoor robot navigation. Thrun (1995) states that analytical learning is the most widely studied machine learning approach to provide a theory of the domain which typically consists of a set of rules. Thrun (1995) categorizes analytical learning in a three-step procedure of explain, analyze, and refine, as summarized below:

- *(1) Explain.* Explain the training example by chaining together domain theory rules. *(2) Analyze.* Analyze the explanation in order to find the *weakest precondition* under which this explanation leads to the same result. Features that play no part in an explanation are not included in this weakest precondition. The generalized explanation forms a rule, which generalizes the training example. (3) *Refine.* Add this generalized explanation to the rule memory. (Thrun 1995, p. 303)

Thrun (1995) makes the point that people learn analytically by explaining, analyzing, and refining the information.

Mitchell (1997) also mentions analytic learning in his book *Machine Learning*. Mitchell (1997) states that analytical learning uses prior knowledge and deductive reasoning to augment the information provided by the training. Mitchell (1997) indicates that in analytical learning, prior knowledge is used to analyze and explain how each observed training example satisfies the target concept so that training examples can be generalized based on logical rather than statistical reasoning. Mitchell (1997) follows:

- One way is to develop learning algorithms that accept explicit prior knowledge as an input, in addition to the input training data. Explanation-based learning is one such approach. It uses prior knowledge to analyze, or explain, each training example in order to infer which example features are relevant to the target function and which are irrelevant. These explanations enable it to generalize more accurately than inductive systems that rely on the data alone . . . Inductive logic programming systems . . . use prior background knowledge to guide learning. However, they use their background knowledge to infer features that augment the input descriptions of instances, thereby increasing the complexity of the hypothesis space to be searched. In contrast, explanation-based learning uses prior knowledge to reduce the complexity of the hypothesis space to be searched, thereby reducing sample complexity and improving generalization accuracy of the learner. (Mitchell 1997, p. 308)

Mitchell (1997) summarizes the three perspectives on analytical learning or explanation-based learning (EBL) "as [1] theory-guided generalization of examples,. . . as [2] example-guided reformulation of theories,. . . as [3] 'just' restating what the learner already 'knows' " (Mitchell 1997, pp. 319–320). According to the first perspective, domain theory is utilized to make rational generalizations from examples; relevant and irrelevant attributes can thus be differentiated. The second perspective refers to the reformulation of the original domain theory through deduction and classification of what is observed in the examples' specific inferential steps and then combining them to form a rule. The third perspective refers to the sufficiency of the original domain theory when it can adequately explain and predict the classification of the observed examples (Mitchell 1997). These perspectives help to understand the capabilities and limitations of analytical learning or explanation-based learning.

A

Langley (1989) compares analytic learning with empirical learning. According to Langley (1989), analytic learning transforms domain knowledge into some other form but empirical learning uses domain knowledge to rewrite instances in another language. Langley (1989) emphasizes that analytic learning influences efficiency of performance while empirical learning influences accuracy of performance:

- Learning involves some change in performance, and one of the main goals of *machine learning* is to develop algorithms that improve their performance over time. However, there are many different aspects of performance. For instance, early work on empirical methods emphasized classification accuracy on training sets, while more recent work has focused on transfer of accuracy to separate test sets. In contrast, most work on analytical learning has been concerned with increasing the efficiency of the performance system. (Langley 1989, p. 253)

Langley (1989) also states that analytic learning uses deductive reasoning method while empirical learning uses inductive reasoning method.

- A more substantive issue concerns the nature of the learning process. Empirical learning methods extend a system's original knowledge base, leading it to behave differently on some situations than it did at the outset. Yet such methods involve an inductive leap from instances to general rules or schemas, and this leap is inherently unjustified. . .. In contrast, many analytic methods simply compile the results of a proof into a different form. The resulting rule is justified, in that it does not change the deductive closure of the system's knowledge . . . As a result, most analytic techniques have no means for moving beyond the knowledge they are given. The rules they generate may alter their processing efficiency, but these rules do not change the system's external behavior, as do inductive learning methods. (Langley 1989, p. 255)

Langley (1989) concludes that analytic methods cannot lead to behavioral changes but can lead to changes in external behavior:

- Analytic methods cannot lead to behavioral changes – also holds only under unrealistic assumptions. All performance systems have effective limits on their memory and processing time. As a result, the addition of rules that reduce memory load or increase efficiency can allow successful completion of tasks that were not possible before learning . . . Thus, analytic methods can lead to changes in external behavior, though in different ways than do empirical techniques. (Langley 1989, p. 255)

Minton (1993) describes how meta-level theories are used for analytic learning. According to Minton (1993), "analytic learning systems are characterized by a *theory-driven* component that generates hypotheses by analyzing a domain and several analytic approaches have been used for *speed-up* learning, in which the goal is to improve problem-solving efficiency" (p. 922). Analytic learning exploits problem-solving experience through explaining, analyzing, and making generalizations on the domain.

Important Scientific Research and Open Questions

An individual's learning style is determined by a combination of five factors (Terregrossa et al. 2009):

- Environmental (e.g., noise, light, temperature, and design)
- Emotional (e.g., motivation, persistence, conforming, and structure)
- Sociological (e.g., learning from peers vs learning alone)
- Physiological (e.g., visual, auditory, tactual, and kinesthetic)
- Psychological (global-deductive vs analytic-inductive)

Terregrossa et al. (2009) state that analytic and global learners have different environmental, emotional, sociological, physiological, and psychological preferences. According to the empirical study conducted by Terregrossa et al. (2009), preferences for noise, light, design, persistence, and intake distinguish analytic learners from global learners. Terregrossa et al. (2009) summarize the differences between analytic and global learners:

- Analytic learners prefer to learn alone, while global learners prefer to learn in pairs, with peers, or as part of a team.
- Analytic learners process information by induction, reasoning from specific facts to a general conclusion, while global learners process information by

deduction, reasoning from a general conclusion to specific facts.

- Analytic learners learn best in a quiet, brightly lighted, and formal learning environment, while global learners learn best with background noise, soft light, in a relaxed learning environment.
- Analytic learners prefer to start and finish one project at a time, and do not snack while learning; however, global learners simultaneously work on several projects, take frequent breaks, and enjoy snacks when learning.

According to Riding (2001), the analytic learner has focused attention, noticing and remembering details, has an interest in operations, procedures, and proper ways of doing things, and prefers step-by-step, sequential organizational schemes. However, the wholist or global learner attends toward scanning, leading to the formation of global impressions rather than more precisely articulated codes. The analytic learner is gifted at critical and logical thinking but the wholist or global learner is more gifted at seeing similarities than differences (Riding 2001). Both the analytic and the wholist have its strengths and weaknesses. In order to compensate for the weaknesses of each, Riding (2001) suggests that:

- Wholists benefit from information in advance of learning, which shows the structure of a topic, its components, and analytical map.
- Analytics benefit from information in advance of learning that gives an overview of the whole topic and provides the holistic approach.

Terregrossa et al. (2009) investigate how a natural experiment occurring in the teaching of principles of microeconomics allows examining the relationship between student achievement, student learning styles (analytic versus global), and the dichotomous nature (analytic versus global) of the method of instruction. Terregrossa et al. (2009) indicate that better exam performance is linked to global learning style preferences and global teaching methods, but there is little evidence to conclude that better exam performance is linked to analytic learning style preferences and analytic teaching methods:

> ► In learning the more analytical content, students with a preference for conforming to professor instructions did better, ceteris paribus, on exams. Students who prefer greater physical mobility in the learning process performed more poorly. However, there is little evidence to suggest that students with more analytical learning preferences did better. In learning the more global course material, a preference for conforming to professor instructions was again found to be more productive, as was stronger motivation. Students with a preference for auditory (lecture) learning were at a disadvantage in this segment of the course. Importantly, in the more global part of the course, student exam performance was found to be directly related to food intake and inversely related to the formality of design of the study venue and persistence in the completion of tasks. These three results were statistically significant and support the hypothesis that students with global learning style preferences perform better when consonant teaching methods are in place. (Terregrossa et al. 2009, p. 1)

Dunn, Dunn, and Price (as cited in Terregrossa et al. 2009) developed the productivity environmental preference survey (PEPS) to identify participants' learning style profiles. Terregrossa et al. (2009) conclude that five of the 20 learning style variables from the PEPS survey instrument can be utilized as discriminators in order to categorize a student as an analytical learner or a global learner: preference for noise, preference for strong light, preference for greater formality of design in the location where the studying/learning takes place, preference for being persistent (avoiding interruptions while studying), and preference for food intake while studying.

Cross-References

► Explanation-Based Learning
► Metalearning
► Sequential Learning

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Analytical Learning

► Analytic Learning

Analytical Psychology and Learning

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Synonyms

Complex psychology and learning; Jungian psychology and learning

Definition

It is analytical psychology's view that in the structure of the ego and its involvement in the learning process lies its major contribution to accounts of formal learning. There are three key consequences from this view of the ego: higher order learning is distinguished from lower order learning by its greater abstraction and differentiation of psychological contents along functional lines; individual preferences exist in the abstraction process, leading to implications for learning styles; and the ego is active in both the conscious and the unconscious, suggesting learning occurs in both conscious and unconscious states.

The ego structure comprises the attitude pairing of extroversion and introversion and two functional pairings, the rational pair of thinking and feeling, and the irrational pair of sensation and intuition. The attitude pairing governs whether the ego's interest is primarily given to the object of learning (extroversion) or to the existing conscious contents that relate to the learning object (introversion). Both attitudes are necessary for successful learning, but will dominate at different points in the process. The functional pairings allow the ego to differentiate or abstract new contents along a rational or irrational trajectory. Undifferentiated learning comprises a crude mixture of rational and irrational functions. Higher learning comprises contents that have been fully abstracted along one of the functional lines. With greater abstraction comes increased ego utility of the content; stripped of its context, the content is more generally applicable and easier to reflect upon. The great success of science rests on the capacity to abstract via the thinking function.

Although this ego structure is common to all, its use is not uniform from person to person. We each display a preference for one pole of the pair over the other, a strength and weakness typified respectively by stamina or tiring of attention and concentration during the learning process. This account of ego variation is one of the earliest psychological theories to argue that an individual shows a preference in their approach to learning and was a forerunner to various learning style theories (Jung 1977). As a personality preference, it has formed the basis of the widely used and researched Myers-Briggs Type Inventory (Briggs Myers and Myers 1995).

We tend to think of learning as a primarily conscious process; however, the ego is also thought to function in unconscious processes, for example, the ego is present in dreams. The learning processes of consciousness described above are understood to continue unconsciously. This gives explanation to new insights appearing spontaneously in consciousness and is a justification for including "downtime" in the learning process.

Theoretical Background

In analytical psychology, the formulation of ego structure and its involvement with psychological contents and learning derives from the central concept of the complex (Jung 1969). This view of the complex has its origin in the accounts of early psychologists and psychiatrists such as Eugene Bleuler, Pierre Janet, and Sigmund Freud. Jung extended these ideas through his experimentation with word association studies to formulate his unique model.

Generally speaking, a complex is a structured arrangement of elements comprising a whole. In analytical psychology, it signifies the unit of psychic content as an arrangement of irrational perceptions, rational apperceptions, and a feeling intensity. Each complex is both conscious and unconscious. A strongly conscious complex is typified by substantial abstraction of the contents and a low feeling intensity; the reverse is true for a strongly unconscious complex.

Developmentally speaking, the earliest complexes are acquired and not formally learnt. They arise from a collision of the infant's nature and their experiences with the environment (Samuels et al. 1986). In the first few years of life, islands of consciousness emerge and coalesce to form the ego complex (the ego itself is considered a complex). Complexes arising during this time are strong in feeling tone and largely unconscious. It is possible, particularly in later life, to bring the unconscious contents of these complexes into consciousness, but this is a personal process of integration rather than one of formal collective learning and will not be pursued further in this discussion.

With formal education comes the targeted development of conscious complexes; these are akin to schemas. They contain differentiated contents that are relatively known and can be recalled at will, freely associated with and directed through attention by the ego. Such learnt content involves the processes of accommodation and assimilation as elaborated in developmental cognitive theories. Analytical psychology's unique contribution to formal learning is the situating of accommodation and assimilation processes within the attitude and functional structure of the ego.

As mentioned above, the ego is structured to engage the world through extroverted and introverted attitudes. This structure has its informal historical antecedents in Antiquities' notion of the four temperaments, or the writings, for example, of Friedrich Schiller, Frederick Nietzsche, and William James. When seeking to understand an external event (idea or physical object) through extraversion, the learner applies their existing understandings of an object to "give themselves over" to the whole object. They transfer their subjectivity to the external object, giving it primary value and interest. The introverted act is the reverse where the learner withdraws interest from the object, abstracting partial elements of the object's nature and relating these to conscious contents. It is now the conscious contents that are given primary value. Successful learning requires both extroversion and introversion.

The four functions of ego have quite specific elaborations in analytical psychology. Sensation is the perception of sensory information of an outer event and informs us that something *is*. In order to know *what* this outer event is, what we think about it, existing conscious contents are applied and the event becomes recognized. Such recognition may happen almost instantaneously or require substantial directed concentration. This matching or differentiating of contents is an apperceiving process. Feeling, the other rational apperceptive process is an evaluative response to the event, it tells us *how* it is for us, whether the event is emotionally pleasant or unpleasant. Intuition tells us the *possibilities* surrounding an event, the implications or outcomes. These possibilities are not consciously processed thoughts, but appear spontaneously fully formed in the mind and are thus an irrational process. The ego may abstract the initial sense made of the external event along any of the four functional avenues.

Abstraction through the thinking function leads to rational, logical concepts and is the most (Western) culturally developed function; abstraction through the feeling function gives an evaluative content of the event; abstraction through the sensation function yields an aesthetic content; and finally abstraction through the intuitive function gives a symbolic content. All physical events can be abstracted along any of the four functions.

Of particular importance to formal learning is the abstraction leading to scientific concepts. Their learning process tends to move from the concrete to the abstract. Initial attempts at new learning will foster initial contents that are blurred across multiple functions. For example, many children hold in mind the sensual description of an object while they consider its functional properties (an alloy of thinking and sensation). Ideally, a scientific concept should be fully abstracted along the thinking function and this means discarding the sensual elements, so the contents are no longer concrete. There is a great advantage in fully abstracting a content for it allows the ego to maneuver it with greater mobility and applicability than if it were still concrete. The sensual information makes it more cumbersome to hold in mind and more jarring to apply outside its physical qualities.

A key implication for learning is the varied preference each learner has in attitude and for abstracting contents along functional lines. The Myers-Briggs Type Indicator has made this individualizing tendency a measurable personality indicator and brought great attention to Jung's typology (Briggs Myers and Myers 1995). A marked limitation to abstraction arises from the finding that at least one of the four functions will lag in its facility in comparison to the others. This *inferior* function will tire more easily than the others and contents within this function will wish to remain coalesced with other functional contents and require greater effort to abstract. This fact, born out through the copious studies of the Myers-Briggs Personality Type Indicator, is not obviously explained, but is thought to be connected to the relationship of ego to the unconscious (von Franz 1980). When the psyche as a whole, both conscious and unconscious, is considered, it becomes evident that the inferior function plays a special role for the unconscious and therefore, its functionality in consciousness is weakened.

Important Scientific Research and Open Questions

There are now a great many personality typologies that have been articulated by researchers. A question arises as to whether a typology is a mere orientating device, which captures a reasonable portion of human functioning, but has no other claim to validity for the personality constructs it employs. Statistical validation has weeded out some of the more ambiguous typologies but cannot provide a definite answer to this question. Jung became convinced that the structural description within which his typology rests did indeed have objective validity. This claim has not been greatly explored and remains an open question.

Jung and others, notably the Nobel physicist Wolfgang Pauli, argue that if one tracks back in history to the origin point of a particular scientific concept, they would find the earliest conception involved an archetypal idea. For example, the theory of combustion sits abstractly above direct experience of a burning flame. One can imagine the beginnings of ideation some thousands of years in the distant past, where images of a flame sparked the emergence of the archetypal idea of "transmutation" (the changing of form). With many intermediary steps, we now have the concept of combustion, but still within this concept is the archetypal idea of transmutation (Neumann 1970). We tend to only value the abstract, highly conceptual contents, for they are the goal of higher learning. However, this historic view to the learning of an individual opens up new questions around the validity of undifferentiated contents. Indeed, in relation to their abstracted siblings, they may well be the fundamentals through which comprehensive learning is found not only historically but also for the individual.

Cross-References

► Adaption and Learning
► Associative Learning
► Jungian Learning Styles
► Personality and Learning
► Personalized Learning
► Psychodynamics of Learning
► Schema
► Theories of Unconscious Learning

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Anchored Instruction

► Situated Cognition

Anchoring Framework

► Advance Organizer

Anchoring-and-Adjustment Effects in Causal Learning

► Judgment Frequency Effects in Causal Learning

Andragogy

► Adult Learning Theory

Angelic Doctor

► Aquinas, Thomas (1225–1274)

Animal Behavior and Human Learning

► Learning from Animals

Animal Cognition

► Animal Intelligence: Schemata for Ordering Learning Classes

Animal Culture

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Synonyms

Animal traditions; Socially transmitted "memes"

Definition

Cultural changes in animal societies are said to occur when animals learn new habits of living and pass them along to the next generation. In such a situation, the spread of a certain innovation results in stable conservation of a new custom that is further maintained and transmitted in a train of generations through social learning.

Culture itself is a difficult phenomenon to define. Some behavioral scientists have proposed that the words "culture" and "tradition" should be considered synonyms (see Galef 1992 for a review), whereas others treat tradition as neither necessary nor sufficient condition for culture (McGrew 2004). How to treat "animal culture" much depends on its definition. Many definitions in the literature attribute cultural traits only to humans. At the other end of the scale is considering culture as a "meme pool" (sensu: Dawkins 1976) in populations which can include all cases of the regular use of public information in populations basing on relatively simple forms of social learning (Laland and Brown 2002). Given this situation, Lycett (2011) has suggested that animal culture may usefully be characterized as an emergent property of the "descent with modification" (sensu: Darwin 1859) process mediated by the combination of variation, social learning, and sorting.

Many animal behaviorists agree that cultural behavior in animals includes a package of behaviors rather than single traditions such as "bottle opening" by British birds (see Lefebvre 1995, for a review). Defining animal culture as a set of socially transmitted behavioral patterns, the working description given by Nishida (1987) is useful: "Cultural behaviour is defined as behaviour that is: (a) transmitted socially rather than genetically; (b) shared by many members of the group; (c) persistent over generations and (d) not simply the result of adaptation to different local conditions."

Theoretical Background

The notion of animal culture dates back to Charles Darwin who was the first to suggest what became known as social learning and imitation in animals. The association of animal behavioral actions with the actual word "culture" was firstly brought forward with the discovery of socially transmitted food habits ("potato washing") in macaques made by Japanese primatologists in the 1940s (see: Nishida 1987).

The possibility of culture in chimpanzees, the most "cultural" after our own species, surfaced early in Jane Goodall's (1964, 1986) studies, stimulated by youngsters' intense observations of skilled adult tool use. Studies at other sites later began to map local behavioral variations including as many as 39 behavioral patterns across Africa. Some of them concern tool use, such as ant-dipping, termite-fishing, nut-cracking, honey-dipping, drinking water with leaves, and so on. Others concern characteristic behavioral habits such as rain dances, handclasp grooming, details of courtship rituals, and so on. The researchers found no evidence that habits vary more between, than within, the three existing subspecies of chimpanzees. So genetic cannot account for the observed variability (Whiten et al. 1999; Whiten 2007; McGrew 2010).

Recent studies of animal traditions have taken the chimpanzee research as a template, and the following steps to identify cultural traditions have been elaborated: (1) show that behavioral differences between populations are not consistent with genetic explanations; (2) check that the behavioral differences cannot be explained by ecological factors such as availability by suitable raw materials for making tools; (3) study the transmission processes used by animals in controlled experiments: Can they learn by watching others? If so, what kind of things do they learn?

Important Scientific Research and Open Questions

Ethologists have investigated the problem of animal culture for decades but only in the last years has a clear picture of cultural diversity in several species begun to emerge (see Reznikova 2007, for a review). Chimpanzees display the highest level of manufacturing ability but they are not the only nonhuman species which possess elements of "material culture." Thirty years of field observations of the Southeast Asian orangutans have enabled an international group of researchers to reveal 24 examples of behaviors that have been defined as cultural variants, and among them using sticks to dig seeds out of fruit and to poke into tree holes to obtain insects, using leaves as napkins or as gloves, and so on (van Schaik et al. 2003).

Marine mammals can also be added to the catalogue of "cultural" animals. In Shark Bay, Australia, bottlenose dolphins apparently use marine sponges as foraging tools. Dolphins have devised a way to break sponges off the sea floor and wear them over their snouts as a kind of gloves to protect their sensitive rostrums when they probe for prey in the substrates (Krützen et al. 2005). The DNA analysis showed that the spongers were closely related, probably descending of a recent "Sponging Eve." However, the pattern of sponging among the dolphins could not be explained by a "gene for sponging." The researchers conclude that this behavioral pattern is culturally transmitted, presumably by mothers teaching their skills to their calves. Tool use is the most amazing but not the only population-specific behavioral trait that enables cetacean biologists to claim that marine mammals possess culture or at least traditions. Mann and Sargeant (2003) have listed many population-specific patterns concerning foraging strategies, styles of diving, patterns of social interactions, and many of them have been clearly demonstrated to be transmitted by means of social learning.

Such studies are becoming taxonomically more diverse, extending to social and foraging patterns among capuchin monkeys (Perry and Manson 2008), Japanese macaques' stone-play habits (Leca et al. 2007), and variations in bower-birds' decoration preferences (Madden 2008). The new study may reinforce bridge-building between the work of those focused on human and nonhuman forms of culture and further the exciting prospect of a more integrated "science of culture" (Whiten 2007).

However, there is much work to be done to understand which factors limit and which favor the acquisition of new behavioral traditions in animal communities. The main methodological difficulty on the way of studying animal culture is to recognize innovations in the field. Even when the origin of a certain innovation had been observed, it is difficult to predict a living trajectory of this innovation. Of many innovative behaviors observed, only a few will be passed on to other individuals, and seldom will they spread through the whole group. For example, Goodall (1986) observed two instances of the use of stones by adolescent chimpanzees to kill dangerous insects. She supposed that this usage of stones would become customary in that reference group. But this had not happened since, and the innovation faded away. All these incite researchers to search for reasons why some innovations are supported in animal communities while others are not.

Given the suggestion about the genetic predisposition of animals to learn certain behaviors much easier than others, Reznikova and Panteleeva (2008) considered a previously unknown way of propagation of behavioral traditions in animal communities using hunting in ants as an example. The authors suggest that *distributed social learning* plays an important role in spreading new traditions in animal communities: initial performances by a few carriers of an "at once and entirely" available behavioral pattern propagate this pattern among specimens which have only dormant "sketches" of it, and thus are genetically predisposed to learn the whole pattern. Spread of these behaviors in populations is based on relatively simple forms of social learning such as social facilitation which underlies species' predisposition to learn certain sequences of behavioral acts. To be triggered, carriers of dormant "sketches" of a relevant behavioral pattern should encounter performances of this pattern with sufficient frequency. This strategy can be called "triggering of dormant behavioral patterns." In principle, it could be useful for populations to have dormant "sketches" of complex behavioral patterns being implemented in several carriers and then spread by means of simple forms of social learning under suitable circumstances.

In general, "culturing" and social learning are based on differences existing between members of animal communities, that is, on behavioral specialization in populations, and in some situations, on cognitive specialization of individuals (see the entry "► Altruistic Behavior and Cognitive Specialization in Animal Communities" in this volume). This returns us to the Darwin's characterization of evolution which is based on the variation between individuals.

Cross-References

► Altruistic Behavior and Cognitive Specialization in Animal Communities
► Cognitive Aspects of Deception
► Intelligent Communication in Animals
► Social Learning in Animals

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Animal Intelligence: Schemata for Ordering Learning Classes

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Synonyms

Animal cognition; Animal rationality; Animal reasoning; Animal thinking

Definition

Animal learning and intelligence define how nonhuman beings solve their living problems based on their individual and social experience. Learning performs adaptive tuning to a changeable environment, and intelligence helps animals to use their learned experiences in new situations. Individual adaptive behavior involves different kinds of learning together with innate behavioral patterns. Classification of learning classes involves basic forms of learning. The modern schema for ordering learning classes makes it easier to work with different forms of learning in animals in comparison with humans and artificial agents.

Theoretical Background

The rise of scientific study of animal intelligence may be portrayed as progressive changes in experimental methods. The development of objective methods of analysis of animal intelligence is attributed to researches studying animal mind in the nineteenth century, based on Darwin's evolutionary ideas. In 1870, D. Spalding (1873) experimentally investigated innate and learned behaviors in birds and mammals, and J. Lubbock (1882) was one of the first to introduce apparatus and quantification into the study of animal intelligence. Apart from being a powerful stimulus to the development of experimental investigations, Darwin's ideas of succession in animal and human thinking gave new arguments for anthropomorphic approach to animal intelligence, and the most known example is the G. Romanes' book "Animal Intelligence" (1881). The predominance of anecdotal evidence of animal intelligence led one of the pioneers of comparative psychology, L. Morgan (1896), to construct the idea of animal intelligence based on quantitative studies of animals' reactions to different stimuli. Morgan's lecture on habit and instinct in animals prompted E.L. Thorndike (1911) to elaborate a novel experimental approach based on the study of animals escaping from puzzle boxes. At the beginning of the twentieth century, two scientific schools that approached learning basing on insight (Gestaltism) and on conditioning (behaviorism, with its Pavlovian and Skinnerian branches) had started almost simultaneously on their efforts to describe learning quantitatively and objectively. After half a century of battles, W. Köhler (1959) invited students of animal intelligence to "forget about schools" and proceed in another direction. The coherent development of ethology and experimental comparative psychology has resulted in cognitive ethology, that is, the comparative, evolutionary, and ecological study of animal minds, including rationality, information processing, and consciousness. Revolutionary experimental paradigms have been developed for studying animal "linguistic" capacities, numerical competence, abilities for rule extraction, sophisticated tool use, complex forms of communication, social learning, and social navigation (for a detailed review see: Reznikova 2007).

Important Scientific Research and Open Questions

Animal intelligence has been experimentally studied for not much longer than a century and controversial ideas still exist about how animals learn and to what limits they understand relations between things and their properties, as well as relations between members of their social groups. Many elegant experimental schemes have been elaborated for investigating how complex are the problems that animals are able to solve. However, there is no common metric for measuring animal intelligence. There is a growing body of evidence that members of different species can solve very complex problems but their cognitive abilities lie within a narrow domain of "species genius." For example, ants appeared to be more competent (Reznikova and Ryabko 2011) than chimpanzees (Beran 2009) in numerosities, and New Caledonian crows (Kacelnik et al. 2004) are even more advanced than chimpanzees (McGrew 2004) in tool manufacture. There is much work to be done to extend our understanding of whether at least some species share advanced characteristics of intelligence with human beings, or whether all animals think about the world in a way radically different from our own.

To complete the multifaceted panorama of animal intelligence, the working schema of learning classes is needed that involves recent discoveries in the field.

Since W.H. Thorpe (1963) proposed the labeling system of learning classes, there were several updates following a course of development of cognitive ethology. R.K. Thomas (1996) synthesized a list of eight fundamental types of learning from which any and all examples of learning are derived:

Level 1 – Habituation or Sensitization.
Level 2 – Signal Learning (Classical or Pavlovian Conditioning).
Level 3 – Stimulus–response Learning (Instrumental or Operant Conditioning).
Level 4 – Chaining (Learning Sequences of Stimulus–response Learning Units).
Level 5 – Multiple Discrimination Learning: Concurrent Discrimination Learning (CDL) or Learning Set Formation (LS).
Level 6 – Absolute and Relative Class Concept Learning.
Level 7 – Using Class Concepts in Conjunctive, Disjunctive, or Conditional Relationships.
Level 8 – Using Class Concepts in Biconditional Relationships.

A new variant of the labeling system of learning classes that integrates data from cognitive, ethological, and ecological studies was suggested in (Reznikova 2007):

1. Habituation
2. Associative learning
   (a) Classical conditioning (Stimulus–Reaction)
   (b) Operant conditioning (Stimulus–Reaction–Stimulus)
3. Catalog learning (Stimulus–Pattern)
4. Guided learning
5. Imprinting
6. Latent learning and exploration
7. Learning set formation
8. Rule extraction
   (a) Classification and categorization
   (b) Concept formation at different levels of abstraction
   (c) Causal reasoning
9. Social learning
   (a) Social facilitation
   (b) Emulation
   (c) Imitation
   (d) Teaching

It should be noted that whereas latent learning, learning set formation, rule extraction, and social learning can be attributed to cognitive abilities, catalog learning, guided learning (Gould and Marler 1987), and imprinting (Lorenz 1935) are based on innate predisposition to build up one set of associations more readily than another. Among these more or less "pre-programmed" forms of learning, "catalog learning" has been described only recently and means animals' ability to select quickly and to manipulate readily with innate behavioral patterns. Animals look like "cataloging" their repertoire of innate patterns in order to optimize their response to a certain repetitive event (Reznikova 2007). This is a relatively simple, universal, and quite "natural" form of learning that possibly underlies cognition.

The schema for ordering learning classes aims at completing the picture of interactions between different forms of learning in human and nonhuman mentality, and can be applied in cognitive ethology, comparative psychology, and robotics.

Cross-References

▶ Abstract Concept Learning in Animals
▶ Accounting and Arithmetic Competence in Animals
▶ Categorical Learning
▶ Conditional Reasoning by Nonhuman Animals
▶ Contingency in Learning
▶ Evolution of Learning
▶ Habituation
▶ Individual Learning
▶ Learning Set Formation and Conceptualization
▶ Operant Behavior
▶ Reinforcement Learning in Animals
▶ Social Learning in Animals
▶ Theory of Mind in Animals
▶ Tool Use and Problem Solving in Animals

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Animal Numerical Competence

► Numerical Skill in Animals

Animal Perceptual Learning

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Synonyms

Learning through perception and animals; Perceptual learning of animals

Definition

Perceptual learning refers to the set of processes by which experience with similar stimuli increases the ease with which they can be discriminated. In nonhuman animal this is revealed by enhanced acquisition in a task in which the critical stimuli are associated with different outcomes (and thus come to control different responses); also by a reduction in the extent to which a response trained to one of the stimuli will generalize to the other. It reflects the fact that experience with the stimuli enhances the perceptual effectiveness of features that differentiate them and/or reduces the effectiveness of features they hold in common. It can be produced not only by explicit training but also by mere exposure to the stimuli.

Theoretical Background

The ability of nonhuman animals to perform subtle discriminations is legendary; and it is confirmed by experimental study. For example, appropriately trained dogs can detect the presence of human odor on a microscope slide touched by a human finger 3 weeks previously; they can determine the direction of a 1-h-old odor trail left by a human given access to only five footsteps; they can detect the difference between cancer patients and healthy controls on scent alone, given access exhaled breath samples. These examples rival (perhaps surpass) the achievements of human experts (e.g., wine tasters, tea blenders), achievements that have been taken to be prime instances of perceptual learning.

Laboratory studies undertaken to reveal the nature of the mechanisms involved have been more mundane. In one procedure, widely used with rats, discrimination is required between two flavors, A and B. After training in which A is associated with experimentally induced nausea, the degree to which the aversion that is established to A will generalize to B is tested. Failure to generalize indicates that the rats can discriminate A from B. In fact such generalization commonly occurs (especially as it is customary to add a third flavor to both, making the stimuli AX and BX and thus making them more similar). Generalization is reduced, however, (i.e., discrimination is enhanced) if the rats are given prior exposure to the flavors. It is concluded that such preexposure allows perceptual learning to occur.

A common theoretical analysis applies to all the various examples of the phenomenon. Any two stimuli can be conceived of as being composed of sets of features, some of which are unique to each individual stimulus, others of which are held in common. Similar stimuli will have a high proportion of common features. Discrimination is evidenced when an animal makes different responses to the different stimuli. In order for this to be achieved, behavior must come under the control of the unique rather than the common features. Thus, to pursue the example just outlined, generalization will occur between AX and BX to the extent that training with AX establishes an aversion to the common feature X; on the other hand, discrimination will be enhanced if the rat learns principally about the unique feature A during conditioning and/or its behavior is chiefly controlled by the unique feature B on the test. Procedures (like preexposure to the stimuli) that enhance discrimination may be assumed to do so because they promote control by the unique features. Experiments with animal subjects have been conducted to elucidate the processes by which this might occur.

Important Scientific Research and Open Questions

Much work has focused on the role of explicit discrimination training. In such training the animal experiences presentations of the stimuli associated with different outcomes (e.g., response to AX is followed by food and response to BX is not). When differential responding is established (e.g., the animal chooses to approach AX rather than BX) we conclude that the unique features have gained control over behavior. Standard theories of associative learning are designed to explain this result; according to such theories, the predictive cues, A and B, gain associative strength at the expense of nonpredictive (X) cues, which become "neutralized." This learning process may be enough in itself to supply an explanation for the abilities of experts (humans and canines), as these abilities are typically established by means of (extensive) explicit discrimination training. To that extent, these skills would not strictly involve perceptual learning according to the definition offered above, as the proposed mechanism would not necessarily involve changes in the perceptual effectiveness of the stimuli.

It remains possible, however, that in addition to the associations it establishes, discrimination training might produce a change in the perceptual effectiveness of the stimuli. This notion is central to Mackintosh's (1975) theory of animal discrimination learning, with its proposal that the ability of a stimulus feature to command attention is enhanced by training in which that feature has accurately predicted its consequences. Evidence for this form of attentional learning has been sought in transfer tests – after initial discrimination training with one set of stimuli the animal is shifted to a new task in which the same stimuli are used but which involves different response requirements, so that the associations acquired in initial training will be irrelevant. Positive transfer might thus be taken to indicate that the initial training had produced a change in the properties of the stimuli. Such transfer was demonstrated early on in the study of animal discrimination learning. It should be acknowledged, however, that alternative accounts have been offered and that the proper interpretation of such transfer tests continues to be debated (see Hall 1991).

Perceptual learning does not require explicit training; mere exposure to the stimuli has been found to facilitate subsequent discrimination between them. An early, and influential, example was provided by Gibson and Walk (1956), who showed that the ability of rats to discriminate shapes (triangle from circle) was enhanced when the rats had been raised with these shapes displayed in the home cage. The instance mentioned above, reduced generalization in flavor-aversion conditioning after preexposure to the flavors, constitutes a modern example of the same phenomenon. This simple case has been investigated in detail in the hope of establishing learning principles that might be applied to explain perceptual learning more generally.

The best known effect of mere exposure to a stimulus is *habituation* – a form of learning that shows in a reduction of the ability of the stimulus to evoke its usual response. A habituated stimulus is effectively less salient than a novel one. This simple learning process can supply a partial explanation for the perceptual learning effect. Preexposure to the stimuli will allow habituation to occur to all their various features, but especially to the features they hold in common. Animals exposed to AX and BX experience X on every trial and thus this feature will experience twice as much habituation training as the unique features, A and B. The effective salience of A and B will thus be high relative to that of X, and behavior will be more likely to be controlled by these features, resulting in an enhanced ability to discriminate between AX and BX.

Evidence that this process cannot be the sole source of perceptual learning after mere exposure comes from experiments investigating the effects of different schedules of stimulus presentation. Symonds and Hall (1995) gave some rats alternating presentations of two compound flavors (AX/BX/AX/BX... and so on); other rats received equivalent exposure except that the flavors were presented on separate blocks of trials (AX/AX...BX/BX...). In spite of the fact that in both conditions the common element X was presented on every trial, only the first schedule produced a sizeable perceptual learning effect. This result, the superiority of the alternating over the blocked preexposure schedule, has been confirmed many times, and with a variety of species and training procedures. It has been taken to support the proposal that perceptual learning occurs best in circumstances that allow the possibility of comparison between the stimuli (the assumption being that comparison will be facilitated by a procedure in which the critical stimuli are presented in alternation).

It remains to specify the mechanisms by which the comparison process might work. One possibility is that when BX, for example, is experienced immediately after AX, habituation of the common (X) features, allows the unique feature (B, in this case) to stand out, so that this feature receives particularly efficient processing and is accurately encoded in memory. This mechanism seems plausible for procedures in which the stimuli are presented in quick succession, but the alternating schedule is effective in producing perceptual learning in rats even when stimulus presentations occur several hours apart. For this case it has been argued that associations formed among the constituent elements of the stimuli play an important role in producing the perceptual learning effect (see McLaren and Mackintosh 2000; Hall 2003) but there is, as yet, no consensus as to what this role might be.

The phenomena of animal perceptual learning are important for two reasons. First, standard theories of learning, based largely on studies of animal conditioning, have treated "the stimulus" as something defined solely by its physical properties. The fact that the way in which a stimulus is perceived can be modified by experience means these theories need to be supplemented by an account of the learning processes responsible for such modification. Second, in human, as in nonhuman animals, discrimination will be facilitated by processes that enhance the perceptual effectiveness of unique features of the stimuli to be discriminated (and/or reduce the effectiveness of features the stimuli hold in common). Evidence from experiments on animals can help elucidate the learning mechanisms involved in perceptual learning generally.

Cross-References

► Animal Learning and Intelligence
► Association Learning
► Discrimination Learning Model
► Expertise
► Habituation
► Perceptual Learning
► Perceptual Similarity

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Animal Rationality

► Animal Intelligence: Schemata for Ordering Learning Classes

Animal Reasoning

► Animal Intelligence: Schemata for Ordering Learning Classes

Animal Thinking

► Animal Intelligence: Schemata for Ordering Learning Classes

Animal Traditions

► Animal Culture

Animal–Human Communication

► Referential Vocal Learning by Grey Parrots

Animals

► Accounting and Arithmetic Competence in Animals

Animated Pedagogical Agents

► Pedagogical Agents

Animation and Learning

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Synonyms

Dynamic visualization; Multimedia information; Noninteractive simulation

Definition

Adopted in the 1980s by the multimedia community, animation technically refers to a series of static frames displayed at high rate in order to give the illusion of continuous motion. From a psychological point of view, the distinguishing feature of animation over static graphic is to depict change over time in a realistic and explicit manner. With the advances of personal computer capacities and programming language, animation has become a natural component of computer-based learning material, together with text, sound, and traditional static graphics. Animation can be used to (1) attract attention, (2) convey information related to the state of a process (e.g., loading file bar), (3) demonstrate the execution of a procedure (e.g., software tutorial), and (4) depict dynamic phenomena involving changes over time, such as weather forecast, circulatory system, or four-stroke engine. Some other more domain-specific uses can be found, like in algebra or physics conveying relationships between variables in abstract graphics. In this chapter, we will be interested in the most extensive use of animation in multimedia instruction: the depiction of natural or artificial systems that involve change over time.

Theoretical Background

Though animation has been extensively used in multimedia instruction, there is still little knowledge on what makes an animation effective for learning. The spontaneous assumption is that, due to its dynamic nature, animation facilitates understanding of dynamic phenomena involving changes over time. Motion and trajectories are directly perceived in animation, while they have to be inferred from static graphics. However, the research did not provide clear evidence that animation benefits learning compared to a series of static graphics (Lowe and Schnotz 2008). What appeared clearly is that animation does not systematically lead to better understanding. Recently, the question has shifted from knowing whether animation facilitates learning to knowing why, which requires identifying the perceptual and cognitive processes underlying the observed learning effects.

From a psychological point of view, the comprehension of dynamic phenomena, whether it has a pragmatic finality (e.g., reproducing a procedure) or an epistemic one (knowing how a four-stroke engine works), requires constructing a mental model of the phenomenon. Mental models of dynamic phenomena not only entail the elements and their spatial configuration, but they also contain functional and temporal information (Narayanan and Hegarty 2002). Furthermore, complete mental models not only enable recognition of the different states in which the dynamic system evolves, but also anticipation of future states and detection of malfunctioning.

A reasonable question now is: Why would animation be more effective than a series of static graphics in promoting understanding of dynamic phenomena? The more intuitive answer is that animation depicts explicitly the relations between steps, and particularly the "microsteps," which have to be inferred by visual and conceptual reasoning from static graphics. Making inference is not necessarily detrimental for learning on the contrary, but it has three major drawbacks: First, learners may draw the wrong conclusion, for example, mistaking a gear rotation direction in a pulley system. Second, this inference reasoning is cognitively demanding and may distract learners from higher-level understanding, as demonstrated by the cognitive load theory. And finally, learners may just be unable to infer the dynamic relations from static graphics. To conclude, for learners with little domain knowledge, animation is beneficial if it supports cognitive processes that learners could not perform from static graphics (*enabling* function) or if it facilitates the construction of the mental model by the visualization of accurate dynamic information.

Then why has animation not always proved beneficial? Though animation explicitly depicts the minute changes over time, it does not necessarily lead to an accurate perception of dynamic information. For example, novice students in meteorology were found to pay quasi-exclusive attention to perceptually salient dynamic information and fail to identify information that was conceptually relevant but perceptually not salient. Moreover, even when the relevant dynamic information is accurately extracted, it does not necessarily ensure the comprehension of the underlying functional model. In mechanics, several movements may occur at the same time, which does not bring any information regarding the causal chain of events (does air enter because the valve opens, or does the valve open because air enters?). Finally, the continuous flow of information in animation does not allow easy reinspection of previous steps, contrary to a series of static graphics. Information regarding relative location of components on previous steps should be kept in memory. As a consequence, animation imposes a heavy demand on working memory load that, ultimately, may impair learning.

In order to circumvent the previous bottlenecks, several guidelines regarding the design of animation have been enunciated (Tversky et al. 2002). First, animation should be designed in order to facilitate the identification of conceptually relevant information, the one that is required to understand the functional relations between events and components. In other word, animation should convey the information that is relevant to conceptual understanding, rather than aiming to be fully realistic. In the previous example, the precedence of the valve opening over the air entering should be made explicit, or conversely. A second recommendation is to decrease perceptual load by using very simple, not to say austere, design, and avoid fancy graphical fantasy as 3D perspectives or light effects, unless it is necessary to disambiguate dynamic information. As third guideline to overcome the attraction of perceptually salient information over conceptually relevant one, it is advisable to integrate some signaling devices (like blinking arrows, highlights, zooming in) to emphasize dynamic information. Finally, in order to decrease memory load due to the continuous flow of information, learners can be provided with control over the pace of the animation. A simple "continue" button, with an animation pausing automatically after each step, was shown to effectively improve memorization and understanding. Providing full control over the pace and direction of the animation could be a good way to allow easy reinspection of previous steps, though it can also bring confusion to novice learners (Bétrancourt 2005). Another solution is to provide key static frames of relevant steps of the dynamic system, which was found to be effective for learners studying individually.

From an instructional point of view, it is important that novice users are able to accurately identify the components and basic spatial configuration of the system before being presented with an animation of its dynamic functioning (Narayanan and Hegarty 2002). Furthermore, one of the instructional risks of animation is a passive attitude toward the animation and illusion of understanding. That is the reason animation is preferably not shown as a simple demonstration performed by the instructor, but rather manipulated by learners (Bétrancourt 2005). For example, the animation may be used to provoke a cognitive conflict between usual naïve conceptions and scientific models, like trajectory of falling objects from moving platforms or speed of falling objects not depending on their weight. Another active use is to have learners explore the animation and answer specific questions, which orient attention toward relevant features and guide exploration of the animated instruction.

Important Scientific Research and Open Questions

As the research progresses, the scientific issue shifts from demonstrating that animation is more effective than static graphics to the identification of the underlying mechanisms that explain the occurrence of a beneficial effect. From a fundamental cognitive perspective, research tries to better identify the perceptual and conceptual processes underlying the comprehension of dynamic visualization. From a perceptual point of view, what animation changes fundamentally is the type of information that is made salient and the format in which it is conveyed, i.e., through change over time instead of graphical device or accompanying text. Taking weather maps as an example, the movement and transformation of warm fronts over time is visualized in the animation in a global and continuous way, rather than compartmented in successive static graphics. From a conceptual point of view, contrary to static graphics, animation can depict change over time directly, in a way that is analogical to the phenomenon represented. Consequently, transformations or transitions can be perceived instead of mentally reconstructed. Current research tries now to identify the effect of animation on online perceptual processes, meaning extracting relevant information, and not only comprehension as measured in a posteriori tests. In this regard, eyetracking research has recently provided a new insight in understanding how animation affects perceptual processes.

A second recent trend is to try to avoid overgeneralization and to refine findings to specific issues. No instructional method is effective in every situation. Among the relevant factors, the research has identified the type of learning objectives (procedural, factual, or conceptual knowledge), characteristics of learners, particularly previous domain knowledge and visuospatial abilities, and the type of information depicted, assuming that some information is more congruent with the dynamic nature of animation than others.

Finally, as animation is usually displayed on personal computers, concrete delivery features have to be taken into consideration. As stated before, the control over the pace and direction if the animation has been found to dramatically affect comprehension, but not always in the same direction, depending on the factors listed above. A program subtly coordinating lab research and field studies is needed to identify how instructional, interindividual and delivery factors interact to affect perceptual and conceptual processing of dynamic visualizations, in order to guide the design of effective instructional animation.

Cross-References

► Cognitive Load Theory
► Mental Models
► Multimedia Learning

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Anthropological Aspects of Learning

► Bateson, Gregory (1904–1980): Anthropology of Learning

Anthropology of Learning and Cognition

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Synonyms

Cognitive anthropology; Cultural anticipatory behavior; Cultural models; Cultural schema–based expectations

Definition

The anthropology of learning and cognition belongs to the anthropological subfield of psychological anthropology which deals with the cultural psychological aspects of human meaning making processes in relation to learning, perception, motivation, emotion, and cognition. Where mainstream psychology deals with the psychic processes of "generalized Man" the anthropology of learning and cognition asks questions about how culture and psyche make each other and, through research in cultural aspects of learning and cognition, tries to probe deeper into the problems on how culture and learning influence behavior and mental processes.

Theoretical Background

The field of psychological anthropology is so closely affiliated with the field of cultural psychology (see e.g., Cole 1996; Jahoda 1992) that many psychological anthropologist would agree with Richard A. Shweder, when he claims that he is simultaneously a cultural anthropologist and a cultural psychologist (2003, p. 3).

As culture can no longer be considered "islands" of essential difference (Appadurai 1996), anthropology has to look for ways of explaining cultural diversity in non-essentialist and non-relativistic ways. Contrary to theories of generalized Man in psychology, which often compartmentalize research in "learning" and "cognition," the anthropological approach makes it possible to scrutinize the *relationship* between learning and cognition as it evolves in particular cultural settings through engagement in specific activities forming particular organizations of cultural cognition. The concept of learning and its relation to cognition becomes a road to develop a holistic concept of culture which can encompass complexity and change as well as homogeneity and self-evidence.

In this entry, I shall first present selected examples from the vast and dispersed anthropological engagements and theories dealing with learning, cognition, and the relationship between them as they appear in the interdisciplinary field of cultural psychology. I have organized the anthropology of learning and cognition in four selected subfields with a range of specific theoretical approaches ramifying and crossing each other as well as other affiliated subfields within the field of cultural psychology.

The four subfields are: (1) systemic learning theory with a focus on learning and information; (2) cultural epidemiology theory attempting an evolutionary approach to culture inspired by natural sciences; (3) situated learning theory with an inherent critique of cognitive theory; and (4) cognitive anthropology and cultural models, which explicitly explores the relation between mental models, learning, and agency in peoples' everyday lives. As the first three subfields are treated elsewhere in this encyclopedia and as we are given the clearest vision of the *relation* between learning, cognition, and culture in the theory of cultural models, I shall proceed with a closer introduction to the subfield of cognitive anthropology and the specific theory of cultural models developed in this field. I conclude by discussing the critique against cognitive anthropology as well as the critique raised by cognitive anthropologists against mainstream anthropology.

From the Torres Strait–Expedition to Cultural Psychology

Psychological anthropology of learning and cognition has, since the British A.C. Haddon-expedition to Torres Strait, New Guinea in 1898, connected itself with the growing interdisciplinary field of cultural psychology linking anthropologists with psychologists, philosophers, and linguists in discussions of the relation between learning, cognition, and culture (see e.g. Cole 1996; Jahoda 1992).

Many consider Haddon's psychologist companion and collaborator, W.H.R. Rivers, the first psychologist to conduct cross-cultural psychological experiments. He, among others experiments, tested how natives from Torres Strait differed in their visual acuity from islanders of Helgoland of the German coast (Cole 1996,

p. 42). This type of cross-cultural studies of psychological difference and likeness across ethnic groups and the general historical development of human kind lies behind much research in psychological anthropology following the general psychological approaches in its endeavor to unfold the universal aspects of the human psyche, in spite of cultural influence, through studies of the evolvement of human cognition and learning with cultural aspects of cognitive domains and the evolution of the human mind as major topics.

Other, especially American, anthropologists like Margaret Mead, Ruth Benedict, and Edward Sapir have opened the field of cultural psychology to the diversity of personality, emotions, and language in relation to thought. The concepts of "learning" and "cognition" have frequently been used in these studies, and in those of their followers, as explanatory devices for how culture comes into being. Yet in spite of the concept's salient presence in anthropological texts, the focus of research has not contributed to theoretical developments of theories, which explicitly connects the three concepts of learning, culture, and cognition in one coherent framework.

One notable exception to this (and connected to the American group of culture and personality anthropologists by his marriage to Margaret Mead) is the British anthropologist Gregory Bateson, who has made a substantial contribution to an anthropology of learning and cognition.

Systemic Learning

Inspired by the cybernetic discussion in the 1950s and through participation in the famous Macy Conferences on Cybernetics Gregory, Bateson together with Margaret Mead developed a new understanding of the importance of information in relation to learning and cognition. In the seminal collection of articles and essays *Steps to an Ecology of Mind* (1972), Bateson contributes an explicit attempt to combine learning and cognition in a single framework drawing on insights from a range of disciplines (biology, informatics, and psychiatry being among them), which were combined with his anthropological insights. He connects aggregates of ideas in what he calls "mind" and asks the question how these ideas interact and – inspired by the biology of ecologies – asks if there are some sort of natural selection taking place. In some essays he is developing a theory of learning in relation to the ecology of mind – albeit in a very general and systemic manner. Most notably the theory is unfolded in the essays on "Double Bind" and "The Logical Categories of Learning and Communication" (Bateson 1972/1989, pp. 271 ff*)*. In these essays Bateson operates with the assumption that what in a certain sense can be considered the "same" situation can be learned to be reflected at different levels because we can learn how information is contextually framed. Systems can learn to select information by understanding the wider context in which it is presented. If learning of this contextual framing is not taking place, frustration emerges. Frustration grows when we discover that, contrary to what we initially thought, we do not know the context in which we act (Bateson 1972/1989, pp. 276–277). The implications of Bateson's theories of learning and cognition have inspired many in the general field of cultural psychology not least the activity theory of Yrjö Engeström (1987) (see entries ► Bateson, ► Activity Theories of Learning).

Cultural Epidemiology Theory

In what I have chosen to define as the field of cultural epidemiology (mainly inspired by Dan Sperber's book *Explaining Culture* 1996), cognition, and to a lesser extent learning, are evoked to explain how human cultures and human beings as *cultural* beings evolve through a variety of general approaches (e.g., Tomasello 1999; Atran 1998; Sperber 1996; Boyer 1994; Hirschfeld and Gelman 1994; Bloch 2005). The discussions of learning and cognition in this subfield places themselves in the space between evolutionary and cultural psychology and one of the main concerns is, like in Bateson's discussions, connected to how human ideas interact and evolve. There is, especially in Dan Sperber's work, a particular focus on the propagation of beliefs, representations, and humans' cognitive and conceptual modules of organized knowledge as well as cultural domains of modules. Discussion partners are often the Darwinian propagators Daniel Dennett and the "inventor" of the biological counterpart to the "gene," the "meme," Richard Dawkins. Though constructive cognitive processes are evoked in much of this work and learning is mentioned in relation to cognitive processes there are no attempts to make a new grand theory of learning in connection with the epidemiology of beliefs, ideas, and representation and interestingly enough Gregory Bateson's work, which seem so closely connected to the discussions in the subfield, is rarely mentioned (see ► Bateson).

Situated Learning Theory

In situated learning theory, most clearly formulated by the anthropologist Jean Lave in collaboration with her colleague Etienne Wenger (1991), we find an explicit connection between learning and cognition in so far especially Lave builds her development of learning theory on a critique of mainstream cognitive theory. In *Cognition in Practice* (1988), Lave criticizes the general compartmentalized approach to cognition in psychology treating cognition as "extractable" cognitive structures, domains, and mental models – because these approaches exclude the cultural aspects of cognition which evolves as we learn in practice through everyday "doings." Her showdown with cognitive science extends to a methodological discussion criticizing the field's general methodology of experimental laboratory studies, which excludes acknowledgement of everyday practice (Lave 1997). The same line of thinking is found in many studies by her anthropological colleagues and collaborators like, for example, Ed Hutchins (1995) and Roy McDermott (1993). In the framework developed as *situated learning*, the individual learner is learning participation rather than cognitive abstract knowledge as acquired fixed mental representations which can be transported to be used later. This complete rejection of cognition in relation to learning has been met with critique from many in the field of cultural psychology even though the main point of the relevance of the practices of everyday life for learning has been accepted and the question of the place of cognition in situated learning remains to be resolved (see ► Situated Learning).

Cognitive Anthropology and Schemas

The subfield of cognitive anthropology, and especially the development of the theory of cultural models, is in many ways an answer to many of the problems presented in the above subfields which either deal mainly with cultural cognition in an abstracted or systemic manner or move so close to practice-based situated learning that concepts like culture and cognition disappear from view altogether.

In cognitive anthropology there is an explicit attempt to connect culture learning, and cognition with studies of everyday practices – and further link these concepts with other relevant psychic processes such as motivation and emotions – in a coherent framework.

Roy D'Andrade has presented an introduction to the field in *The Development of Cognitive Anthropology* (1995). Here he describes how the approach has its origin in cross-cultural analysis of human cognition, which originally also has inspired D'Andrades' work with his colleague Kimball Romney and his supervisor Melford Spiro building on the well-known anthropological engagement in kinship-classification and componential/feature analyses developed by Walt Goodenough and Floyd Lounsbury (D'Andrade 1995, p. 21; Spiro and D'Andrade 1958; D'Andrade et al. 1972).

The point of departure for D'Andrade himself has been the famous phrase by Goodenough that culture is "whatever it is one has to know or believe in order to operate in a manner acceptable to its members" (op. cit. D'Andrade 1995, p. xiii), a formulation which raises a number of new questions. Humans learn cultural knowledge, but what *is* the knowledge Goodenough refers to? Taxonomies? List of propositions? To D'Andrade the answer can be found in models of the mind as formulated in "cognitive anthropology" which is the "study of the relation between human society and human thought" (ibid., 1). The basic unit of analysis is the schema which is inspired by linguists (e.g., Lakoff 1987) and cognitive psychologists (e.g., Rumelhart 1980) where schemata are seen as the building blocks of cognition. This approach built on feature analysis of kinship terminology and the like seeks a relation between learning a language and thought, but underlines that schemas are culturally shared mental constructs with *directive* force.

We have cultural schemas for almost anything we do. When shopping in the grocery store, we put apples in a bag and hand over money to the grocery store clerk – this simple transaction can be analyzed as a *commercial transaction* schema (D'Andrade 1995, p. 152). It builds on internalized organizations of cultural knowledge, which makes it possible for us to act and understand other people's acts with minimal cues. These cultural organizations of knowledge are behind our ability to understand commercial slogans, maxims, proverbs (e.g., White 1987), morality tales (Mathews 1992) as well as conduct acts, which are culturally recognizable. We learn to take transactions, like how to buy apples, for granted as we learn and connections are reinforced. Schemas build up through such processes of learned connections, which over time make it possible that we will be able to perform tasks such as buying apples without any deeper reflections. This does not mean we *will* buy apples – schemas only have potential for directing our acts, but does so in culturally rather stabilizing ways. "A schema is an interpretation which is frequent, well organized, memorable, which can be made from minimal cues, contains one or more prototypic instantiations, is resistant to change etc." (D'Andrade 1992, p. 29). Schemas influence our goals and also our feelings about, for example, paying the right price for the apples and organizing personal memories around prototypical events, which we might contrast with our own experiences. We might remember an episode where apples are given away for free because it counters the internalized schema of *commercial transaction*. In this capacity they are "learned internalized patterns of thought-feeling that mediate both the interpretation of on-going experience and the reconstruction of memories" (Strauss 1992a, p. 3).

We have all kinds of schema-like organizations of cultural knowledge for simple acts in everyday life. Once learned our mental schemas fill out information for us through default values. When we walk in the street and see a man through a window putting money beside a half empty plate of food our internalized schema fill out the rest of the information we need to understand what is and has been going on as a prototype sequence: it is likely that the man has ordered food from a waiter, eaten it, and now is paying for it and that he is seated in what we know to be a "restaurant." A schema is not just a rule-based representation but a *processor*, which can be weakened or reinforced through experience as an interconnected pattern of interpretive elements is activated. It has to be learned to trigger patterns of recognition. In fact, D'Andrade underlines, simple schemas are connectionist models which can be used to explain both cultural regularity and change because they are formed in culturally diverse learning processes which might not be connected explicitly to language or rules (as also noted by Block 1992). In this view culture is an ongoing learning process rather than a "content" as material culture. When the connections in a schema are reinforced they come to function as mental devices for recognition, which "*creates* a complex interpretation from minimal inputs" rather than being a representational picture in the mind (D'Andrade 1995, p. 136). The anthropological contribution to schema theory is the underlining of schemas as *cultural* – thus pointing to the connections of culturally shared knowledge which are self-evident for those sharing the same neural networks of connections.

The Theory of Cultural Models

Cultural models are composed of schemas, but are not necessarily schemas themselves. As an analytical tool they are more complex structures than schemas (D'Andrade 1995, p. 152). An array of analysis of cultural models has been presented especially in the three anthologies *Cultural Models in Language and Thought* (Holland and Quinn 1987), *Human Motives and Cultural Models* (D´Andrade and Strauss 1992), and *A Cognitive Theory of Cultural Meaning* (Strauss and Quinn 1997) which since the 1990s have set the stage for new directions in general anthropology placing the relation between culture, learning, and cognition in the middle of research and methodology. The theory of cultural models proposes as it is stated by Strauss and Quinn, "a new theory of cultural meaning, one that gives priority to the way people's experiences are internalized. Drawing on 'connectionist' or 'neural network' models as well as other psychological theories, in [cultural models] cultural meanings are not fixed or limited to static groups, but neither are they constantly revised or contested" (1997, p. i).

In the theory of cognitive models, cognitive schemas "learned in a specific cultural context are linked to one another and to goals for action" (Strauss 1992a, p. 3). The cultural models are complex (more complex than schemas) organizations of shared implicit cultural knowledge behind talk about, e.g., gender types (Holland and Skinner 1987), marriage (Quinn 1987, 1992), the American Dream of "getting ahead" (Strauss 1992), and romance (Holland 1992b). Whereas schemas are relatively simple to learn, cultural models are involving thoughts, motivation, and feelings, and will evolve in a continuous learning process, which make individuals differ in how they have internalized the models.

Building on a neo-Vygotskian framework (see ► Vygotsky's Philosophy of Learning), which underlines a developmental approach (Holland 1992, p. 63), individuals do not share cultural understandings in any simple manner. It is in the very process of learning that the cultural model's organization of knowledge come to gain salience for us. In an analysis of an American cultural model of romance, Dorothy Holland, for example, shows how the way young students talk about romantic relationships rests on a complex cultural model of romance organizing an array of taken-for-granted knowledge about the ideal male/female relationship in a coherent pattern. Through analysis of students talk the researcher can posit "a simplified world populated by a set of agents (e.g., attractive women, boyfriends, lovers, fiancés), who engage in a limited range of important acts or state changes (e.g., flirting with, falling in love with, dumping, having sex with) as moved by a specific set of forces (e.g., attractiveness, love)" (Holland 1992, p. 65). The student's internalization of this model differs in relation to how salient it becomes. Though most students can recognize the elements of the model and also how they are related, they do not "become desire" nor have "directional force" to the same extent for all learners. But the more they learn about the model of romance, and the more they learn to master its elements, its directional forces are reinforced.

Important Scientific Research and Open Questions

The theory of cultural models in cognitive anthropology is opening up for new and less schematic and rule-based ways of understanding the role of cognition in culture than the ones criticized by Lave, yet taking practices of everyday life into account. Cultural diversity – which appears as differences in, for example, organizations of knowledge around marriage – is not a compartmentalized entity or an object, but an ongoing learning process forming recognition of self-evident simplified worlds, which directs people to act in particular ways and thus reinforce the patterns of recognition. The cultural models are not *determining* people's individual acts. As noted by Claudia Strauss people may know a lot of culturally shared and distributed knowledge about societal ideals (such as "The American Dream"), for example, from mass media without being directly motivated by it (1992b).

Contrary to the cultural epidemiology theory, peoples' imaginaries (or cultural beliefs) are not completely shared cultural schemas, but should be analyzed through "person-centred methods to study real rather than abstract cultural subjects, if we insist on a deeper understanding of the psychological processes involved, and if we respect complexity at both the psychological and social levels" (Strauss 2006, p. 322). Culture in this line of thinking may be seen as distributed (Hutchins 1995), and contested and negotiated (Strauss and Quinn 1994) yet at the same time remain relatively stable because of all the taken-for-granted knowledge in cultural models. The self-evident recognitions are forming the background for our negotiation (of relationships as well as the price for apples). This approach, taking not only local situated learning and public discourse into account but also "personal semantic networks," does not only reject psychobiological determinism, but sociocultural determinism as well (Strauss 1992a, p. 1). We cannot take shared cultural knowledge for granted in ethnic groups just because we discursively can frame them as "Americans" or "Japanese."

Critique and Counter-critique

In many ways the theory of cultural models can be seen as an answer to what the anthropologist behind interpretive anthropology Clifford Geertz once called "the cognitivist fallacy," (Geertz 1973, p. 12). The fallacy is the notion that culture consists of mental phenomena to be analyzed through formal methods rather than understanding culture as an "imaginative universe" within which "acts are signs" which are familiar to some and unfamiliar to others (Geertz 1973, p. 13). D'Andrade comments on this cognitivist fallacy and underlines that Geertz had initiated the discussion of cultural models (in the article "Religion as a Cultural System" and the book *The Interpretation of Culture* from 1973). Contrary to the approach in cognitive anthropology Geertz limits "cultural models to perceptible embodiments – external physical structures – and exclude internal, mental constructions. Geertz argued that anthropologists should not try to find out what is in people's heads, but rather should study public, out-there-in-the-world-for-all-to-see physical representations" (D'Andrade 1995, p. 157). For Geertz "culture is public because meaning is" (Geertz 1973, p. 12). By taking this stand, however, Geertz opens for a discussion of what is meant by "public" which has been addressed in an array of books and articles which present the theory of cultural models as a way to overcome the cognitivist fallacy as well as explaining how culture comes to motivate and change people's emotions. Cognitive anthropologists also criticize the general use of culture as an explanatory concept in anthropology rather than as the focus of study in itself. Cognition and culture are connected to the problem of meaning-making (Shore 1996), and meaning-making is not a simple process. Strauss, for example, sharply criticized Geertz for what she terms his "fax-model"of culture, where public symbols are unproblematically copied into the individual psyche – a notion she argues lies implicitly in Geertz's work (Strauss 1992a). Naomi Quinn and Strauss also criticize Geertz for letting the relation between culture and actor slip away in his famous distinction between "model of" and "model for." It is evident that he prefers to discuss "models of," and Quinn and Strauss claim this is because he does not want to acknowledge the contributions by the cognitive anthropologists (Strauss and Quinn 1997, pp. 13–20).

The theory of cultural models has however also been criticized for being overly mentalist and methodologically to narrowly concentrated on peoples' talk or public discourse with too little interest in the importance of bodily movements and the materiality of artifacts in the internalization of schemas. The latter has, to some extent been opened up through the concept of "figured worlds" in which artifacts play an important part for internalization and elicitation of cultural knowledge (Holland et al. 1998).

The subfield of anthropology of learning and cognition dissolves the notion of generalized Man into cultural meaning making processes involving the whole of the psychic system with both diversity and homogeneity as a result.

Cross-References

► Anthropology of Learning and Cognition
► Bateson, Gregory (1904–1980): Anthropology of Learning
► Culture of Learning
► Situated Action and Learning
► Situated Cognition
► Situated Learning
► Vygotsky's Philosophy of Learning

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Anticipation and Learning

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Synonyms

Prospectivity; Prospective adaptation

Definition

The English word *anticipate* derives from the Latin *anticipare*, literally "to take before," with an original sense of "to cause to happen sooner." By c. 1640, *anticipate* acquired the sense "to be aware of (something) coming at a future time." This latter sense comes with a caveat, however, as *anticipate* has an element of preparation that prevents its use as a strict synonym for *expect* or *predict*. To wit, a prediction might engender anticipation. With respect to learning, anticipation refers to the prospective nature of adaptation.

Theoretical Background

Since Pavlov, there has been an appreciation of the link between anticipation and learning. Briefly, in typical Pavlovian conditioning, an *unconditioned stimulus* (US) has some natural or a priori *unconditioned response* (UR). Classic examples of US-UR pairs include food-related salivation and vasoconstriction due to exposure to cold. Any stimulus that is regularly contingent, either preceding or concurrent, with the US is a potential *conditioned stimulus* (CS), for example, the ringing of a bell. The end result of Pavlovian conditioning is a *conditioned response* (CR), which either mimics or compensates for the UR. In either case, the CR is anticipatory with respect to the US. Anticipation is most clear when the CR and UR are of the same kind, for example, salivation, but compensatory responses, such as those that play a role in drug tolerance, have an anticipatory coping function discussed at length by the functional school of Pavlovian conditioning (Domjan 2005).

There are numerous aspects of learning theory, however, of which Pavlovian conditioning is only one. More modern approaches include probabilistic or statistical theories such as the Bayesian approach.

Bayesian learning deals with conditional probabilities: the probability of a hypothesis being true given some context. Bayesian inference combines the inherent likelihood of a hypothesis with the retrospective prior probability of the context, resulting in a posterior probability. Within Bayesian learning, this posterior probability is concerned with future events, and is fundamentally prospective.

Problems in motor learning highlight a common, but quite important, condition for anticipation. The visuomotor system, regardless of one's theory of motor control, is fraught with transport delays due to mechanical linkages and the finite conduction speeds of neural activations over sometimes very long distances. At least in part, motor learning is concerned with compensation for, or otherwise neutralization of, these delays. For instance, learning of a motor skill involving visually guided control must contend with loop delays of up to 300 ms (Miall and Wolpert 1996). That is, if a motor action is deemed "off the mark," the registration of this state of affairs comes up to 300 ms after the fact, and any corrective maneuvers begun at this time would be undoubtedly moot by the time they were executed.

All three of the preceding cases illustrate the close ties between learning and anticipation. Fundamentally, mere reaction takes some amount of time. Biological processes set off by the presence of food, Bayesian updates, and visually guided action are all inherently reactive; each comes with some characteristic delay. After successful learning, the result of what was once a reaction happens earlier, often just in time. That is, salivation happens *when* the food is present, not after. One might even say that the problem of learning is, in effect, how to begin a reaction before its stimulus. This is clearly a sense of anticipation as defined above. As such, various theories of learning typically contain implicit theories of anticipation, be they associationist, probabilistic, or concerning internal forward models.

Important Scientific Research and Open Questions

It is clear that organisms from amoeba (Saigusa et al. 2008) to humans (Foulkes and Miall 2000) are capable of anticipation – and learning – on significant timescales. While many learning experiments maintain an implicit relation to anticipation, some research focuses on it explicitly; the most obvious of which are learning tasks involving delayed feedback. In these experiments, the implicit or inherent delay associated with learning tasks is made explicit by the application of additional delay.

Foulkes and Miall (2000) perform just such an experiment in which human subjects learn to synchronize hand movements with a complicated trajectory presented visually. Delayed visual feedback requires that hand movements also be anticipatory, in order to make up for applied delay. Past studies have investigated manual tracking with delayed visual feedback (e.g., Vercher and Gauthier 1992); however, Foulkes and Miall (2000) repeat conditions several times in order to allow for learning to take place, which it indeed does.

Connecting back to a more classical notion, Dworkin (1993) develops a model of Pavlovian conditioning in the context of physiological regulation and so-called learned homeostatic responding. The model itself is interesting here because of its clear linkages between a classic theory of learning and clearly anticipatory phenomena in physiology. In fact, the model formally treats the conditioned response as a kind of dynamical state that comes to anticipate a disturbance function.

As research continues to flow across the boundary between anticipation and learning, some issues remain uncertain, most notably the nature of the boundary itself. Assuming that there should be a boundary at all, it is not immediately clear how theories of anticipation and theories of learning should best interface. While not likely that all issues of one could be reduced to the other, it does appear there is a substantial middle ground that might share the same theoretical foundations. As these areas progress, it will become increasingly important to discern what this foundation looks like, whether it resembles either anticipation or learning, or something yet unforeseen.

Cross-References

▶ Anticipatory Learning
▶ Bayesian Learning
▶ Motor Learning
▶ Pavlovian Conditioning

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Anticipatory Behavior

► Anticipatory Schemas
► Many Aspects of Anticipation
► Surprise and Anticipation in Learning

Anticipatory Learning

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Synonyms

Curious learning; Ideo-motor principle of learning; Learning of predictions; Sensorimotor learning

Definition

Anticipatory learning is sometimes considered synonymous with the general mechanism of learning to generate predictions or learning a *predictive* or ► forward model of an encountered environment or problem. However, the term ► anticipation usually does not simply refer to predictions, but rather to predictions that are expected to be relevant to an organism and that are used to effectively adapt decisions and behaviors of organisms. Therefore, anticipatory learning is not merely about learning to predict, but learning to predict those aspects that are relevant for the learning system. Such predictions may start on a very low sensorimotor level, such as learning how body movements feel in order to be able to focus on other sensory information. On a higher level, action-dependent contingencies may be learned that are highly useful for decision making and planning processes, such as the capability to open a door. Similarly, contingencies in the external environment may be learned that do not depend on own actions, such as the reasoning that dark clouds often lead to rain.

On the other hand, anticipatory learning also refers to the exploitation of predictions for the improvement of further learning progress. Available predictions allow the filtering of expected, uninformative information and thus to focus on unexpected, novel information. In addition, the anticipatory learning mechanism can bias the sensory processes and motor activities to guide and improve the learning process itself. In this case, anticipatory learning induces ► curious and epistemic behavior in the search for new, informative, useful bits of information. This form of behavior requires prior knowledge about the future in order to trigger information-seeking actions that are expected to yield the highest information gain and thus the fastest learning progress.

Theoretical Background

The roots of anticipatory learning of predictions lie in the ideo-motor principle (IMP) of cognitive psychology, which was first postulated in the nineteenth century by William B. Carpenter, Thomas Laycock, Johann F. Herbart, Herman R. Lotze, Emil Harless, and William James (Stock and Stock 2004). The IMP addresses the problem of how an organism may be able to develop goal-oriented behavior. Since at the beginning of development the mind cannot know much about the functionality of its associated body, only reactive muscular activity can supply initial bodily information. The IMP suggests that such reactive bodily movements quickly lead to the learning of *forward models* about action-dependent sensory changes, that is, action–effect correlations – such as the realization of how the arm moves while it is outstretched. Moreover, a learned forward model can be inverted, yielding an *inverse model*, which can activate goal-oriented behavior – such as the activation of a stretch movement when stretching is desired. Since advanced learning stages are only possible if the sensory consequences of own-body movements are ignored by means of a forward model, the IMP may not only constitute an initial learning mechanism in higher organisms, but also one of the most fundamental ones.

Despite its fundamental importance, the IMP has only recently regained consideration and appreciation. The behaviorist movement in the early twentieth century prevented its earlier general acceptance. Despite the dominance of behaviorism, Edward C. Tolman (1932) realized that rats are well able to learn cognitive maps of their environment without the provision of any type of reinforcer: after an initial learning phase without reward, he introduced a reinforcer (such as food pellets) at a certain position in a maze and showed that rats would move very directly to the maze location once the food was detected – even without having encountered the actual path–food correlation. He proposed the term ► latent learning for learning environmental properties or behavioral contingencies without the availability of any type of reinforcer.

Both, latent learning and the IMP propose the learning of forward models that can also be used for inverse, goal-directed control. With respect to the IMP, inverse control may be due to the activation of a desired bodily feeling and its consequent associated motor activations. In the case of latent learning, a location may be activated and a movement may be planned inversely toward that location. Thus, in both cases some form of bidirectional situation-action-effect triples are learned in anticipation of their useful usage during self-motivated, goal-directed behavior. The theory of *anticipatory behavioral control* integrates the IMP, latent learning, and other insights from psychological experiments into one psychological theory of learning and behavior (Hoffmann 2003).

Forward–inverse structures have an equivalent in control theory, where the notion of internal modeling has been proposed to study motor control in living organisms. Inverse models (or controllers) calculate the next motor command on the basis of action goals, actual and predicted stimuli. Forward models (or predictors) calculate the expected next stimuli, that is, the reafference, on the basis of an efference copy of the motor commands produced by the controller. Various architectures have been proposed that learn such combinations of forward and inverse models. A combination of multiple forward–inverse neural models may be the most direct implementation of this concept (Wolpert and Kawato 1998).

In general, two kinds of anticipatory learning can be distinguished: (1) When learning *payoff anticipations*, condition-action-payoff associations are learned. This is the simplest and least flexible form of anticipatory learning and may also be covered by behaviorist learning theories. (2) *Sensorial and state anticipatory learning* forms predictions of sensory changes, most often in the form of condition-action-effect relations. While sensorial anticipations refer to immediate sensory consequences, state anticipatory mechanisms produce more complex forms of expectations, such as event anticipations, that support decision making and execution.

The learned predictions can be used not only *online* for action control, but also *offline* to plan and simulate (potential) actions (Grush 2004; Jeannerod 2006). Ideally, the same mechanisms (forward models) that support online predictions can be reenacted to produce offline simulations of potential actions. Due to the accumulation of small prediction errors, abstraction mechanisms are necessary to be able to generate further reaching predictions with sufficient accuracy – albeit on a more coarse-grained level. Generally, the study of how to produce predictions at different time scales and levels of abstraction is still in its infancy in machine learning.

Although learning to predict action effects is probably the most widely studied aspect of anticipatory learning, there are other forms that are equally important. Organisms can learn the contingencies of the external environment, irrespective of their own actions. However, recent studies in neuroscience have revealed that the motor system is involved in encoding sensory dynamics despite the absence of actual motor actions. This insight suggests that the brain uses motor encodings also for processing purely sensory information. Thus, the motor system may be even more strongly involved in anticipatory learning than previously thought.

The social aspect is also highly important in anticipatory learning and may actually constitute one of the evolutionary pressures for increasingly better state anticipatory capabilities in higher organisms. For effective social interactions to take place, it is vital to anticipate the actions and intentions of others. Recent theories in neuroscience indicate that individual anticipatory capabilities are reused to recognize and to understand the intentions behind actions performed by others.

Particularly the activity of *mirror neurons* correlates with current behavioral goals of oneself or of observed others. Thus, anticipatory learning extends into the realm of social learning, including learning to cooperate, to empathize, and to communicate.

Besides the learning of predictive models for *goal-directed action control*, anticipatory mechanisms can be used to improve the efficiency of learning itself. In this form of anticipatory learning, the goal is to learn novel predictions as well as to improve the accuracy of already available predictions where necessary. This leads to ► curious learning behavior, where the learner searches for the detection of novel experiences and causalities. Developmental psychology research associates these mechanisms with *intrinsic motivations* in children that want to learn even without external reward, such as food or approval from the parents. For example, a child that plays with blocks may initially mainly want to learn how the blocks behave during interaction or a child that plays peek-a-boo may want to learn how the interacting partner reacts. Thus, anticipatory learning intrinsically motivates behavior toward situations in which the outcome is uncertain but appears predictable to some extent, that is, in which a high information gain can be expected. Note that this is not equivalent to behavior toward mere novel situations, since these can be potentially dangerous and may not lead to any information gain, because the situation may be too complex or noisy to comprehend. *Epistemic behavior* may be considered a higher form of curious behavior. It is not only involved in anticipatory learning but also in anticipatory behavior, such as the anticipatory search for a concealed item.

Anticipatory sensory processing allows for learning higher forms of predictive models. Generally, predictive models may be built on various levels of abstraction. Starting from the IMP, first simple direct sensorimotor correlations need to be learned. However, once such correlations are available to the learner, they can be used to filter the incoming sensory stimuli and thus allow higher anticipatory learning processes to focus on the most informative, novel aspects of the incoming stimuli. While small differences in predictable information may be used to adjust the available predictive model, large and unexpected differences may be used to generate new predictive models on a higher level of abstraction. This top-down predictive filtering of information may be the reason for the huge amount of neural back connections from higher cortical areas toward primary sensory processing areas.

Important Scientific Research and Open Questions

There are numerous ► machine learning techniques for anticipatory learning including *unsupervised*, supervised, and ► reinforcement learning techniques. In ► reinforcement learning, a distinction can be made between model-free and model-based methods. Model-free methods, such as *Q-learning* and *TD-λ learning*, do not learn explicit action–effect pairs, but they use payoff anticipations for the direct or indirect optimization of their behavioral policy. This procedure has been recently associated with the role of dopamine as a predictive reward signal. Model-based methods instead, such as *Anticipatory Learning Classifier Systems*, are state anticipatory learning methods that learn explicit situation-action-effect correlations. *Hierarchical reinforcement learning* addresses the problem of learning and exploiting useful hierarchical representations for behavioral control.

Although anticipatory learning constitutes one of the most fundamental learning processes in higher animals and humans, a rigorous study of its functionality and most appropriate learning mechanisms and representations involved still lacks sufficient research effort. At this time, various predictive machine learning algorithms are available for time-series learning, dynamic policy learning, predictive model learning, etc., but nearly no algorithms are available that combine these techniques effectively. Especially the development of anticipatory learning mechanisms that automatically build useful hierarchical anticipatory representations is still pending. Seeing the availability of various techniques, the largest current challenge may be to understand each of their particular strengths and weaknesses and to consequently combine the techniques appropriately in order to address both the generation of flexible, versatile, anticipatory adaptive cognitive systems as well as the understanding of how the brain generates such cognitive systems during development (see Pezzulo et al. 2008, for further insights on these issues).

Cross-References

► Association Learning
► Bayesian Learning
► Curiosity and Exploration

► Latent Learning
► Machine Learning
► Online Learning
► Reinforcement Learning
► Schema-Based Architectures of Machine Learning
► Supervised Learning

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Anticipatory Learning Mechanisms

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Synonyms

Adaptive systems; Constructivist agents; Predictive model learning algorithms

Definition

In the artificial intelligence domain, *anticipatory learning mechanisms* refer to methods, algorithms, processes, machines, or any particular system that enables an autonomous agent to create an anticipatory model of the world in which it is situated. An *anticipatory model of the world* (also called *predictive environmental model*, or *forward model*) is an organized set of knowledge allowing inferring the events that are likely to happen. For cognitive sciences in general, the term *anticipatory learning mechanism* can be applied to humans or animals to describe the way these natural agents learn to anticipate the phenomena experienced in the real world, and to adapt their behavior to it.

Theoretical Background

When immersed in a complex universe, an agent (natural or artificial) needs to be able to compose its actions with the other forces and movements of the environment. In most cases, the only way to do so is by understanding what is happening, and thus by anticipating what will (most likely) happen next. Therefore, a predictive model of the world can be very useful to an agent as a tool to guide its behavior; the agent has a perception of the current state of the world, and it decides what actions to perform according to the expectations it has about the way the situation will probably change.

Butz et al. (2003) have made a comprehensive review of the different forms of anticipatory behavior present in artificial intelligence, including simple implicit anticipatory systems (in which the anticipatory behavior is programmed into the agent as useful predefined action rules), payoff anticipatory systems (in which the agent estimates the future rewards), and model-based anticipatory systems (in which the agent effectively anticipates the world transformations using a predictive environmental model). Very often, these artificial anticipatory systems are inspired by real adaptive mechanisms found in nature.

Nevertheless, even if most of researchers in artificial intelligence agree that anticipation is a fundamental characteristic of intelligent behavior, there is no consensus on what kind of model a "strong" intelligent agent should possess, much less on how it can learn it in a feasible way. Moreover, for a wide range of complex or realistic problems, it is very hard to provide the agent with a complete model of the world in advance; the agent has no alternative but to incrementally learn how the universe evolves, from its own experiences, in order to adapt its behavior to it. This is the advantage of being endowed with an anticipatory learning mechanism.

The necessity of such a mechanism is more evident when the agent is fully situated and completely autonomous; that means, when the agent is by itself, interacting with an unknown, dynamic, and complex world, through limited sensors and effectors, which give it only a local point of view of the state of the universe and only partial control over it. In other words, the agent is not omniscient (it is not aware of the complete state of the universe), and is not omnipotent (it is just one among other possible sources of perturbation affecting the environment). In this case, it is very hard to predefine static solutions (like automatic behaviors) designed to deal with all possible situations the agent can face throughout its existence.

An autonomous and situated agent is necessarily self-motivated; it is a creature that has goals. Sometimes these goals are implemented as explicitly defined states to be reached or specific tasks to be accomplished; but in general, the agent is just motivated by sporadic reward signals, or intrinsically evaluative sensations that it wants to experience or avoid (like pleasure and pain). In any case, predefined reactive behaviors can properly work only in a restricted set of problems where the important variables are fairly known and controllable. The remaining problems can only be successfully faced by cognitive agents, who will be compelled to discover the regularities that govern the universe, understand the causes and the consequences of the phenomena, identify the forces that influence the observed changes, and especially master the impact of its own actions over the ongoing events. So, in the machine learning community, it is common to consider two subproblems: on the one hand, the construction of a predictive model of the world (i.e., structured knowledge that allows the agent to anticipate the environment dynamics); on the other hand, the definition of a policy of actions (i.e., a behavioral strategy that guides the agent in its plans and decisions according to its objectives). Generally, for a situated agent, there is no separate training phase; the learning mechanism needs to create both the model of the world and the policy of actions online (while the agent is already performing its activities).

Important Scientific Research and Open Questions

Over the last 20 years, several anticipatory learning mechanisms have been proposed in the artificial intelligence scientific literature. Even if some of them are impressive in theoretical terms, having achieved recognition from the academic community, for real-world problems (like robotics) no general learning mechanism has prevailed. Until now, the intelligent artifacts developed in universities and research laboratories are far less wondrous than those imagined by science fiction. On the other side, neuroscientists, psychologists, and philosophers have been working hard to try to explain how intelligence works, in particular how animals and humans learn, and how things are modeled and represented in their brains and minds. Even if some important findings have been done, we are still far from being able to explain in detail the main part of intelligent processes, and, in the current state of the art, we are not able to present a complete and definitive model neither of the intelligence in general, nor of the faculty of learning in particular. Within the artificial intelligence community, it is possible to highlight at least four lines of research more or less explicitly related to the conception of anticipatory learning mechanisms: constructivist AI, automata learning, model-based reinforcement learning, and anticipatory classifiers systems.

Drescher's book (1991) can be considered the first impacting work published on the subject of constructivist models. He presented the *schema mechanism*, an algorithm conceived to reproduce in machine some aspects of the human cognitive development as described by ► Piaget's learning theory, representing anticipatory knowledge as (computational) ► schemas, in the form [context] + [action] → [result], similarly to the classical Fikes and Nilsson's *STRIPS* system. The schema mechanism inaugurated an interesting line of research called *constructivist artificial intelligence*. After Drescher, some other authors tried to follow the same way proposing a variety of constructivist learning mechanisms, often focused on *abstract concept creation* (i.e., how the agent can develop its own representational vocabulary beyond its basic sensorimotor signals). Guerin (2011) present a good review about these algorithms, including Chaput's *CLA*, Holmes and Isbell's *PST*, and Perotto, Buisson, and Alvares's *CALM*.

The *automata learning* research community also played an important role in the development of model-based anticipatory learning algorithms. The problem of finding the structure of an automaton (a finite-state machine) from examples is similar to that in which an agent has to learn a model of the environment from the observation. Another essential reference is the *reinforcement learning* research community (in AI), concerned with the *decision-making* problem. Reinforcement learning algorithms are generally designed to estimate the utility of state-actions pairs, and to establish a policy of actions to maximize the rewards received by the agent over time. This problem is popularly modeled as a *Markovian decision process.* The classical MDP model is represented as a state machine; at each time step, the machine is in some state *s*, and the agent may choose some action *a* to carry out; at the next time step, according to some (nondeterministic) transition function, the process changes into a new state *s*', giving the agent a corresponding reward *r*. This formalism has been extended to deal with partial observability; in this case, the agent does not know *s*, only perceiving an observation *o*, which works as an indirect and incomplete indication to the underlying state of the process. Several algorithms have been proposed to solve MDPs and POMDPs (i.e., to find the optimal or near-optimal policy, to maximize the average or cumulative discounted reward over time), and a good overview about them can be found in the Feinberg and Shwartz's book (2002).

Another important line of research related to anticipatory learning mechanisms was generated within the *evolutionary computation* (or genetic algorithms) community, from where the *Anticipatory Behavior in Adaptive Learning Systems* conference series emerged. Sigaud et al. (2009) present the *anticipatory learning classifier systems* framework, including representative algorithms like Stolzmann's *ACS*, Butz's *ACS2* and *XACS*, and Gerard's *YACS* and *MACS*, comparing it with other related models. In recent years, a convergent movement of all these research branches toward the use of factored MDPs have been noticed; in a factored MDP the state space is decomposed into a set of variables or properties, which permits to avoid an exhaustive enumeration of states.

Thus, an MDP can be extended to become at the same time factored and partially observable, and it is so called FPOMDP. In order to be factored, the original set of states S is decomposed and replaced by the set $X = \{X_1, X_2, \ldots X_n\}$ of properties or variables; each property X_i is associated to a specified domain, which defines the values the property can assume. Furthermore, in order to be partially observable, the set X is divided into two subsets, $X = P \cap H$, where the subset P represents the observable properties (those that can be accessed through the agent sensory perception), and the subset H represents the hidden or non-observable properties. The set $C = \{C_1, C_2, \ldots C_m\}$ represents the controllable variables, which compose the agent actions; $R = \{R_1, R_2, \ldots R_k\}$ is the set of (factored) reward functions, in the form $R_i : P_i \rightarrow \mathbb{R}$; and $T = \{T_1, T_2, \ldots T_n\}$ is the set of transformation functions, in the form $T_i : X \times C \rightarrow X_i$, defining the system dynamics (which can be nondeterministic).

When the agent is immersed in a system represented as a FPOMDP, the complete task for its anticipatory learning mechanism is both to model the transformation function and to define a sufficiently good policy of actions. The transformation function can be described in the form of a *dynamic Bayesian network*, i.e., an acyclic, oriented, two-layers graph, where the first layer nodes represent the environment situation in time *t*, and the second layer nodes represent the next situation, in time $t + 1$. A stationary policy $\pi : X \rightarrow C$ defines the action to be taken in each given situation in order to optimize the rewards received by the agent over a potentially infinite time horizon. Certain algorithms create stochastic policies, and in this case the action to take is defined by a probability.

Degris and Sigaud (2010) present a good overview of the use of this representation in artificial intelligence, referring several related algorithms designed to learn and solve FMDPs and FPOMDPs, including both the algorithms designed to calculate the policy given the model (like Boutilier's *SVI* and *SPI*, Hoey, St-Aubin, Hu, and Boutilier's *SPUDD* and APRICODD, Guestrin, Koller, and Parr's *FALP* and *FAPI*, Poupart's *VDCBPI*, Sim and Kim's *SHSVI*, and Shani, Brafman, and Shimony's *FSVI*) and the algorithms designed to discover the structure of the system (like Degris and Sigaud's *SDYNA*, *SPITI*, and *UNATLP*, Strehl, Diuk, and Littmann's *SFL*, and Jonsson and Barto's *VISA*).

Despite the growing interest in anticipatory learning mechanism within the artificial intelligence community, some questions have not yet been convincingly answered. How can an agent enrich its perception with high-level, conceptual, or abstract understanding? How can it consistently solve the exploration–exploitation dilemma (find the good compromise between exploring new possibilities in order to learn new things, and taking profit of the knowledge already learned)? How can the agent correctly identify the relevant properties of the situations and discover the causal relations of the world? How can it efficiently deal with continuous, nondeterministic, nonstationary, noisy, large, and complex universes (like most of real-world problems)? These important questions still remain open.

Cross-References

▶ Adaptation and Anticipation: Learning from Experience
▶ Adaptive Learning Systems
▶ Anticipatory Learning/Anticipation and Learning
▶ Anticipatory Schema(s)
▶ Belief-Based Learning Models
▶ Computational Models of Human Learning
▶ Developmental Robotics
▶ Incremental Learning (Definition)
▶ Learning Algorithms/Machine Learning
▶ Mental Models of Dynamic Systems
▶ Piaget´s Learning Theory

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Anticipatory Schemas

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Synonyms

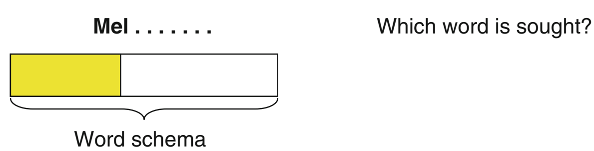
Anticipatory behaviour; Schema-based expectations

Definition

Anticipatory schemas direct how adaptive learners (such as humans and animals) explore their environments. What happens to them is rarely completely unexpected. Actually, one important distinction among schema-based architectures is their reactive or anticipatory nature. Reactive schema-based architectures of cognition assume quick and automatic responses to dynamic environments whereas anticipatory schema-based architectures include anticipatory mechanisms, which generate and exploit expectations about the next stimuli to be processed. These anticipatory aspects are inspired by psychological theories of action control, indicating that anticipated effects of (possible) actions play a fundamental role in regulating the agent's behavior.

Theoretical Background

Research on anticipatory schemas (and behavior, respectively) in adaptive learning systems gains increasingly more recognition and appreciation in various research disciplines, such as cognitive psychology, neuroscience, linguistics, artificial intelligence, machine learning, robotics, and others. However, the idea of anticipatory schemas can be traced back to the seminal work on productive thinking from Otto Selz in 1913. It is strongly associated with *complex completion* due to an activated schema. This can be illustrated with the example of a word schema.



"The consciousness of the particular word to be found transcends from the consciousness of not specified word to the consciousness of a word which begins with 'Mel —'. We should conceive the development of this consciousness in a way that an empty schema of a concrete word will be filled through the insertion of a spoken series of phonemes at its beginning, i.e. a combinatory process" (Selz 1913, p. 113 f.).

The development of anticipatory schemas facilitates the completion of a complex, i.e., and is based on three regularities:

- A given totality, which functions as a part of a complex, tends to initiate the reproduction of the entire complex.

- An anticipatory schema has the tendency to initiate the reproduction of the entire complex.
- There is a determination aiming at the completion of a schematically anticipated complex (Selz 1913, p. 128).

An anticipatory schema is a structured pattern of knowledge, which serves two purposes: First, it prepares the adaptive learning system (a human or animal) to accept information that will modify the schema. For example, if a person intends to exit an unfamiliar room that has four doors, then the person can invoke a general "room schema." This "global" schema probably has information about common characteristics of rooms like the presence of walls, a floor, a ceiling, and an exit. These characteristics are what the person anticipates with regard to a room. By activating this anticipatory schema, the person is now ready to accept certain kinds of information, like the locations of the doors. Once picked up, this information modifies the activated schema, thus adapting it to the particular room and to process other information (e.g., what is behind each door). The second purpose of an anticipatory schema is to direct actions. For example, if one knows that a door is blocked by a brick wall, then, because one anticipates the wall, there is no need to spend time exploring the possibility of traversing that route. This component of the cycle, therefore, posits that complex mechanisms in the mind are involved in perception, making it compatible with theories of perception, which propose that perception results from perceptual set and hypothesis testing.

Important Scientific Research and Open Questions

For a long time, anticipatory schemas were a special topic of psychology but since some years, also computer scientists, psychologists, philosophers, neuroscientists, and biologists are increasingly interested in anticipatory behavior of adaptive learning systems (cf. Butz et al. 2007).

So, for example, research in the field of animal learning and neuroscience provides some evidence on anticipatory brain mechanisms, which enable animals (e.g., rats) for anticipatory behavior. From observational studies, we know that animals are able to anticipate future stimuli and events, to make choices that will maximize future rewards, and to memorize past experiences in order to perform better in future. However, research into the brain mechanisms of anticipatory learning are at the beginning. Nevertheless, neuroscience addresses neural mechanisms found in the mammalian cerebellum, basal ganglia, and the hippocampus that give rise to such adaptive anticipatory behavior (Butz and Hoffmann 2002; Fleischer 2007).

Another emerging field of research on anticipatory learning is machine learning and robotics. Here, especially schema-based architectures have been developed as a methodology for designing ► autonomous agent architectures that can be used for both anticipatory behavior experiments and simulations. Theoretically, these architectures are based on the integration of anticipatory learning mechanisms. However, the functions of anticipatory schemas are not sufficiently integrated in these approaches although forms of implicit and explicit anticipatory learning mechanisms constitute the fundamental basis of procedural learning algorithms.

Within the realm of machine learning, a special field of interest is building robots with anticipatory behavior based on analogies with past episodes. Anticipatory schemas are used to make predictions about the environment and to control selective attention and perception. In the related literature, ► integrated architectures are presented, which perceive the environment, reasons about it, makes predictions, and acts physically in this environment.

Cross-References

► Action Schema(s)
► Adaptability and Learning
► Adaptation and Anticipation: Learning from Experience
► Anticipatory Learning
► Schema(s)
► Schema-Based Architectures of Machine Learning

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Anti-intellectual

► Narcissistic Learning

Anxiety Disorders in People with Learning Disabilities

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Synonyms

Anxiety: nervousness, disquiet, fretfulness; Learning disability (UK): intellectual disability mental retardation

Definition

Anxiety is a normal response to stress or danger and can improve performance in a range of situations. It is considered to be a mental health problem only when it is long-lasting, severe, causing significant distress, and is interfering with everyday activities. Anxiety Disorder could hence be perceived as the pathological exponent of normal fear manifest by disturbances of mood, as well as of thinking, behavior, and physiological elements.

Anxiety disorder (*AD*) *is a generic term* constituting a group of illnesses involving manifestations of extreme or pathological fear and increased arousal. These include:

- *Generalized anxiety disorder* (*GAD*): Excessive and inappropriate worrying that is persistent (lasting some months (ICD-10), 6 months or longer (DSM-IV) and not restricted to particular circumstances)
- *Panic disorder*: Recurrent unexpected surges of severe anxiety ("panic attacks"), with varying degrees of anticipatory anxiety between attacks
- *Social phobia*: A marked, persistent and unreasonable fear of being observed or evaluated negatively by other people, in social or performance situations, associated with physical and psychological anxiety symptoms
- *Specific, simple, or isolated phobia*: Excessive or unreasonable fear of (and restricted to) single people, animals, objects, or situations (e.g., flying, dentists, seeing blood, etc.) which are either avoided or are endured with significant personal distress (avoidance must be prominent for ICD-10 diagnosis)
- *Posttraumatic stress disorder* (*PTSD*): A history of exposure to trauma (actual or threatened death, serious injury, or threats to the physical integrity of the self or others) with a response of intense fear, helplessness, or horror: and the subsequent development of reexperiencing symptoms (intrusive recollections, flashbacks, or dreams), avoidance symptoms (e.g., efforts to avoid activities or thoughts associated with the trauma),and hyper-arousal symptoms (including disturbed sleep, hypervigilance, and an exaggerated startle response)
- *Obsessive–compulsive disorder* (*OCD*): Recurrent obsessional ruminations, images, or impulses, and/or recurrent physical or mental rituals, which are distressing, time-consuming, and cause interference with social and occupational function. Common obsessions relate to contamination, common rituals include washing, checking, cleaning
- Others categorized under anxiety disorders include adjustment disorders with anxious features, anxiety disorders due to general medical conditions, substance-induced anxiety disorders
- *Anxiety disorder not otherwise specified* (DSM-IV-TR) (residual category)

Intellectual Disability (*ID*) is a generalized disorder characterized by significantly impaired cognitive functioning and deficits in two or more adaptive behaviors with onset before the age of 18 (ref DSM/ICD). The causes of ID include

- Prenatal factors (e.g., chromosomal/gene disorders, e.g., Down's syndrome; adverse environmental influence, e.g., fetal alcohol syndrome)

- Perinatal factors (e.g., birth trauma)
- Postnatal (e.g., head injury, infection)

Theoretical Background

AD ranks among one of the commonest categories of mental health disorders. Chronologically, AD can be episodic, continuous, or stress related.

There is evidence that ADs are under-detected and undertreated in the general population and more so in people with intellectual disability (PWID). As a consequence of failure to diagnose the anxiety component of their problem, these patients may not receive the correct treatment and may undergo unnecessary and costly investigations, in particular for their physical symptoms (Hales 1997). All types of ADs have been recognized in PWID.

Prevalence in PWID

Prevalence studies in PWID are unreliable because of methodological problems. The available evidence indicates that ADs are at least as common as in the general population (Deb et al. 2001a) where the estimated prevalence is 18% (Kessler et al. 1994). Longitudinal studies in the general population demonstrate a higher prevalence of symptoms of anxiety in adults with mild intellectual disabilities when compared with the general population (Richards et al. 2001). Bailey and Andrews (2003) concluded that many studies fail to make a definite diagnosis, reporting only the prevalence of anxiety symptoms, which range from 6% (Ballinger et al. 1991) to 31% (Reiss 1990).

Coexisting depressive symptoms (comorbidity) are common, particularly in patients with severe anxiety. Many, including PWID simultaneously fulfill diagnostic criteria for anxiety and depressive disorders. Masi et al. (2000) carried out a study in adolescents with ID which suggested high rates of comorbidity. ADs were identified as more prevalent in individuals with self-injurious behavior than in those without such behavior (Moss et al. 2000).

Diagnosis and Classification

Diagnosis of AD in PWID utilizing the current classificatory systems (ICD-10/DSM IV-TR) can be problematic (Stavrakaki 2002). This is because diagnostic criteria in both are validated only on individuals with average intellectual functioning and firmly entrenched in language-based phenomenology that rely heavily on cognitive and linguistic skills (Cooray et al. 2007). Owing to heterogeneity of abilities and communication skills across the whole spectrum of ID, it is also difficult to use single standardized criteria for diagnosing ADs in PWID (Cooray and Bakala 2005). Nevertheless, ADs are well recognized in people with ID (Bailey and Andrews 2003), but may be underreported (Reiss et al. 1982) and under-diagnosed (Veerhoven and Tuinier 1997).

Two recent publications have aimed to improve diagnostic reliability of mental disorders including AD in PWID. The DC-LD (Diagnostic Criteria-Learning Disability) is a consensus-based classificatory system reflecting expert opinion developed by the Royal College of Psychiatrists (Cooper et al. 2001). This provides operational diagnostic criteria for mental disorders for use in adults with moderate, severe/profound IDs and can complement the ICD-10 or DSM-IV. The Diagnostic Manual-Intellectual Disability (DM-ID) proposes supplementary guidelines to The DSM-IV-TR, incorporating behavioral equivalents within the context of cognitive, developmental and adaptive functioning. Emphasis is placed on utilizing objective manifestations of anxiety rather than subjective elements in those who have limitations in cognitive and linguistic abilities (Fletcher et al. 2007).

Impact of ID on the Presentation of the Clinical Features of Anxiety Disorders

The clinical features of anxiety have cognitive, physiological, psychological and behavioral components. The psychological/cognitive elements may present as fearful anticipation, irritability, concentration, memory problems, repetitive worrying thoughts, fear and in extreme instances fully fledged panic. Physiological manifestations include dry mouth, difficulty in swallowing, flushing, sweating, pallor, palpitations, tremor, hyperventilation, chest pain/tightness, headache, backache, fatigue, muscle tension, diarrhea, increased urinary frequency, paresthesia, heightened startle response and insomnia. Avoidance of the specific situation precipitating symptoms is a common behavioral manifestation of AD.

In those with more severe ID only behavioral symptoms can be assessed reliably. This often makes it difficult for all the criteria of an AD to be met (Matson et al. 1997). When diagnosing AD in PWID, Khreim and

Mikkelson (1997) highlight the need to place relatively greater emphasis on phenomena such as agitation, screaming, crying, withdrawal, regressive/clingy behavior or freezing, all of which could be interpreted as manifestations of fear. Smiley (2005) noted that many ADs are misdiagnosed as problem behaviors in those with severe and profound ID.

Assessment for AD involves evaluation of symptoms, utilizing behavioral equivalents of anxiety within the context of the ICD-10/DSM-IV criteria, the duration of these symptoms, the extent of persons' functional impairment and distress and coping resources. Assessment also needs to include evaluation of the symptoms of other comorbid conditions such as depressive disorders, dysthymic disorder, given both the overlap of symptoms (for differential diagnosis) and the comorbidity between AD and these other disorders.

Risk Factors

PWID are more vulnerable to ADs because of adversity, inadequate social supports and poor coping skills which contribute to stressful life events. There are certain genetic causes of ID which are specifically associated with anxiety including fragile-X syndrome (social anxiety disorder), Rubinstein–Taybi and Prader–Willi syndromes with (OCD; Levitas and Reid 1998) and Williams syndrome (GAD, specific phobias; Dykens 2003; Einfeld et al. 2001). Hyman et al. (2002) noted significantly high prevalence of compulsive behavior in those with Cornelia de Lange syndrome.

Management and Treatment

Treatment of AD in PWID broadly parallels strategies used in the general population. Anxiety symptoms exist on a continuum and many with milder degrees and of short duration may be self limiting; ADs are responsive to a wide variety of psychotherapies. More severe and persistent symptoms also may require pharmacotherapy. Some studies suggest that optimum results are achieved by combining psychological and pharmacological interventions (Fineberg and Drummond 1995; Kandel 1999). The aim of treatment is to relieve symptoms, restore function, and prevent relapse.

Psychological therapies include reassurance; counseling; anxiety management, such as relaxation training; anger management; and self-help such as bibliotherapy (selection of developmentally appropriate reading material for a client that has relevance to their life situation; it can be complemented with discussion or play activity). De-sensitization and exposure therapy are extremely effective in OCD and social phobia. One fundamental principle underpinning this intervention is that prolonged exposure to a feared stimulus reliably decreases cognitive and physiological symptoms of anxiety (Marks 1969; Barlow 1988), leading to greater confidence and willingness to encounter other feared stimuli.

Behavioral therapy and cognitive behavior therapy (CBT) alone or in combination have demonstrated robust evidence of efficacy in the treatment of AD (Michels 1997). In people with mild ID and AD, evidence from case studies supports the effectiveness of CBT (Lindsay 1999). Overall, involving patients in an effective partnership with health-care professionals and using comprehensible and clear communication both improve outcomes (National Institute for Clinical Excellence, CG 22 2004).

Pharmacotherapy

A variety of medicines with differing pharmacological properties can be effective in the treatment of ADs. Increasing awareness of numerous neurochemical alterations in ADs is likely to lead to the future development of new classes of drugs. The choice of treatment ultimately should be a consequence of the assessment process and shared decision-making, with emphasis on safety, tolerability and the patient's preferences within the context of best available evidence. Significant coexisting depressive symptoms should guide treatment choice toward prescription of antidepressant drugs.

Selective Serotonin Reuptake Inhibitors (SSRIs) such as Citalopram and Sertraline are effective across the range of ADs and suitable for first-line treatment. Serotonin and noradrenalin reuptake inhibitors (SNRIs), e.g., Venlafaxine and Duloxetine are effective in GAD. Venlafaxine requires regular monitoring and specialist supervision due to concerns regarding potential safety in overdose.

Tricyclics may be used as second-line intervention for all of these conditions with the exception of social phobia. Other treatments with a weaker evidence base or which are less well tolerated include buspirone (OCD, GAD, short-term use; British National

Formulary 2009) and antipsychotics (Quetiapine or Risperidone as antidepressant augmentation for OCD).

Benzodiazepines are effective in many ADs but used only short term (2–4 weeks) because they are commonly associated with the development of dependence and tolerance (physiological or behavioral symptoms after discontinuation of use; Royal College of Psychiatrists: 2005).

In children, adolescents and the elderly, pharmacological treatment should be reserved for those who are unresponsive to psychological interventions with close monitoring for adverse side effects.

Maintenance of Medication

In GAD where drug treatment is helpful, current guidelines suggest continuation over the next 6–12 months, subject to satisfactory tolerance and efficacy with an individualized approach depending on the needs and preferences of the patient (Davidson et al. 2010; National Institute for Clinical Excellence, CG 22 2004).

Important Scientific Research and Open Questions

Overall in PWID there is dearth of information that guides robust evidence-based practice with regards to all aspects of mental health including ADs. Ethical concerns over capacity and consent have resulted in the exclusion of this disadvantaged and underserved sector of the population in "gold standard" research studies such as randomized controlled trials. Mental health care for PWID has been mostly extrapolated from adult psychiatry or mental health services. This may not always be beneficial for PWID since they may have special needs. There is consequently an urgent need to overcome such hurdles with strategies such as better education and public awareness aimed at facilitating equity of access to high-quality-research-based health care.

Cross-References

► Achievement Deficits of Students with Emotional and Behavioral Disabilities
► Attention Deficit and Hyperactivity Disorder
► Behavior Modification, Behavior Therapy, Applied Behavior Analysis and Learning

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Anxiety: Nervousness, Disquiet, Fretfulness

► Anxiety Disorders in People with Learning Disabilities

Apathetic Students

► Apathy in Learning

Apathy

► Boredom in Learning

Apathy in Learning

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Synonyms

Apathetic students; Disengaged learners; Unmotivated learners

Definition

Apathy in learning is an expression of indifference, lethargy, and/or disengagement in the classroom environment. The original Greek word for apathy (apathḗs) can be translated to mean unfeeling. Things such as personality type of the student and teacher, educational structure facilitated by the teacher, perceived value by the student, or external stimuli outside the classroom may be responsible for encouraging the onset or increasing severity of the expressed apathy. Although schools and teachers do not have direct control over aspects such as external stimuli that can encourage apathy, they do have control over the curriculum and resulting instruction that also directly affects apathy in the classroom.

Theoretical Background

Although apathy is often associated with a lack of feeling, in the educational setting, apathy more commonly involves a lack of interest or concern. The root manifestation of apathy in learning varies widely, but an engaging and stimulating learning environment is one of the best solutions for this epidemic that plagues classrooms at most every school. Apathy in learning has been juxtaposed to the concept of flow – a state of near euphoria where one becomes totally engrossed in the event, task, or project (Csikszentmihalyi 1997). As an antonym to flow, apathy seems most prevalent when students are situated in learning environments where both the level of challenge posed to the student and the skill level of the student are low. Any low-rigor, low-expectation class encourages apathy to flourish. Apathy can begin with or be accelerated by many external issues that often are beyond the control of the teacher, such as peer pressure, family issues, poverty, and prior experiences. However, effective instruction, although not able to eradicate poverty or negative peer pressure, can begin to create an engaging environment that is conducive and supportive of motivated learning. When well implemented, strategies that are highly engaging and challenging to students, such as inquiry-based instruction, have been shown to lower apathy in educational settings. It takes time to transform instruction and to more engaging forms of learning such as inquiry. Radical switches to new types of instruction can also encourage apathy, although this may be more temporary and can be corrected with the proper scaffolding of instruction that addresses the concerns of the students.

Important Scientific Research and Open Questions

Apathy evidenced in the classroom is relatively easy to identify, but the most important, yet most challenging, step comes in proposing and then implementing solutions to solve the problem. Several books (Bransford et al. 2000; Marshall 2008) address how to understand and then more effectively interact with students that demonstrate apathy in the classroom, and several themes consistently appear in this literature. First, effective learning is not something done to students but rather done with students. Social constructivists have long supported the view that students learn to make sense of new concepts and the world around them via interaction with the culture in which they live and learn (Vygotsky 1978). Thus, learning occurs when students are able to link their prior understandings with new ideas in a specific social context. Next, to properly address the needs of the learner, learning must tie to prior knowledge with new experiences. Even when misconceptions exist in the prior knowledge, their current understanding needs to be confronted and engaged before new or more correct ideas can be developed. Finally, learning environments that are low apathy, high engagement are often cocreated with the students and provide a learning climate that encourages ideas, questions, and sharing while discouraging put-downs and complacency.

Students typically begin their initial years of school excited to learn – devoid of apathy. Then, somewhere around age 10–12 a dramatic shift often begins to occur as students learn to separate schooling and learning. Robert Fried (2001) has called this distinction the "Game of School." In many educational systems, schooling becomes an environment that is built on structure, rules, and compliance. Such an environment fosters apathy if not properly addressed. Meaningful learning, on the other hand, is engaging, thought-provoking, and relevant to the learner. The goal of facilitating meaningful learning in classrooms is certainly not new – even if it is often not put into practice. John Dewey (1938) proposed that effective education is built upon two major tenets: continuity and interaction. Though the words may differ, the message is the same – educators need to provide powerful interactions between the students and the curriculum, which is continuous with their prior experiences. These tenets provided the foundation for the social constructivist movement that is active today. When implemented effectively, instructional practices such as inquiry-based learning that integrate social constructivist theory can engage students in a manner that negates apathetic tendencies.

Cross-References

▶ Aligning the Curriculum to Promote Learning
▶ Alignment of Learning, Teaching, and Assessment
▶ Constructivism
▶ Interests and Learning
▶ Motivation Enhancement
▶ Motivation, Volition, and Performance
▶ School Motivation

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Ape Language

▶ Linguistic and Cognitive Capacities of Apes

A

Appearance Effect

► Revelation Effect

Appetitive-Aversive Motivation

► Approach and Avoidance Motivation

Application

► Ego State Theory: Utilization of Dreams
► Retention and Learning

Application of Family Therapy on Complex Social Issues

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Synonyms

Couple and family therapy; Family systems therapy; Marital and family systems model; Relational therapy; Systemic therapy; Systems psychology; Systems theory

Definition

Family therapy, a systemic therapy, views individual and family problems within a relational and interactional framework. As a professional mental health discipline, it is heavily influenced by systems theory, encompassing both general systems theory (Bertalanffy 1968) and cybernetics, the science of information processing and feedback mechanisms. Systems theory focuses on the interconnectedness of elements or component parts within a given system; change in one part of the system affects all other parts of the system. From this perspective, family therapy practitioners recognize two different orders of change within the system. These are first-order and second-order changes. By definition, first-order changes do not alter the basic organization of the system; whereas, second-order changes transform both the existing structure and functioning of the system. Systems theorists and practitioners are interested in both change (morphogenesis) and stability (morphostasis) in the system.

Theoretical Background

Family therapy was strongly shaped by the work of significant personalities like Gregory Bateson, Nathan Ackerman, Jay Haley, Murray Bowen, Carl Whitaker, Salvador Minuchin, and Virginia Satir. The work of Gregory Bateson and his team on schizophrenia and the family was one of the early influences on the emergence of family therapy in the 1950s. Salvador Minuchin's work with the families in the slum is notable in taking into account the families' social environment as being critical in helping families change. Historically, family therapy has sought to understand and alleviate family distress by looking at individuals within the context of families, and families within their larger sociocultural contexts.

With globalization, the sociocultural political context in which individuals and families are embedded has become increasingly complex. Race, gender, socioeconomic status, sexuality, class, spirituality, political ideologies, age, and other dimensions of diversity intersect in ways that bring about an array of complex social issues that have local and global implications for individuals, families, and communities. Hence, training the next generation of family therapists necessitates attention to the development of skills in applying family therapy concepts to complex situations and in diverse contexts. Today, some contemporary approaches to family therapy pay increasing attention to issues of social justice and emphasize sensitivity to cultural context (e.g., Cultural Context Model), gender (Feminist Family Therapy), and subjective realities (postmodern approaches such as Narrative Therapy). At the same time, evidence-based models represent the new generation of family therapy prevention and intervention programs for specialized problems with attention to treatment context and a culturally diverse client population (e.g., Functional Family Therapy and Multisystemic Therapy for adolescent behavior problems).

Some major social issues facing us today include homelessness, incarceration, school failure, Internet safety, poverty, health care, terrorism, human trafficking across international borders, forced migrations, to name a few. The pedagogical question family therapy programs are now asking is how to relate theory to practice and how to bridge the classroom to the field so that learning is not in isolation of real-world problems. This question asks for the kinds of instructive strategies that lead to learning that is meaningful, not one that is mechanistic or decontextualized. Among family therapists who view social change and social justice as central to their work, the question concerns the kinds of teaching approaches that help students to develop the kind of critical consciousness (Freire 1973) that questions and challenges dominant discourses on social issues in ways that can be transformative. Recent approaches to family therapy such as the Cultural Context Model (Hernandez et al. 2005) pay attention to the key processes of critical consciousness, accountability, and empowerment in effecting change in individuals, families, and communities. Anchored within a postcolonial perspective, it addresses complex social issues through deconstructing and transforming dominant discourses and practices that are oppressive. It also attends to issues of power, privilege, and oppression and seeks to effect second-order change in the sociocultural context of the family system.

Current practices of teaching view learning as a collaborative and social process, not one in which knowledge is simply transmitted from teacher to students. ▶ Meaningful learning occurs when students are engaged in authentic and ▶ transformative learning processes and when they interact with information in ways that foster ▶ active enquiry (Jonassen 2005). The teacher's role is conceptualized as a designer of learning spaces; spaces where students actively construct knowledge through dialog, reflection, and hands-on activities. As applied to family therapy, the teacher creates opportunities for the students to engage in ▶ higher-order learning where they apply their knowledge of systemic ideas and understanding of theory to real-life issues affecting individuals and families. These include, but are not limited to, ▶ experiential forms of learning such as on-site clinical training with supervision, immersion experiences in cross-cultural settings, and an increase in opportunities for students to be engaged in the community, including participatory action research projects. These opportunities are designed to help the students gain the competencies required in family therapy practice.

Recent instructional strategies in family therapy training have incorporated the ▶ use of technology in ways that are beneficial for students. Besides using technology to enhance supervision and the delivery of courses, innovative approaches such as the WebQuest (Dodge 1995) can be effective in helping students integrate theory to practical realities. WebQuest design involves ▶ constructivist learning and is supported by four constructs: critical thinking, knowledge application, social skills, and scaffold learning. In the WebQuest, scaffolding includes resource links and guidance on social and cognitive skills; these are provided to facilitate the students' development. As a web-based ▶ inquiry learning, the WebQuest is effective in tapping into the synthesis and application aspects of learning. Furthermore, because WebQuests are group projects, learning is collaborative.

The WebQuest on *Child Trafficking/Prostitution: Applications from Family Therapy Perspectives* (http://questgarden.com/00/25/1/050525170739/) (Lim and Hernandez 2007), for example, challenges students to design culturally appropriate and multisystemic interventions to address the complex issue of child trafficking/prostitution across international borders. Students work in teams to explore the extent of the problem, identify the various systemic levels involved in the perpetuation of the problem, select aspects of the various family therapy models that are applicable in addressing the issue, design systemic intervention tools for working with families who have experienced the impact of child trafficking, and present their final recommendations for systemic interventions. Students assume different roles within their teams and through a consensus process, design their intervention program using a particular family therapy model or a combination of family therapy approaches. Space is provided for students to think creatively and to integrate knowledge across disciplines (e.g., in addressing societal ideologies on ethnicity, gender, children, economic issues, and migration; incorporating an understanding of trauma and its impact on youth) while applying various family therapy models in working with the youth, their relatives, and their community.

The WebQuest, as used in family therapy training for developing skills in application of systemic understandings to complex social issues, illustrates an innovative way of using instructional technology in the classroom. Trainers can facilitate student learning in many more innovative and collaborative ways that generate new experiences and the construction of creative ways of generating solutions to complex social issues. This necessarily includes an increase in culturally centered models that work well for ethnically diverse populations. It also means an increase in family therapy competencies that students can translate to any challenging and complex social situation.

Important Scientific Research and Open Questions

With its emergence in the 1950s, the field of family therapy is relatively new and open to innovative ideas. Because there are many different systemic theories in family therapy, students can choose a particular theory or adopt a theoretical stance that integrates different elements of various theories in their clinical practice. As such, there is room for a lot of creativity in the application of family therapy in different contexts and at different systemic levels. Within the postmodern tradition in family therapy, the idea that reality is socially constructed opens doors to scholars and practitioners alike to question how dominant discourses have shaped the lives of individuals, families, and communities and how these constructions constrict and become problematic for people at various systemic levels. Deconstruction of the dominant discourses that are perceived as oppressive can lead to both first-order and second-order changes; the latter involves structural changes that transform or reorder society.

Tension exists in family therapy training between trainers and training programs that focus on modern (classical) theories and those that favor postmodern (constructivist) theories. Each privileges its own epistemology with its own idea of what constitutes reality; each has its own conception of symptomatic behavior as well as how change can be effected; and each has varying perspectives on the role of the family therapist as a social justice advocate influencing social change. Authentic learning necessitates the teacher creating space for the learners to choose or formulate a theoretical stance that best fits their worldview or belief system, not one that is imposed. The issue of ethical teaching and learning, one that respects epistemological stances of different learners, becomes an important consideration in family therapy training. Further, within systems theory, the idea of both stability and change is important. Application of family therapy to complex social issues needs to be cognizant of these dialectical tensions so that there is both continuity and change.

Research on the application of family theory to complex social issues is somewhat limited as family therapy is a relatively new and evolving field. Empirical evidence of the effectiveness of particular approaches or therapeutic modalities that alleviate distress in particular client populations continue to be a need. At the same time, there is a lot of room for new and creative approaches in the teaching and application of family therapy, especially those that incorporate technology in response to an increasingly digitalized and globalized world.

Cross-References

► Collaborative Learning
► Constructivist Learning
► Critical Thinking and Learning
► Cultural Learning
► Experiential Learning
► Group Learning
► Inquiry Learning
► Socio-Constructivist Models of Learning
► Technology-Based Learning
► Transformational Learning

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Application of Learning

► Transfer of Learning

Applied Quantum Probability Theory

► Quantum Information Processing Theory

Appraisal

► Assessment in Learning

Apprehending

► Reading and Learning

Apprehension and Communication

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Synonyms

Communication anxiety; Communication aversion

Definition

Communication apprehension is an emotional state expressed as an anxiety experienced by an individual in relation to anticipated or actual communication with another person or persons (McCroskey 1977). The impact varies from person to person but, for many of those affected, communication apprehension tends to be associated with certain circumstances or contexts such as interpersonal communication, public speaking, and participating in meetings and group presentations.

Theoretical Background

Communication apprehension is linked to communication avoidance and has been the focus of research for more than 40 years. The phenomenon was originally defined by McCroskey (1970) as an anxiety related to oral communication. The focus and meaning of communication apprehension has since evolved to represent an anxiety experienced by an individual in relation to anticipated or actual communication with another person or persons (McCroskey 1977). Apprehensive individuals usually adopt avoidance and withdrawal behaviors and are less likely to engage in communication.

Communication apprehension theory posits that communication apprehension is a personality trait which remains relatively constant across different communication situations. Individual traits such as introversion, anomie, low self-esteem, neuroticism, cultural divergence, and underdeveloped communication skills are often viewed as antecedents to communication apprehension (MacIntyre 1994). However, situational attributes such as formality, status imbalance, conspicuousness, and unfamiliarity can also give rise to anxiety about communication (McCroskey 1984). There are four fundamental kinds of communication apprehension. Communication apprehension can relate to an anxiety that is (1) context-based in that it is associated with a particular type of communication; (2) audience-based where anxiety is related to communication with a particular individual or group of individuals; (3) situational in that it is associated with a particular combination of context and audience; and (4) an attribute of the individual or a personal trait that persists in different situations and for different audiences (Richmond and McCroskey 1998).

Communication apprehension has the potential to inhibit the development of an individual's communication competence, and educators have reported negative expectations about the scholarly ability of apprehensive communicators (McCroskey and Richmond 1987). In organizational settings, apprehensive communicators are less likely to be hired or promoted and will tend to self-select employment with low communication requirements despite a potential for less job status and lower income (Richmond and Roach 1992).

The Personal Report of Communication Apprehension (PRCA) is the most commonly used operationalization of communication apprehension in the literature (McCroskey 1982). The PRCA instrument is composed of 24 statements addressing feelings about communicating with others in four areas: (1) group discussion, (2) meetings, (3) interpersonal communication, and (4) public speaking (McCroskey 1982). Empirical studies have consistently shown that public speaking creates the most anxiety for individuals with up to three out four adults reporting some apprehension.

Important Scientific Research and Open Questions

The research domain of communication apprehension has changed greatly during the past 40 years. While earlier research emphasized the oral communication domain, communication apprehension research has been substantially broadened by later researchers to include apprehension about writing, performance, public speaking, as well as emergent factors such as technology apprehension and the mediating role communication technology plays in modern communication practices. A popular view is that communication technologies accentuate communication apprehension. Although further research is required to test this link, there is evidence that apprehension to computer, communication, and computer-mediated communication is interrelated (Scott and Timmerman 2005). There is also evidence that richness and social presence afforded by communication technologies are important considerations for communication apprehension particularly in organizational communication environments where user aversion and anxiety have the potential to impact perceptions of task, processes, and performance (Campbell 2006) and strategies of identity used by some individuals to cope with conflict situations (Campbell et al. 2009). Potential research questions relating to this area of enquiry include: How different communication technologies mitigate or increase communication apprehension, how communication apprehension and conflict affect team performance in virtual working environments, and what measures can be adopted by organizations to minimize the impact of communication apprehension.

The relationships between communication apprehension, ethnicity, and other cultural variables have gained great attention in recent years (for example, see Wrench et al. 2006). There is scope for improving understanding of communication apprehension from a cultural perspective and in relation to other social and cultural attributes. The link between communication apprehension and communication avoidance has long been established. However, further research is required to investigate how individual and social traits mutually enact one another and their impact on communication apprehension. Consequently, there are several research questions requiring investigation which include: How communication technologies impact communication apprehension for individuals from diverse social and ethnic backgrounds, and the impact of communication apprehension on participation in online social networking applications in both private-life and work-life contexts.

The emergence of artificial intelligence techniques, methods, and applications, along with the development of virtual world environments for social and organizational purposes, has given rise to new opportunities for understanding communication apprehension. Although far removed from the initial focus of oral communication, researchers have begun to examine human communication apprehension phenomena from new perspectives including human-to-machine (Nomura et al. 2008), and human-to-avatar communication (Cox et al. 2009). The convergence of artificial intelligence with virtual world environments is already impacting on interpersonal communication and social interaction (Boellstorff 2008). Further research is required to better understand these developments and their likely impacts on communication and communication apprehension. Research questions of interest include: Design of human-to-avatar and other forms of human-to-machine virtual interfaces; and developing a better understanding of the impact of intelligent agents and virtual interfaces on communication apprehension in social, cultural, and interpersonal contexts.

Cross-References

► Anxiety, Stress and Learning
► Communication and Knowledge Production
► Communication and Learning
► Communication Theory
► Fear of Failure
► Technology-Based Learning

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Apprenticeship

► Coaching and Mentoring
► Learning in Practice (Heidegger and Schön)

Apprenticeship Learning in Machines

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Synonyms

Imitation learning; Learning from demonstration

Definition

Apprenticeship learning is a branch of *machine learning*, which is the study of computer algorithms that improve with experience. In apprenticeship learning, a learning agent called the *apprentice* is able to observe another agent, called the *mentor*, behaving in an environment. The goal of the apprentice is to learn a *policy* – i.e., a concrete prescription of how to behave in the environment – that is at least as good as the mentor's policy. Each state of the environment is associated with an unknown *reward*, and the goodness of a policy is measured by the amount of reward that the policy collects. Apprenticeship learning algorithms can be applied to problems such as learning to drive a car, operate a robotic arm, or play a game. Apprenticeship learning is closely related to *reinforcement learning*, with a few key differences: In reinforcement learning, the reward function is assumed to be known, no observations from a mentor are available, and the goal is to learn an optimal policy (i.e., the policy that collects the most reward), not just one that is at least as good as the mentor's policy.

Theoretical Background

Learning behavior from a mentor has a long history in machine learning. This approach to learning is sometimes called *imitation learning* or *learning from demonstration*. Some of the earliest and most influential work was by Pomerleau (1989), who trained a neural network to drive a car. However, the idea of mimicking mentor behavior via a reward function was relatively unexplored prior to the introduction of the apprenticeship learning framework by Abbeel and Ng (2004).

Apprenticeship learning was designed to address a serious drawback of reinforcement learning: its assumption that rewards can always be directly and unambiguously observed. In other words, the feedback to reinforcement learning algorithm is assumed to be a part of the environment in which the learning agent is operating, and is included in the agent's experience of that environment. However, in practice, rewards are usually manually specified by the practitioner applying the learning algorithm. Unfortunately, the behavior learned by most reinforcement learning algorithms can be quite sensitive to the specific numerical values of the rewards. As a result, in practice, specifying a reward function that elicits the desired behavior from the learning agent can be a subtle and frustrating design problem.

Abbeel and Ng (2004) made the following observation: even when rewards are difficult to describe exactly, it is usually easy to specify what the rewards must depend on. For example, when a person drives a car, the rewards that she is maximizing depend on just a few key factors: the speed of the car, the position of other cars, the underlying terrain, etc. What is unclear, however, is how the rewards encode the trade-offs among these various factors. For example, exactly how much more should the driver prefer traveling fast over avoiding other cars? With this observation in mind, Abbeel and Ng (2004) proposed an algorithm that learns from a mentor by assuming that the true rewards are unknown linear combination of a set of known *features*. Their algorithm provably converges, after a small amount of computation, to a policy that is nearly as good as the mentor's policy, as measured by the unknown reward function.

The apprenticeship learning framework is closely related to *inverse optimal control* and *inverse reinforcement learning*. In both of these settings, the objective is to learn a reward function for which an observed policy is optimal. Traditionally, inverse optimal control is applied in environments with linear dynamics, while inverse reinforcement learning is concerned with environments that are modeled as Markov Decision Processes with discrete state spaces. Note that recovering the reward function is the explicit goal here, unlike apprenticeship learning, where the true reward function need not be learned. Also, the terms "inverse reinforcement learning" and "apprenticeship learning" are often used interchangeably in the literature, although they are distinct problems.

Important Scientific Research and Open Questions

Syed and Schapire (2008) extended the approach of Abbeel and Ng (2004) and described an algorithm that assumes that the sign of the correlation between the true rewards and each feature is known. This prior knowledge about the relationship between the features and the rewards allows their algorithm to learn policies that are, in some cases, substantially better than the mentor's.

Although recovering the reward function itself is not an explicit goal of apprenticeship learning, in some cases it is an effective method for learning a good apprentice policy, particularly when one makes the additional assumption that the mentor policy is optimal. For example, the goal of Neu and Szepesvari (2007) was to learn a reward function for which an approximately optimal policy with respect to that reward function approximately mimics the mentor. They formulated their problem as nondifferentiable optimization and solved the optimization via a subgradient method.

Similarly, the maximum margin planning algorithm of Ratliff et al. (2006) learns a reward function so that, with respect to this reward function, the demonstrated policy is nearly better than all other policies. The magnitude of this advantage over each comparison policy, also known as the margin, scales with the loss of the policy, which is usually defined as a measure of how different it is from the demonstrated policy.

Most apprenticeship learning algorithms assume that it is easy for a mentor to provide complete trajectories demonstrating the desired behavior. However, Kolter et al. (2008) studied a setting where it is only feasible for a mentor to provide partial trajectories. In particular, they studied a quadruped locomotion task, in which a mentor is only able to provide advice at two hierarchical levels (an overall plan for moving through an obstacle course, and how to navigate around individual obstacles). These partial trajectories are used to learn policies at each hierarchical level, which are then combined into a single policy.

Cross-References

▶ Imitation Learning from Demonstration
▶ Learning Algorithms
▶ Reinforcement Learning
▶ Robot Learning from Demonstration

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Apprenticeship-Based Learning in Production Schools

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Synonyms

Learning in apprenticeship; Learning in the vocational and educational system

Definition

Learning processes in production schools can be defined as an institutionalized arrangement where aspects of apprenticeship learning are used in a school context.

Theoretical Background

Production school is a Danish phenomenon developed to educate students that are tired of participating in conventional schooling. Even though production schools are a local phenomenon, they contain original ideas for learning research since they have an ambition to integrate central aspects of apprenticeship learning into formal educational institutions. In the light of high youth unemployment in the 1970s, the original intent of production schools was to create an alternative to the traditional school system that allowed for hands-on training in small workshops in schools that were based on the processes of production. In 1981, production schools began to be considered an integral part of the educational system in Denmark. The total number of production schools nationwide was highest in 1999, when there were 109 schools. In 2006, there were 99 production schools scattered across the country. Nationally, 14,224 students attended production schools in 2004, of which 60% were male. The length of each student's stay at production school varied; 30% of students stayed at least 6 months, while 34% stayed more than 2 months. The average length of a student's stay was 20.3 weeks, or 5 months (Kirkegaard and Nielsen 2008).

Production school is characterized by a different organizational structure and set of teaching practices than those in the traditional educational system. In production school, teaching takes place primarily in various workshops. The artifacts produced in the workshops are sold and any profit goes to the production school. There are no genuine exams at production schools, and attending a production school does not qualify students for further education. However, there are a number of characteristics common to production schooling and vocational training as they are organized in Denmark. Both combine hands-on learning and classroom-based education. Vocational education and training in Denmark is organized as a dual system, where students alternate between learning in the workplace and staying at a vocational school. Production schools in Denmark are organized in such a way that classroom-based education and hands-on training are located in the same institution.

There are several important elements of production schools. Firstly, practical work is the pivotal learning process. All tutoring and other formal educational activities are centered on the educational work done in the workshops. In this context, the focus is on work as a socializing and identity-building process rather than work as a profitable endeavor. Secondly, the teachers at production schools are not primarily school teachers, but artisans anchored in professional crafting cultures who seek to provide students with a craft identity. Thirdly, relationships between teachers and students are characterized by a greater degree of intimacy than those in the formal educational system. Finally, production schools can be characterized as offering a participatory learning culture where students' personal development is a central part of education (Clemmensen et al. 2000).

There are many reasons why a growing number of students choose to attend production schools. The rising intellectualization of elementary schools poses a problem for pupils that have low academic abilities or limited interest in scholarly pursuits (Lausch and Størner 2002). The intellectualization of the educational system in Denmark has raised the dropout rate, especially in the vocational system, and a large proportion of students who drop out of the vocational system begin at production schools. In many respects, production schools serve as a last bastion for young people who could easily drop out of the education system completely and fail to earn a secondary education. In the vocational system, education takes place in two separate training environments (school and workplace) where there are independent and often mutually contradictory norms, cultures, communication, and professional progression. This split between the different kinds of environments is difficult to handle for a large group of students (Wilbrandt 2002). Finally, a segment of youth culture is generally critical to attending schools and strongly identifies with work-based training (Wilbrandt 2002).

In many respects, the central educational idea in production schools is apprenticeship-based learning. In apprenticeship, the notion of learning through participation in practice is central and understood as a process in which apprentices' participation changes from simply taking part to becoming a responsible participant in a community of practice. If we look at the learning that takes place in practical situations, it is rarely the result of direct teaching. In apprenticeship, learning is incorporated into daily activities; one hardly notices that learning takes place. Carrying out an assignment appears as a daily routine without being seen as learning. Imitation of other participants in a community of practice, and also identification with more experienced agents of the subject, takes place unintentionally. Learning through bodily action and the use of tools is incorporated in the daily contact with the surroundings, and learning may take place without a deliberate plan. In apprenticeship, shared responsibility for production also involves a responsibility for others' learning. Praise, recognition, or positive feedback makes apprentices grow through their own self-knowledge, whereas criticism, triviality, or negative feedback is experienced as hurtful (Nielsen and Kvale 2006). In the production schools, these principles of learning are pivotal.

Important Scientific Research and Open Questions

Few studies have researched learning processes at production schools. In an older study, Jacobsen and Ljung (1984) showed how the practical organization of the workshops at production schools allowed a large group of young people with social problems to reenter the educational system. In a study of learning at production schools, Clemmensen et al. (2000) found that students with significant social problems seemed to learn from being part of the production school, especially the practical workshops. Kirkegaard and Nielsen (2008) published a study of what and how students learned at three production schools in Denmark. The results revealed that production schools were organized into small teams that were firmly anchored to specific workshops, a structure that seemed to ensure security and consistency, and support the students' learning processes. Even more important, the study showed that anchoring the students to small workshops gave them the opportunity to develop personal relationships with the teachers. These relationships seemed to be an important precondition for learning to take place. It allowed the teachers to understand students' behavior and prepare them to better address the students' problems in the workshops. It was remarkable that teacher–pupil relationships were functioning relatively smoothly at production students, compared to the situation in the elementary school system where most of the production school students had significant conflicts and problems with teachers. Furthermore, the study showed that processes of collaborative learning were central to student success. When working together in the workshops, students learned a lot from each other. Another important aspect of production schools disclosed by the study was that students received immediate and concrete feedback on their work. Moreover, it was especially important that students' effort was recognized and appreciated by the teachers and other students in the workshop. The obligation to produce and sell products to external customers offered a range of different learning opportunities for students. Students learned through the feedback they received from the people who bought their products.

Cross-References

► 21st-Century Skills/Competencies
► Adaptive Instruction System(s) and Learning

► Adaptive Learning Through Variation and Selection
► Adolescent Learners' Characteristics
► Authenticity in Learning Activities and Settings
► Compulsory Education and Learning
► Learning in Practice and by Experience
► Learning, Social Practice, and Gender

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Approach and Avoidance Motivation

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Synonyms

Appetitive-aversive motivation; Approach-withdrawal motivation

Definition

Approach and avoidance motivation is composed of three conceptually distinct components. Approach indicates a propensity to move toward (or maintain contact with) a desired stimulus. Avoidance indicates a propensity to move away from (or maintain distance from) an undesired stimulus. Motivation is defined as the energization and direction of behavior. The valence of stimuli is at the core of the distinction between approach and avoidance, with positively valenced stimuli typically leading to approach and negatively valenced stimuli typically leading to avoidance. Stimuli can be external or internal, implicit or explicit, conscious or non-conscious.

Theoretical Background

The distinction between approach and avoidance has roots extending back to the time of the ancient Greek philosophers. Philosophers such as Democritus and Aristippus used the concept of hedonism to describe how people should live. The idea that humans approach pleasure and withdraw from pain was further articulated by the British philosopher Jeremy Bentham (1748–1832) in which he argued that not only do pleasure and pain act as indicators of how life should be lived, they are also responsible for actual behavior. The distinction between approach and avoidance was also present in the theorizing of the first scientific psychologists: Wundt (1887) and James (1890) posited that pleasure and pain were often the impetus for action. The first systematic utilization of the terms approach-avoidance to explain behavior was made by Lewin in his work on Field Theory. After years of refinement and further specification, researchers have concluded that approach and avoidance motivation are fundamental to all forms of life.

Indeed, it has been argued that approach and avoidance responses are hardwired into all species. The tendency to avoid aversive stimuli is likely an adaptive mechanism, which ensures survival in the face of danger or pain. In contrast, the drive to approach positive stimuli likely leads to thriving and increases psychological, social, and physical resources (Fredrickson 2001). Biologists have found that even the most rudimentary protozoa responds with approach (to a weak light) and avoidance (to a strong light) behaviors (Schneirla 1959). Similar findings have been reported for humans as well. It appears that people immediately and nonconsciously evaluate nearly all encountered stimuli on a good or bad dimension. Rather than being mediated by higher-order cognitive processing, recent research suggests that these automatic evaluations have distinct neural pathways in the brain (e.g., Crites and Cacioppo 1996). One consequence of this independent neural processing is that responses to positive and negative stimuli, automatically and instantaneously, evoke approach and avoidance predispositions, respectively.

It is important to note that while approach and avoidance motivation might be fundamental to all forms of life, its complexity varies considerably among species. The most rigid and predictable responses can be observed in the simplest life forms such as protozoa, with increasing variability in responses to stimuli corresponding with increases in biological complexity. Though automatic evaluation of stimuli on a good–bad continuum predisposes individuals to approach or avoid, people have the capacity to override these initial responses. For instance, people sometimes approach aversive stimuli in the service of obtaining a desirable outcome (e.g., taking a difficult class to graduate from college) or avoid a positive stimulus because obtaining it would ultimately lead to an undesirable outcome (e.g., not eating chocolate cake when on a diet). Research has shown that in more complex organisms, a hierarchy of approach and avoidance motivation often guides behavior (Elliot and Church 1997). In addition to the interspecies variation described above, intraspecies variation in approach and avoidance motivation has been shown in a wide array of taxa, such as cats, dogs, fish, and of course, humans.

Due to the fundamental nature of approach and avoidance motivation, this distinction may be conceptualized as an organizing framework for the study of motivation. This is not to say that the approach–avoidance distinction can explain motivation in its entirety. Rather, this distinction is proposed to serve an integrative function that theories of motivation can profitably utilize to expand our understanding of behavior.

Important Scientific Research and Open Questions

The approach–avoidance distinction has been applied in a variety of psychological domains. Research on topics such as emotion, competence, self-esteem, and relationships have all utilized and benefited from this motivational model. Elliot and McGregor (2001) proposed a 2 × 2 hierarchical model of achievement motivation that has proved to be particularly generative. The model integrates two theoretical traditions that were separate for much of psychology's history: Approach–avoidance motivation was combined with mastery and performance goals (which have also been referred to as task and ego goals or learning and performance goals, respectively). Goals, as defined by the hierarchical model, are mid-level representations of higher-order competence motivations, that act to direct motivational energies. Mastery goals are focused on the attainment of task mastery or the development of competence for intrapersonal reasons. Performance goals are focused on normative, interpersonal competence.

The 2 × 2 model proposed a bifurcation of both mastery and performance goals by the approach–avoidance distinction. The resultant four goals are known as mastery-approach, mastery-avoidance, performance-approach, and performance-avoidance. After several years of empirical scrutiny and many tests of the validity of this model, it appears able to reliably explain and predict achievement behavior. Yet, an interesting question about mastery goals remains to be answered. Specifically, as noted above, mastery goals are formed with the desire to attain task mastery *or* intrapersonal competence. Research is needed to determine whether these differing motivational foci are responsible for unique outcomes. If so, division of mastery goals might be warranted, though caution is recommended, as additional complexity risks reducing the model's parsimony.

Future research should also address the reasons people give for adopting achievement goals. The 2 × 2 model proposes that competence motives are focused on either fear of failure or the need for achievement. Fear of failure orients people toward the avoidance of failure while the need for achievement orients people toward the possibility of success. Avoidance goals are often preceded by fear of failure motives, while approach goals commonly stem from need for achievement motives. Interestingly, researchers have yet to examine how adoption of these competence-related motives uniquely influences subsequent performance. Performance-approach goals, which can be motivated by either the need for achievement or fear of failure, are of particular interest in this regard. It seems likely that the outcome of adopting a performance-approach goal (e.g., academic performance; psychological and physiological functioning) depends to a large extent on which type of motivation energizes and underlies behavior.

Cross-References

- ► Achievement Motivation and Learning
- ► Fear of Failure in Learning
- ► Field Theory of Learning
- ► Mastery Learning

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Approaches to Learning

► Cognitive Learning Strategies for Digital Media

Approaches to Learning and Studying

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Synonyms

Learning processes; Learning strategies; Study strategies

Definition

"Approaches to learning" describe the contrasting ways in which students carry out learning tasks. The main distinction is between a surface approach and a deep approach to learning, while "approach to studying" includes the further dimension of strategic approach, involving organized and directed effort. Although having individual differences with some stability over time and context, they are also affected by the kinds of teaching, learning, and assessment experiences encountered by the individual, and so vary across different conditions of learning.

Theoretical Background

Marton and Säljö (1984) in Gothenburg introduced the term *approaches to learning*. They carried out naturalistic experiments at the university level in which students read an academic article individually and were then interviewed to discover what they had understood about the article and how they had gone about reading it. The main difference between this work and previous psychological studies was in the description of the outcome of learning in terms of qualitative differences in *understanding*, rather than using quantitative measures of accurate recall. That difference proved crucial.

Qualitative differences were found both in the understanding reached and in the ways in which the task had been tackled. The main differences in the latter depended on the *intention* of the student – whether the students wanted to understand the meaning for themselves or were simply trying to recall the information for the interviewer. The contrasting intentions led to very different learning processes and so to equivalently different outcomes. Students seeking meaning were consciously interacting with the text to follow the author's argument and examining the evidence and logic being used – a *deep approach.* Those students concentrating on recall were scanning the text to decide which information was likely to be tested and then committing that to memory – a *surface approach.* Differences could also be seen in whether the students were making sense of the whole article or just unrelated bits of knowledge from it, and to what extent they were integrating the parts by using appropriate organizing principles.

In another experiment, students were asked to read articles that differed in terms of their relevance and conducted in situations that were either relaxed or anxiety provoking. Initially, no significant differences were detected between these conditions, but students were also asked how they had felt about those conditions. Those students who found the article relevant and felt no anxiety about the situation were more likely to adopt a deep approach and to understand the meaning of the article more clearly. This finding introduced an important additional element, namely the *perceptions* that students had of the learning task and the conditions under which they were learning, which also influenced the approach adopted.

In London, Gordon Pask (1988) also carried out naturalistic experiments, and these drew attention to the existence of contrasting *preferences* among university students in how to go about learning. These preferences led to differing learning strategies, which, if used consistently, could be described as distinct ► learning styles. Pask saw this distinction in terms of *holists*, who wanted to see the whole picture right from the start of a task and *serialists* who preferred to build up their understanding step by step by focusing on details. Although understanding could be reached using either style, being too fixed in one style could become a pathology, interfering with a successful outcome. Being *versatile* – combining the two processes in relation to the demands of the task – led more quickly to fuller understanding. This combination was subsequently seen, in general terms, as the main learning processes involved in a deep approach.

In subsequent work, Noel Entwistle and his colleagues in Lancaster, UK used both inventories and interviews to investigate how students carried out their *everyday studying* (described in Entwistle 2009).They confirmed the existence of deep and surface approaches to learning, but found an additional difference in how students tackled their academic work – *approaches to studying*. These were described in terms of the amount of effort being put into a task and the extent to which well-organized study methods were also being used, with a distinction between a *strategic approach* directing effort toward high achievement and an *instrumental approach* that involved just "getting by."

The combination of these four categories provides an indication of how well students are likely to understand academic material (deep, strategic) and to obtain high grades (strategic, but either deep or surface depending on the assessment criteria). The publication of these findings led to extensive related research, first to corroborate and elaborate the distinction between deep and surface approaches, then to examine the processes through which understanding was reached, and finally to explore the effects of different kinds of teaching on approaches and outcomes of learning at university level.

Important Scientific Research and Open Questions

One line of research has involved the development of inventories to operationalize the approaches identified from interviews (Biggs 2003; Olkinuora and Lonka 2004). Several instruments have been produced, with multivariate analyses of the items generally producing three main factors – deep, surface, and strategic or achieving. The items are rated by students on Likert scales and scored from scales based on the factor structure. Deep has been separated into the intention or motive to understand, and processes – relating ideas and using evidence – based on Pask's learning strategies. Surface has been defined by a habitual reliance on narrow forms of learning, such as rote memorization or mimicking the teachers' understanding, and a lack of confidence about understanding. The strategic approach depends on the intention to work hard, and involves organized studying, systematic time management, and concentration. The instrumental approach is defined mainly by low levels on the strategic scale, but also by a narrow concentration on meeting assessment criteria and being content just to satisfy course requirements.

The inventories were used across subject areas on the assumption that the processes involved in the three main approaches would be largely similar. While this holds true for the strategic and surface approaches, the deep approach proves to be partly discipline dependent. Although the intention to understand is a defining feature of the deep approach across all subject areas, the specific learning processes that lead to understanding, and the nature of that understanding in contrasting disciplines, are importantly different. Ideally, therefore, scales describing a deep approach should include disciplinarily specific items.

There have been disagreements about how consistent an approach to learning is likely to be. Marton and other researchers using student interviews have stressed the dependence on content and context, implying inevitable variability. While agreeing with the idea that content and context are important, other researchers have argued that the extent of consistency and variability depends on the individual as well as the circumstances. Where students are encountering largely similar topic areas and types of teaching, more consistency is found, as students become habituated to the approach that they find most effective. Where there is more variety in subject matter and teaching, variability becomes more noticeable. However, students also differ individually in the extent to which their approaches are consistent irrespective of circumstances, in part due to differing academic goals and partly due to continuing dispositions to learn in different ways. Some students are concentrating mainly on passing examinations: this may lead them to seek understanding for themselves, but as an end point. Other students, with a ► disposition to understand for themselves in most circumstances, are alert to ways of developing their understanding further, and using it (Entwistle 2009).

Another line of research has been looking at the qualitative differences in outcomes of learning related to the two approaches. Marton investigated the differing conceptions of academic concepts held by students through a research approach called *phenomenography.* This established a particular form of interviewing in which students were encouraged to explain and reflect on their understanding, and also a method of qualitative analysis that allowed distinct categories of conceptions to be identified. Qualitative differences have also been found in the *forms of understanding* that students revising for final examinations were seeking. Some students actively using deep approaches were found to build *knowledge objects* to represent their own understanding of topics. These were described as tightly integrated forms of understanding that could be seen in the mind, with a structure and logic that guided the writing of essays. And recent work, using dialogic mapping techniques, has suggested ways in which students can be guided toward a more conscious monitoring of the connections between ideas and the structures of their emerging understandings.

There are generally significant relationships between approaches to learning and perceptions of teaching and assessment, with those pedagogical methods that are seen to encourage ideas and understanding being related to deep approaches, and those that emphasize the learning of facts and details being associated with memorization and surface approaches. It is found that the influence of assessment is particularly strong, as grades are the currency through which students are rewarded. The relationship between perceptions and approaches is, however, complicated, as the causality is bi-directional. If students are habitually using a deep approach in their studying, teaching that encourages it will be perceived favorably (approach causing perceptions). But that form of teaching will also encourage many of the students in the class to move toward deep approaches, thus reversing the direction of causality (teaching, and perceptions of it, causing approaches).

The relationship between perception of teaching and approach to learning will also be seen differently when looking at an individual or a whole class of students, being more closely related in an individual than in a class as a whole. The weaker relationship at class level is, nevertheless, important as it can be used to monitor the balance between deep and surface approaches in relation to the specific methods of teaching and assessment being used.

Interviews with faculty members show that there are variations in approaches to teaching which parallel the approaches to learning of students, with some faculty members viewing their teaching just from the perspective of the discipline, without seeing the need to translate their understanding of it into a form readily accessible to a novice. Others see the importance of helping students to develop deep approaches and conceptual understanding, and so aim to teach in ways likely to bring that about. One crucial outcome of research into student learning has been the recognition that, in teaching, it is important not just to teach the content in a clear and well-structured way, but also to show students how to develop an academic understanding of the discipline and the nature of its discourse.

There is a host of open questions remaining. Some relate to attempts to understand how an individual student learns a specific topic in a particular discipline. Current research into this question is going well beyond the notion of approaches to learning as it seeks to understand, in detail, how an individual student interprets the tasks set and how previous experiences and continuing aspirations affect subsequent learning and understanding. It is also using detailed case studies to see how all these aspects relate to students' self-concept as learners and to their emerging identity as future professionals within their field of study.

Other questions focus on how best to arrange a whole ► teaching–learning environment within a university course so as consistently to encourage deep approaches to learning in as many students as possible (Baeten et al. 2010). And that depends on being able to understand the nature of academic understanding within the course and to describe, and appropriately support, the specific learning processes involved in a deep approach to learning in that subject area.

Cross-References

► Attitudes and Learning Styles
► Cognitive and Affective Learning Strategies
► Learning About Learning
► Learning and Understanding
► Learning Strategies
► Learning Style(s)
► Perceptions of the Learning Context and Learning Outcomes
► Phenomenography
► Self-regulated Learning

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Approaches, Inquiries, and Paradigms in Music Education Research

► Research Methods in Music Instruction and Learning

Approach-Withdrawal Motivation

► Approach and Avoidance Motivation

Appropriability

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Approximate Learning of Dynamic Models/Systems

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Synonyms

Approximate learning; Asymptotic performance; Dynamical system

Definition

Dynamical systems model the evolution of a system with unknown parameters. The goal of a learning procedure is to estimate the parameters of the system, possibly from a set of known examples, such that the system behavior on future inputs is accurately predicted. Such a learning procedure typically uses methodologies from techniques in statistics and computer science and can be computationally intractable for some systems.

Theoretical Background

A dynamical system models the state-space evolution of a system. In the discussion below, we refer to free parameter that models the change in dynamics by "time." Many versions of such systems are possible, depending on whether the state variables are continuous or discrete (quantitative), the time variables are continuous (e.g., partial differential equation, delay equations) or discrete (e.g., difference equations, quantized descriptions of continuous variables) and whether the model is deterministic or probabilistic in nature. In addition, such a model can also be hybrid in nature in the sense that it may combine continuous and discrete timescales and/or continuous and discrete time variables. For example, the dynamics of a discrete-time continuous-state system with a single output can be written down as

$$x_i(t+1) = f_i(x_1(t), x_2(t), \cdots, x_n(t), z_1(t), z_2(t), \cdots, z_m(t)),\quad i = 1, 2, \cdots, n$$
$$y(t+1) = h(x_1(t+1), x_2(t+1), \cdots, x_n(t+1))$$

where $x_1, x_2, \ldots, x_n$ are the state variables, $z_1, z_2, \ldots, z_m$ are the m variables representing inputs to the system, y is the output variable that provides information about measurable performance of the system, t is the time variable governing the dynamics and f_i's and h are real-valued functions with unknown parameters (also called weights) characterizing the nature of the dynamics. For example, the function f_i's could be the so-called sigmoidal function:

$$f_i(x_1(t), x_2(t), \cdots, x_n(t), z_1(t), z_2(t), \cdots, z_m(t)) = \left(1 + e^{-\left(\sum_{i=1}^{n} \theta_i x_i(t) + \sum_{j=1}^{m} \theta'_j z_j(t)\right)}\right)^{-1},$$

where $\theta_1, \theta_2, \ldots, \theta_n$ and $\theta'_1, \theta'_2, \ldots, \theta'_m$ are the unknown real-valued parameters and $\boldsymbol{e}$ is the base of natural logarithm. We will use Θ to denote the vector of unknown parameters.

In a typical learning scenario, we have an unknown function $g(x_1, x_2, \ldots, x_n)$ that we would like our system to compute. We "train" our system by providing a set of inputs, drawn from a probability distribution, with their corresponding value of the g function, to the system, say one at a time, for a finite time period t_0. The goal is to efficiently compute the parameters in Θ such that the generalization error, namely the expected error in the output of the system to the true output that we desire for the next input drawn from the same distribution, is minimized (or, within a desired bound).

For further details on dynamical systems see standard textbooks such as Sontag (1998) and for further details on basic learning theory see Kearns and Vazirani (1994). For some interesting applications of dynamical systems to systems biology see the excellent survey paper Sontag (2005).

Important Scientific Research and Open Questions

Dynamical systems exhibit a fascinating interplay between several areas such as biology, control theory, discrete mathematics, and computer science, and have a wide range of applications in modeling and simulation in many diverse areas such as modeling biological processes, in quantum computing, in self-assembly problems in nanotechnology applications and social networks. Broad scientific investigations in modeling of dynamical systems include difference in convergence to steady states, effect of feedback loops on stability and dynamics, robustness in presence of noise, etc. Furthermore, there are interesting special subclasses of dynamical systems, such as piecewise-linear systems and monotone systems, that have been of considerable interest in recent times especially due to their applications in systems biology but are still far from being completely understood.

There are several directions of research associated with the training and computational capabilities of dynamical systems; below we outline several directions.

One direction of research deals with the computational capabilities of such dynamical systems, typically in specific settings such as artificial neural network models, assuming that the number of state variables is unlimited. This type of research can be traced back to its origin to the old work of the famous mathematician Kolmogorov (1957) who essentially provided the first (nonconstructive) result on the representation capabilities of simple types of dynamical systems obtained by superposition of a set of basis functions. This type of research ignores the training question itself, asking instead if it is at all possible to exactly or approximately compute arbitrary or interesting classes of functions. Many of the results and proofs in this direction are existential only and serve to provide the limiting computational capabilities of dynamical systems.

Another direction of research in learnability of dynamical systems takes an approximation theoretic point of view. This direction overlooks the parameter estimation phase in learning and instead is concerned with bounding the overall error if the best possible parameters with a given system architecture were to be eventually found. An example of such results is Barron (1991).

The third direction research deals with is related more closely to the training phase of learning problems via the so-called sample complexity questions that attempts to quantify the amount of information (number of examples) needed in order to characterize a given unknown input-output mapping. An important technical development in this area culminated in deriving information-theoretic bounds for sample complexities via VC-dimensions (Vapnik 1982) and their suitable extensions to real-valued computations.

A fourth research perspective in approaching theoretical questions regarding learning lies in investigating, for a given architecture of the dynamical system, if there exists a fundamental barrier to training, namely a barrier that is insurmountable no matter which particular parameter estimation algorithm one uses. This line of research was motivated by a frequent observation that many parameter estimation algorithms often runs very slowly for high-dimensional data and is frequently referred to as the "curse of dimensionality." Of course, if we are allowed to adapt the architecture of the dynamical system to the data such as in incremental learning techniques, then we would not be subject to such a barrier.

Cross-References

► Connectionist Theories of Learning
► Formal Learning Theory
► Hierarchical-Network Model for Memory and Learning
► Learning in Artificial Neural Networks
► Mathematical Models/Theories of Learning
► PAC Learning
► Probability Theory in Machine Learning
► Supervised Learning

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Approximate Number System

► Accounting and Arithmetic Competence in Animals

Approximative

► Approximative Learning Vs. Inductive Learning

Approximative Learning Vs. Inductive Learning

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Synonyms

Approximative; Learning

Definition

As explained below, there is no unique definition of this term available. Vaguely speaking, any learner that is not aiming at the definite, exact identification of a concept, but is rather content with obtaining (learning) a concept that comes close to the target may be termed approximative.

Theoretical Background

In the (mathematical) theory of learning, the term approximative learning is used in different meanings. To ease understanding the concepts, briefly recall what inductive learning means: upon receiving (positive or negative) evidence, the learner (often also called inference machine) formulates hypotheses that should, over time, (always) yield a correct one. This notion goes at least back to Gold, 1967. This concept leads to several natural questions:

1. What is a "correct hypothesis?" This can be answered on a purely syntactic level (leading, e.g., to the notion of EX[planatory]-learning) or on a more semantic level (behaviorally correct [BC-] learning). We provide an example referring to language learning below.
2. Should we weaken the assumption that an exactly correct hypothesis is required in the end of the process? This leads to (possibly domain-specific) notions of approximative learning.
3. Should we weaken the prerequisite that the learner must always find a good solution? From a practical perspective, it might be enough that the learning goal is achieved with high probability.

The best studied framework that addresses the second and third item is the setting of ► Probably Approximatively Correct Learning, or ► PAC Learning for short, as introduced by Valiant (1984). From a bird's eye perspective, this learning scenario expects learners to almost always (in a probability sense, so with a probability of [close to] one) converge to a hypothesis that comes very close to the target; this closeness is meant in a topological sense, relying on some quality measure for the hypotheses or properties thereof. Obviously, many details are still to be filled out, possibly depending on the concrete application scenario. For example, we might require a learner that works for any probability distribution, or we might optimize a learner toward an expected probability distribution. Also, different quality aspects measuring the hypotheses will require different learning algorithms. Because of the sketched technical details, the literature should be studied with a careful consideration of the employed definitions. A lot of these mathematical details are exhibited in (Menzel et al. 2003), based on the exposition provided by Vidyasagar, 1997.

Last but not least, everything said above may depend on the objects or concepts that should be learned. The arguably most prominent example is ► language learning first formulated with the hope of modeling ► language acquisition, *see* (Gold 1967). Language learning is mostly formalized as ► Grammar Learning (also known as ► Grammar Induction or as ► Grammatical Inference), although the entities that should be learned (languages) could be formally described in many ways: grammars, automata, (regular) expressions, and so forth. Coming back to the first item of our list above, when we talk about grammar learning, the hypotheses would be grammars of some form (e.g., right-linear grammars representing the lowest level of the Chomsky hierarchy of languages), so convergence of the learning process would be naturally expressed by some notion of closeness within the space of grammars (usually formalized by the discrete metric). This idea would allow to formally express the notion of explanatory learning. The semantics behind is the languages that can be described by the chosen grammar formalism. Convergence, in this sense, would correspond to behaviorally correct learning.

Kobayashi and Yokomori (1995) introduced the notion of ► upper-best approximation in the context of language learning, which interestingly also applies if the target concept cannot be expressed within the envisaged hypothesis class. The idea is to learn a superset Y of the target language X, such that there is no possible hypothesis grammar that describes some superset Z of X, which is also a subset of Y. This notion can be seen as a purely set-theoretic formalization of approximate learning and fits very well within the framework of inductive inference. For example, although (Gold 1967) showed that the regular languages cannot be EX-learned from positive examples only, they can be upper-best approximated by 0-reversible languages, as shown by Kobayashi and Yokomori, 1997.

When types of concepts different from languages are to be learned, yet other notions of approximate learning should be defined.

Important Scientific Research and Open Questions

Although PAC learning is surely the prominent representative among the possible scenarios of approximative learning, it is not the only choice. It would be valuable to have criteria at hand that suggest, in a concrete application situation, which of the notions would be the appropriate one to pick, if any.

Cross-References

- ▶ Formal Learning Theory
- ▶ Grammar Learning
- ▶ Language Acquisition and Development
- ▶ PAC Learning
- ▶ Statistical Learning Theory and Induction

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Aptitude

A measure of an individual's potential to learn music. Tests have been developed by researchers such as Edwin Gordon to measure music aptitude.

Cross-References

- ▶ Abilities to Learn: Cognitive Abilities
- ▶ Learner Characteristics and Online Learning

Aptitudes and Human Performance

- ▶ Ability Determinants of Complex Skill Acquisition

Aptitude-Treatment Interaction

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Synonyms

Attribute-treatment interaction

Definition

Aptitude-treatment interaction (ATI) research is a research paradigm that attempts to examine how an outcome depends on the match between individuals' specific aptitude(s) and the treatment they receive. When a treatment and an individual's aptitude(s) are matched, the effect of the treatment is optimal. While an aptitude refers to any measurable personal characteristic that would have an impact on achieving goals in the designed treatment, a treatment refers to any manipulable situational variable. An interaction occurs when a treatment has an effect on one type of individual and a different effect on another.

Theoretical Background

The Goal of ATI

According to ATI, individuals differ in their readiness to profit from a particular treatment at a particular time, and individuals may adapt their situations to fit their own characteristics. Therefore, ATI offers a framework for interpreting aptitudes as personal readiness to profit from particular treatment situations.The goal of ATI is to find the interactions between alternative treatments and learners' aptitudes and therefore to create an environment in which the treatments match the aptitude of the learner, in other words, to achieve optimal learning (Cronbach and

Snow 1977). Notably, ATI methodology is designed to evaluate the degree to which alternative treatments have different effects on learners with different aptitudes and thus to determine whether particular treatments should be chosen or adapted to fit particular learners optimally (Snow 1991). Accordingly, ATI allows for the interactive creation and construction of knowledge, which in turn would enhance educators' ability to create more customized individual learning environments.

Development of ATI

The concept of ATI was first proposed by L. J. Cronbach in 1957. Cronbach encouraged psychologists to observe the experimental effects for participants of varied characteristics and to conduct investigations to find aptitude-treatment interactions (ATIs). However, R. E. Snow is thought of as the pioneer who conceptualized and investigated how combinations of aptitudes interacted to produce differential educational outcomes. Based on his studies, Snow proposed "aptitude complexes," which emphasize that aptitudes should not be treated as isolated variables and that the interactions of different aptitudes can produce differential educational outcomes.

Two dissertations supervised by Snow in 1976 provided important support for the concept of aptitude complexes. The first study used ninth-grade students as participants and found significant ATIs between four teaching approaches and three aptitudes: namely, ability, anxiety, and conformance. The second study included participants from high schools and found that combinations of conative and personality factors interacted with the ability level and the treatments involving high or low structure. By the late 1980s, the existence of different aptitude complexes had been supported by many studies. Though most of the evidence of this complex interaction between aptitudes and treatments was indirect, this orientation became the theoretical precursor to later studies on strategy training (Ackerman 2003).

Application of ATI

An ATI research design allows for a complex analysis of interactions between personal aptitude and the effects of experiential learning transformation. ATI has been employed to enhance learning in many fields, such as general classroom instruction, instructional multimedia, special education, teacher training, and medical studies. To date, most ATI studies have been conducted to determine whether the effects of different instructional methods are influenced by learners' individual aptitudes. In this line of research, many studies have examined the concept of aptitude complexes. Aptitude complexes have emerged from the recognition that different aptitude combinations sometimes interact with the same treatment contrasts. For example, empirical studies of college students and adults found that three aptitudes – self-concept, interest, and motivational trait – were correlated with domain knowledge and ability measures (Ackerman 2003). Therefore, aptitude complexes can be determined from extant assessment measures, and aptitude complexes play an important role in determining the level of effort toward knowledge and skill acquisition.

In the area of multimedia instruction, ATI also plays a major role in delivering the basics for the development of "adaptive instructional systems." Related ATI studies suggest that web-based learning could be significantly enhanced by adapting presentation and instructional methods to styles in the wholist–analytic dimension (Cook 2005). Moreover, a study employing an ATI approach and focused on motivation training found that a combination of attention and relevance strategies improved motivation to learn, especially for those students with low levels of pre-motivation (Astleitner and Koller 2006).

To date, many ATI studies have been employed in the field of special education for students who are either gifted or in need of assistance. Some of the origins of the popularly used individual education plans (IEPs) in special education are derived from ATI theory and practice. In addition, ATI research and ATI methodologies have been used in teacher training for special education and in the delivery of individualized career planning workshops (Merz and Szymanski 1997).

ATI studies were also found in general teacher training research. For example, a study was conducted to examine whether teacher traits would interact with the designed treatments and therefore influence preservice teachers' improvement of teacher behaviors during a computer-simulated training session. The findings suggest that important ATIs occur during computer-simulation training; more specifically, positive personal traits – including critical-thinking dispositions, judicial and legislative thinking styles, critical-thinking skills, and intrapersonal intelligence – influence how preservice teachers learn and adapt to information, feedback, and teaching practices (Yeh 2007).

Comparatively, only a few ATI studies have been conducted in the medical field. During the medical treatment period, the most important question is what treatment is best or better for whom, when, and why? ATI offers a research paradigm for understanding exactly how outcome depends on the match or mismatch between patients' specific characteristics and the treatments they receive. Therefore, ATI research offers invaluable insights into the multifaceted package of care typically delivered in complementary and alternative medicine/integrative medicine (Caspi and Bell 2004).

Research Design of ATI

The most commonly used methods for ATI research are standard experimental design, regression discontinuity design, and change curves (or growth curves) design. These methods allow the researcher to explicitly test the possibility that one or more aptitudes moderate or mediate outcome/outcomes through an interaction with one or more treatments (Caspi and Bell 2004).

1. Standard experimental design: This is the most commonly used design in ATI research. In such a design, participants are randomly assigned to two or more groups that receive the same treatment, and the outcome is assessed with respect to different levels of an aptitude or a set of aptitudes.
2. Regression discontinuity design: This design is especially appropriate for ATI research when randomization is not feasible. In this design, participants are assigned to conditions based on a cutoff score of a certain aptitude measure taken prior to the treatment. The assignment variable must be an ordinal, interval, or ratio variable.
3. Change curves (or growth curves) design: This design focuses on analyzing how participants change in an outcome variable over time. The main advantages of this approach are that (1) growth curves preserve the data at the individual level; and (2) growth-curve analysis does not necessarily require suitable control conditions, which are crucial to demonstrating treatment effects in comparative trial designs.

To ensure the occurrence of ATI, alternative treatments and the inclusion of two psychological variables are suggested. To be differentially effective for various types of participants, the alternative treatments should demand different abilities for successful performance. Moreover, ATI is more likely to occur when two psychological variables are included in the experimental design where one psychological variable correlates substantially with success in one treatment and the other correlates substantially with success in the other treatment (Cronbach and Snow 1969).

Important Scientific Research and Open Questions

ATI studies contribute to the construction of theories for effective instruction, medical treatment, and adaptive learning. For ATI findings to be meaningful and feasible, however, ATI research should be driven by plausible hypotheses based on data-based theories rather than simply being a hit-or-miss fishing exploration fueled by spurious statistical associations (Caspi and Bell 2004). Moreover, personal characteristics abound in correlations, and aptitude complexes play an important role in knowledge construction and skill acquisition (Ackerman 2003). Therefore, when employing ATI, aptitude complexes should be considered and multiple aptitudes and higher order interactions should be analyzed. The tendency to oversimplify or to reduce complex relationships into simple paired relationships should be overcome in order to fully benefit each individual learner. In addition, incorporating e-learning and neuroscience into educational and psychological studies has become a new paradigm. Determining how to integrate e-learning and neuroscience into ATI research to develop new theories and to understand the underlying brain functions during learning is worth trying. Such related findings will shed light on the development of ATI research.

Cross-References

► Adaptation to Learning Styles
► Adaptive Blended Learning Environments
► Adaptive Learning Systems
► ARCS-Model of Motivation
► Attitudes and Learning Styles
► Critical Thinking and Learning
► E-learning
► Learning Style(s)

- ▶ Motivation to Learn
- ▶ Multimedia Learning
- ▶ Neuropsychology of Learning
- ▶ Personality and Learning
- ▶ Personality Effects on Learning
- ▶ Self-Concept and Learning
- ▶ Simulation-Based Learning

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AQ Learning

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Synonyms

Algorithm quasi-optimal; Star-learning

Definition

AQ learning is a form of supervised machine learning of rules from examples and background knowledge performed by the well-known AQ family of programs and other machine learning methods. AQ learning pioneered separate-and-conquer approach to rule learning in which examples are sequentially covered until a complete class description is formed. Derived knowledge is represented in a highly expressive form of attributional rules.

Theoretical Background

The core of AQ learning is a simple version of A^q (algorithm quasi-optimal) covering algorithm, developed by Ryszard S. Michalski in the late 1960s (Michalski 1969). The algorithm was initially developed for the purpose of minimization of logic functions, and later adapted for rule learning and other machine learning applications.

Simple A^q Algorithm

A^q algorithm realizes a form of supervised learning. Given a set of positive events (examples) *P*, a set of negative events *N*, and a quality measure *Q*, the algorithm generates a cover *C* consisting of complexes, that is, conjunctions of attributional conditions, that cover all events from *P* and no events from *N*. It uses a beam search to reduce to a computationally tractable number the potentially very large number of generated complexes. The algorithm starts by focusing on a single positive event *e*, called a *seed*, which is then generalized by creating all maximally general complexes that cover the seed and do not cover any events from *N*. This maximally general set of complexes is called a star $G(e, N)$. The best complex *c* is selected from $G(e, N)$ according to a user-defined quality measure *Q*, and added to the cover *C*. All events covered by *c* are removed from *P*. If the set of examples *P* is empty, the cover *C* is returned; otherwise another seed is selected from *P* and the operation is repeated until *P* is empty. This process is presented in Algorithm 1. For simplicity of description, we can assume here that a complex is equivalent to a rule.

The generation of star $G(e, N)$ uses *extension-against* operator that generates a maximally general set of rules that cover one example (positive) and do not cover another example (negative). The result of the extension-against operation is called a *partial star*, *PS*.

This operation is denoted by $PS(e, n) = e \dashv n$. The intersection of all partial stars for the seed e and all negative examples from N forms the star $G(e, N)$. Because of the potentially very large number of possible rules (complexes) in a star, a beam search is used to keep track only of the most promising ones. Algorithm 2 is a basic version of the algorithm used to generate stars. It takes as an input the seed e, the set of negative examples N, a beam search control parameter *maxstar*, and the quality measure Q, and returns a set of best complexes in the star $G(e, N)$. Note that there is no need to generate all complexes in the star, because only the best complex is selected by A^q algorithm.

Algorithm 1: A^q – simple version

```
Input: P, N, Q
Output: C
C ← Ø
Repeat:
    Select a seed e from P
    Generate a star G(e, N)
    Select the best complex c from G(e, N)
    Include c in C
    Remove from P examples covered by c
Until P is empty
Return C
```

Algorithm 2: Star generation

```
Input: e, N, Q, maxstar
Output: PS
PS ← Ø
Repeat
    Select a negative example n from N
    PS(e, n) ← e –| n
    If PS = Ø, PS ← PS(e, n)
    Else PS ← PS ∩ PS(e, n)
    Keep only maxstar best complexes in PS,
    according to Q
    Remove from N examples not covered by PS
Until N = Ø
Return PS
```

Quality Criteria

Multiple quality criteria can be used in the selection of complexes. AQ programs use the *lexicographical evaluation functional* (LEF), which is a multi-criteria evaluation method. Given a set of elemental criteria and tolerances (C_i, t_i), $i = 1, 2, \ldots$, LEF sequentially evaluates a set of complexes through these criteria. All complexes that do not fall within the tolerance of the best complex for each criterion in the sequence are removed. Among elemental criteria included in AQ learning are positive coverage, negative coverage, simplicity, cost of attributes, and several statistical measures whose goal is to maximize positive coverage and minimize negative coverage of complexes.

Forms of Rules

Programs from the AQ family learn attributional rules, the main knowledge representation form in *attributional calculus*, a logic of reasoning system that supports inductive learning in forms natural to people (Michalski 2004). Three important forms of such rules are (1)–(3).

$$\text{CONSEQUENT} <== \text{PREMISE} \tag{1}$$

$$\text{CONSEQUENT} <== \text{PREMISE} \lfloor \text{EXCEPTION} \tag{2}$$

$$\text{PRECONDITION} \lceil \text{CONCEQUENT} <== \text{PREMISE} \tag{3}$$

where CONSEQUENT, PREMISE, EXCEPTION, and PRECONDITION are complexes. When learning rules are in the forms (1)–(3) for a given class, CONSEQUENT is always the same; thus, for simplicity only PREMISE, PRECONDITION, and EXCEPTION are used. Attributional conditions are in the form

$$[\text{L rel R} : \text{A}] \tag{4}$$

where L is an attribute, an internal conjunction or disjunction of attributes, a compound attribute, a counting attribute, or a simple arithmetic function of attributes; rel is one of $=$, :, $>$, $<$, $\leq$, $\geq$, or $\neq$; R is an attribute value, an internal disjunction of attribute values, an attribute, or an internal conjunction of values of attributes that are constituents of a compound attribute; and A is an optional annotation that lists statistical information about the condition (e.g., p_c and n_c are condition coverages, defined as the numbers of positive and negative examples, respectively, that satisfy the condition).

Important Scientific Research and Open Questions

Research on AQ learning includes topics considered in many machine learning methods. These include creating knowledge in forms that are easy to interpret, learning from very large datasets, learning from very small datasets, using background knowledge to guide learning process, computational efficiency of algorithms, and others. A special focus of research on AQ learning is in creating knowledge in forms that can be easily understood by people not trained in machine learning by incorporating constructs that directly correspond to natural language (Kaufman and Michalski 2005).

Major Modifications

Since its inception, AQ learning has gone through several major modifications and improvements. More advanced versions of the AQ method extend it in a variety of ways: using several seeds (to protect the method against noise), employing different concept representations (attributional or relational), generating rules with different interrelationships (independent, disjoint, or sequentially ordered covers), using different methods for handling data inconsistency (minimum, maximum, free and statistic-based generalization), learning rules in batch or incremental mode, seeking rules that represent the best trade-off between their consistency, coverage, and simplicity, using different criteria of rule optimality, involving operators for deriving more relevant attributes (data-driven, hypothesis-driven, or multistrategy constructive induction), applying prior knowledge (a- and l-rules, knowledge-driven constructive induction), post-optimization of learned descriptions (TRUNC/s and TRUNC/sg), generation of single or alternative descriptions, learning rules with exceptions or preconditions, use of different types of attributes (nominal, structured, graph, ordinal, interval, ratio, absolute, set-valued, and compound), reasoning with meta-values (unknown, not applicable, and irrelevant), and others.

Main Programs Developed

Over 4 decades of research have resulted in several implementations of AQ learning. Among the best-known programs from the AQ family are:

- AQVAL1/AQ7 (1975), which was developed in the PL/1 programming language to infer optimal or sub-optimal disjunctive formulas in VL_1variable-valued logic system.
- AQ11 (1978), which was derived from earlier systems, but included several novel features such as incremental learning and event selection.
- AQ15 and AQ15c (1986, 1995), which included several novel features, such as truncation of learned rules.
- AQ17 (1991), which included constructive induction methods for automatically improving the representation space.
- AQ19 (2001), which included new methods of handling noise in the data, including pattern discovery mode in which a set of general patterns is discovered rather than regular complete and consistent covers.
- AQ21 (2004) is to date the newest implementation of AQ learning. The program includes the largest number of features from previous implementations, as well as several new ones, such as generating alternative covers, generating natural language descriptions, handling meta-values, and handling additional attribute types. The program is currently being extended with new features.

Several independently developed rule learning programs are based on AQ algorithm or its variants. One such well-known program is CN2 developed by Peter Clark and Tim Niblett.

Cross-References

► Constructive Induction
► Rule Learning
► Supervised Learning

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Aquinas, Thomas (1225–1274)

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Synonyms

St Thomas; Angelic Doctor

Life Dates

Thomas Aquinas was born at Roccasecca in the Kingdom of Naples, in 1225 or 1226 to Theodora, Countess of Teano and Landulph, Count of Aquino. His family was connected to the Emperors Henry VI and Frederick II, and to the Kings of Argon, Castile, and France. Disappointing his aristocratic family's expectations, he chose to become a Dominican friar, devoted to academic life, principally at the University of Paris, as a theologian and philosopher (Finnis 1998, p. 1, 15). He died at Fossanova Cisterican monastery on 7 March, 1274 and was canonized on 18 July, 1323. Aquinas is generally regarded as the greatest of medieval philosophers and theologians.

Theoretical Background

While primarily a natural theologian, seeking to illuminate God and Creation through natural reason rather than scriptural exegesis, Aquinas was a considerable philosopher. His use of the newly available works of Aristotle became the main route by which Aristotelian philosophy was reintroduced to Western Europe. The Middle Ages were very different from the modern era, but it is wrong to caricature them as benighted, resistant to intellectual endeavor, and dominated by a church suspicious of heresy and demanding unquestioning obedience. The political tumults of the time are not reflected in Aquinas' works, but philosophical controversies are. Aquinas was a devout friar but he was quite unafraid of disputation about matters central to his beliefs. He held that faith and reason complemented each other. Moreover, he was a strong advocate for values not dissimilar from those held dear in educational circles today. To illustrate this, consider his views on authority, argument, and doubt.

Contribution(s) to the Field of Learning

Aquinas' theory of knowledge relies on the senses accurately representing the world, and on the understanding grasping immediately the nature of truths. Error, however, comes from judgments, which can be mistaken because judgment pronounces upon the world by way of comparison and affirmation and denial of similarities. We might believe, for example, that water boils at 100° and judge – incorrectly – that water boiling in a hut on a 3,000 m mountain was 100°. We could correct this error by ourselves or be corrected by others. Should we choose to pursue the matter, we might eventually arrive at a true scientific understanding of boiling points through the Clausius–Clapeyron equation. The correction of error by education is an obvious and economical way of learning. It might appear from the theological context of Aquinas' views about education that he would argue from authority. Indeed, he cites authorities, Christian and non-Christian, copiously but he also recognizes the limits of appeal to authority. Hence, in disputes to remove doubts about a matter of fact, authority has its place. For example, if one is addressing Jews, one can appeal to the authority of the Old Testament. With Christians, the authority of the Old and New Testaments and the Church Fathers may be invoked. With those who accept no authority, arguments employing "natural reasons" are appropriate. Disputes of a pedagogical nature also require the employment of reasons, "reasons which track down the root of the truth and create a real knowledge of how it is that your assertions are true. Otherwise, if professors settle questions by bare authorities, listeners are indeed told that such-and-such is so, but gain nothing in the way of knowledge or understanding, and go away empty" (Finnis 1998, p. 12).

Doubt for Aquinas is not the mark of skepticism but of inquiry. He held that doubt derives from reasons, that is, it is not mere unbelief but puzzlement arising from a problem. Philosophy is the unrestricted consideration of truth arising from doubt (Finnis 1998, p. 12, n. 14).

Clear though this debt to Aristotle might be, Aquinas' philosophical views have to be distilled from a theological context. Moreover, as he wrote no work dedicated to the philosophy of education, Aquinas' views about teaching and learning have to be gathered from a number of his writings, principally from his magnum opus, the *Summa Theologiae* (Summation of Theology), and the *Quaestiones Disputatae de Veritate* (Disputed Questions on Truth). These are works of metaphysics, and so his views of teaching and learning are not only dispersed, but are also embedded in some difficult Aristotelian philosophy.

Most relevant here is the Aristotelian view of forms, which differs greatly from those of his teacher, Plato. Plato explained the persistence of objects, such as horses or triangles, by the existence of a realm of "forms," separate from the concrete particulars to which they gave shape. How is it that we learn what a horse or triangle is by looking at examples, but are then able to recognize other horses or triangles not having the particular characteristics of the examples? For Plato, "horseness" and "triangularity" existed in a realm of unchangeable forms that gave stability to the world of flux and variety, in which there are many possible types of horses and objects of triangular appearance. Aristotle rejected this doctrine of forms but not the need for an explanation of our understanding of general concepts. He located the forms not in a separate realm, but in the intellect. For Aristotle, it is intellect that abstracts forms from matter – the universal concept "horse" from viewing a particular horse. This abstracting function he called the "agent intellect." That part of intellect that receives, understands, and stores abstractions he called the "possible intellect."

Within a Christian context, Thomas Aquinas explicitly rejects Plato's theory of knowledge, and adopts Aristotle's view of the intellect (Aquinas 1265–8, 1, Q 84 & 117). Persons neither have innate knowledge nor are their intellects passive machine-like recorders of information. On the contrary, states Thomas, "the passive intellect of the human soul is in pure potentiality to intelligible (species), as Aristotle says (Aristotle, 350 BC, iii, 4: Aquinas 1265–8, 1, Q 117, a. 1). This kind of Aristotelian language permeates the works of Aquinas. It indicates the methodological strategy of seeing temporal change in terms of potency and act – or potential and actualization. Hence, persons by their very nature possess an intellective soul, and this is what distinguishes them from other animals. Persons are potential knowers, acquisitive inquirers about the world, and not mere passive receivers of sense data (Donohue 1968, p. 68f.). Although the senses produce knowledge, they cannot do so by themselves. Sense data are transformed into knowledge by the intellect, so there must be an active faculty in the intellect for this to occur, for the abstraction of general principles from a world of particular objects in flux (Aquinas 1265–8, 1, 84, a. 6). There is in the human person, "a certain principle of knowledge namely the light of the active intellect," which holds the potential to make universal principles immediately understood (Aquinas 1265–8, Q 117, a. 1). As the source of that light, God is ultimately the cause of understanding, but at the basic level of sensory acquaintance with the world, the agent intellect is the means by which we acquire our store of concepts about it. It is the agency which accounts for the mental change that occurs with the acquisition of knowledge. Following Aristotle (Aristotle, 350 BC, iii, 5), Aquinas argues that the agent intellect moves from ignorance to knowledge, from quiescence to thinking. The more the intellect is able to abstract from the particular objects, the more sure the knowledge. "The perfect intellectual operation in man," writes Aquinas, "consists in an abstraction" from mental images and the more free intellect is from images the better able it will be to understand (Aquinas 1265–8, II-II, Q. 15, a. 3, 3). For the material conditions that originate sense knowledge also obscure it to an extent by their very materiality. Hence, sight is the best of the senses because it is "the least material" (Aquinas 1265–8, I, Q. 84, a. 2).

Important Scientific Research and Open Questions

Knowledge may be acquired by discovery or by instruction (Donohue 1968, p. 83f.). As indicated above, the light of the agent intellect enables us to learn through grasping universal principles of knowledge as soon as they are proposed. When these universal principles are applied to particular sensory experiences or memories, a person moves from what he or she knows to what was not previously known. A similar process occurs in teaching. Instruction from a teacher is a less accurate means of learning than personal discovery. Instruction can point pupils toward conclusions, but the mere provision of information or conclusions is neither teaching nor learning. Without understanding, the pupil does not truly know: he or she has not been taught and has not really learnt.

According to Aquinas, "the teacher causes knowledge in the learner by reducing him from potentiality to act." This strange way of putting the matter reflects a point of view that sees a real, if immaterial, change in the learner's mind after that mind acquires knowledge. A materialist theory of knowledge acquisition would find in sense impressions sufficient cause for alteration of the mind. Just as an impression might be made on wet clay, so sense data would make physical changes in the brain that we might call knowledge. Aquinas takes the contrary view: the mind is immaterial and so cannot be changed directly by sense data, which he takes to be physical. The agent intellect abstracts from sense data and in an intellective act changes the mind. It now contains the abstracted understanding of what was observed. This is a peculiarly human form of learning (Aquinas 1265–8, 1, Q. 117). The mind comes to possess the object that it learns about in an intellective, immaterial fashion, not as the result of the action of stimuli on a passive and material organ of thought. It will be obvious that learning on this understanding is always accomplished by discovery (*inventio*), even if assisted by formal instruction (*disciplina*). The art of the teacher is significant, but like the art of the physician, it is indirect. The physician does not impart heath directly to a patient, but uses his art or skill to assist nature to heal. So too, a teacher cannot cause knowledge directly in a pupil, but can nevertheless by skill cause an ignorant person to become learned. Like the doctor, the teacher leads by the path which is most natural. And just as the body will heal itself if so led, the pupil will learn if led along the path by which she would most effectively learn.

The role of the teacher is to motivate learning in the pupil, and to propose to them signs so that they may form "intelligible concepts" by the power of their own intellect (Aquinas 1265–8, 1, Q. 117, 3.). Teaching can take two forms. According to the first, the teacher offers the pupil familiar examples or propositions of a less general kind that draw on the pupil's previous knowledge and which allow them to make comparisons of likenesses and differences and so extend their knowledge. The teacher leads the learner from things known to new discoveries. Aquinas cites the principle from Aristotle: "All teaching and all learning proceed from previous knowledge." Secondly, the teacher might strengthen the intellect of the pupil in a kind of demonstration of the order of principles underlying conclusions (Aquinas 1265–8, I, Q 117, a. 1). One cannot passively know something. A set of conclusions is not really known unless the premises that led up to them are understood.

There is another reason that the role of the teacher in imparting knowledge is indirect. Because a teacher uses signs to instruct and because knowledge of principles, not of signs, gives us knowledge of conclusions, then true learning is always a matter of discovery by the learner. We can never come to know about the nature of things through signs alone. The teacher must, however, use signs – usually words – to guide the pupil to apply principles known self-evidently (*per se nota*) by the light of the intellect to concrete particulars and determinate conclusions about them (Aquinas 1256–9, Q 11; Aquinas 1265–8, 1, Q. 117). The question of principles known self-evidently raises a host of arguments, but Aquinas' point may be illustrated by principles such as the sum of angles in a triangle being equal to the sum of two right angles; or that color is coterminus with extension. The truth of such propositions is immediately evident to the intellect. With respect to the material world known through the senses, it is the action of the agent intellect that abstracts intelligible forms directly from sense experience to produce an "intelligible likeness" of sensory observations in the mind. The instruction of the teacher can produce an effect on the agent intellect by presenting the pupil with "signs of intelligible things" from which the agent intellect may derive "intelligible likenesses (which cause) them to exist in the possible intellect" (Aquinas 1256–9, Q 11, Art. II).

Obviously, learning on this account is not something that can be "outsourced" to a teacher or an education system. A teacher cannot fill a pupil's head with knowledge, and a system cannot "deliver" education as material goods, such as a pizza, might be delivered. Aquinas does not diminish of the role of the teacher, for his argument is metaphysical, not practical. Rather, he affirms the potential and accomplishment of the learner: the teacher cannot make the pupil know, but when the teacher has taught the pupil, then the pupil's knowledge will resemble that of the teacher (Aquinas 1265–8, II-II, Q 171, a. 6).

Cross-References

► Aristotle (384–322 BC)
► Epistemology and Learning in Medieval Philosophy
► Plato (429–347 BC)

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ARCS Model

► ARCS Model of Motivation

ARCS Model of Motivation

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Synonyms

ARCS model; Motivational Design; Motivation to learn

Definition

The ARCS model (Keller 1983) is a motivational design process that includes a synthesis of motivational concepts and theories that are clustered into four categories: attention (A), relevance (R), confidence (C), and satisfaction (S). Each of these major categories contains subcategories that consist of smaller, more homogeneous subsets of concepts. The categories resulted from grouping motivational concepts based on shared attributes. The categories and subcategories provide a basis for analyzing the characteristics of learner motivation to determine how to create motivational strategies and learning environments that stimulate and sustain people's desires to learn. The design process can also be used to identify deficiencies in specific areas of learner motivation so that remedial strategies can be developed.

Theoretical Background

The categories that emerged were based on an empirical examination of the attributes of each concept and in relation to underlying theories such as expectancy-value theory, reinforcement theory, intrinsic motivation theory, and cognitive evaluation theory (Keller 1983, 2010). Concepts were placed in given categories depending on whether their primary area of influence was on gaining learner attention (A), establishing the relevance of the instruction to learner goals and learning styles (R), building confidence in regard to realistic expectations and personal responsibility for outcomes (C), and making the instruction satisfying by managing learners' intrinsic and extrinsic outcomes (S).

The conceptual foundation for the first category, attention, is based on attributes related to gaining attention, building curiosity, and sustaining active engagement in the learning activity. Research on curiosity, arousal, and boredom illustrates the importance of using a variety of approaches including such things as interesting graphics, animation, or any kind of event that introduces incongruity or conflict or that stimulates a learner's sense of inquiry. Another aspect of this category refers to attention span in relation to sensation seeking needs, or boredom susceptibility. People differ with respect to their optimal arousal levels.

The second category, relevance, includes concepts and strategies that establish connections between the instructional environment and the learner's goals, learning styles, and past experiences. Learner goals can be motivated by extrinsic requirements, intrinsic desires, or a combination of these as explained in self-determination theory. Other concepts that help explain relevance are motives such as the needs for achievement, affiliation, and power, competence, flow, and authenticity.

Confidence, the third category, incorporates variables related to students' feelings of personal control and expectancy for success. When students are motivated by beliefs that success is primarily due to their own abilities and efforts rather than to luck or the task being too easy, they are more likely to persist in their achievement striving behavior. Thus, the confidence category includes areas of motivational research such as self-efficacy, attribution theory, locus of control, and goal orientation theory; that is, if people are focused on the task and/or process of learning, which are controllable foci of effort, then they are more likely to be less anxious about outcomes and be more productive than if they are focused on outcomes such as people's attitudes about them and about how successful they will be, which can be called a performance or ego orientation.

These first three categories pertain to conditions that are necessary to establish a student's motivation to learn while the fourth category, satisfaction, is necessary for learners to have positive feelings about their learning experiences and to develop continuing motivation to learn. This means that extrinsic reinforcements, such as positive rewards and recognition, must be used in accordance with established principles of behavior management, and must not have a detrimental effect on intrinsic motivation. Finally, a sense of equity, or fairness, is important. Students must feel that the amount of work required by the course was appropriate, that there was internal consistency among objectives, content, and tests, and that there was no favoritism in grading.

Important Scientific Research and Open Questions

Research on the ARCS model has seen a shift in emphasis from model-validation studies to design-based studies that focus on the improvement of instructional materials as in the design of motivationally adaptive instruction (Song and Keller 2001), and the development of the concept of reusable motivational objects (RMO) (Oh 2006). This research also focuses on learner support as in the incorporation of animated pedagogical agents in computer-based instruction (Baylor 2007), and the incorporation of personal motivational message in face-to-face and blended learning environments (Kim and Keller 2008).

There are important questions that can be asked in all of these areas, but one that is particularly challenging in both basic research and design-based research is the identification of motivational deficits that are salient at the time a motivational intervention is being introduced. This process can be assisted by the use of measurement surveys and the analysis of specific motivational challenges to learner motivation (Keller 2010). However, this is an area that can benefit from additional research on the development of indicators that help distinguish symptoms from causes and that can be administered in action, or design-based research settings.

Cross-References

▶ Motivation and Learning: Modern Theories
▶ Motivation Enhancement
▶ Motivation, Volition, and Performance
▶ Motivational Variables in Learning
▶ Self-Regulation and Motivation Strategies

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Argument by Analogy

▶ Analogical Reasoning

Argumentation and Learning

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Synonyms

Dialogue; Social interaction; Social learning

Definition

Argumentation and learning typically are not thought about in tandem, particularly because the word "argumentation" can conjure notions of divisiveness and acrimony. However, argumentation can be not only combative, but also cooperative. Psychologists and educators, who study how people learn, consider argumentation to be an important influence on learning. How engaging in argumentation influences the learning of individuals is the subject of this entry.

Theoretical Background

Scholarship on how argumentation influences learning can be organized into a number of approaches. One approach is to identify activities that, in general, support individuals' learning, and then to consider which of these are happening when people engage in argumentation. For example, it has been found that when people make knowledge explicit, their learning is supported. During argumentation, making one's ideas explicit is required because communication demands it. Learning researchers also have argued that learning is supported when one encounters ideas that differ from one's beliefs, because this motivates efforts to resolve the differences. During these efforts, much is learned about the ideas themselves and whether and how they apply to the situation at hand. Finally, learning researchers have found that when people talk about ideas and their application, they contribute to knowledge that is co-constructed. That is, when one individual contributes some ideas, and another individual contributes others, the resulting shared understanding is comprised by elements of both contributions, which is by definition greater than what either individual could have learned alone. Andriessen (2006) represents a very accessible review of the research that could be considered under this approach.

Another approach to studying the relationship between argumentation and learning is to consider the differences between two points of view in terms of the cognitive conflict these produce. The role of cognitive conflict is central to ► Piaget's learning theory (this volume), who posited that humans have a fundamental need to make sense of their environment and experiences. From a very young age, the human mind develops cognitive structures in various forms (e.g., ideas, schemas) that interpret the environment and make sense of experiences as a person interacts with it. As more interactions are experienced, some novel aspects are experienced for which the current cognitive structures are insufficient. Driven by a need to make sense (what Piaget called *equilibrium*), the human mind appeals to one of two strategies. If possible, the mind tries to alter the sense that can be made of the novelty by interpreting it through existing cognitive structures. If this is not possible, the cognitive structures themselves are altered, either by addition or change, to achieve sense of the novelty. (Piaget labeled the former *assimilation* and the later *accommodation*).

Early in his career, Piaget had an interest in the way conflict between alternative ideas arises between children when they interact, that is, from a social source. Although his career did not continue to focus on this so-called *sociocognitive conflict* (see entry on ► Social-Cognitive Influences on Learning), other researchers in this tradition, (now referred to as *neo-Piagetians*) have continued this approach to study how argumentation influences learning. Researchers within this have considered learning to be traced through social interactions themselves. For example, if one person puts forward an idea and another person differs with that idea by critiquing it, then the first person often changes the original idea in some way. Because the idea has been changed in the process of argumentation, it can be thought of as an instance of learning. Although this is a very simple example, it demonstrates a framework that is used within this approach.

Another popular approach to studying argumentation and learning focuses on the structure of arguments and how structure underpins sound reasoning. Kuhn (1991) is a developmental psychologist who has focused on how arguing and sound reasoning are related. In a series of interviews about social issues, she invited people to voice their opinions and the reasons for them, often motivating argument by presenting alternative points of view. She found that people very often do not reason in sound ways, and that one common error is to cite one's opinion as the evidence for it or the reasons behind it. In other words, people tend to allow their beliefs to color the information they consider to bear on those beliefs. Kuhn noted that this is an issue of structural integrity. An argument that keeps a distinction between beliefs and evidence is structurally sound, whereas an argument that blends the two is not. It is only when beliefs and evidence are held apart as distinct categories that evidence can serve as an objective, independent reference for judging those beliefs.

Other research within the structural approach to studying argumentation has focused on the discipline-specific aspects of arguments (i.e., academic disciplines or school subjects). One of the underlying assumptions of these efforts has been that learning of disciplinary content involves not only what is known (the accepted ideas in a discipline), but also how it is known, or what are called the epistemic aspects of it. Science learning has been a particular focus of the structural approach. Some researchers, convinced about the importance of discipline-specific aspects of argumentation, appealed to literature in science studies (a field comprised by history, philosophy, and sociology of science) to gain understanding of how science constructs knowledge through argumentation. A particularly popular version of this was put forward by Toulmin (1958). The Toulmin Argument Pattern is a scheme for parts of arguments and how these parts are related. It highlights the claim, the evidence for it, warrants (reasons why the evidence supports the claim), as well as counterarguments, rebuttals, and the like. Although Toulmin has noted that his intent in creating this scheme was not to provide an analytical tool for education or linguistics, it has nevertheless been a very productive tool for such scholars. The Toulmin Argument Pattern is used in linguistic scholarship for characterizing the texts of completed arguments and in education as structural prompts for students to argue and through arguing, to learn scientific ideas and the reasons behind them.

The scholarship of D. Kuhn and Toulmin put forward a structural account of what comprises good arguments. That is, arguments are good if the evidence (and other structural parts) supports them sufficiently. An alternative approach is represented in the work of Argumentation Theorists (van Eemeren and Grootendorst 2004). Rather than the structure of an argument determining whether it is good, Argumentation Theorists assert that arguments are good when they successfully persuade a reasoned critic. This point of view highlights the dynamic nature of arguments, and even the criteria by which they should be judged, by centering these not on some abstract category of evidence, but in the reaction of another person. Moreover, whereas a structural approach provides a static picture of arguments, a dynamic view could help illuminate the very *raison d'être* of evidence as independent from belief. That is, whereas the structural view merely notes that evidence is part of a good argument, in argumentation as it develops, evidence – and more fundamentally, a *need* for an independent reference – emerges when two or more parties disagree. When more than one alternative idea is in play, and when a choice among them must be made, successful resolution often depends upon information that is independent of those ideas. Thus, it is from interaction with and the reaction of an audience that the concept of evidence as an independent adjudicator emerges.

The role of social interaction generally on learning during argumentation is an approach that is currently gaining attention of scholars. Asterhan and Schwartz (2009) studied pairs of undergraduate students as they learned key ideas in evolutionary biology. Students were instructed on the notion of natural selection and were provided examples of phenomena that this explains. They were then presented with an organism's feature (webbed feet of ducks) and asked to explain how this feature might have evolved. Later, all students were tested on the key ideas. Asterhan and Schwartz organized the student pairs into two groups according to whether they learned natural selection or not. They then identified features of student discourse that were correlated with learning. They found that dialectical discourse (in which one of the students disputed or challenged an idea) was related to learning. Moreover, learning also depended on one of the students identifying with the idea that was being challenged, rather than it being hypothetical or not belonging to someone. This study is particularly interesting because in contrast to expectations, consensual discourse, (when students agree and build upon each other's ideas) was not related to learning. Asterhan and Schwartz note that consensual discourse may be necessary, but it clearly is not sufficient.

The combination of consensus with challenge during argumentation is also considered important by Mercer and Littleton (2007). In a series of studies of classroom learning, Mercer and Littleton note three kinds of talk are common during argumentation, but that only one is particularly important for learning. *Disputational talk* is characterized by disagreement and individualized decision-making, when students make few attempts to pool resources or build on each other's ideas. *Cumulative talk* is when students affirm each others' ideas and accumulate them together. *Exploratory talk*, which is most related to learning, is when students engage *both* critically and constructively with each other's ideas. Statements may be challenged and counter-challenged, but challenges are justified and alternatives are offered. In exploratory talk, knowledge is made publicly accountable and reasoning is made visible.

Important Scientific Research and Open Questions

It remains unclear in what ways consensus and challenge contribute to learning during argumentation, and more research is needed. On the surface, it seems that consensus and challenge stand in opposition. But it is undeniably the case that academic disciplines themselves construct knowledge using both. That is, during the process of peer review, colleagues critique ideas put forward by their peers. It is only when ideas pass peer review, when the critiques have been answered, that new knowledge is put forward as accepted by the community. Some psychologists have argued that individual reasoning is influenced by community practices. It remains an open question how learning on an individual level might be influenced by participation in social processes like peer review.

Cross-References

► Argumentation and Learning in Science Education
► Learning and Understanding
► Piaget's Learning Theory

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Argumentation and Learning in Science Education

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Synonyms

Line of reasoning; Logical argument; Ratiocination

Definition

If language is considered as playing an important role in science, since 10–20 years now research and education practices turn attention to argumentation as a critically important epistemic discourse process in science education. Argumentation in science, i.e., the interactive coordination of evidence and theory to support or refute an explanatory conclusion, model, or prediction, may help to construct scientific knowledge. Argumentative practices to learn are defined as activities in which interlocutors cooperate in solving or exploring a particular problem to which a number of hypothesis or solutions are proposed, by engaging in reasoning.

Theoretical Background

At first glance, argumentation to learn in science education might look paradoxical as argumentation is often seen as a kind of discursive practice used to take decisions, deliberate, or persuade actions or opinions. Deductive thinking and use of proof would be more relevant to scientific domain. In school context, science has long been considered from a "positivist perspective" which states that science is based on empirical processes, where claims to truth are grounded in observation, and conclusions are unproblematic deduction from such observations. Research in the everyday activities of scientists show however that they are engaged in "argumentative" practices of evaluating the validity and the reliability of competing theories. Science is therefore a social process of knowledge construction that involves conjecture, rhetoric, and argument. Argumentation can thus be seen as "the language of science" (Driver et al. 2000) since this kind of discourse means to critically examine and evaluate transformations of evidence into explanations.

In this perspective, argumentation in science education provides a "literacy in science," sustaining the development of the scientific reasoning that students will use to investigate, discover, represent, communicate, assess, and evaluate knowledge claims. They will search for reasons, examine the available data, test alternative hypotheses, etc., which allows them to realize that science is more about trying to construct and resolve problems in specific theoretical frames than a matter of "discovering" things that might have been hidden since the beginning of the world. Argumentation in teaching science is meant to facilitate the comprehension of scientific arguments which is a crucial part of scientific literacy, and an important step in the development of critical, cultivated citizens (Osborne 2002).

This shift in defining the scientific activity associated with both the enhancement of the socio-constructivist and sociocultural approaches of learning in school and a concern with the development of a critical reasoning toward scientific and technical facts in a complex society probably explain the growing interest about argumentative practices in science education.

Important Scientific Research and Open Questions

Argumentation means a relationship with an "other" who physically or virtually provides a rupture in the action and a reflexive turn toward his/her own claim and perspective. The presence of another person is not only a characteristic of argumentation as a special form of communication; it is also the source of thought and learning. A sociocultural perspective draws attention to the fact that development and learning are embedded in social interactions in which talk plays a central role. Education is a dialogic process in which both the talk between teachers and learners and talk among learners are a tool for creating a shared framework of understanding (see for example the chapter of Mercer, in Muller Mirza and Perret-Clermont, 2009).

Research have shown that particular verbal interactions in which sociocognitive conflicts arise may be a source of development and construction of new knowledge under certain conditions: the child must be ready from a developmental point of view for this destabilizing sociocognitive encounter, and the search for a common solution to the conflict should avoid subordination and blind acquiescence (Muller Mirza and Perret-Clermont 2009).

Argumentative interactions, implying a conflict of perspectives resolved by the means of discursive coordination, might support the elaboration of scientific concepts: the notions are made clearer by the fact that the students have to justify their claims and provide information, knowledge are more articulated, epistemological obstacles are identified, weak hypothesis are put aside as they do not resist to the counterarguments or as they are not linked to the empirical data, and data are articulated to theoretical frames. Moreover, it seems that the students are more focused on evidence rather than on (uncritical) authority from textbook or teacher (Jiménez-Aleixandre and Erduran 2007).

However, using argumentation as a learning tool in the context of school raises questions and difficulties at different levels, psychosociological, interpersonal, institutional, and cultural. If argumentation is conceived as "helping to recognize" the reasonableness of a position and involves at least justification and negotiation operations, these main features are objects of development by the child. Argumentation means to be able to decentrate, in the piagetian terms, to consider the point of view of another person rather than just one's own. It also means to master linguistic and cognitive tools. Argumentation however cannot be reduced to its developmental and intrapersonal factors. Such practices must be seen as "situated" in specific contexts. At the institutional level, argumentative activities are sometimes considered time consuming when curricula are already overloaded. These activities require social skills from the teachers, as well as ad hoc teacher training and assessment practices. At the interpersonal level, argumentation means confronting other people's perspectives, situations which are often avoided since participants perceive them as a risk to the self and to the relationship. At the cultural level, argumentation means the acceptance that social harmony is not threatened by the expression of a plurality of opinions, that authority is not sufficient, and that discussions are permitted even when relationships are asymmetrical (Muller Mirza and Perret-Clermont 2009).

In the specific field of science education, one must not overlook that scientific reasoning is complex, even for scientists. Researchers observe, for instance, difficulties by the children in constructing scientific argumentation: to conclude before providing enough data, to not consider sufficiently the evidence, etc. Difficulties rise also by the fact that from the teachers' point of view, using argumentation in their lessons means not only to change vocabulary, but to adopt a more dialogical communication, in brief, a new way of understanding science.

Taking into account all these difficulties and the fact that everyday argumentation, made by children and even adults, rarely shows sophisticated elaboration (Kuhn 1999), leads to raise an important issue: how to design learning activities in which productive argumentation can develop. Different (sets of) conditions or principles, which can be the frame of an "argumentative design" have been suggested by researchers (see for instance the chapters of Jiménez-Aleixandre, in Erduran and Jiménez-Aleixandre (2007), or of Andriessen & Schwarz, in Muller Mirza and Perret-Clermont 2009). These conditions focus on the "prerequisites" from the point of view of the students (motivation, initial cognitions, etc.), on the role of external resources such as texts and devices that provide information and feedback, on the way to organize the design through different kinds of "chained" activities (around the same topic but with different motives), on the ways to structure the argumentative interactions (that include teacher's interventions oriented toward epistemic and/or social dimensions, and rules to set up argumentative norms of talk). In this line, from several years now, electronic environments have also been developed aiming not only at facilitating argumentation but also at providing a space for specific argumentative dynamics, which in turn affect the whole pedagogical activity (Andriessen et al. 2003). The role of the teachers to elaborate these designs in order to promote argumentation, taking into account the specificities of their own pedagogical and institutional context, is seen as essential to educational improvement.

Argumentation in science meets contemporary approaches in education claiming that learning does not mean simple acquisition of "ready-made" objects of knowledge but implies complex meaning-making processes, deep conceptual changes, and thus the active participation of the learner with other people in well-structured activities. Research in argumentation in science education is nowadays a growing field which deals with open issues yet. Alongside to the questions about teachers training, arguments and argumentation assessment, and environment designing, let us suggest some relatively new fields of exploration. If argumentation is conceived as a psychological tool for learning, the question of the relationship between the learners and the content under discussion, i.e., the affective and identity dimensions of argumentation, have probably been underestimated as well as the epistemic specificities of the object of knowledge itself. Arguing about capital punishment, sound in physics, or life evolution on earth does not mean the same sociocognitive involvement and differ following the age of the participants and the general context in which the discussion takes place. Recent studies show that social representations, personal values, identification processes, emotions play an important role in argumentation about scientific topics. Another issue concerns ethical and epistemological questions: in certain situations argumentation might reinforce social inequalities and legitimate invalid thesis. Moreover, since argumentation can mean "troubling" learners' believes, about what is real, valuable, and right, a particular attention to the frame of discussion is needed. Research, in collaboration with teachers, is therefore important in order to further understand the conceptual and psychosocial issues of argumentation in science education.

Cross-References

- ► Argumentation and Learning
- ► Learning and Understanding
- ► Models and Modeling in Science Learning
- ► Science, Art and Learning Experiences
- ► Socio-Constructivist Models of Learning

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Aristotle (384–322 B.C.)

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Life Dates

Aristotle, one of the greatest philosophers, was born in Stageira in northern Greece. His father was the personal physician to the king of Macedon. At about the age of 18, he went to Plato's Academy in Athens and remained there for nearly 20 years, only leaving at Plato's death in 347 BC. King Philip II of Macedon invited Aristotle to educate his son Alexander the Great. Aristotle's work spans biology, logic, metaphysics, and political theory. Many of the works attributed to him consist of a series of notes compiled by his students.

Theoretical Background

Aristotle constantly emphasized education as a civic responsibility. This was an unconventional position in a society where all education was private. His one systematic discussion of education occurs in the last parts of the Politics. It turns on four questions: (1) Should everyone learn the same things? He suggests they should insofar as doing so leads to virtue. (2) Should education be aimed at the mind or the character? The education of the body precedes that of the mind. We learn first through habit imposed on us and later we learn the reasons that justify those habits. We coerce children to avoid fire until they learn why to do so. By then the habit is set. He implies that the polity must educate the minds of citizens. Character is formed by a wider range of influences than direct instruction alone. (3) Should the education of the mind aim at the useful or not? The young should learn some useful knowledge like reading and writing, but they must not learn a trade. The educated class is a leisured class defined in part by not earning a living though a trade. Thus he speaks of an education that befits a free person: reading, writing, music, gymnastics, drawing, and other cultured pursuits. Music education is not a means to any other ends than the enjoyment of music. It is not useful in any sense and is all the more valuable for that, but akin to music appreciation courses offered in colleges and universities. He cautions against developing anything like a professional interest in creating or performing music. None of his citizens would become musicians, still less carpenters like Rousseau's Émile. (4) What can education contribute to virtue? His suggestion is the Aristotelian mean – all things in moderation.

After this prologue there follows a technical discussion of aspects of music, harmony, and gymnastics. The purpose in each case is to assess how that field of learning can contribute to the whole man. Though it is not said explicitly, the overall character of Aristotle's political theory makes it clear that only the sons of citizens would be educated in mind and character. Earlier in the *Politics*, in a few words, he dismisses Plato's arguments for the education of women.

Contribution(s) to the Field of Learning

In contrast to Plato, Aristotle found truth in the empirical world and he was an omnivorous collector of data; he compiled specimens of all manner of objects from seashells to constitutions. Empiricism as an epistemology and scientific practice both trace back to him. He is credited with the first personal library which was also a museum of natural history with its collections of objects and specimens. In time wealthy gentlemen collected books and specimens as he did. In this, too, he set an example, which later researchers and educators followed. Moreover, Aristotle implicitly distinguishes between education of the cultured mind and vocational training. The former is for male citizens. The latter is not. The curriculum that he outlined for the cultured mind of the citizen was followed by many in Europe and institutionalized in some universities. More generally, the gentleman amateur scientist played a part in European history, partly, albeit unconsciously, inspired by Aristotle's example. Educators, be they private tutors or members of universities, ranged over the fine arts, eschewing the practicalities necessary to make a living, with their charges for many generations inspired and justified by the echoes of Aristotle's argument. This distinction between intellectual and vocational education remains entrenched. Music appreciation but not auto mechanics figures in many college degrees. Yet it is clear that nearly all graduates will drive a car but very few will develop an abiding interest in any aspect of music.

His influence was immense. He provided the primary intellectual source for much of Western European society from the fall of Rome. His works were widely distributed in the Roman Empire and he had interpreters among Arabic thinkers, too. He was a reference point for the intellectual leaders of Christianity like Saint Thomas Aquinas. Such was his stature that he was sometimes referred to simply as The Philosopher, as if there were no other. While his scientific works are now a part of the archive of experience, his social and political works on ethics and government are still read as testing accounts of the evaluation of human goals and institutions. Moreover, his empirical method now dominates the sciences and more. Libraries and museums continue in evolved states as digitization spreads.

Cross-References

- ▶ Aristotle on Pleasure and Learning
- ▶ Plato (429–347 BC)
- ▶ Rousseau, Jean Jacques (1712–1778)

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Aristotle on Pleasure and Learning

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Synonyms

Cognitive pleasure; Satisfaction

Definition

The relationship between learning and pleasure is fundamental in Aristotelian thought: "Naturally, all men desire to know (*eidenai*)," reads the opening sentence of the *Metaphysics* (1.980a22). Similarly, several statements in the *Rhetoric* emphasize the connection: "learning things and wondering about things are pleasant as well, in general" (1.1371a31–32); "to learn (*to manthanein*) easily is naturally pleasant (*hedu*) to all; and words designate something; thus whenever words bring about knowledge in us, they become more pleasurable" (3.1410b10–12).

Aristotle generally defines pleasure as an activity and end (*Nicomachean Ethics* 7.1153a10 = *Eudemian Ethics* 6). But pleasures complete activities without, in themselves, being activities (*Nicomachean Ethics* 10.1174b–1175a). Thus, pleasure is described as a completion of an activity: "as a supervening end" (*Nicomachean Ethics* 10.1174b32). Learning is described as acquiring knowledge from demonstration or definition (for an example, see *Metaphysics* 1.992b–993a1).

Theoretical Background

Aristotle's treatment of pleasure raises several problems, especially whether Aristotle's account is consistent and coherent. For example, pleasure is seen as "a movement by which the entire soul is brought into its normal state in a conscious manner," as well as the opposite of pain (*Rhetoric* 1.1369b–1370a), which recalls Plato's description of pleasure as restoration (e.g., in the *Philebus*), whereas the accounts of pleasure in the ethical treatises appear to go well beyond Plato's account (for a comparison between Plato and Aristotle's views, see Taylor 2003). In the *Nicomachean Ethics*, Aristotle deals with pleasure from different angles, as the two above-mentioned definitions suggest (generally, see Riel 2000, pp. 43–78). A particularly important and novel Aristotelian concept is that of *proper pleasure* (*oikeia hedonê*) of an activity, developed in the *Nicomachean Ethics*, Book Ten. Pleasure completes every type of activity, in the sense of supervening the activity (*Nicomachean Ethics* 10.1174b–1175a). Thus, pleasures are as diverse as the activities they complete (*Nicomachean Ethics* 1175a23; 25–26). Overall, pleasure represents a good, and crowns an activity properly done.

Important Scientific Research and Open Questions

Aristotle assumes that learning is inherently pleasurable (Lear 1988, pp. 1–14), as the above-quoted passages from the *Metaphysics* and *Rhetoric* clearly suggest. Does Aristotle presume that any kind of learning is pleasurable for everybody, at all times? In fact, a hierarchy is outlined: everyone enjoys a type of basic learning, but only some people (philosophers, for example) seem to enjoy learning more than others, and therefore they acquire a more sophisticated kind of learning. This division can be observed, for instance, in a famous passage from the *Poetics*, in which Aristotle deals with imitation (*mimesis*). Imitation, a key-notion in Aristotle's writings about art (Halliwell 2002, pp. 151–206), is understood both as a natural (e.g., children acquire language by imitating their parents) and an artistic process (e.g., tragedy is an imitation of an action), and it produces cognitive pleasure: "it is natural that everyone enjoys mimetic representations. A common evidence of this comes from the following: we enjoy contemplating the most precise images of things whose actual sight is distressing, such as the forms of the most repulsive animals and of corpses. The explanation for this is that to learn (*manthanein*) is very pleasurable (*hediston*) not only to philosophers (*philosophois*) but likewise to other (*allois*) people, although the latter share in it less (than the former). This is why people take delight in looking at images: while contemplating them it happens that they learn (*manthanein*) and infer (*syllogizesthai*) what each element is, for example, this is that" (*Poetics* 4.1448b8–17). Scholars have mainly used this observation in the *Poetics* to examine the cognitive pleasure of artistic *mimesis* (Heath 2009). In the context of linking pleasure and learning, however, the most interesting point is that people seem to be separated into categories of *common* and *intellectually gifted* (philosophers, as Aristotle calls the latter) by the degree of pleasure that they feel when they learn.

Several questions remain open to interpretation. First, why do certain people enjoy learning more than others? Presumably, innate abilities play a role here, but it is, perhaps, a matter of education that divides people in this respect, since all share the desire to learn, as stated in the opening of the *Metaphysics*. Most people, we hear in the *Nicomachean Ethics* (1.1095b), choose pleasure (here certainly of a nonintellectual type) as the highest good and a life of enjoyment, which is less valuable than a life of action in politics or a life of contemplation. Is that because, overall, people are not sufficiently taught to appreciate the pleasure of learning? Second, why do certain people seem to enjoy a particular type of learning, as opposed to another type? Pleasure intensifies an activity, while pain brings it to a halt, as, for example, is the case with calculating sums (*Nicomachean Ethics* 10.1175b17–19). Again, Aristotle probably believed that one is naturally inclined toward certain types of learning (e.g., mathematical). It remains, then, to be established: What exactly is the common, basic type of learning that all people enjoy? What is the specialized type that some may like while others may dislike? Further, what role does pleasure play in the process of learning as opposed to feeling pleasure once having learned or mastered something?

Cross-References

► Aristotle (384–322 B.C.)
► Learning Activity
► Learning and Understanding

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Arithmetic Learning Difficulties

► Dyscalculia in Young Children: Cognitive and Neurological Bases

Artificial Neural network modeling

► Connectionism

Arousal and Paired-Associate Learning

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Synonyms

Associative learning; Emotion

Definition

Arousal is a psychological and/or physiological increase in excitation that is typically the consequence of experiencing an emotional event.

Paired-associate learning is a classic memory paradigm that is used to understand how people encode and retrieve newly formed associations among stimuli. In a typical study using paired-associate learning, people are asked to learn unrelated word pairs (e.g., stove–letter). At a later time point, memory for those pairs is tested by having them either recall one of the words in response to the word it was paired with during encoding (e.g., recall the word that was paired with "stove") or by asking them to distinguish between word pairs that were encoded together (e.g., stove–letter) and word pairs composed of two words that were studied, but were not paired during encoding (e.g., stove–dance; known as *associative recognition*).

Theoretical Background

A key question that memory theorists are interested in is how emotional responses such as arousal influence the ability to remember events. Similarly important is how events that create arousal affect memory for non-arousing events that occur near arousing events in time and space. As an illustration of the importance of this question, consider a situation where a person witnesses a robbery during which the perpetrator pulls out a gun. In this situation, the gun is a stimulus that creates arousal due to the threat it poses. While it is important for a witness to remember that the criminal was carrying a gun, numerous other aspects of this situation will be important for the witness to remember, such as the events that preceded the criminal pulling out a gun, what the criminal looks like, and the things that the criminal says. As a result, it is important to understand not only how the arousal created by seeing the gun influences people's ability to remember the gun and features of the gun (type, color), but also how the arousal created by seeing the gun impacts memory for other parts of the event where the gun was seen.

There are three primary theories that attempt to explain arousals' effects on memory, and all can be applied to understanding the learning of newly formed associations in paired-associate learning. The *attention-narrowing hypothesis* (Easterbrook 1959) suggests that arousal focuses attention on the event that caused arousal. Because attention is limited in capacity, the focus of attention on arousing events reduces the amount of attention that is available to process and encode other events that occur in close proximity to arousing events. Thus, the attention-narrowing hypothesis generally expects that memory for events that produce arousal (e.g., that the perpetrator was holding a gun) is enhanced. However, improved memory for the arousing event comes at a cost – memory for events that occur in close proximity to arousing events (e.g., what the perpetrator looks like) is reduced.

A second theory, *priority binding theory* (MacKay and Ahmetzanov 2005), argues that arousal enhances memory processes that serve to bind, or tie together, an event that causes arousal to other aspects of the event that are directly linked to it. Thus, according to priority binding theory, arousal potentially improves memory for many aspects of an arousing event by tying together arousing information such as a gun and non-arousing information, such as what the perpetrator holding the gun looks like and the events that preceded the perpetrator pulling out the gun. As a result, arousal should improve memory for many parts of an event, provided the relationship between non-arousing events and an arousing event is accessed when the person is retrieving a memory.

Finally, o*bject-based binding theory* (Mather 2007) suggests that arousal produces relatively selective effects on memory, such that it binds together the pieces of the event that produced arousal (e.g., the details of the gun's appearance, as well as the appearance of the perpetrator). However, the binding produced by the arousing event does not extend to non-arousing events, such that memory for events unrelated to the arousing event is not improved (e.g., what the clerk of the store being robbed looked like or the events that preceded the perpetrator pulling out the gun). Thus, the positive influence of binding mechanisms is restricted to the object, or event, that produced arousal.

Important Scientific Research and Open Questions

While much of the literature has been concerned with how stimuli that produce arousal are remembered in comparison to stimuli that do not produce arousal, paired-associate learning offers the opportunity to examine how arousal influences the ability to remember events that are not naturally arousing, but are learned in the presence of arousing stimuli. Generally, research has shown that paired-associate learning improves when one of the members of the pair is arousing (Kleinsmith and Kaplan 1963; Guillet and Arndt 2009), suggesting that arousal enhances the formation of novel associations in memory.

There are, however, outstanding questions about how arousal influences paired-associate learning, as well as memory in general. For example, paired-associate learning generally utilizes words as stimuli, so it will be important for future research to determine how general is the result of arousal's effects on paired-associate learning with stimuli other than words. While not a perfect analog of paired-associate learning, research with pictorial stimuli has often shown that arousing aspects of pictures harm memory for surrounding pictures, as well as non-arousing aspects of a picture that contain arousing stimuli (Kensinger et al. 2007). Additionally, most of the research regarding arousal's effects on memory in general, and paired-associate learning in particular, have used stimuli that have inherently arousing characteristics. Thus, a second open question regards how sources of arousal that are not related to any of the stimuli in a scene or paired associate impacts memory. Answering these questions serve as key challenges for research on arousal's impact on memory in the coming years.

Cross-References

▶ Abilities to Learn: Cognitive Abilities
▶ Associative Learning of Pictures and Words
▶ Cued Recall
▶ Emotional Memory
▶ Mood and Learning
▶ Mood-Dependent Learning
▶ Paired-Associate Learning

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Arousal Level

How calming or soothing, versus how exciting or agitating, a particular stimulus or event is perceived to be.

ART

▶ Action Regulation Theory

Articulation

▶ Covert Pronunciation and Rehearsal

Artifacts

▶ Learning Through Artifacts in Engineering Education

Artificial intelligence

This is one of the fields of study in computer science that endow human intelligence onto the computer. It makes up for the weak ability in the current computer system such as human's learning ability, inference ability, perception ability, and natural language understanding ability, and it will implement it into the program. It has a branch of expert systems, case based reasoning, natural language processing, neural networking, agent systems, and fuzzy systems.

Cross-References

► Adaptive Game-Based Learning
► Cognitive Artifacts and Developmental Learning in a Humanoid Robot
► Learning Algorithms
► Learning to Sing Like a Bird: Computational Developmental Mimicry
► Mathematical Models/Theories of Learning (TL)

Artificial Intelligence in Education

► Advanced Learning Technologies

Artificial Life

► Cognitive Modeling with Multiagent Systems

Artificial Societies

► Agent-Based Modeling

Artificial Society/Economy/Market

► Learning Agent and Agent-Based Modeling

Ascription

► Attribution Theory in Communication Research

Asperger's Disorder

► Diagnosis of Asperger's Syndrome

Asperger's Syndrome

► Diagnosis of Asperger's Syndrome

Assessing Student Progress in Learning

► Evaluation of Student Progress in Learning

Assessment

► Diagnosis of Learning
► Feedback and Learning

Assessment for Learning

► Formative Assessment and Improving Learning

Assessment Grid

► Learning Criteria, Learning Outcomes, and Assessment Criteria

Assessment in Learning

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Synonyms

Appraisal; Evaluation

Definition

Assessment in the educational context typically refers to inferences made about student's behavior, sometimes their achievement and sometimes their affective states. In this article, the term assessment will be used to denote the process by which information is gathered, either formally or informally, about the status of students' learning. Assessment is an activity which for many years was the province of the teacher through the use of examinations, shorter quizzes, recitations, or longer assignments like research papers or science projects. The goals of classroom assessment were twofold: to gauge the progress the student was making, and thereby to provide feedback, and to sum up, in one manner or other, the students' levels of attainment for the purpose of being given a mark or grade, such as A, B, or C.

Theoretical Background

In the last third of the twentieth century, three forces combined to change this use of assessment. The first was the applied focus that learning was significantly affected by teachers and they might judge their students and themselves by specifying explicit objectives and measuring their attainment or even the change from pretest to posttest. These goals may have been very specific, applicable to a day or more of instruction, or apply to a more extended period of time. But the practice reinvigorated an earlier idea that learning is a measurable outcome of teaching. A second force was the need to evaluate, at least in the USA, the impact of financial support provided to students at risk. The Elementary and Secondary Education Act provided extra resources to children who were underperforming, and widespread tests were commercially developed to monitor their progress. Simultaneous, other tests that had been used in a benign system monitoring way became more important, with progress and scores on them associated with both political and economic consequences. The commercial testing companies became very big business. In many countries and in the USA in particular, national examinations sampled performance and gave periodic estimates of progress in basic subjects. The third and continuing force was the power of published international comparisons. Beginning in the second part of the twentieth century, multinational comparative studies using common examinations were conducted by the International Association for the Evaluation of Educational Achievement (IEA), and later under the auspices of the Organisation for Economic Cooperation and Development (OECD). Although the goals of the two groups were similar, IEA studies were designed and managed by teams of international experts, and funding for both national and international participation was often a struggle. In contrast, OECD studies were funded by member countries, perhaps disproportionately by some, but had the power of governments to help determine the topics and frequencies of assessment and the necessary national compliance with the sampling plan, standardization, and so on.

Assessment transformed in the last quarter of the twentieth century from being principally a measurement process that was undertaken at the close of a sequence of instruction, although that function remained, and turned into a strategy for developing outcomes themselves. Test-driven, evidence-driven examinations, tests, and so on, became more of a governmentally endorsed approach to educational reform. As a result, many educators and practitioners focused instruction on what was to be measured. In the USA, this typically meant on multiple choice test items that were relatively shallow samples of very general goals. It was only sensible, given vague or non-clear curricula, for teachers to focus on what was to be tested. And in some places, the curriculum and teaching narrowed to that which was on externally mandated tests.

Any test or assessment attempts to measure a particular construct or domain. The construct may be inferred from the patterns of test performance; whereas a domain is typically pre-specified, and usually focuses on the subject matter of the examination, national literature, mathematical concepts and computations, and biological sciences, for example. Assessments sample only a small subset of the entire construct or domain, because there would never be sufficient time to measure one in its entirety. Another key point is that all assessments include error and should be thought of as estimates rather than precise values that label any particular student.

Reactions to the political use of tests occurred periodically, with early attempts at performance-based assessments seen in the USA on its National Assessment of Educational Progress (NAEP) and in England for younger children following the Brown Act of 1988 when teachers were encouraged to give students objects and extended tasks in order to assess their deeper understanding. In the USA, the movement focusing on extended performance, such as portfolios of student work, research projects, and the like, began in the 1990s and significantly lagged behind efforts in other countries, including Australia and Germany. Performance assessments were overcome as a plausible accountability option by problems in the reliability of scoring, the cost of marking, and ill-defined boundaries of the domain or construct. Subsequent efforts to revive such forms of assessment have occurred, and there are common expectations in parts of the world for teacher marking of student papers required to pass a school leaving or advanced certification examination. In these cases, supported by an extensive research literature, approach to preparing competent markers of student work involved the development of operational scoring rubrics that incorporated expectations. Careful training on examples of students work illustrating various strengths and weaknesses removed the lack of scorer reliability. However, studies that found tasks by student interactions suggested that the assessments were not selected from the same domain, had not been well instructed, or both. In the late 1990s and persisting through the first part of the twenty-first century was a call for systematic formative assessment or assessment for learning. In these cases, assessments were to be given by teachers, who would infer diagnostic meaning for individual students, provide feedback, and suggest courses of action to improve student performance. The utility of this approach depends of course on the teachers' ability to design situations that would expose strengths and weaknesses, have skill in inferring possible causal links to explain inadequate performance, and have a repertoire of options that they could apply adaptively to students with particular needs. This sequence, called formative assessment (Black and Wiliam 1998), was a takeoff on formative evaluation, that is, the process of improving a program or system while it was under development. Formative assessment appeared to be a good idea, and some might say it incorporated key features of previously advocated instructional paradigms. Nonetheless, educational authorities have stepped in a provided "formative assessments" to teachers to be used to assist their teaching and to support student learning. These assessments may or may not be scored or evaluated by teachers, and results may or may not be given to them in a timely fashion. In some venues, instruction is fairly rigidly paced, so there may be no discretionary time to enable the reflections, identification of shortfalls, and repair of weak concepts or problem-solving skills. In some cases, formative assessments were used as part of the accountability system itself, weighted in some manner in combination with a more formally monitored end-of-course examination.

Important Scientific Research and Open Questions

A current reaction to formal tests that emphasize less advanced thinking skills has been the movement toward twenty-first century skills. Beginning also in the last century, certain researchers derived key cognitive requirements for schooling, university, and the workforce. These were gleaned from research on student learning and from questionnaires, and interviews of college and workforce personnel. The combined list of twenty-first century skills is very long, but most contain notions of problem solving, communication, teamwork, conceptual and procedural content knowledge, and the ability to think metacognitively about one's own learning process. There is an underlying theme related to the importance of applying such knowledge, not only in well-defined content areas, but in transferring performance to new, unforeseen situations. These twenty-first century skills have in the past served as the basis for some measures of individual differences, where people might be differentiated by their general, problem-solving ability. In the present case, there is a mix of applications, where some attribute of a twenty-first century skill is particularly domain specific. For example, the ability to communicate certain information clearly may be very audience dependent, and certain strategies may be learned to focus on particular rhetoric for particular audiences. Similarly, certain problem-solving tasks are extraordinarily knowledge driven. If problems need to be discerned and found in a particular setting, the student must understand the content more deeply than if the problem is made explicit and the student must only select from among learned procedures which to apply. In almost every case, it is true that the psychometrics needed to estimate the quality of longer, more-complex tasks do not exist, or have significant missing pieces. A great problem is to determine the comparability of scenarios or other extended tasks that take many days to complete. It is difficult to infer from performance whether low marks are the result of poor instruction or incredible difficulty. In addition, these twenty-first century skills are now being included in content standards, central to the current form of assessment driven reform, known as standards-based learning. Standards are verbal statements, which can be illustrated by examples. Yet, there is plenty of opportunity for misunderstanding by teachers and students of what is wanted. To avoid regressing to practicing test items, certain research has been undertaken to develop explicit graphical representations of domains to be taught and assessed. These are useful to assure transparency, to resolve differences in interpretation, and to allow teachers and students to understand in advance what is important to learn. Called ontologies, these approaches usually involve network representations of content and have been used in the sciences and computer fields for many years. Their application to education suggests that they can help resolve issues of sampling and of instructional sequencing, although order of learning may not be a simple or single path.

The instance above leads us to the topic of validity, that is, how one knows that the assessment is leading to the appropriate inferences and actions. Validity depends on test purposes (Messick 1989) and is not a coefficient or inherent in a particular artifact, like test paper or writing prompt and rubric. Validity depends on the purposes for the examination or assessment, the inferences that will be drawn from the results, and some would say the consequences that follow on those inferences. Because consequences can be stringent or benign, and because any assessment includes some error, experts have argued that no single assessment should be used to make a high stakes or consequential decision about an individual (American Educational Research Association, American Psychological Association, and National Council on Measurement in Education 1999; Heubert and Hauser 1999). These warnings have, for the most part, been ignored. As mitigation, some authorities permit the retaking of high-stakes examinations multiple times, but such an option is not in the spirit of the dictum. These new evidentiary basis of assessment has been adopted by some as a model for development (Baker and Linn 2004; Mislevy et al. 2002; Pellegrino et al. 2001). This purpose orientation of validity supplants particularistic methods recommended for content validity, predictive validity, criterion validity, and so on. Depending on purpose such validity inferences may be appropriate, but they are not tied necessarily to unique analyses.

Some authors have described features or characteristics of assessments that should lead to their greater validity, despite particular purposes (Linn et al. 1991; Shepard 2005; Sweller 2005). These characteristics include the domain definition, correctness of content, challenge of cognitive demands, clarity of scoring options, generalization and transfer, and appropriate linguistic requirements. The last point related to the language of the test illustrates a more general precept that the test score should not involve construct-irrelevant variance (Messick 1989) obscuring the purpose and inference of intended performance. Because of such strictures and the overarching need to assure fairness, accommodations for tests have been developed that attempt to simplify overwrought language so as not to disadvantage students who are immigrants or non-native speakers of the language of the tests (Abedi 2008). Other accommodations in tests involve providing more time in a speeded examination, and physical help, larger font sizes, readers, or other support for physically disabled students.

A particular problem with the current validity frame is the issue of assessments with multiple purposes. An assessment may be used for teacher accountability, for system quality, for student certification, or to inform teachers and educators of needs for improvement. Some tests are intended to measure attainment as well as to serve as selection measures for tertiary educational opportunities. Evidence to support all of these purposes may be in conflict, and it may be difficult to optimize designs to meet all intentions. Nonetheless, some elements are important for certain uses. If one is engaged in selection, then it is simply a matter of choosing the highest (or in some cases the lowest) performing students to be admitted to a special program. Often the decision is made based on how many spaces exist, so the quality of applicants to be teachers or physicians may vary with the number of individuals seeking the number of available positions. For measures of effectiveness, either of the learning of the student, the educational system, or the teacher, there must be clear evidence that the assessments are sensitive to instruction and that scores would be different if no quality instruction occurred. If students' talents were sufficient for particular outcomes, the schools would serve little purpose. Validity of measures in terms of their sensitivity to learning opportunities (as well as the motivation of students) should be obtained.

Most of the foregoing discussion applies to measures of status, except for formative assessment within classrooms or courses. Newer statistical approaches are focusing on policy desires to measure students' growth over time, to understand their learning trajectories, and to assure they reach goals overall rather than limited to a particular point in the educational sequence. A second, similar desire is using value-added models to look at teacher performance over time, with different cohorts of students. Both of these approaches are popular with policymakers, but do not take sufficient account of the error in the tests, in the sample of individuals, or moderate the inferences to be drawn from these types of analyses. Serious problems occur when tests vary in difficulty and when different grade levels may have assessments that do not have the same range available for growth. Secondly, many of the statistical models used assume that there is only one major construct to be measured, but many newer examinations have significantly different components and would seem to require multidimensional approaches. These methods are only just evolving, and may not keep pace with policymakers' expectations or use of findings.

Solutions for some technical difficulties may come through the use of technology to design, administer, adapt, and mark responses. The adaptive assessment movement is only at its beginning. Interesting explorations of computer-scored essay and other open-ended examinations have been made, but more agile methods will need to be found. Their integration with game technologies and other high-fidelity simulations may allow for extended practice needed by some learners and for greater challenge needed by others.

One must close a top-level discussion of assessment with suppositions about the future, based on current research and development. Of great interest are studies of brain images and electrical impulses as various interventions are applied to the respondent. One obvious idea is that activation of various brain sectors may be a more accurate measure of learning than responses to more global problems. The difficulties inherent in scaling up such processes include the limited quantities of technology and the invasive nature of the measures. However, current researchers have developed sensors such that some significant aspects of performance can be inferred from physiological changes. If that line of inquiry becomes plausible and distributed, then we will be spared more investment in marking performance. We will still be required to design good assessment tasks, however.

Cross-References

- ► Aligning Learning, Teaching and Assessment
- ► Diagnosis of Learning
- ► Dynamic Assessment
- ► Evaluation of Student Progress in Learning
- ► Formative Assessment and Improving Learning
- ► Learning Criteria and Assessment Criteria

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Assessment Matrix

► Learning Criteria, Learning Outcomes, and Assessment Criteria

Assessment of Academic Motivation

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Synonyms

Assessment of motivation toward education; Assessment of motivation to learn

Definition

The assessment of academic motivation involves the use of specific techniques for the evaluation of the quality and the quantity of students' motivation toward education.

Theoretical Background

The various different techniques for the assessment of academic motivation can be distinguished on the basis of the data collection strategies employed (e.g., observations, self-report measures, interviews), the method adopted (quantitative, qualitative, mixed methods), and the conceptualization of academic motivation applied (e.g., unidimensional construct vs. multidimensional construct). Although there is a wide range of data collection strategies, those that are based on self-report measures are certainly the most extensively used. Over time several instruments of this kind have been proposed.

For example, in the early 1980s Susan Harter developed the scale of intrinsic versus extrinsic orientation in the classroom using pupils from grade three through grade six. The scale, based on White's model of "effectance motivation," is a 30-item questionnaire designed to assess, along an intrinsic to extrinsic continuum, various different components of the student's orientation toward schoolwork. A total of five components is measured: (a) preference for challenges vs. preference for easy schoolwork, (b) curiosity in the subject vs. getting grades or pleasing the teacher, (c) independent mastery vs. dependence on the teacher, (d) independent judgment vs. reliance on the teacher's judgment, and finally, (e) internal criteria for success vs. external criteria for success. Harter's scale uses a format of structured alternatives that contrast intrinsic orientation with extrinsic orientation and the student is then asked to make a second 2-point judgment as to whether the selected statement is "really true" or "sort of true."

Another example of a self-report measure is the children's academic intrinsic motivation inventory (CAIMI) developed by Adele Eskeles Gottfried in the mid-1980s for students from the fourth to eighth grades. The CAIMI is a 122-item measure based on intrinsic motivation theories, and provides a general scale in addition to four subject area scales referring to reading, math, social studies, and science. Items in the four subject areas are identical except for the reference to the specific subject. Students respond to all the items on the CAIMI on a basis of 5-point Likert scale ranging from strongly agree (1) to strongly disagree (5). There is also a simplified version of the CAIMI, the Y-CAIMI for young children (grade 1–3).

In the early 1990s, Pintrich and his colleagues developed a further self-report measure, the motivated strategies for learning questionnaire (MSLQ), with the specific purpose of investigating the factors that influence academic performance. The instrument includes 56 items on student motivation, cognitive strategy use, metacognitive strategy use, and management of effort. Students answer the various items on a 7-point Likert scale (from 1 – not at all true of me, to 7 – very true of me). The MSLQ has gone through many revisions and refinements and has been used with both college and high school students.

In the current scientific literature (Alivernini and Lucidi 2008), many studies on academic motivation are based on assessment instruments that refer to the self-determination theory (SDT). The SDT (Deci and Ryan 2002) claims that there are different styles of regulation as regards academic motivation in students, which reflect differences in their relative levels of autonomy. Academic motivation can thus be placed on a continuum starting with amotivation and moving on to extrinsic motivation and intrinsic motivation according to the various levels of motivation, which differ theoretically, functionally, and experientially. The two most commonly used scales for the assessment of academic motivation according to the SDT are the academic self-regulation questionnaire and the academic motivation scale.

The academic self-regulation questionnaire (SRQ-A, Ryan and Connell 1989) was elaborated for children from elementary school to middle school age. It investigates the reasons why students do a series of activities related to school, both at home and in class, and seeks to determine the commitments needed to achieve good academic results and overcome difficulties regarding studying. The SRQ-A, which uses a four point response scale (very true, partly true, not very true, not true at all) has four subscales: external regulation, introjected regulation, identified regulation, and intrinsic motivation. For the SRQ-A, a single score is usually calculated, called RAI (relative autonomy index), attributing different weights to each of the various types of motivation depending on their position on the self-determination continuum. Various studies have shown that the SRQ-A scales have a good degree of reliability in terms of internal consistency. As regards concurrent and criterion validity, Ryan and Connell (1989) showed that:

- SRQ-A scales correlate with scores in other motivational questionnaires such as Harter's Scale of intrinsic versus extrinsic orientation in the classroom.
- As one would expect from the theory, the SRQ-A internal dimensions of regulation (intrinsic and identified) correlate more closely with more adaptive strategies for coping with school and with perseverance in study, while the external dimensions of regulation (external and introjected) have a closer correlation to anxiety.

The academic motivation scale (AMS, Vallerand et al. 1992) was originally formulated in French and a version in English was subsequently published. The questionnaire has been used to assess academic motivation in college and high school students. The AMS consists of 28 items that represent possible reasons why students go to school. Students have to respond to the items on a seven-point scale ranging from "not at all" (1) to "exactly" (7). The AMS includes seven scales: amotivation, external motivation, introjected motivation, identified motivation, intrinsic motivation to know, intrinsic motivation to achieve things, and intrinsic motivation to experience stimuli. In the most recent literature, the AMS is frequently used in a simplified version with five scales, which has a single dimension of intrinsic motivation (intrinsic motivation to know). As regards reliability and validity, various studies have shown that the AMS has:

- Good reliability both in terms of internal consistency and in terms of test–retest reliability
- Good factorial validity, also as regards longitudinal cross-gender factorial invariance
- Good construct validity according to the predictions of the SDT both in terms of correlation with antecedents and consequences of academic motivation and in terms of the pattern of correlation between the scales
- Concurrent validity when compared to other motivational scales such as the CAIMI

Although the academic self-regulation questionnaire and the academic motivation scale differ as regards the age of the subjects they are aimed at and the number of motivational constructs they measure, their use has led to comparable results.

Important Scientific Research and Open Questions

In the past, a common approach to the problem of assessing academic motivation was to think of student motivation as a single characteristic of an individual, and as a unidimensional construct. According to this point of view, if one asks the question "how motivated is a student?" it is possible to have a simple answer such as "he/she is highly motivated" or "he/she is not motivated." The assessment approaches most often used in more recent scientific literature, however, tend to consider academic motivation as a multidimensional construct, in which each dimension must have its own appropriate evaluation. According to this trend, some authors have proposed assessment instruments, which further articulate the multidimensionality of academic motivation. For example, Green-Demers et al. (2008) developed the academic amotivation inventory (AAI), an instrument based on the idea that amotivation, one of the dimensions of academic motivation according to the SDT, is, in turn, further articulated into sub-dimensions.

Another area that is also of interest for the assessment of academic motivation is the combined use of quantitative and qualitative methods. In fact, mixed methods approaches can integrate the in-depth exploration of various aspects of an issue, which is possible in qualitative methods, with the reliable forms of analysis typical of quantitative methods. For example, a mixed methods assessment of academic motivation (Alivernini et al. 2008) makes it possible to:

1. Discover new features of students' academic motivation by means of a reliable data-driven approach
2. Use various theoretical perspectives for analyzing the data collected
3. Integrate the results obtained and evaluate them by means of a rigorous statistic assessment

Cross-References

► Academic Motivation
► Mixed Methods Research on Learning

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Assessment of Motivation to Learn

► Assessment of Academic Motivation

Assessment of Motivation Toward Education

► Assessment of Academic Motivation

Assessment Rubric

► Learning Criteria, Learning Outcomes, and Assessment Criteria

Assessment Schemes

► Learning Criteria, Learning Outcomes, and Assessment Criteria

Assessment Validity

► Validity of Learning

Assignment of Credit

► Contingency in Learning

Assimilation

This term is used differently in various disciplines. For instance, in biology "assimilation" refers to the incorporation or conversion of nutrients into protoplasm. In linguistics it refers to the change of a sound in speech so that it becomes identical with or similar to another, neighboring sound. In psychology, "assimilation" refers to the process of responding to new facts and situations in accordance with what is already known and retrievable from memory. In terms of Piaget's epistemology, assimilation and accommodation are the two complementary processes of the adaptation of intelligent systems to their environments.

Cross-References

► Enculturation and Acculturation
► Internalization

Assimilation Hypothesis

► Assimilation Theory of Learning

Assimilation Theory of Learning

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Synonyms

Assimilation hypothesis

Definition

The assimilation theory of learning is a cognitive learning theory developed by David Ausubel in the early 1960s and widely applied to the area of meaningful verbal learning. It is based on Piaget's genetic epistemology and focuses on the *assimilation hypothesis*, which assumes that new learning experiences are always integrated into preexisting knowledge structures. Accordingly, the assimilation theory of learning states that new information is subsumed or incorporated into an anchoring structure already present in the student.

Theoretical Background

> If I had to reduce all educational psychology to just one principle it would be this: The most important single factor influencing learning is what the student already knows. (Ausubel et al. 1978, p. 163)

The assimilation theory of learning emerged in the 1960s as a consequence of the paradigm shift in psychology sometimes referred to as the "cognitive revolution," which was "an all-out effort to establish meaning as the central concept of psychology" (Bruner 1990, p. 2). The assimilation theory of learning is closely related to meaningful verbal learning (in contrast to rote learning) and presupposes two stages: (1) initial acquisition and immediate post-learning and (2) retention and forgetting. Accordingly, learning refers to the process of acquiring or constructing meanings from new learning material, retention refers to the process of maintaining the availability of new meanings (or at least some part of them), and forgetting refers to a decrement in the availability of separable meanings.

Ausubel's assimilation theory states that meaningful learning occurs as a result of the interaction between new information that the individual acquires and a particular cognitive structure that the learner already possesses and that serves as an anchor for integrating the new content into prior knowledge. This interaction results in the assimilation (or functional incorporation) of both the new and the stored information to form a more detailed or comprehensive cognitive structure. Ausubel and Robinson (1969) have described the process of assimilation as follows: We want to teach a new idea (or meaning) *a*, for instance the concept of a rhombus. Due to previous learning experiences the concept *A* of rectangles should already be stored in the learner's memory. According to the assimilation theory, meaningful learning occurs when the learner creates a link between *a* and *A*, resulting in an interactional product *A′a′*, which includes both *a′* as the meaning of *a* (rhombus) and *A′* as the meaning of rectangle. Early and later retention of the meaning *a′* depends on the dissociability of the new meaning *a′* from *A′a′*. Although *A′* and *a′* will remain closely linked with each other, the learner should still be able to recall the meanings *A′* and *a′* independently of each another, at least immediately after acquiring the new meaning. The basic assumption is that *a′* and *A′* remain dissociated from the product *A′a′*. Remaining within the example, the learner can still differentiate the concept *rectangle* as well as the concept *rhombus* from their common superordinate concept *parallelogram* and remember the defining characteristics of each of them.

During the first stage of assimilation, the initial learning and immediate post-learning of *a* is closely linked with *A* and is anchored in the ideational complex *A´a´*. This anchoring makes it possible for the learner to retain concept *a* permanently, but of course only as long as *a´* can be dissociated from *A´a´*. To explain how successful this process of retention is, Ausubel and Robinson introduced a variable *dissociability strength*. It is of course fairly simple to dissociate *a´* from *A´a´* immediately after the meaning of the former has been acquired. This is due to factors such as the affinity between *A* and *a´*, the stability and clarity of the anchoring concept, and the extent to which new ideas can be differentiated from the anchoring concept. If, for example, the anchoring idea *A* itself is unclear, one will not be able to distinguish it from *a´* very clearly. This also holds true if *a´* is only an insignificant variation or modification of *A*, making the two hard to distinguish from one another. In this case, both meanings are included in one and the same idea.

During the process of assimilation, the new meaning gradually loses its discrete identity as it becomes part of the modified anchoring structure, i.e., newly acquired meanings tend to become assimilated into more comprehensive meanings. This process is termed ► obliterative subsumption and is dependent on dissociability strength. If the dissociability of *a´* falls below a certain level, then *a´* can no longer be distinguished from *A´a´*. This gradual loss of separable identity ends with the meaning being forgotten when the idea falls below the *threshold of availability*. This threshold is the level below which an idea cannot be retrieved, but the level is subject to variation, for instance due to anxiety. Ausubel and Robinson describe two critical degrees of dissociability, the higher of which is linked to the reproduction of *a´*. If dissociability falls below this level, the person will no longer be able to remember the exact meaning of *a´* but will still be able to recognize corresponding objects. Remaining within the example, although the learner is no longer able to provide a definition for a rhombus, he or she can select a rhombus from a group of various geometrical figures on the first attempt. Later on, of course, the learner will reach the point at which the dissociability of *A´a´* reaches zero and individual meanings are no longer available at all. At that point, the learner will have forgotten the meaning of *a´*. Figure 1 summarizes this argumentation by referring to the example of meaningful learning of a subordinate meaning.

Similarly, Ausubel and Robinson described the learning and retention of superordinate meanings.

Ausubel's assimilation theory is a comprehensive approach for explaining both the acquisition and the forgetting of knowledge. It also forms the fundamental basis of his ideas concerning the organization of instruction and the main variables affecting school learning. One of the key strategies for learning advocated by Ausubel is the concept of "advance

I Meaningful learning or acquisition of subordinate meaning *a´*	New potential meaningful idea *a*	Applied to and assimilated by	An idea which is established in the cognitive structure *A*	**Product of the interaction: *A´a´***
II Consolidation and initial retention of meaning *a´*	The new meaning *a´* is dissociable from *A´a´*	***A´a´* ⇔ *A´* + *a´*** (High dissociability strength)		
III Long-term retention of meaning *a´*	Gradual loss of the dissociability of *a´* from *A´a´*	***A´a´* ⇔ *A´* + *a´*** (Low dissociability strength)		
IV Forgetting of meaning *a´*	*a´* is no longer effectively dissociable from *A´a´*	The dissociability of *a´* from *A´a´* lies below the threshold of availability: *a´* is reduced to *A´*		

Assimilation Theory of Learning. Fig. 1 Learning and retaining a subordinate meaning (Ausubel and Robinson 1969, p. 108) organizers," a strategy introduced in advance of any new material in order to provide an anchoring structure for it.

Important Scientific Research and Open Questions

The assimilation theory of learning is closely linked to the name David Ausubel and his research on school learning. Closely related to and influenced by the assimilation theory is the theoretical approach of generative learning and in particular the idea of concept maps advocated by Novak (1998). The assimilation theory of learning had its heyday in the 1980s; only the idea of advance organizers has survived and is still a key concept in educational psychology.

From the perspective of Piaget's epistemology, the assimilation theory of learning is strictly limited to assimilation and thus does not include accommodation. Assimilation is certainly a central form of learning, but not the only one. Another form of learning consists in restructuring knowledge and understanding new experiences on the basis of accommodative activities. An elaborate form of *accommodation* is the construction of *mental models*, which learners construct on the basis of their world knowledge in order to process new tasks or solve problems for which no appropriate schemas are available (Seel 1991). As long as new information can be assimilated into the structures of previous knowledge, there is no need to construct a mental model. However, neither mental models nor schemas have been incorporated into the assimilation theory of learning, although a central argument of Piaget's epistemology is that schemas regulate the assimilation of new information into preexisting cognitive structures. Another critical comment is concerned with the substantial lack of research on the assimilation theory. The only aspect that has been investigated extensively is the concept of advance organizers.

Cross-References

► Advance Organizer
► Ausubel
► Generative Learning
► Meaningful Verbal Learning

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Associability

► Attention and Pavlovian Conditioning

Association

► Contingency in Learning
► Infant Learning and Memory
► Inhibition and Learning

Association Psychology

► Associationism

Association Theory

► Associationism

Associationism

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Synonyms

Association psychology; Association theory

Definition

"Associationism" can refer to a well-defined historical tradition or, more controversially, to a range of approaches influenced by the former. The historical tradition, developed from the seventeenth to the nineteenth century mainly by British philosophers, appealed to the association of mental contents with one another to explain the nature of human thought and knowledge. Current forms of associationism assume that complex psychological units are built from simpler elements on the basis of experience and through a process ("association") that is both general across domains and structure-independent. This process is typically sensitive to coincidences, correlations, or statistical dependencies among events, and the psychological units formed on its basis come to reflect such dependencies.

Theoretical Background

The philosophical tradition of associationism can be traced back to Aristotle, but it developed mainly from the seventeenth to the nineteenth century through the effort of scholars, most of them English, interested in the origins and nature of human knowledge (Warren 1921). Important exponents of associationism include, in historical order, Thomas Hobbes (1588–1679), David Hartley (1705–1757), Étienne Bonnot de Condillac (1715–1780), James Mill (1773–1836), Thomas Brown (1778–1820), John Stuart Mill (1806–1873), Alexander Bain (1818–1903), and Herbert Spencer (1820–1903). Associationism also can be found in the philosophical works of John Locke (1632–1704), George Berkeley (1685–1753), and David Hume (1711–1776), reflecting its dual importance for psychology and epistemology. The associationist philosophers relied on the introspective method and the phenomenological investigation of thought sequences to uncover the psychological principles that might underlie the latter. Most of these philosophers also speculated on the nature of the physiological machinery that made association possible. All invoked associative principles (not necessarily under that name) through which complex mental contents could be produced out of simpler ones.

Beyond this shared commitment, associationist philosophers differed among themselves in ways that anticipate current debates in behavioral and cognitive sciences. Important differences concerned the scope of the associative process. Did it apply to rational thought, for example, or only to haphazard mental sequences forged out of coincidences? Did the associative process account for all of psychological structure, or should it be supplemented by faculties responsible for the organization of mental contents? Other differences concerned the nature of the elements being associated. Could they include sensory presentations, feelings, or motor elements, as well as mental contents? Could volition and motor control be built on associative principles? The modes of association, simultaneous versus successive, were also the subject of controversy. Some associationists admitted simultaneous association as a genuine process so as to account for perceptual organization (with different visual components, for example, combined into a single scene), but others emphasized the successive associations necessary to produce trains of thought. The principles of similarity and contrast were debated, with some associationists attempting to reduce contrast to a combination of identical elements paired with different associates. Another important debate opposed "mechanical" to "chemical" conceptions of association (Warren 1921). Did the components of a complex thought preserve their identity through the association process, or did they merge so as to produce a mental configuration irreducible to its antecedents?

Associationism strongly influenced experimental psychology at the end of the nineteenth century and the beginning of the twentieth century. Research aimed at associationist principles involved the investigation of memory and the effect of practice on behavior, the measure of reaction times in the production of verbal associates, and the use of verbal association in the study of individual differences, development, intelligence, and psychopathology. Warren (1921) also mentions the "conditioned reflex" as a case of "motor association" and suggests that "the conditioned reflex belongs to the present and future of association psychology" (p. 257).

Applying the label of "associationism" to any theory formulated after the early twentieth century, however, faces a serious conceptual problem. In the twentieth century, the emergence of behaviorism shifted the methodological ground of psychology from introspection to behavioral evidence (Brunswik 1952), and the information-processing theories formulated after the establishment of behaviorism often appealed to representational constructs that may not be accessible to consciousness. Thus, contemporary psychological theories typically do not involve the association of conscious contents with one another. The associationist label can retain its usefulness only if a definition of "associationism" can be provided that is broad enough to cover widely different perspectives but not so broad as to exclude nothing.

Anderson and Bower (1973) have risen to the challenge and proposed a definition of "associationism" in terms of four basic assumptions (p. 10):

- Psychological units are connected by experience.
- Complex units can be reduced to a limited stock of primitive units.
- These primitive units consist of sensations.
- Units combine through simple additive rules.

Although this characterization of associationism as relying on elementary sensations may be adequate to mentalistic psychology, it fails to capture the associationism (if any) of behavioral psychology, the basic units of which are certainly not sensory experiences. Following on Anderson and Bower's proposal, therefore, Fodor (1983) has defended a broad definition of "associationism" that is better designed to cover "the classical mentalist or the more recent learning-theoretic variety" (p. 27) of associationist psychology. According to Fodor, associationism entails:

- A set of basic elements out of which more complex structures are built
- A relation of association defined over these elements and structures
- Principles of association whereby experience determines which structures are built
- Theoretical parameters of the associative relation and its terms

Fodor explicitly admits behavioral as well as mental elements in his definition of "associationism," so the latter does cover the full range of approaches that may be reasonably called associationist. His definition accommodates the philosophical tradition of associationism (in which mental contents are associated with one another) as well as current connectionist models of cognition (in which the links between nodes are strengthened on the basis of experience) and behavioral forms of associationism in which the conditional probabilities between stimuli and operant actions change through reinforcement.

At the same time, Fodor's (1983) definition is not so general as to be vacuous. An important point, left implicit in the 1983 definition but later emphasized by Fodor and Pylyshyn (1988), is that not any relation or structure-building process among psychological components qualifies as association. To qualify as the latter, the process that builds more complex units out of simpler ones must proceed on the basis of experience (expressed as contiguity, correlation, or statistical dependency) and *regardless of the structure of the components being related*. The issue with associationism, therefore, is not whether psychological states are structured. All parties in the debate agree on this score. The issue is rather whether the processes that build complex psychological states are structure-sensitive or not. The claim that they are not is characteristic of associationism.

In current behavioral theories, for example, reinforcement depends on the temporal correlation between responding and its consequences and operates regardless of the organization of the action being reinforced. Whether the latter consists of a simple response or a complex hierarchy of interlocked actions is irrelevant to the reinforcement process (although the speed with which conditioning takes place may depend on the duration of the reinforced unit and other temporal parameters). Similarly, the strength of the links in a connectionist network is modified by statistical and temporal relations among activation values regardless of the internal structure (if any) of the connected nodes and of what they are supposed to represent. And in the philosophical tradition of associationism, mental contents are associated by experience regardless of their intrinsic organization.

By contrast, in the theory of mind as a physical symbol system, the *computational* (not associative) operations that produce new states out of previous ones are sensitive to the structure of these states (Fodor and Pylyshyn 1988). Thus, when a desktop computer prints "17" in response to "13 + 4" and "35" in response to "31 + 4," what is printed does not depend on a history of association between inputs and output – a history which, under different circumstances, might just as well have linked "31 + 4" to

"17" and "13 + 4" to "35." Rather, the printed output depends on a sequence of built-in operations such that structural differences in the input ("13 + 4" versus "31 + 4") lead to structural differences in the output ("17" versus "35") through different intermediate steps. Such structure-dependent operations are characteristic of the computational theory of mind and other approaches to cognition that oppose associationism (Fodor 1983).

Associationism and the computational theory of mind, however, do not exhaust all theoretical possibilities. The analysis of development in ecological psychology, for example, qualifies neither as computational nor as associationist, since the principles it proposes operate neither according to associative principles nor on the basis of internal representations. Neither are associationism and representational systems mutually exclusive, since representational models may combine aspects that are structure-independent (as when objects are linked to a cognitive map regardless of their composition) with others that are structure-sensitive (as when combining two paths into a novel one). Furthermore, authors may disagree on whether a model is or is not strictly associative, depending on what they stipulate to be the defining features of "associationism" (besides the broad notion of a building process indifferent to the structures that it relates). The label of "associationism," although useful in pinpointing shared issues, should not obscure the variety and richness of the theoretical views to which it has been applied.

Important Scientific Research and Open Questions

Associationism in a broad sense assumes principles of development or psychological change that are structure-independent. A set of associative relations defined over a collection of components, however, is itself a form of organization. According to associationism, the latter organization has been derived from experience. The main question with respect to associationism, therefore, is the question of the origins of psychological structure; in particular, the extent to which psychological structure can be attributed to regularities in experience, and the extent to which other sources of organization must be postulated. In the case of syntax acquisition, for example, the issue may concern how much of a child's linguistic organization derives from statistical regularities in the child's input.

There is no guarantee that this sort of question has a unified answer across domains or even phenomena within the same psychological domain. Associationism may well fail in some cases while applying to others. The basic phenomena of Pavlovian conditioning, for instance, seem to call for explanations with associationist aspects. (The researchers who attribute conditional responding to the formation of cognitive maps may want to deny this, but their denial would simply reflect a narrower definition of "associationism" than the one adopted here.) As formal models developed in the field of conditioning are extended to cover features of human perception, memory, and language, the limits of associationist explanations in psychology should become clearer.

In many cases, a successful associationist account of the data may require relations among elements, as well as the elements themselves, to be subject to association. If the structure-building operation proceeds regardless of the nature of the relations involved, then the resulting models will remain within the province of associationism as we defined it (although they may fail to qualify on a narrower definition). The most difficult cases for any associationist account involve cognitive phenomena in which structure is paramount: in particular, inference and reasoning through language-like processes. Whether such phenomena can be accommodated within a broadly associationist framework may depend on the development of more powerful theoretical formalisms.

Cross-References

► Associative Learning
► Connectionism
► Statistical Learning in Perception

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Associative Learning

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Synonyms

Causal learning; Conditioning; Contingency learning

Definition

Associative learning is the ability of living organisms to perceive contingency relations between events in their environment. It is a fundamental component of adaptive behavior as it allows anticipation of an event on the basis of another. Despite its name, it is theoretically neutral: While many theories of associative learning are indeed associative, others are not. A cornerstone of classic behaviorist learning theories from the 1950s (such as Hull's), associative learning was then viewed as a very elementary process of association between stimuli or response and stimuli which would form the building block of more complex activities. Work on associative learning since the 1970s has totally shattered this view by showing the critical role of cognitive processes in conditioning and the overall cognitive sophistication of associative learning.

The two main experimental procedures for the study of associative learning are Pavlovian (aka classical) and operant (aka instrumental) conditioning. Pavlovian conditioning involves the learning of a contingency relationship between two stimuli. In most animal procedures, one of these stimuli is a biologically relevant event (unconditioned stimulus – US) with either appetitive (food, water…) or aversive (electric shock) properties while the other is a biologically neutral stimulus (conditioned stimulus – CS). Learning of the CS–US relationship is assessed by measuring the conditioned response (CR) which the CS triggers as the consequence of its pairing with the US. Biologically relevant US is necessary in animal studies in order to induce behavioral changes that will allow us to assess the development of associative learning but is not necessary for associative learning itself to take place. It can be shown that even nonhuman animals will learn relationships between neutral stimuli. Indeed, most studies of Pavlovian conditioning in humans do not involve biologically relevant stimuli at all: Subjects are usually presented with a series of cues (list of a patient's symptoms, list of food items eaten by a patient, or simply abstract visual shapes) followed by a series of outcomes (disease that the patient has, presence or absence of an allergic reaction, abstract visual shapes) and are then asked to rate the contingency relationship between a cue and an outcome. Despite these procedural differences, the models developed in the context of nonhuman animal experiments using biologically relevant stimuli apply just as well to human studies using biologically neutral ones (Bouton 2007).

Operant conditioning involves the learning of a relationship between a response and a stimulus. The response is usually called an operant and the stimulus either a reinforcer or a punisher, depending on whether the learning of the response–stimulus relationship leads to an increase or a decrease in the probability of emission of the operant. Because the experimenter has no control on when the subject decides to emit the response in operant conditioning, those who are interested in the mechanisms underlying associative learning usually favor Pavlovian conditioning. Operant conditioning is more used by researchers interested in how the feedback loop between a behavior and its consequence affects the activity of an organism. Hence, since this entry is mainly dealing with the variables affecting associative learning and the theories developed to account for them, it will focus primarily on Pavlovian conditioning.

Theoretical Background

Stimulus salience and temporal contiguity between the CS and the US were among the first variables identified as having an impact on associative learning (Bouton 2007). More salient CS and US usually lead to faster learning. The US magnitude also affects the asymptotic level of the CR. Good temporal contiguity between the CS and the US seems also necessary: The longer the CS–US interval (the time between the CS and the US onset), the less efficient conditioning seems to be. This statement needs, however, to be qualified as, in most conditioning preparations, the relationship between the CS–US interval and the efficiency of conditioning (as measured by the magnitude of the CR or the probability that a CR is emitted in presence of the CS) is usually an inverted U-shaped function: No or poor conditioning is observed if the US is presented before or simultaneously with CS onset while it seems to get better with increasing CS–US interval up to the point where an optimal interval is reached. After that, further increase of the CS–US interval leads to poorer conditioning. While this seems to fly in the face of the idea that the efficiency of conditioning increases with temporal contiguity between the CS and the US, it is very likely that the increasing limb of the CS–US interval function reflects a performance rather than a learning deficit. CRs anticipate the US and functionally, prepare the organism for the US. Hence, there would be no reason for their emission in situations where the US has already been or is currently presented, even if the subjects had learned the relationship between the CS and the US. Indeed, using appropriate experimental techniques, it is possible to show that the subject has learned this relationship in backward and simultaneous conditioning paradigms, even though the CS does not trigger any CR.

The role of temporal contiguity needs also to be put in perspective: Good temporal contiguity between the CS and the US is necessary for associative learning, but what constitutes good temporal contiguity is relative. First, it depends on the type of behavioral system recruited by the learning situation. A CS–US interval superior to 500 ms greatly impairs associative learning in a rabbit nictitating membrane response conditioning procedure while learning is still observed in a taste aversion paradigm even if several hours separate the presentation of the CS from the one of the US (Bouton 2007). Second, it seems that what matter is not so much the CS–US interval per se but the so-called C/T ratio, that is to say the ratio between the CS–US interval and the intertrial interval (time between CS offset and the next CS onset): The lower this ratio, the better the conditioning. Moreover, if the CS–US interval is lengthened but the intertrial is also lengthened so as to keep the C/T ratio constant, there is no decrease in the efficiency of conditioning (Bouton 2007; Gallistel and Gibbon 2000).

The most critical insight on associative learning from the last 30 years of research is the finding that temporal contiguity is not sufficient for conditioning: The information value of the CS, how much information it brings regarding the issue of US onset in the future, is also, if not more, critical. This conclusion derives mainly from three fundamental experimental findings, first demonstrated in the 1970s: The contingency effect, the blocking effect, and the relative validity effect (Bouton 2007; Rescorla and Wagner 1972). The contingency effect is the fact that the amount of conditioning sustained by a CS is proportional to $\Delta P = P(US|CS) - P(US|no\ CS)$. Hence, maintaining $P(US|CS)$ constant and varying $P(US|no\ CS)$, one can modify the conditioning of a CS, even though the temporal contiguity between the CS and the US is not affected. The contingency effect is also a good illustration of the level of sophistication of the process underlying associative learning as ΔP is a rational measure of the causal link between the CS and the US as well as of the amount of information the CS carries about the US. For conditioning to take place, ΔP must be different from 0, that is to say, it must bring some information regarding the US. The same conclusion can be drawn from the blocking phenomenon, where responding to a stimulus X conditioned in compound with a stimulus A is greatly reduced if A has previously been conditioned to the US. In this case, X does not bring much more information about the US relative to A. The same way, in the relative validity effect, subjects are exposed to compound stimuli AX and BX. If the US is only presented after AX and never after BX, A has a higher information value than X. On the other hand, if the US is presented equally after AX and BX, X has a higher information value than A. Indeed, when tested in such a design, subjects show a stronger responding to X in the later than in the former condition.

Phenomena such as the contingency effect, blocking, and relative validity lead to the development of the Rescorla–Wagner model (Rescorla and Wagner 1972), probably the most influential work on associative learning since Pavlov, Thorndike, and Skinner's seminal research. The Rescorla–Wagner model postulates that associative learning is basically a prediction process where the subject tries to predict the US on the basis of environmental stimuli and that learning only takes place when the subject is surprised, that is to say when there is a mismatch between what is predicted and what actually happens. For instance, in blocking, the subject is not surprised by the US because A is already predicting it and hence no new learning, notably of the X–US association, occurs. Formally, the Rescorla–Wagner model assumes that each CS as an associative strength representing the US prediction in presence of that CS. Those associative strengths are updated on a trial-by-trial basis according to the following equation:

$$V(X) = V(X) + a^{*}b^{*}\left(R - \sum V\right)$$

where V(x) is the associative strength of stimulus x, a and b are learning rate parameters (one determined by the CS salience, the other by the US salience), R is the US intensity on that trial and ∑V is the sum of the associative strengths of all the CSs present on that trial. Since V(x) is the US prediction for stimulus x, ∑V is the total US prediction for the trial, and R-∑V is the mismatch between this prediction and the actual US magnitude R. Learning occurs only when R-∑V is different from 0, that is to say when the subject is surprised.

Despite its simplicity, the Rescorla–Wagner model is able to account for a wide range of phenomena (including the contingency effect, blocking, the relative validity effect, and other so-called cue competition effect where conditioning of one cue interferes with the conditioning of another, some of which actually predicted by the Rescorla–Wagner model. See Bouton, 2007) explains its long-lasting importance in the field. Notably, its core idea that associative learning is underlined by a surprise-driven prediction process has proven extremely influential and can be found in almost every model of conditioning developed since 1972. This influence goes actually beyond psychology as reinforcement learning algorithms, developed in artificial intelligence for the adaptive control of autonomous agents and which have played a critical role recently in the interpretation of the role of midbrain dopamine neurons in learning, are basically real-time extension of the Rescorla–Wagner model (Maia 2009). Also, by emphasizing the role of expectations in learning, the Rescorla–Wagner model started the shift toward more cognitive explanations of conditioning. Mackintosh on the one hand and Pearce and Hall on the other, have proposed models emphasizing the role of attention in conditioning (Bouton 2007). In both models, attention is necessary for the encoding of a CS–US association. In the Mackintosh model, attention to a CS increases when a CS is a better US predictor than the other stimuli present at the time. In the Pearce and Hall model, attention to stimuli increases when the subject is surprised and decreases otherwise. Wagner's SOP model is an artificial-network model synthesizing insights from the Rescorla–Wagner model and Atkinson and Shiffrin's cognitive architecture for memory and exploring the implications of short-term memory priming and short-term memory limited capacity for associative learning (Bouton 2007).

All the models mentioned until now have in common the fact that they all view cue competition phenomena such as blocking as the consequence of a learning deficit. In the Rescorla–Wagner model, for instance, responding to X is decreased in the blocking paradigm because, due to the lack of surprise of the subject when the US was presented following AX, the X–US association was never encoded in the first place. Other models have considered that, on the contrary, cue competition is a performance deficit: The association between the CS and the US has been encoded but is not expressed in behavior for some reasons. Cheng's probabilistic contrast model (Bouton 2007) assumes that organisms keep track of both P(US|CS) and P (US|no CS) and then compute the ΔP difference between them to decide whether they should expect the US in presence of a CS. The same idea of animals as intuitive statisticians can also be found in Gallistel and Gibbon's model (Gallistel and Gibbon 2000), where the subject is assumed to record the rate of US delivery in the presence of every CSs and CS combinations and to infer from this database the simplest causality model consistent with the data. Not all performance-focused models of conditioning assume this degree of sophistication from the organism. Notably, Miller's comparator model (Bouton 2007; Denniston et al. 2001) is a straightforward associative performance-focused model where temporal contiguity between a CS and the US is regarded as necessary and sufficient for the encoding of the CS–US association. Difficulties arise when this association is retrieved: Presenting the CS not only retrieves the CS–US association but also associations between the US and other stimuli with which the CS had itself become associated through the principle of contiguity. These associations interfere with the behavioral expression of the CS–US association.

The strongest empirical argument for performance-deficit models of cue competition comes from the existence of so-called retrospective reevaluation phenomena where manipulation of the associative strength of a CS allows responding to another CS with which it was interfering to recover (Bouton 2007; Denniston et al. 2001). For instance, in a learning paradigm, if, following the blocking phase, A is presented not followed by the US (an extinction procedure which will reduce the conditioned responding to A through the unlearning or the inhibition of the A–US association), responding to X might recover. Although it is still not clear in which conditions such retrospective reevaluation phenomena will be observed or not (they are notably more easily obtained in procedures not involving biologically relevant stimuli and, as a consequence, easier to get in humans than in nonhuman animals), many studies have been able to replicate them. Learning deficit model of cue competition such as the Rescorla–Wagner model cannot account for them because they do not have a mechanism by which the associative strength of a stimulus not present on a trial can be modified. Yet modifications of the Rescorla–Wagner model and of Wagner's SOP having this exact feature have recently been proposed and are able to handle retrospective reevaluation phenomena (Bouton 2007; Denniston et al. 2001). Hence, the controversy between learning-deficit and performance-deficit accounts of cue competition remains open.

Important Scientific Research and Open Questions

If a rat is presented with a CS followed by a shock US, it will rapidly developed conditioned fear responding to the CS. Presenting the CS by itself, not followed by the US, will extinguish this responding. But, if the extinction takes place in a context different from training, the fear CR will reappear when the CS is presented in the training context (Bouton 2007). This well-known phenomenon, called renewal, is highly relevant clinically. One of the great successes of conditioning is its application to behavioral therapy, notably exposure treatments of anxiety disorders and phobia. The basic idea is that the anxiety generated by the phobic stimulus is a CR caused by the stimulus due to its prior pairing with an aversive US. The goal of exposure therapy is to extinguish the anxiety CR by presenting the phobic stimulus by itself, so that the patient learns that it is not a predictor of the US. The problem is that since the exposure treatment usually takes place in a specific context (the clinic), anxiety CR to the phobic stimulus renews once the context is changed, notably once the patient returns to his or her everyday life (Bouton 2007).

Hence, considerable amount of research has recently been devoted to renewal and how to avoid it. They have revealed that the context plays a critical role, not so much by signaling the nonoccurence of the US (a so-called conditioned inhibitor) as predicted by most models of conditioning, but by modulating directly the CS–US association (Bouton 2007). Stimuli having such a role are called occasion-setters. Their discovery is relatively recent and as such are not yet integrated into current models of associative learning. More research needs to be done to understand under which conditions a stimulus acts as an occasion-setter instead of a CS, as well as the mechanisms by which an occasion-setter is able to modulate the association between a CS and a US (Bouton 2007). Research on renewal also made clear that the view of extinction as the mere unlearning of a CS–US association, held by many models of conditioning including the Rescorla-–Wagner, is inadequate.

Partly due to the populariry of the Rescorla–Wagner model, cue competition has been the main focus of research for the last 30 years with very little attention paid to other forms of cue interaction, notably cue facilitation where conditioning of one cue *improves* the conditioning of another. Such phenomena are well-documented in taste-aversion learning paradigms and are usually considered as consequences of the adaptive specialization of the taste-aversion learning system but recent research seems to suggest that they have less to do with the idiosyncrasies of the taste-aversion system and more with some procedural specificities of taste-aversion procedures (Bouton 2007). If confirmed, that would mean that by manipulating the relevant experimental variables, one could determine if cues interact in a competitive or coorperative way. That would indicate that cue processing is much more plastic and fluid than aknowledged by current theories of conditioning, which are all calibrated to account only for cue competition. Similarly, it seems that experimental parameters determine whether compound stimuli are processed as combinations of more elemental stimuli or as configural wholes distinct from their elements rather than the subjects processing them on a default elemental or configural mode (Melchers et al. 2008).

Focusing mainly on the variables and mechanisms determining when a stimulus becomes a fully conditioned CS, research has comparatively neglected the study of the mechanisms determining the CR, a fundamental problem if one wants to understand behavioral adaptation to associative learning in situations involving biologically relevant stimuli, such as fear learning. The old view that the CR is simply the unconditioned response triggered by the US now triggered by the CS is clearly inadequate. Research has made clear that CRs are anticipatory adaptive responses, whose shape is determined by many variables including the CS, the US, and the CS–US interval, and where species-specific adaptations play an important role (Bouton 2007). Yet, a coherent and comprehensive theoretical framework is still missing. A related, unresolved and understudied issue concerns the relations between the associative learning mechanisms in Pavlovian stimulus–stimulus learning and the ones in operant response–stimulus learning. Contrasting with early views such as Skinner's who considered that Pavlovian and operant learning were two radically forms of learning, it is now widely held that the differences between Pavlovian and operant conditioning are mainly procedural and that the underlying associative learning mechanism is the same. Though there are good theoretical reasons to think so, the empirical evidences supporting this claim are few and not as convincing as one would want. Hence, more research needs to be devoted to this issue, notably in the light of recent neurophysiological findings that different brain areas process stimulus–reward and response–reward associations (Maia 2009).

Cross-References

▶ Animal Learning and Intelligence
▶ Arousal and Paired-Associate Learning
▶ Associationism
▶ Behaviorism and Behaviorist Learning Theories
▶ Biological and Evolutionary Constraints of Learning
▶ Comparative Psychology and Ethology
▶ Computational Models of Classical Conditioning
▶ Connectionist Theories of Learning
▶ Cross-Situational Learning
▶ Extinction Learning
▶ Hebbian Learning
▶ Human Causal Learning
▶ Human Contingency Learning
▶ Internal Reinforcement Hypothesis
▶ Law of Effect
▶ Nonassociative Learning
▶ Matching
▶ Mathematical Models/Theories of Learning
▶ Neuropsychology of Learning
▶ Operant Behavior
▶ Paired-Associate Learning
▶ Pavlov, Ivan P. (1849–1936)
▶ Perceptual Learning
▶ Reinforcement Learning
▶ Reinforcement Learning (Focus on Animal Learning)
▶ Skinner B.F. (1904–1990)
▶ Statistical Learning in Perception
▶ Temporal Learning in Humans and Other Animals
▶ The Role of Attention in Pavlovian Conditioning
▶ Tool Use and Problem Solving in Animals

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Associative Learning in Bees

▶ Bee Learning and Communication

Associative Learning in Early Vision

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Synonyms

Associative sensory learning; Hebbian learning in the visual cortex

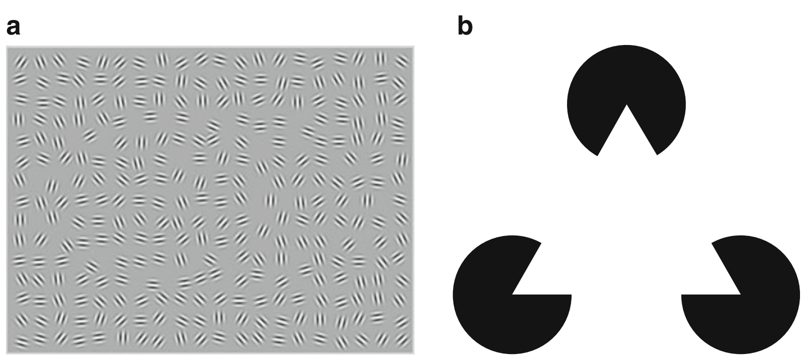
Definition

Associative learning in early vision refers to experience-dependent modification of lateral interactions in the visual system. This type of perceptual learning improves the integration of spatial information and is manifested via improved performance on simple visual tasks such as integrating local line elements into contours. Learning is modeled using associative rules, expressed as increased (Hebbian) or decreased (Anti-Hebbian) strength of connections between elementary sensory units (neurons) that are activated in temporal proximity by distributed visual stimuli.

Theoretical Background

Two, or more, visual stimuli that tend to appear together, such as parts of an object, generate correlated brain events. Associative learning in the brain, which is the acquisition of knowledge about correlations between events, is thought to be implemented by modifying the neuronal connectivity between cell assemblies having correlated activities. Associations are formed by strengthening synaptic connections within neuronal networks co-activated by input patterns that are distributed in space and time. Such networks are expected to restore memorized patterns by partial activation, so that a part may enhance the recall of objects within which it is embedded. Hebbian learning rules provide a possible learning mechanism for forming such associations. Accordingly, a neuron A, within the network, whose activation is assisted by the consistent contribution of another neuron B, improves its connectivity with the activating neuron (B) so that an activation of B suffices to activate A. This mechanism allows for associations between simultaneous, or nearly simultaneous events, enabling the learning of complex sensory patterns and of sensory-motor associations. The reverse, Anti-Hebbian learning rule was also suggested. On this rule, the strength of connectivity from B to A is reduced as a result of the failure of B to activate A. Thus, associations can be broken by independent presentations of the associated stimuli.

Hebb (1949) believed that associations play an important role in visual perception, and suggested that associations are formed by strengthening connections between cells in primary visual areas 17 and 18. Such connections were thought to be formed during early development, within the "critical period" after which neuronal connectivity in sensory brain regions stabilizes. Clearly, the ability to form associations across the visual field has the potential to solve some open problems in visual perception, such as figure completion under conditions of incomplete retinal evidence owing to, for example, occlusion or noise (Fig. 1). Here, the associative properties of perception allow patterns to be visually completed based on partial information (filling-in). More recent research suggests



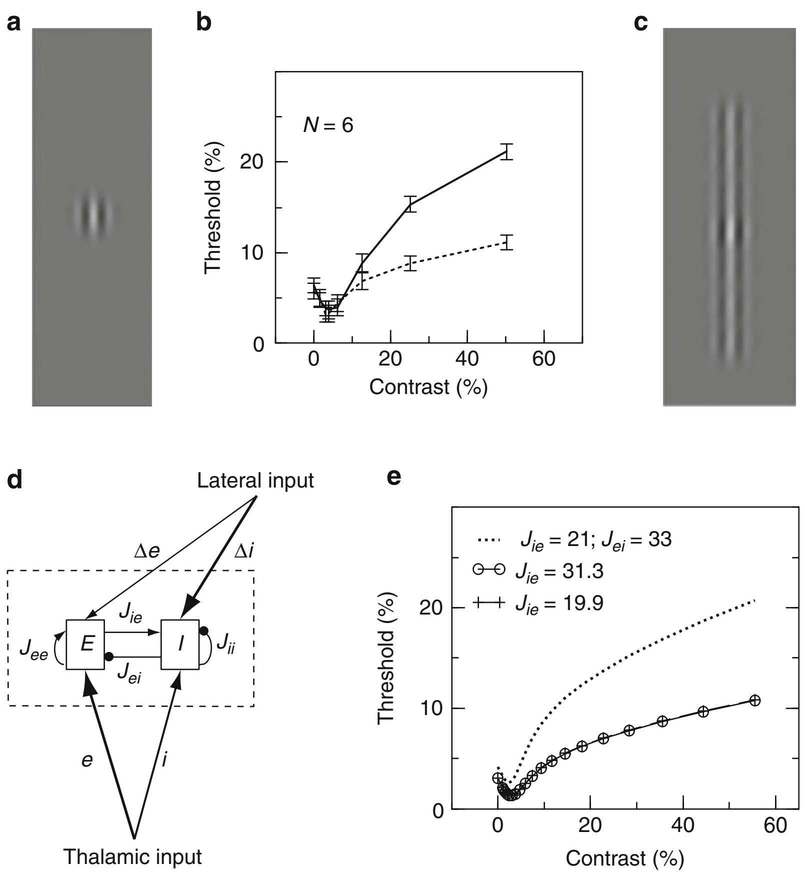
Associative Learning in Early Vision. Fig. 1 Visual associations. (**a**) Humans have the ability to bind together similar, proximal elements that form a "Gestalt." It was suggested that this ability is based on associative (lateral) connections in the brain, and on mechanisms such as those that were demonstrated in the experimental paradigm presented in Fig. 2 . (**a**) The elipse created by the closely aligned (Gabor) patches can be detected even in the presence of noise (after Kovács 1996), demonstrating that grouping by quasi-collinearity enhances the saliency of visual objects. (**b**) The illusory contours, as shown in the Kanizsa illusion, are thought to result from associations between local edge detectors implemented by lateral interactions in the visual cortex (Fig. 2) that such associations can be formed in the adult visual system (perceptual learning), possibly by modifying lateral connectivity within the primary visual cortex (Polat and Sagi 1994). More specifically, detection of an oriented target is improved in the presence of flanking patterns of similar orientation, aligned with the target. This facilitation of neuronal activity corresponding to the gap in between the flankers is thought to be generated by the mechanism the brain uses while filling-in for missing information. Although this basic function of associative filling-in is available to the untrained observer, experimental results indicate that it can be modulated by learning; associations can be strengthened or weakened depending on the spatio-temporal relationship between the visual stimuli. Thus, it was suggested that associations within early visual areas are formed using the existing connectivity between neurons. This connectivity was thought to be established during development, as Hebb (1949) already suggested. In this way, correlations existing within the visual world, to which the newborn is exposed, can be captured. Psychophysical, electrophysiological, and anatomical results support the existence of a well-defined architecture within early visual areas, including short- and long-range connections, with the latter transmitting neuronal information between neurons responding to co-aligned stimulus features (Kovács 1996). But, in contrast to the classical notion of a critical period early in life which imposes a finite maturational window, our results indicate that these interactions can be modulated by experience in the adult brain. Accordingly, we suggest that perceptual learning shares basic mechanisms with early development and thus can compensate for insufficient development caused by environmental or neuronal issues. An interesting example here is Amblyopia ("lazy eye") which is caused by misalignment of the eyes (squint) during development. Here, the visual cortex receives conflicting images from the two eyes and as a result the input from one eye is suppressed in the brain leading to reduced vision through this eye. Recent results indicate that once the squint is fixed, perceptual learning can be used to restore vision through the "lazy" eye (Polat et al. 2004).

The scheme previously outlined can be used to explain much of the phenomenology that ushered in the Gestalt theory of perception: percepts reflect wholes rather than a collection of parts. The neuronal mechanism considered here, while consisting of basic elements responding to image parts, integrates image parts to form a global percept. In addition, the current scheme accounts for the dependence of perception on previous experience, such as is observed in perceptual learning and adaptation. Taken together, with the extended understanding of neuronal processes subserving visual perception, associative phenomena in visual perception are thought to serve as a tractable, well-defined model for studying mechanisms underlying learning and association in the brain. Given the surprising similarity in the anatomy of different cortical regions, the neural mechanism of associations is thought to be uniform across the different sensory and non-sensory brain areas.

Important Scientific Research and Open Questions

Much insight into learning can be gained from studying experience-dependent long-term modifications in perception. Perceptual learning refers to improvements in sensory tasks that are gained through practice. The phenomenology of perceptual learning is rich and diverse, indicating a multiplicity of underlying mechanisms (for a recent review see Sagi 2011). Most importantly, this type of learning can be found in simple visual tasks, such as orientation and contrast discrimination, and thus it is more tractable. Learning such elementary visual tasks was found to be specific to the task at hand and to basic image features, such as orientation, spatial-frequency, target location, and the eye of stimulation. The task-dependency of learning was thought to indicate that learning is controlled (gated) by high-level cortical areas. The high feature-specificity of learning predicts that some of the learning takes place at relatively low-level cortical areas, where the neurons selectively respond to these features. Considering that perceptual tasks can be of different types (detection, discrimination, and recognition) and are applied on stimuli of different complexities (light, texture, and patterns), one can expect that the learning mechanisms will differ accordingly. Several models have been proposed, depending on the stages of visual processing involved (Sagi 2011). Though models may differ in the assumed cortical architecture, there is a broad consensus regarding the learning rules used by the learning process. Hebbian rules can be found in models assuming an association formed within a visual area (Adini et al. 2002) and between areas when a feedforward architecture is assumed (Lu et al. 2010). Of particular interest to our topic is the low-level-stage model based on a finding related to learning of contrast discrimination tasks in different contexts. These experiments provide the experimental support needed for associative networks in early vision.

Although training improves the performance of humans on a variety of visual perceptual tasks, the ability to detect small changes in the contrast of simple visual stimuli (Fig. 2a) could not be improved by mere repetition. However, Adini et al. (2002) showed that the performance of this basic task could be modified (Fig. 2b) after the discrimination of the stimulus contrast was practiced in the presence of similar laterally placed stimuli (Fig. 2c). This suggests that context affects the local neuronal circuit involved in the task. Remote flankers had a stronger effect on target detection when the space between them was filled with other flankers (Fig. 2c). The detection threshold is therefore affected by the dynamics of large neuronal populations in the neocortex, with a major interplay between excitation and inhibition. However, most interestingly, these remote flankers rekindled learning in the local network, which was otherwise unmodifiable. We considered a model of the primary visual cortex as



Associative Learning in Early Vision. Fig. 2 Experiments and models supporting associative learning in early vision. (**a**) An isolated Gabor Signal (GS) used in contrast discrimination tasks. (**b**) Contrast discrimination thresholds for an isolated GS, before and after practice with chains of flankers (shown here in **c**). Before training observers exhibit the classical increase in increment thresholds when base contrast is increased (Weber Law); however, after practice increment thresholds are independent of base contrast above some contrast level. Such result cannot be achieved by practicing an isolated target (**a**), only when contextual elements are present (**c**). (**d**) The basic unit of our model, namely, a pair of balanced E-I neuronal networks with lateral inputs destabilizing the E-I balance, thus reducing inhibitory effects (underlying the Weber Law) and inducing long-term plasticity. (**e**) Model simulation (adapted from Adini et al. 2002).

a network consisting of excitatory and inhibitory cell populations, with both short- and long-range interactions (Fig. 2d). This model exhibited behavior similar to the experimental results throughout a range of parameters (Fig. 2e). These experimental and modeling results indicated that long-range connections play an important role in visual perception, possibly mediating the effects of context. Based on combining Hebbian and Anti-hebbian synaptic learning rules compatible with these results, a mechanism of plasticity in the visual cortex was suggested, which is induced by a change in the context.

A major problem with Hebbian learning is the risk of explosion: connections may become increasingly stronger until synaptic strength reaches its maximal value. In such cases, differences between synaptic weights may diminish and the information stored in the connections may be lost. The model presented above includes a feedback mechanism to protect against such saturation. Other suggestions include homeostatic processes operating during sleep, supported by experimental results showing reduced learning owing to overexposure, which can be counteracted by sleep (Sagi 2011).

Summary

Accumulating experimental results during the last two decades, in both humans and animals, support the view that sensory regions in the adult cortex, including the primary visual cortex, can be modified throughout the whole lifespan. It is suggested that early development, during the critical period, and adult learning form a continuum. Psychophysical and neurophysiological evidence support a theory of perceptual learning, according to which, learning is governed by associative Hebbian and Anti-Hebbian learning rules. The challenge faced now is to generalize these concepts to non-sensory brain functions and to account for associative learning of abstract concepts.

Cross-References

- ► Abnormal Learning Behavior
- ► Adaptation and Learning
- ► Associative Learning
- ► Context and Semantic Sensitivity in Learning
- ► Development and Learning
- ► Network Models of Learning and Memory
- ► Perceptual Learning
- ► Perceptual Processing and Learning
- ► Statistical Learning in Perception
- ► Visual Perception learning

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Associative Learning of Pictures and Words

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Synonyms

Classical conditioning; Learning mechanism; Operant conditioning

Definition

Associative learning is a learning process by which ideas or responses become linked through reinforcement and statistical covariation. Operant conditioning and classical conditioning are both types of *associative learning* and have been put forth as explanations for many aspects of behavior in humans and nonhuman species, including spatial navigation, language acquisition, and memory. *Associative learning of pictures and words* is one theory of how individuals learn to understand and use communicative signals.

Theoretical Background

Pictures and words are both ► symbols that can refer to, or stand for, entities in the environment. It has been argued that symbolic knowledge is a uniquely human capacity (Deacon 1997). Certainly, the ability to use symbols has transformed humans as a species. It has allowed us to transmit knowledge across cultures, refer to things that are not present in space and time, and has been argued as an explanation for how our species has rapidly evolved communication abilities (DeLoache 2005).

One central debate is whether individuals who use these signs for communication actually understand the symbolic relation between pictures, words, and their corresponding referents. This debate is relevant to child development, primate research and other animal studies, and also particularly important when considering individuals with ► Autism Spectrum Disorder (ASD), who are noted to have strengths in associative learning, but difficulty with language acquisition and usage, and with other forms of symbols such as pictures and gestures.

According to a symbolic account, there is a meaningful relationship between a symbol and what it refers to. In this way, symbols are used purposefully and are based upon the intentions of the user of the symbol (Bloom 2000). Symbolic knowledge of pictures and words requires an individual to have a ► mental representation of the relationship between a picture, word, and its corresponding real world referent; this is because very often pictures and words stand for, and are used to signify, items that are of out sight (DeLoache 2005).

An alternative interpretation of the mapping between words/pictures and their referents is that it is associational. Associative mappings may be created between any arbitrary stimuli, as when a tone signals shock or predicts reward following a bar press. Associative mappings are governed by statistical input and classical laws of association (Rescorla and Wagner 1972), reflecting frequency and temporal contiguity of pairings of stimuli.

These two accounts have very different predictions for how an individual (whether a typically or atypically developing human child or a primate) both learns about and uses symbols. For instance, associative learning of pictures and words would predict that these entities are used mainly in the contexts in which they were learned, and only become generalizable to different exemplars after repeated exposure or reward. On this account, words and pictures are non referential and non symbolic. Alternatively, symbolic understanding is more flexible, which would manifest in novel symbol combinations and facile use of pictures and words in new surroundings and contexts, including non-ostensive situations.

Important Scientific Research and Open Questions

There is evidence that young typically developing children demonstrate the symbolic understanding of pictures and words by the time they are 2-years of age. In the real world, parents will often teach their child a new word for a novel picture in a book (e.g., "look, a *giraffe*!"). If the child is taken to a zoo later in the week, will he know that the word he learned for the picture actually refers to the funny looking creature with the long neck? Or will he instead think the word applies only to the picture itself? This reflects the critical debate regarding symbolic understanding, and has been demonstrated empirically. Specifically, when 18- and 24-month old children were shown a novel picture and told a label for it (e.g., this is a "whisk"), they selected the previously unseen real object as the referent of the word rather than the picture that had been previously paired with it (Preissler and Carey 2004). This suggests that very young typically developing children know that pictures and words are referential.

However, when the same word-picture pairing is taught to children with ASD with cognitive impairment, they tend to think the word applies only to the picture, and fail to generalize it to a real world exemplar. This reflects associative learning, and suggests that at least some individuals on the autistic spectrum do not understand the referential nature of pictures and words. This is consistent with other research suggesting associative learning is intact in individuals with ASD, and underpins memory, visual processing, and the metaphorical or "literal" use of language.

In similar studies of lexigram learning in bonobos, the issue of symbolic understanding vs. associative learning remains an important debate. On one hand, researchers claim that progressive bonobos such as Kanzi have demonstrated symbolic knowledge by producing novel combinations of picture symbols

(Savage-Rumbaugh et al. 2001); however, critics claim that the hundreds of trials taken to learn new picture-action sequences and the profound reinforcement required to consolidate such learning are more reflective of an associative learning mechanism.

There are several open questions regarding associative learning of pictures and words. One question concerns the origin of symbolic understanding; perhaps very young infants begin to learn about words and pictures as associative pairs, but then exhibit a conceptual change and consequent shift to a symbolic way of thinking. In this way, many children with ASD or primates never achieve this conceptual understanding, but instead rely upon the associative mechanisms which may support more general types of learning.

Another open question concerns the specificity of symbolic systems in the brain. Is symbolic understanding domain-general, for instance, in that it stems from a faculty in the brain which supports all types of symbolic understanding? Or perhaps symbolic skills are domain-specific, meaning that gestures, words, pictures, and object substitution (e.g., pretend play) all originate from a different source and are unrelated in development.

Cross-References

► Associative Learning
► Infant Language Learning
► Paired-Associate Learning
► Word Learning

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Associative Memory and Learning

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Synonyms

Associative network; Attractor neural network; Autoassociative memory; Content-addressable memory; Heteroassociative memory

Definition

Associative memories are neural networks (NNs) for modeling the learning and retrieval of memories in the brain. The retrieved memory and its query are typically represented by binary, bipolar, or real vectors describing patterns of neural activity. *Learning* consists of modifying the strengths of synaptic connections between neurons in the network so that neural activity can flow from memory queries to memory contents. During *memory retrieval*, the query pattern sets the initial activity in the neural network and the memory content is represented by the activity pattern emerging from the activity flow through the synaptic connections. Associative memories permit error-tolerant retrieval; that is, a memory can be recalled not only by the exact original query used during learning, but by all input patterns that are similar to the original query. The similarity measure for error-tolerance is typically the inner product or the Hamming distance between two patterns of neural activity. There are two different types of operation in associative memories. In *autoassociation*, each memory is identical to the query that is associated during learning. Because the retrieval is error-tolerant, autoassociation can be used to restore incomplete or noisy query patterns, for example, when completing missing words in sentences or de-noising sensory inputs. In *heteroassociation*, the query and content patterns differ. For example, an associative memory can be trained to associate the visual appearance of objects with their function.

Theoretical Background

Plato (428–348 BC), Aristotle (384–322 BC), and Zeno the Stoic (334–262 BC) anticipated ideas that memory function is based on associations between mental concepts that are governed by similarity, contiguity, and contrast. William James (1842–1910) hypothesized that similarity-based mental associations could be executed by flow of neural activity in the brain if learning through experience could shape the activity flow. In 1949 and 1952, respectively, the psychologist Donald O. Hebb (1904–1985) and the economist Friedrich Hayek (1899–1992) formulated independently a simple rule of synaptic plasticity, which can perform this type of learning. Meanwhile, a large body of experimental evidence is supporting the existence of ► Hebbian synaptic plasticity in the brain.

Synaptic plasticity and learning schemes: The most common form of synaptic plasticity in associative memories is Hebbian plasticity. This type of plasticity is local as it depends only on signals that are locally available at the synapse. Models of associative memories can be classified by the type of synaptic plasticity and by the learning scheme, i.e., the scheme by which the data are presented for driving synaptic plasticity:

- In *one-shot learning*, the most common learning scheme, synaptic plasticity is driven by presenting each association between query and memory only once to the network (Willshaw et al. 1969; Hopfield 1982). One-shot learning is the fastest possible learning scheme but it cannot guarantee that all learned associations can be retrieved perfectly. Specifically, retrieval is impaired by cross talk between different stored associations.
- *Iterative learning schemes* revisit training examples multiple times and thus are slower than one-shot learning. Further, they typically involve nonlocal learning rules that rely on error values or other signals to be propagated to each synapse requiring additional machinery, e.g., pseudoinverse learning, error back-propagation (Kohonen 1984). Iterative learning schemes can guarantee error-free retrieval but they come with other problems, such as reduced error-tolerance during retrieval.
- *Palimpsest learning* includes synaptic decay mechanisms for erasing unused memories. Such a forgetting mechanism can avoid catastrophic memory loss due to cross talk that can occur if a critical number of memories is surpassed (Amit 1992).
- *Spike-timing-dependent learning* is another form of experimentally observed synaptic plasticity that has been proposed for associative memories built with spiking neurons (Gerstner 2002).

R*etrieval schemes*: Retrieval in associative memories depends on the type of neuron involved and the network architecture. Common neuron types are binary threshold neurons (Willshaw et al. 1969; Hopfield 1982), units with sigmoid transfer function (Hopfield 1984) or biologically more realistic spiking neurons (Gerstner 2002). The network architecture can be feed-forward or feedback. Retrieval in feed-forward architectures (Willshaw et al. 1969) is fastest (requiring the minimum number of neural updates), but can be more accurate in feedback networks as looping of the neural activity permits iterative refinement of the memory recall. The computational function of feedback is determined by the attractors in the network dynamics, which, in turn, reflects properties of the synaptic matrix formed during learning. The following types of feedback associative memory are possible:

- A*ttractor network associative memories* (Hopfield 1982) employ autoassociative Hebbian learning, which forms a symmetric synaptic matrix for which the dynamics can be proven to converge to fixed points, ideally corresponding to the memory states. However, depending on the number of stored memories, mixtures of memories will also become fixed points (spurious states) and can reduce the error-tolerance in the retrieval. These networks are typically used for content-addressable memory and the de-noising of data.
- *Bidirectional associative memories* (Kosko 1988) are feedback networks with heteroassociative Hebbian learning that use the synaptic connections bidirectionally to iteratively arrive at a fixed point. These networks are used to perform associative mappings between different types of representation.
- *Sequence associative memories* (Kohonen 1984) are recurrent networks with an asymmetric synaptic matrix that is formed by Hebbian learning of heteroassociations between successive states in sequences of patterns. Thus, loops of learned sequences form limit cycles of the network dynamics. When initialized to a pattern in a learned sequence, the network will replay the sequence.

Important Scientific Research and Open Questions

► *Memory capacity and sparse coding*: A prerequisite for analyzing and optimizing models of associative memory is the measurement of memory capacity. Interestingly, sparse coding is a prerequisite for optimizing the memory capacity in networks with local learning rules. The relationship between sparse associative memory and the theory of sparse neural coding of sensory signals is an active field of current research to reveal underlying principles of cortical computation.

Online associative memory: In classical models of associative memory, the learning and retrieval phase are separated in time, which is an unrealistic assumption for the brain where learning and retrieval might temporally coexist. Recent work on online associative memories explores the coexistence of learning and retrieval.

Invariant associative memories: Traditional associative memory cannot perform invariant pattern recognition; for example, a memorized visual pattern cannot be retrieved by shifted or scaled versions of the pattern. Building on earlier research by C. von der Malsburg, E. Bienenstock, C. Anderson, and B. A. Olshausen, a recent model of invariant associative memory by D. Arathorn – the "map-seeking circuit" – shows very promising performance in invariant pattern recognition.

Neurobiological evidence: Associative memories have served as computational models for the function of various brain structures, such as the cerebellum, cortical areas, hippocampus, the olfactory bulb, and many others. However, empirical testing of such theories of neuronal computation is still ongoing. Current research focuses on the design of models that allow for testable predictions and the development of recording techniques and data analysis methods for simultaneous recordings of large numbers of neurons. Another active field of research addresses the question of how structural plasticity in the brain, such as spine growth on neural dendrites, affects and constrains functions of associative memory in the brain (Knoblauch et al. 2010).

Technical applications and parallel implementations: Currently, associative memories are implemented in software, that is, run on standard computers. Software implementations can be useful for applications that benefit from the error-tolerant properties of associative memories. However, the full advantage of associative memories in terms of retrieval speed relies on implementations in parallel hardware. Early hardware implementations used mercury relays for implementing adaptive synapses and were not scalable. Efforts to implement associative memories in parallel hardware have started in the nineties (mainly on single instruction multiple data processors). These efforts currently regain momentum due to the foreseeable leveling off of ► Moore's law and due to new discoveries of suited, highly scalable computing structures, such as the ► memristor.

Cross-References

- ► Cued Recall
- ► History of the Sciences of Learning
- ► Memory Codes and Neural Plasticity in Learning
- ► Supervised Learning

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Associative Network

- ► Associative Memory and Learning
- ► Semantic Networks

Associative Sensory Learning

- ► Associative Learning in Early Vision

Associative Strength

A theoretical term representing the strength of relationship between stimuli or between a stimulus and a response. Most mathematical models of Pavlovian conditioning specify how associative strength changes in response to reinforced and nonreinforced presentations of a conditioned stimulus. Associative strength is often thought to reflect the amount of unconditioned stimulus expectation produced by a conditioned stimulus.

Associative Transfer of Valence

► Evaluative Conditioning

Assumptions

► Beliefs About Language Learning

Asymptotic Performance

► Approximate Learning of Dynamic Models/Systems

Asynchronous Learning

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Synonyms

Electronic threaded discussion; Internet-based learning network; Online learning

Definition

Asynchronous learning (derived from the Greek language *Asyn* meaning "not with" and *Chronos* meaning "time") occurs in online educational environments as a means for teacher and student interactions of intermittent communication. Asynchronous learning is time delayed and allows flexibility so that student participants in an online classroom need not engage in a discussion at the same time. It is also referred to as online learning in a computer-based learning modality, where geographically separated learners interact on a given subject, independent of time and place. This modality, or online course management platform, offers an Internet-based network of learners an opportunity to share information in multiple electronic threaded communication formats including, but not limited to, email, threaded discussion groups and blogs.

Theoretical Background

With many advances in educational technology and electronic communication over the last two decades, shifting paradigms are occurring in the dissemination of knowledge and information to students around the world. Currently, the most prominent shift is one of distribution of information and knowledge to one of access. This paradigm shift leads to a learning environment that is accessible at any time and from any where. Asynchronous learning provides opportunity for student-centered environments that are Internet-based, independent of time and place. Currently witnessed is an online community with a student-centered learning environment having moved from a traditional, brick-and-mortar, institution-centered environment. This has occurred in large part due to a societal evolution, whereby information technology has provided the means to the Internet, offering the potential to revolutionize the learning environment. Because of this, a limitless number of people share information through discussions and dialog all over the world in a common online educational platform and, hence, construct knowledge together (Palloff and Pratt 2007). The utilization of asynchronous learning opens the walls of the classroom and eliminates the boundaries by providing new methods of communication with a shifting focus from teacher to student. Ultimately, this shift is helping to develop new types of learning communities with a student-centered approach. Students have increased access to the professor and other students, course information and materials, as well as resources for research with control over their time, place, and frequency of learning.

Asynchronous learning emerged in the early 1980s when colleges and universities around the world began to keenly invest in the use of information technology for teaching and learning. In fact, educators began to heighten their scholarly research largely due to the development of the graphical portion of the Internet called the World Wide Web (WWW) in the early 1990s. Higher education played a key role in the development of the WWW medium and the first navigation tool can be attributed to Tim Berners-Lee (Morley 2010). With rapid growth and appeal, the WWW was the fastest growing portion of the Internet, with its graphic, hypermedia interface, presenting a significant means for asynchronous learning. New online tools and instructional technology platforms, such as Asynchronous Learning Networks, began to emerge as technology was used to access the Internet at homes and in school. The Asynchronous Learning Networks, defined as online learning environments or virtual classrooms, represented one of the most significant advances in education (Hiltz and Wellman 1997). Due to this, the mid-1990s marked the launch of the initial online educational course offerings and online degree programs via traditional and virtual campuses. Individual courses and full-time online degree programs were made available through online course management platforms or systems that hosted video conferencing, threaded discussions, email, and synchronous, real-time chatrooms.

Today, aynchronous learning has grown exponetially and online learning environments employ new technologies providing viable means for geograpically seperated learners to acquire knowledge and resources independent of time and place. These environments are dynamic with interactive platforms including various multimedia, RSS feeds for twitter, blogs, and wikis, online journaling and peer assessment, live video streaming as well as podcasting. More and more online learning environments are reflecting the growth of technology and the globalization of the economy. These changes are causing instructors, students, and administrators to reflect more on the entire educational process. Part of the process has involved the shift from a teacher-centered learning environment to a student-centered learning environment where both the instructor and student assume different roles. Asynchronous learning, therefore, is based on the constructivist theory whereby instructors act more as facilitors, guides on the side, and knowledge disseminators whom ensure that content and curriculum are delivered effectively and efficiently (Tobias and Duffy 2009).

Ultimately, the commitment to asynchronous learning on all levels is to refocus the way information is shared, realized, and communicated. With the growing changes of our environment in an information age, asynchronous learning has emerged as an effective means for providing students significant access to information and knowledge. Especially with the enhancements made to Internet Service Providers (ISPs), giving way to emerging technological delivery systems and innovative course platforms, a heightened number of educational institutions have increased access to academic programs via alternative delivery systems (Morley 2010). Classroom discussions have been replaced with online threaded discussions or blogs; visits to the professor have been replaced by email; and in many cases, class note-taking has been replaced by Web pages or text files from the Internet. It is apparent, that the goal of introducing advanced instructional technology and asynchronous learning into education has been to aid students in the learning process. It can be seen that in doing so, technology provides an even greater vehicle for communication as well as allowing for clarity of presenting course material in a detailed, dynamic, and concise manner any time, any where.

Important Scientific Research and Open Questions

Asynchronous learning is found among a significant number of educational institutions around the world where curriculum is adopted to meet the interests and needs of students. Research has indicated that most students interested in asynchronous learning are those who have multiple life roles and increased demands on their time. Simultaneously, studies have shown that sociocultural changes and declines in budgets and resources have had a significant impact on providing a quality education with larger class sizes and in tandem, competition for enrollments. Instructors are found working harder to apply new approaches to teaching and learning which can be intimidating and threatening to some. Moreover, not every discipline can be delivered technologically. With asynchronous learning, the delivery should be content driven and the instructional technology applied to enhance the online teaching and learning experience.

The use of asynchronous learning may not make teaching simpler. Therefore, research and assessment should take place in order to critically evaluate the condition in which asynchronous learning is applied. For instance, instructors might consider the best fit for their particular teaching style as well as any limitations to instructional technology that might prevent the success of asynchronous learning from occurring. Asynchronous learning can provide an instructor with significant opportunities for student engagement; however, an instructor should be properly trained on delivery and methodology (Matusov et al. 2005). Further research on asynchronous learning is needed to determine outcomes based on students access to the instructor and other students, needs for materials and resources, training and the students increased control over their time, place, and frequency of learning. Certainly, many benefits have been witnessed in asynchronous learning given the interactive features for student participation. However, instructors must be able to communicate well in writing and in the appropriate language. Ultimately, the instructor must be able to create a supportive learning environment that fosters effective student engagement and the acquisition of knowledge.

Cross-References

- ▶ Asynchronous Learning Networks
- ▶ Distributed Technologies
- ▶ Information Gathering and Internet Learning
- ▶ Online Collaborative Learning
- ▶ Virtual Learning Environments

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Asynchronous Learning Networks

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Synonyms

Computer-supported collaborative learning; Learning-community; Virtual classroom

Definition

An asynchronous learning network (ALN) is a form of remote teaching and learning approach where learners communicate with each other from a distance in a structured way. ALNs enable people to build a virtual learning community, which is defined as a social and mutually supportive network of learners. Cooperation between participants takes place using computer-mediated communication (CMC) systems. The collaborative manner is essential to the process, which is based on interactions among the students or between students and an instructor by means of communication tools such as discussion boards or e-mail. The focus on collaboration, which is based on constructivist principles, is what distinguishes an ALN from the notion of e-learning or distance learning, which are not based on any specific learning or teaching models. Another key characteristic of ALNs is the independency of time and place, because interaction takes place asynchronously, meaning that people do not have to be present at the same time. It does not matter if the course is delivered purely online or in a blended mode with alternating online sessions and face-to-face meetings.

Theoretical Background

The key characteristic of an ALN is the collaboration between learners. Collaborative learning is a learner-centered approach derived from social learning theories as well as the constructivist perspective on learning. Both conceptions complement each other insofar as the main goal of collaborative learning is the acquisition and construction of knowledge through social processes. Social learning theories, such as Vygotsky's

Social Development theory (Vygotsky 1978), stress the primary role of communication and interaction in meaning making and cognition. Learning is considered as a social process that is based on interpersonal actions. Vygotsky assumes that meaning making is developed from society to individual in a two-stage process. Knowledge is first shared between people and then gradually internalized. Advocates from the constructivist perspective believe that learning is an individual meaning-making process where individuals create meaning based on their experiences and interactions with the environment (Alavi and Dufner 2005).

The implementation of learning environments that are derived from social learning theories and the constructivist perspective require the application of learner-centered instructional models. The learner-centered conception differs from classical teacher-centered learning environments in that the latter are characterized by a one-way transmission of knowledge with teachers as the only source of information. Learner-centered learning environments, on the other hand, are characterized by individual knowledge construction through mutual exchange of ideas, arguments, and information. Learning occurs when participants' initial ideas and conceptions are modified, using peers as a remote resource for collaborative knowledge construction. Main interactions take place between learners. The instructor takes on the role of a coach whose responsibility is to set up and maintain opportunities for the learners to interact and learn from each other. In this way, learners are required to consider their peers as valuable resources for their individual knowledge creation, rather than perceiving learning as a knowledge transfer from the instructor to the student and thus expecting permanent input from the instructor (Alavi and Dufner 2005; Bransford et al. 2000).

Depending on the underlying instructional model, there are several pedagogical techniques that can be applied in ALNs. The three main areas of application are content transmission, communication, and assessment. Content transmission means that the instructor or the students provide(s) others with files, such as lectures in audio/video format, learning materials, and articles. Communication between learners and instructor as well as among learners includes collaborative tasks like working on group assignments, discussions about specified topics, and information exchange that concerns course/work organization. The last category, assessment, mainly consists of peer evaluation and feedback. Students publish assignments, projects, or ideas, and receive critiques and feedback from their peers, which in turn helps them to develop critical thinking skills and learn from each other (Arbaugh and Benbunan-Fich 2005).

Collaboration between learners occurs in many ways and forms. Important distinctions between collaboration modes include the degree of presence in regard to time and geographic location. Face-to-face settings, for instance, allow for synchronous communication where students work together at the same time and place. New technologies like the Internet have extended these existing collaboration options. Participants in online communities can work together regardless of whether they are geographically dispersed, colocated, or close-by, and technology-mediated collaborative learning allows for synchronous and asynchronous modes of communication. Asynchronous collaboration does not require real-time interactions between learners who are normally not colocated, so each student in an ALN can work at preferred times and at his or her own pace. Students are therefore able to send and receive communications whenever they want. This ongoing conversation has an irregular working rhythm where students will not get an answer right away, but it is likely that someone will have responded when they log in again. Even though students prevalently come together by chance rather than by schedule, ALNs are not limited to pure online courses. Most common are ALN courses in blended modes where learners work together using computer-conference facilities, but also meet face-to-face, for example, in a kick-off meeting.

Important Scientific Research and Open Questions

Many researchers examined the effect of ALNs to explore how well students learn compared to traditional delivery modes. Some argue that ALN courses are not as rich in social cues, doubt the development of a sense of community, and consider the waiting time to receive feedback or a response as problematic. On the other hand, the quality of online discussions is generally considered to be higher than in the classroom and activities are not limited by a scheduled class time, because participants can take as much time as they want to write and refine contributions before submitting them to their peers. Also, students tend to participate more online than in face-to-face settings (Hiltz and Goldmann 2005). The bottom line is that both delivery modes have advantages as well as shortcomings and there is no overall significant difference between ALN and face-to-face communities in regard to effectiveness (Alavi and Dufner 2005). It can further be contended that ALNs are suitable for some learners and not for others. Due to time and place independency, ALNs provide opportunities for particular groups of people, for instance full-time workers, who would otherwise not be able to take courses or participate in collaborative working environments. ALN are also suitable for learners who prefer to work at their own pace. When pedagogical techniques are applied where students become the teachers, ALNs are better for less advanced students who may not present well in oral form (Rice et al. 2005). However, ALNs are not the preferred mode for all faculty and students. Asynchronous learning is not suitable for learners who do not want to engage much in a course, lack self-regulation skills, have deficiencies in reading/writing, or no access to the Internet.

Another body of research is concerned with the design of more effective ALNs by way of identifying and examining the factors determining course effectiveness. The success of a learning environment is dependent on several variables, such as learner and instructor characteristics, course materials, and adequacy of medium as well as technology. Two main approaches can be differentiated within this research subject: those who address the problem by means of practice-based research and those who focus on theory development. An example for the latter is Benbunan-Fich et al. (2005), who argue that further advancement in a particular area, such as learning networks, requires theoretical principles. They developed a theoretical framework called the online interaction model, consisting of individual key concepts and their interrelationships. Arbaugh and Benbunan-Fich (2005), on the other hand, examined contextual factors contributing to the quality of a learning network and identified areas where further research is needed. Open questions regarding factors for ALN effectiveness include the role of course content, the identification and impact of institutional factors, class size, and the interaction effect of different variables. Two factors have received particular attention in the area of ALN research: technology/tools and media.

The question as to what extent media affects learning has been extensively discussed in the past and outcomes are controversial. Even though the extent of media having a direct impact on educational processes and outcomes is uncertain, particular media may be more suitable for specific types of content and pedagogical strategies (Rice et al. 2005). For example, learners may better understand complex processes when given a multimedia simulation that allows them to manipulate objects in an exploratory manner, rather than receiving an image in combination with expository text. Another issue regarding the use of media is the cost-benefit ratio. Students may benefit, for example, from combining text-based materials and communication with other forms of media such as images and video. More research is needed, though, to explore whether additional media leads to a sufficient increase in student learning and satisfaction to justify the increased effort and costs required to include them (Arbaugh and Benbunan-Fich 2005).

Technologies and tools for online communities have developed over the last 20 years. Many ALN courses are based on commercial or open source software platforms like Blackboard©, WebCT©, and moodle©, which enable students to manage the learning process and the learning materials. These modern learning management systems offer a variety of tools to meet the different needs of an ALN. Tools to enable asynchronous group working processes include wikis, e-mail, threaded discussion boards, bulletin boards, link creation to internal as well as external web pages, and file sharing. There are also features to support (peer) assessment, such as the possibility to write comments on an uploaded file, surveys, online quizzes, and exams. Software platforms usually have user management components to protect students' content and communication or create areas only accessible to a selected group of students. Comparative studies of these packages are, however, limited, and furthermore, the impact of system reliability and system quality on ALN effectiveness needs further investigation (Arbaugh and Benbunan-Fich 2005).

Cross-References

- ► Collaborative Learning
- ► Collaborative Learning Supported by Digital Media
- ► Computer-Supported Collaborative Learning
- ► Distance Learning
- ► Network Communities
- ► Peer Learning and Assessment
- ► Virtual Reality Learning Environments

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Attitude Toward Mathematics (ATM)

► Students' Attitudes Toward Math Learning

Atmosphere of Learning

► Climate of Learning

At-Risk Learners

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Synonyms

Populations, learners, or students who are disadvantaged, educationally disadvantaged, low achieving, and underachievement

Definition

The term *at-risk learner* is generally defined as a student who is in danger of failing to complete school with a basic level of academic proficiency. The construct is defined in terms of characteristics situated within the individual, family, and community. Characteristics inherent to the individual include genetic or biological conditions, which can be acquired or congenital (present at birth). Psychological and behavioral concerns are also inherent to the individual student. Within the family, characteristics include race, gender, language, culture, socioeconomic status, abuse, neglect, transience or homelessness, parents' marital status, and parents' level of education. Examples of community aspects concern the availability of quality educational opportunities, social networks, and public services.

Theoretical Background

Within education, *at-risk* has been studied within the frameworks of epidemiological and social constructivist models. The epidemiological model has been borrowed from the medical field to create a process for predicting students who may be *at-risk* for educational failure. Epidemiological reasoning requires integrating biological as well as statistical elements to derive the etiology of a problem. The theory holds that certain conditions can be prevented, ameliorated, or significantly improved through a process of early identification, prevention, and treatment (Lilienfeld and Lilienfeld 1980). When applied within educational settings, this process can be used to target students who require supplemental, strategic, instructional, or behavioral supports. To illustrate, once a student is identified as possessing a learning or behavioral deficit, they are provided with evidence-based strategies or interventions designed to directly address the problem. The overarching objective of the epidemiological model, when applied in education, is to ensure that all students, especially those identified *at-risk* for educational failure, are provided with high-quality instruction and equal opportunities to learn.

The social constructivist theory (Vygotsky 1978) ascribes to the notion that learning is transmitted through interactions with people, objects, and events in the environment that are embedded within social contexts. As Vygotsky explained:

- Every function in the child's cultural development appears twice: first, on the social level, and later, on the individual level; first, between people (interpsychological) and then inside the child (intrapsychological). This applies equally to voluntary attention, to logical memory, and to the formation of concepts. All the higher functions originate as actual relationships between individuals. (p. 57)

Richardson et al. (1989) pioneered application of the social constructivist theory to study *at-riskness* in education. Richardson and his colleagues proposed that a social constructivist theory enables one to account for characteristics that the child brings to the classroom, many of which have been shaped by past experiences in school. For example, the child interacts within a classroom context that includes other students, teachers, and materials. What happens in the classroom is shaped in part by school level factors. School level factors are therefore influenced by local and national political policy. Therefore, the social constructivist framework allows educators to broaden their focus and account for interactions between the students within these nested contexts.

One framework that has been used to understand and identify levels of social construction associated with being labeled *at-risk* is Urie Bronfenbrenner's Ecological Systems Theory (1979). Citing Vygotsky's theory of social constructivism as the foundation for developing the Ecological model, Bronfenbrenner introduced five nested environmental systems believed to shape human development and to clarify why the label *at-risk* is insufficient in and of itself. Placing the child at the center of the model, the five levels of influence that affect development are described as follows: (a) *microsystem*, composed of individual child behavior, characteristics, and skills, as well as immediate familial influences; (b) *mesosystem*, consisting of the interplay between family, school, and peer groups; (c) *exosystem*, the social networks surrounding the child, such as political, governmental, and economic influences; (d) *macrosystem*, which describes general attitudinal and beliefs; and (e) *chronosystem*, or change, continuities, and transitions over time. How these systems intersect and interact can have a lasting effect on academic success. This theory suggests that in order for interventions to be effective, factors within each of the five levels need to be considered. Even further, addressing certain factors within each level of influence can help to mediate between risk and outcomes. In summary, Bronfenbrenner's Ecological Systems Theory is useful in understanding the expansiveness and impact of influencing factors that may place a child *at-risk* during multiple levels of a child's development.

Important Scientific Research and Open Question

Students labeled *at-risk* for academic failure face a far more uncertain future than their *non-risk* peers. For this reason, it is imperative that educators take action to address at-risk learners' academic and behavioral needs. As put forth by the epidemiological and ecological systems theories, an undertaking of this magnitude requires an understanding of identification methods, prevention practices, and treatment options, within multiple levels of a child's development.

A convergence of literature suggests educators provide students predicted to be *at-risk of* educational failure with the following: (a) early interventions that target students who are at highest risk of school difficulties; (b) immediate, consistent, evidence-based academic and behavioral strategies and interventions delivered via small group or at an individual level, until the student is achieving at a rate commensurate with his/her same age peers; (c) a student-centered, structured curriculum approach; (d) limited class size and teacher to student ratios; and (e) high expectations, clearly stated goals and monitoring of student progress toward meeting these goals. It is also essential to provide teachers with ongoing job-embedded professional development, to ensure that evidence-based practices are implemented with integrity in the manner for which they were intended, and to make certain that active family and community involvement is encouraged (Banks et al. 2005).

It is important for policymakers to consider the role that education plays in a country's social and economic stability. Therefore, an essential task of the research community is to identify variables that will aid in predicting students who are *at-risk* for academic failure. Research questions that need to be addressed are whether some predictors of *at-risk* status carry more weight than others, according to country of origin, and how to best respond to each predictor in a way that will efficiently mobilize the student from an *at-risk* to *non-risk* status.

Students labeled *at-risk* in academic settings face a more difficult road to academic success than their *non-risk* peers. It is imperative that students' academic needs are addressed. However, a parent, teacher, or school generally cannot accomplish this individually. Rather, as explained by both the epidemiological and ecological systems, it takes the understanding of identification, prevention, and treatment at multiple levels of the system to best help address students with the label or characteristics of *at-risk*.

Cross-References

► Behavioral Capacity Limits
► Burnout in Teaching and Learning
► Delinquency and Learning Disabilities
► Vygotsky's Philosophy of Learning

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Attention

Attention is the sum of processes and mechanisms which entail that attended stimuli are processed faster and more correctly than nonattended stimuli.

Cross-References

► AIME (Amount of Invested Mental Effort)
► Alertness and Learning of Individuals with PIMD

Attention and Contemplative Discourse

► Attention, Memory, and Meditation

Attention and Implicit Learning

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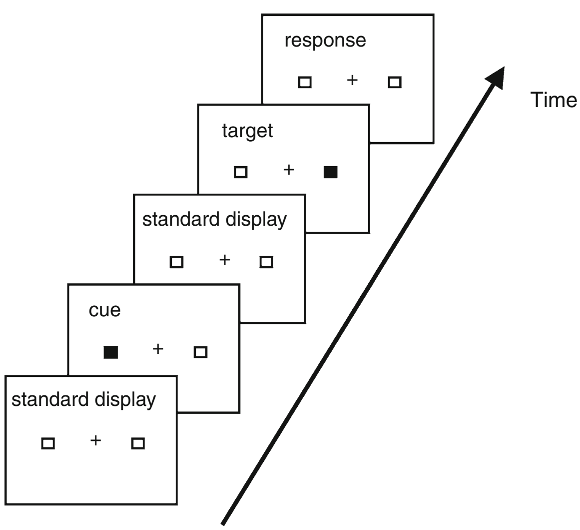
Definition

► Attention is a term that is used to describe the processes and mechanisms which entail that attended stimuli are processed faster and more correctly than nonattended stimuli. It strongly influences how we experience our surroundings. Another fundamental aspect of behavior is an individual's ability to learn. Learning is often categorized into two basic types: explicit and implicit. ► Implicit learning is the type of learning which is non-intentional and takes place in the absence of conscious strategies. There is a strong functional relationship between attention and implicit learning. This relationship is reciprocal and can be subdivided into two unidirectional phenomena: First, there is *implicit attentional learning*. Here, implicit learning of regularities in the stimulus material shapes the deployment of selective attention. Second, there is *attention-dependency of implicit learning*. This refers to the fact that underlying regularities in the stimulus material can only be learned when those stimulus features for which the rule(s) exists are selectively attended. Finally, there is a circular relation between attention and implicit learning: selective attention modulates what is learned implicitly, the result of this learning process determines where selective attention is directed to in the future, what, in a next step, determines what is implicitly learned, and so forth.

Theoretical Background

Attentional orienting can be voluntary, according to the inner goals of the observer, or it can be reflexive, driven by salient stimuli in the environment. In addition, orienting of attention can be biased by implicit learning and prior experience. The *spatial cueing paradigm* is a prominent experimental task to investigate attentional orienting. Here, observers have to respond as quickly as possible to the onset of a target stimulus, which can appear at either of two locations, at the left or at the right of the display. Before the target appears, observers are presented with a cue stimulus which also appears at the left or the right of the display (Fig.1).

In the variant of the cueing paradigm that is used to study attentional learning, there is a predictive relationship between the location of the cue and the location of the target, in that, for example, the target appears at the opposite side of the cue on 70% of the trials. Critically,



Attention and Implicit Learning. Fig. 1 Sequence of events during a trial of the spatial cueing paradigm. Each trial starts with the presentation of the cue which here consists of the filling of one box. After a short interstimulus interval, the target is presented. Cue and target can either appear on the same side or on opposite sides. In the predictive spatial cueing paradigm, the cue predicts the target for either the same or the opposite side with a probability of more than 50%

observers are not informed of this predictive relationship, yet they become increasingly faster in detecting the target at the predicted location. This shows that they pick up the regularity and consequently, shift their attention toward the anticipated location after the appearance of the cue. Participants can thus improve the speed and efficiency of orienting toward an object of interest based on their prior experience. This learning is usually non-intentional and takes place in the absence of conscious strategies and, therefore, has been termed *implicit* attentional learning. In *implicit attentional learning*, a person implicitly learns to use regularities in repeatedly presented stimulus material to consequently allocate attention more efficiently – that is, more quickly and in a more focused way – to the locations indicated by the regularity. It has also been demonstrated in a number of other paradigms like the contextual cuing paradigm (Chun and Jiang 1999).

There are two types of implicit attentional learning which differ with regard to the complexity of the rule to be learned and the speed with which the regularity is acquired.

- *Short-term implicit attentional learning:* a short-term learning effect linking features of objects to attentional deployment so that visual perception and performance are enhanced. For example, if target stimuli have appeared at the same location of a display for several successive trials, the response for yet another target at that location will be faster. This type of learning builds up very quickly, after only one repetition of the stimulus containing the regularity. The knowledge that can be acquired is quite primitive, i.e., more complicated if-then contingencies cannot be learned. The contingencies are also quickly forgotten.
- *Long-term implicit attentional learning:* a rather slow (it takes a larger number of trials to pick up the regularity) and long-lasting learning effect affecting the allocation of attention. Subjects implicitly learn probabilistic regularities within the stimulus material which are predictive of the location of an upcoming stimulus and they subsequently direct their attention to the location predicted by the regularity. At the same time, the participants are not able to consciously recall (i.e., verbalize) any of the regularities, which implies that they had learned those regularities in an implicit

manner. Also complex regularities can be learned. The spatial cuing task presented before is an example of long-term implicit attentional learning.

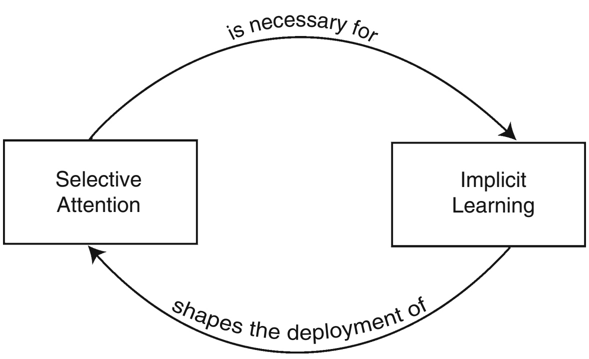
Both types of attentional learning make vision more efficient by using the predictability of the environment. They help build up knowledge that tells us where to look in a certain environmental configuration.

Now, that it has become clear that implicit learning can determine where and how attention is directed, the complementary question arises in how far attention determines what is implicitly learned. Implicit learning has been defined as learning that occurs independently of conscious attempts to learn and largely in the absence of explicit knowledge of what has been learned (Reber 1993). Extending this definition, it was often suggested that implicit learning should be accomplished through completely automatic learning mechanisms which do not require central attentional resources and which are driven in response to stimulus input independently of control processes or selection. In line with this assumption, early research demonstrated that adding a second task to a simultaneous implicit learning task did not deteriorate implicit learning. Thus, although much less attentional resources were available, the participants could pick up the regularities of the implicit learning task. Accordingly, it was concluded that implicit learning does not depend on attention. Yet at this point, it is important to emphasize a distinction between two properties of attention: Attention can be considered as a resource and as a selection mechanism. Both are aspects of the non-unitary concept of attention. In a large number of studies, it has been shown that implicit learning is largely independent from attention as a *resource*. However, a series of other studies has demonstrated that for implicit learning to occur, it is necessary that *selective attention* is directed to the relevant dimensions of the stimulus material, be it color, shape, or location. Suppose, for example, in a ► serial reaction time task, observers are instructed to attend only to the locations of the targets while ignoring their color. They will not be able to pick up any regularity that exists in the sequence of colors. They will only do so if their responses are based on the color of the objects so that this dimension is attended. They need not be aware of the regularity; attending to its component events is a sufficient condition for the learning to occur. The role of selective attention with regard to implicit learning can thus be considered as an instance of the "Attention Hypothesis" of Logan and colleagues (Logan et al. 1999), according to which attention to an event (or in the implicit learning case, two related events) is a necessary and sufficient precondition for the event to be stored in memory (Fig. 2).

It can thus be concluded, that attention and implicit learning share a reciprocal relationship in that implicit learning needs selective attention and that implicit learning can determine the deployment of attention. But this is not where the story ends. Selective attention is now directed by previously acquired implicit knowledge and only the objects that are attended to will in a next step be learned, since selective attention is a prerequisite for (implicit) learning. The relationship between attention and implicit learning thus goes on in a circular fashion.

Important Scientific Research and Open Questions

The topic of attention and implicit learning is an active field of research with some questions not ultimately resolved and constantly new issues emerging. While for a rather long period, the notion that implicit learning is independent from attention as a *resource* was prevailing, a recent study by Shanks et al. (2005) demonstrated the opposite. Thus, the question of whether implicit learning is attention-dependent cannot be unequivocally answered at the moment and needs further research. On the other hand, a large amount of research rather unanimously supports the view that



Attention and Implicit Learning. Fig. 2 Illustration of the relationship between selective attention and implicit learning selective attention is a necessary (and even sufficient) prerequisite for implicit learning (for a review see Chun and Turk-Browne 2008).

The phenomenon of implicit attentional learning has also become increasingly well-confirmed. It keeps being demonstrated with different paradigms, with a recent focus on investigating the special characteristics of the learning mechanism. In addition, behavioral research on implicit attentional learning has recently been complemented by neuroscientific investigations looking for the underlying neural mechanisms. To the same extent that short-term and long-term implicit attentional learning show different behavioral characteristics, both types of attentional learning seem to be mediated by different neural substrates or mechanisms. A hallmark of *short-term* implicit attentional learning is lower activity of the brain regions that are responsible for the analyses of the repeatedly presented stimulus. This reduction is already observable with the second presentation of the stimulus. It is conceivable that this so-called repetition suppression reflects the sharpening of neural responses to a repeated stimulus. In addition, the repetition suppression seems to be correlated with the activation of brain areas that are involved in the operation of visual attention. This suggests that repeated activation of the same brain area initiates the activation of attentional systems. *Long-term* implicit attentional learning, on the other hand, seems to involve brain structures that sustain the formation of long-term memory. Research centers on the medial ► temporal lobe (MTL) with its subregions, hippocampus, parahippocampal cortex, and perirhinal cortex. This formation is also the target structure of research on ► associative learning and previous research suggests that in this brain area, neurons code temporal relationships between events by changes in their activity.

Another topic of ongoing research is the question as to how far implicit attentional learning is a mechanism that is restricted to the visuo-spatial domain or whether it can be extended to other dimensions as well. While for short-term implicit attentional learning, it is conceived possible (yet not investigated) that the learning mechanism may be more general, in long-term learning, it has been shown that the learning can also generalize to other domains. For example, it has been demonstrated, that not only spatial but also temporal associations can be acquired and be used for an efficient deployment of attention. In the same vein, studies have investigated whether associations can be established between features other than space or time (like color or shape) or whether cross-dimensional associations (like, for example, a shape or a semantic category predicting a location) can be formed. Results in this regard have been equivocal and further research is needed.

Cross-References

► Associative Learning
► Automatic Information Processing
► Cueing
► Implicit Learning
► Implicit Sequence Learning
► Incidental Learning
► Procedural Learning
► Short-Term Memory and Learning
► Statistical Learning in Perception

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Attention and Pavlovian Conditioning

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Synonyms

Associability; Classical conditioning; CS processing

Definition

Pavlovian conditioning is a procedure for studying the properties and mechanisms of learning. In this procedure an initially neutral stimulus (the conditioned stimulus, CS) is repeatedly paired with a biologically significant stimulus (the unconditioned stimulus, US). As a consequence of these pairings, the CS comes to evoke a learned response, the conditioned response (CR). The most successful analysis of Pavlovian conditioning is provided by associative theories, which propose that pairings of the CS and US establish an associative connection or link between representations of these stimuli. An issue of continuing theoretical and empirical scrutiny is whether associative connections are determined by (1) variations in the processing of the US or, in contrast, (2) variations in the processing of (or attention to) the CS.

Theoretical Background

Two theories of attention and learning have had a substantial impact upon the Pavlovian conditioning literature. These theories are, at face value, contradictory.

Mackintosh (1975)

According to the theory proposed by Mackintosh (1975), the change in the connection between the CS and the US is determined, on each trial, by the difference between the magnitude of the US and the associative strength of the CS. Importantly, this value is multiplied by a learning rate parameter, α, which reflects the attention paid to a stimulus and changes with experience. More specifically, the value of α increases if the CS is the best available predictor of the US on a conditioning trial, and decreases if it is no better a predictor of the US than any other CS on a conditioning trial. This model builds upon early observations by Krechevsky (1932), which were developed further by Sutherland and Mackintosh (1971). The theory proposed by Mackintosh has been instantiated as a neural network model by Kruschke (2001).

Pearce and Hall (1980)

According to the theory proposed by Pearce and Hall (1980), the change in the connection between the CS and the US is determined, again on each trial, by the product of three parameters, two of which are fixed and are determined by the physical properties of the CS and the US, and the third (again, α), which reflects the attention that will be paid to the CS on the next trial, and again changes with experience. The value of α is equal to the absolute difference between the magnitude of the US and the sum of the associative strengths of all the CS present on that trial. In contrast to Mackintosh's theory, therefore, Pearce and Hall's theory stipulates that learning will progress more to CSs that are followed by surprising, or unpredictable USs. Pearce & Hall's theory was based upon observations first reported by Hall and Pearce (1979), and has been expanded upon by Pearce, Kaye, and Hall (1981). The principles proposed by Pearce and Hall have been incorporated into the neural network model proposed by Schmajuk, Lam, and Gray (1996).

Important Scientific Research and Open Questions

Latent Inhibition

Lubow and Moore (1959, see also Lubow 1973) reported an experiment in which the acquisition of Pavlovian conditioning was retarded if the CS had been pre-exposed in the absence of the US. This effect has been obtained in a variety of Pavlovian conditioning procedures, such as conditioned emotional responding and flavor-aversion learning. In addition, simple pre-exposure to the CS has been shown to attenuate the acquisition of inhibitory conditioning (e.g., Rescorla 1971). Although open to alternative analyses (e.g., Wagner 1981; Bouton 1993) this latent inhibition effect has been taken as evidence for animals learning to ignore the CS. The effect follows from the theory proposed by Mackintosh (1975) as, during pre-exposure, attention to the CS will fall; this follows because the CS is no better a predictor of the absence of the US than is the background context. Latent inhibition also follows from the theory proposed by Pearce and Hall (1980) as, during pre-exposure, the CS is never followed by a surprising US – attention to the CS will therefore fall. Latent inhibition has been taken as a model of the attentional dysfunction that is observed in acute schizophrenia (e.g., Weiner 2003).

Blocking

Kamin (1968) described a series of experiments in which prior conditioning with CS A prevented, or blocked, conditioning with CS X when CSs A and

Attention and Pavlovian Conditioning. Table 1 Design of a blocking experiment

Group	Stage 1	Stage 2	Test (and result)
Blocking	A → US	AX → US	X (weak CR)
Control	–	AX → US	X (Stronger CR)

X were subsequently conditioned in compound (see Table 1). Blocking is a robust property of Pavlovian conditioning and has been demonstrated across a wide variety of conditioning procedures and species. According to the theories proposed by Mackintosh (1975), and Pearce and Hall (1980), prior conditioning with A should result in a loss of attention to X. A number of experiments are consistent with this prediction, for blocked stimuli are resistant at acquiring new associations (Mackintosh 1978). Furthermore, when a surprising upshift or downshift in the magnitude of the US is introduced following AX, blocking is predicted to be attenuated, as attention should be restored. Again, extant evidence is consistent with this prediction (Dickinson et al. 1976). It must be stated, however, that it seems likely that an additional mechanism contributes to blocking. Baxter, Gallagher, and Holland (1999) showed that lesions of the cholinergic inputs of the hippocampus disrupted the attenuation of subsequent learning about a blocked CS but left blocking itself unaffected. These results might be taken to imply that a US processing mechanism (e.g., Rescorla and Wagner 1972) might also contribute to blocking.

Learned Irrelevance

According to Mackintosh's (1975) theory, conditioning will be retarded if the CS has, in the past, been a poor predictor of the US; that is to say, it has acquired irrelevance. Evidence consistent with this prediction has been provided by, for example, Mackintosh (1973) who exposed one group of rats (Group random) to random presentations of the CS and US, before then examining the speed of conditioning in a test stage in which a predictive relationship was established between the CS and the US. Rats in Group random were slower to learn in the test stage than control rats, for whom the initial, random, training was omitted. Random presentations of the CS and US have also been shown to attenuate the subsequent acquisition of inhibitory conditioning (e.g., Baker and Mackintosh 1977). There is, however, an alternative analysis of learned irrelevance which appeals to the summed effects of CS pre-exposure and US pre-exposure – both of which, alone, are known to retard the acquisition of conditioning (e.g., Bonardi and Ong 2003). It remains to be determined if learned irrelevance represents more than the sum of CS and US pre-exposure effects. If it does, it then remains to be determined if these two phenomena can be explained with an attentional mechanism alone.

An alternative method of demonstrating the effect on learning of irrelevance training is exemplified by the superiority of an intradimensional shift (IDS) over an extradimensional shift (EDS). A particularly clear demonstration of the effect was described by George and Pearce (1998) who presented pigeons with different CSs that signaled the presence and absence of the US and which each comprised two features: a color, and lines at a particular orientation. Once learning in stage one was complete the pigeons transferred to a test discrimination, which again involved different CSs that signalled the presence and absence of the US, and which again comprised color and line orientation features. However, the specific colors and orientations were different to those used in stage one. For animals in the IDS group, the dimension that was relevant to the solution of the discrimination in stage1 (e.g., color) was again relevant at test. For the EDS group the dimension that was irrelevant in stage one was relevant at test. The results showed the test discrimination was learned faster in Group IDS than in Group EDS. These results are compatible with Mackintosh's theory as stage 1 training should establish, for example, color, as the best predictor of the US, and thus attention to this stimulus dimension should increase – easing learning in the test discrimination for Group IDS. At the same time line orientation is irrelevant to the solution of the discrimination in stage one, and this dimension should therefore come to be ignored – hardening the learning in the test discrimination for Group EDS. The IDS/EDS effect has, again, been demonstrated in a variety of species using different conditioning procedures. Furthermore, lesions to the medial frontal cortex in rodents (e.g., Birrell and Brown 2000) and the lateral prefrontal cortex in primates (e.g., Dias et al. 1996) have been shown to attenuate the IDS/EDS effect. The Wisconsin card sorting task is a variety of the IDS/EDS task, and is widely used by neuropsychologists to test for attentional dysfunction in patients with frontal lobe injury or mental illness such as schizophrenia. The attenuation of learning by learned irrelevance training is not consistent with the theory proposed by Pearce and Hall (1980).

Continuous and Partial Reinforcement

It follows from the proposals of Pearce and Hall (1980) that if a CS is followed on each trial with a US (continuous reinforcement), attention to the CS will fall. This has been confirmed by Hall and Pearce (1979) who showed that continuous reinforcement of a CS with a weak shock, retarded conditioning of the same CS when it was subsequently paired with a stronger shock. It also follows from the Pearce and Hall theory that if the CS is intermittently paired with a US (partial reinforcement) attention to the CS will be maintained as the presentation of the US – or its omission – will always be surprising. Consequently, partial reinforcement of a CS should facilitate later conditioning. This prediction was confirmed by Kaye and Pearce (1984) who presented a continuously reinforced group of rats with the sequence light-tone-food, and a partially reinforced group the same sequence intermixed among trials in which the light was presented by itself. In a final test stage, the light was paired directly with food: the previously partially reinforced group showed superior conditioning relative to the continuously reinforced group. Kaye and Pearce (1984) provided direct evidence that a partially reinforced CS maintains more attention than a continuously reinforced CS. They examined the extent to which a localized light evoked an orienting response in rats. Their results showed that a CS that was partially reinforced with food maintained an orienting response for longer than a CS that was continuously reinforced with food. Lesion experiments with rodents have identified the amygdala as a crucial structure that mediates the types of attention posited by Pearce and Hall (Holland and Gallagher 1999). The effects of continuous and partial reinforcements that have been investigated by Pearce and his colleagues are not consistent with the theory proposed by Mackintosh (1975).

Hybrid Models of Conditioning and Attention

It should be apparent from the preceding discussion that there exists – at both a theoretical and an empirical level – a contradiction. On the one hand, Mackintosh's (1975) theory stipulates that CSs that are good predictors of the US will come to attract more attention than CSs that are poorer predictors of the US, and a number of studies have supported this stipulation. On the other hand, the theory proposed by Pearce and Hall (1980) stipulates, to the contrary, that CSs that are poor predictors of the US will come to gain more attention than CSs that are good predictors of the US, and again, a number of studies have supported this stipulation. To resolve this contradiction, it has been suggested that the attention paid to a CS is affected by two processes, and it is the net outcome of the interaction between these processes in any conditioning task that determines whether attention to a CS is high or low (Le Pelley 2004; Pearce et al. 1998). A common assumption of these theories, which differ in detail, is that on every conditioning trial, a calculation is made about how well each CS predicts the US (ala Mackintosh) and about the extent to which each CS is followed by an accurately predicted US (ala Pearce and Hall); and evidence which supports this assumption has recently been provided by Haselgrove, Esber, Pearce and Jones (2010). According to Le Pelley's (2004) theory, the product of Mackintosh and Pearce-Hall attention is then used to determine the total attention that is paid to the CS on the subsequent trial, and simulations of this theory have provided a good fit to the existing conditioning data. A crucial goal for future research is to determine the conditions under which attention and conditioning adheres to the proposals of Mackintosh, or the proposals of Pearce and Hall, and indeed whether separate models of attention are required (Esber and Haselgrove 2011).

Cross-References

- ▶ Animal Learning and Intelligence
- ▶ Animal Perceptual Learning
- ▶ Associative Learning
- ▶ Computational Models of Classical Conditioning
- ▶ Conditioning
- ▶ Discrimination Learning Model
- ▶ Formal Learning Theory
- ▶ Mathematical Models/Theories of Learning
- ▶ Pavlov, Ivan P. (1849–1936)

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Attention and the Processing of Visual Scenes

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Synonyms

Scene perception; Visual selective attention

Definition

Visual perception results from the dynamic interactions between incoming "bottom-up" sensory signals and "top-down" knowledge of the world in order to mediate behavioral goals on a moment-by-moment basis. Selective visual attention has been shown to play an important role in shaping the perceptual and neural representations of our visual world. Attention not only enhances responses in the brain to attend the relevant stimuli, but it also alters our sensitivity to sensory input and mitigates the influence of context on what we see. Given the clear importance of attention in guiding our actions, a great deal of theoretical and empirical work has been devoted to how attention shapes the way that we process, perceive, and navigate the visual environment. The following entry describes current empirical and theoretical understanding of how volitional attention serves to influence the processing of visual scenes.

Theoretical Background

The ability to parse scenes into objects and their surrounding backgrounds is a fundamental aspect of visual perception that is crucial in guiding our actions through the environment. Visual scene segmentation represents the initial stages in a feed-forward hierarchy of processing in which the visual system defines parts, objects, and meaning within a scene. Attention, in turn, selects relevant locations, features, or objects while filtering out or attenuating the input from irrelevant elements. As scene segmentation is a fundamental problem that the visual system must solve quite early in processing, much research has focused on the influence of selective visual attention on these early segmentation processes and their behavioral and neural ramifications.

Scene segmentation in its simplest form is based on the separation of areas of visual space that distinguish an object from its surroundings. This elemental separation of object-based "figures" from their "backgrounds" has typically been described as proceeding independent of attentional allocation (Roelfsema 2006). This view of figure-ground segmentation as a pre-attentive process is supported by behavioral findings that elements in the scene can be grouped and separated on the basis of relatively simple cues such as color, orientation, texture, or motion without conscious awareness (Kastner et al. 2000). The pre-attentive processing observed for figure-ground segregation has been echoed in research investigating our ability to search visual scenes. In typical search tasks a target element, located in a field of distracter elements, will be easily detected (i.e., will "pop out") if the target and distracter differ at a basic feature level, such as searching for red shirt in a crowd of blue shirts. As search does not require an effortful serial progression through all the elements in the scene, popout segregation is therefore reasoned to be a pre-attentive process.

This strictly automatic view of segregation, however, has been called into question by studies showing large impairments in performance on segregation and search tasks when observers must also perform a secondary task that requires dividing of their attention. In addition, more complex scenes can only be discerned slowly by an effortful item-by-item (serial) scrutiny, calling into question the notion that segregation is strictly an automatic, pre-attentive process. Therefore, based on a substantial body of behavioral research, it can be concluded that attention and awareness appear to play a modulatory, but not defining, role in figure-ground assignment and perceptual segregation.

While the central involvement of attention in perception has been known since the dawn of experimental psychology, the advent of new techniques for imaging brain function have enabled neuroscientists to map out the set of brain mechanisms and processes that mediate selective attention to visual scenes. From a neural perspective, it is fairly clear that while much of the eventual perception of scenes depends heavily on the allocation of attention, a great number of low-level processes can proceed in the absence of volitional attention.

Numerous neurophysiological and functional human brain imaging findings have demonstrated that figure-ground organization is one such process that proceeds in a manner independent of attention. Previous physiology and neuroimaging studies have demonstrated that responses to figure and background regions of scenes differ even under task conditions that rendered the observers inattentive or unaware of the presence of any figure-ground distinction. Similarly, neurons whose receptive fields process image attributes that pop out receive enhanced processing relative to neurons that do not.

While at least some basic aspects of scene processing, such as figure-ground segmentation and visual popout, can proceed automatically and without the participant's awareness, it is also appreciated that selective attention has substantial modulatory influences on both thalamic and cortical processing. Ubiquitous findings have shown that neural responses to attended objects, features, or locations are larger when they are relevant to the behavioral task, suggesting that attention serves to increase the sensory gain for the attended stimulus. Further, the neural changes supporting endogenously controlled allocation of attention have been shown to involve both enhancement of the "feed-forward" signal associated with sensory processing of relevant features, objects, or locations in a scene, and also "feedback" processing from frontal and parietal regions to visual sensory cortices that serve to shape the underlying neural representation. In this manner, the brain is able to dynamically alter the processing of scenes to allow flexible and accurate neural representations of the rapidly changing environment (Grent-'t-Jong and Woldorff 2007).

In recent years there has been a growing use of computational modeling techniques to tie together the effects of attention on behavioral performance and the neurophysiological results observed when measuring brain function. By accurately simulating neural and behavioral data these models strongly suggest that attention has co-opted the circuits that mediate contrast gain control and in some instances operates by increasing the effective contrast of the attended stimulus (Reynolds and Heeger 2009). By understanding the neural mechanisms and behavioral ramifications of visual attention and scene segmentation, new technologies mimicking this ability can be developed in a variety of contexts, from computational modeling, to a clinical setting, to applications in multimedia entertainment.

In sum, the ability to parse the visual environment into relevant objects and their surrounding backgrounds is essential for adaptive behavioral navigation of our largely visual environment. This function has been demonstrated on behavioral and neural levels to proceed, at least at its most fundamental levels (object boundaries, color, motion), without the necessity of volitional attention. However, the deployment of endogenous attentional resources to relevant aspects of the environment has been shown not only to enhance performance to relevant visual elements, but also neural representations of those elements.

Important Scientific Research and Open Questions

While much visual processing proceeds in the absence of attention, perception is ultimately shaped by how attention is allocated to stimuli in the environment, and therefore an understanding of the function and mechanisms is crucial to any adaptive learning system. The influence of attention on the processing of visual scenes represents an active area of cognitive, computer, and neuroscience research yielding fascinating applications and great promise for future applications.

Important inroads are being made into exploiting brain markers of volitional attention to control devices, communicate desires, and modify behavior. Through brain computer interface (BCI) applications it is now possible to utilize specific neural markers of attention to control external devices. Applications have been developed for a host of useful functions such as controlling wheelchairs and keyboards, and interfacing with video game systems. The use of biofeedback has also been brought into the clinical setting by "feeding-back" attention-related brain signals to individuals with attention deficit hyperactivity disorder in order to train them to better stay on task. Further advances hold additional promise for developing nonliving systems that can "see" autonomously for use in medical settings detecting anomalies in radiological images or in environments too dangerous for humans.

Cross-References

► Attention and Implicit Learning
► Attention, Memory and Meditation
► Attentional Modulation of Spread of Activation
► Spread of Activation Theory

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Attention Deficit Disorder

► Attention Deficit Hyperactivity Disorder

Attention Deficit Hyperactivity Disorder

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Synonyms

ADD; Attention deficit disorder; Hyperactivity; Impulsivity; Inattention

Definition

ADHD is defined as "a persistent pattern of intention and/or hyperactivity–impulsivity that is more frequent and severe than typically observed in individuals at a comparable level of development" (American Psychiatric Association 1994, p. 48). Three subtypes have been identified: predominantly hyperactive–impulsive type, predominantly inattentive type, and combined type (American Psychiatric Association 1994). There is general agreement on prevalence statistics of approximately 3–5% among children, with approximately 50–70% of childhood ADHD cases persisting into adolescence (Barkley 1990, 1997; Purdie et al. 2002). ADHD is comorbid with other conditions and disorders that affect learning. Of relevance to academic life, relatively high levels of oppositional defiance disorder/ conduct disorder are evident among students with ADHD and this has also posed a barrier to student learning (Purdie et al. 2002).

Theoretical Background

A widely recognized model of ADHD is that proposed by Barkley (1997), which posits behavioral inhibition as the central impairment. Barkley links problems with behavioral inhibition to four executive neuropsychological abilities: working memory (holding information in mind, forethought, sense of time); internalization of speech (reflecting on behavior, self-questioning, self-instruction); self-regulation of affect, motivation, and arousal (self-control, perspective taking, goal-directed action); and reconstitution (accurate and efficient communication of information). Other models that tend to center on biology propose that ADHD is a function of disturbances in one or more neurotransmitter and neurofunctional systems. Symptomatic models of ADHD focus more on factors such as poor attention span, decreased problem solving skills, inaccurate coding of information to working and long-term memory, low frustration tolerance, problems with organization and self-regulation (see Purdie et al. 2002; Martin in press for reviews). Motivational models of ADHD in relation to learning and achievement have also been advanced. It has been suggested that students with ADHD experience more task-relevant frustration and do not exert the effort required for completion of difficult tasks. In abandoning tasks sooner than other students, they solve fewer problems, and thus progressively cut themselves off from possible academic learning and success. Limited access to learning and success provides an insufficient basis for the development of academic self-worth important for subsequent learning (Martin in press).

Important Scientific Research and Open Questions

One major research question pertains to the causes of ADHD. Numerous causes have been proposed. Biological explanations tend to receive the most support, with ADHD seen as a result of biological/genetic predisposition (Barkley 1990, 1997). Other causes cited include parental/home factors, including poor parental mental health and maladaptive parenting skills (but note that poor parenting can result from the challenges of parenting a child with ADHD), physical dysfunction, difficult birth, and adverse early life and social experiences. The social construction of ADHD has also been suggested, with the rise in ADHD diagnoses said to be due to shifts in sociocultural values and standards of 'acceptable' behavior. Educational constructions of ADHD position ADHD behaviors and symptoms as a response to disengaging and unmotivating curriculum and pedagogy (see Barkley 1997; Martin in press; Purdie et al. 2002 for reviews of etiology).

Another line of research investigates the effects of ADHD on learning-related outcomes. It seems that ADHD has effects across child and adolescent development (Barkley 1990, 1997; Purdie et al. 2002). However, it is the intersection with the learning domain that seems to pose most difficulties. The tasks and requirements presented to children and young people at school require the very functions that ADHD seems to most impair. Consistent with this, research demonstrates poor performance in mental arithmetic, elevated rates of dyslexia, academic motivation deficits, underachievement, and significantly lower grade point average (Barkley 1997; Purdie et al. 2002).

A further ongoing research question relates to the most effective treatment. For the most part, research tends to examine treatment modes in isolation and so relatively little is known about their comparative efficacy when considered in the one investigation. Meta-analysis is able to aggregate findings to get a sense of this (e.g., Purdie et al. 2002), however, more direct primary empirical analysis comparing diverse treatment modes in the one analytic model is needed. Treatment and intervention generally take the following forms: pharmacological, allied health-related, behavioral, cognitive-behavioral, educational and classroom, and psychoeducational (Martin in press).

Pharmacological intervention (typically in the form of stimulants) is the most common form of intervention (Barkley 1990, 1997), with substantial increases in medication rates over the past 3 decades (Purdie et al. 2002). More recent research has explored 'organic' or 'natural' supplements, with recent interest in the merits of fatty acids. *Allied health interventions* focus on promoting healthy lifestyles and habits that individually and cumulatively seek to assist in managing ADHD symptoms. These include fostering healthy sleep routines, nutrition, achieving optimal weight, adherence to medication plans, and exercise and physical activity. There tends to be less research into these factors (Purdie et al. 2002). *Behavioral intervention* emphasizes reinforcement and punishment to promote and reduce desirable and undesirable behavior. *Cognitive intervention* includes approaches such as cognitive and brain training exercises that target aspects of executive functioning. *Educational and classroom intervention* addresses deficient academic skills, classroom structure, and effective use of time. Other educational accommodations include decreased academic workload, individualized/differentiated instruction, daily planners, reading tests aloud, and using scribes during tests – all aimed at cultivating more facilitating academic conditions that optimize opportunities to achieve to potential (Martin in press). *Psychoeducational intervention* is aimed at addressing students' perceived competence and self-worth, effectively dealing with fear of failure, harnessing personal bests (PBs), attaining an appropriate balance between task challenge and student skill, effective application of behavioral principles, and quality teacher–student relationships (Martin in press).

Cross-References

▶ Attention Deficit Disorder
▶ Working Memory

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Attention Regulation

▶ Mindfulness and Meditation

Attention Training

▶ Mindfulness and Meditation

Attention, Memory, and Meditation

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Synonyms

Attention and contemplative discourse; Meditation, memory, and attention

Definition

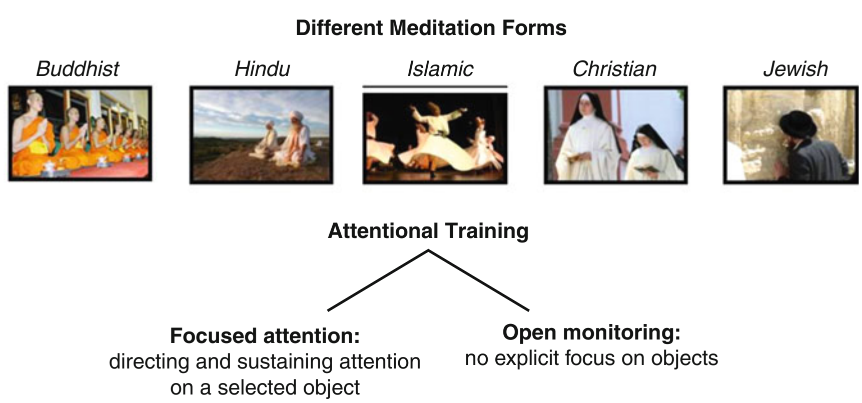
The term "meditation" comes from the Latin "meditatio" which originally indicated every type of physical or intellectual exercise. Meditation has been practiced since antiquity. Generically, it refers to an extremely wide range of practices including Buddhist, Christian, Islamic, Hindu, and Jewish traditions. Some meditative traditions, such as yoga or tantra, are common to several religions. Meditation is also practiced outside religious traditions. It is important to take the problem of terminology into consideration when the impact of meditation on attention, learning, and memory is investigated.

Attention is a major area of investigation within neuroscience, psychology, education, and meditation research. According to William James (1842–1910), the founder of experimental psychology, attention needs no definition. In fact, many of the major debates of James' time remain unresolved. As yet there is still no widely accepted definition of attention available. Attention refers to many separate processes, such as voluntary attention (in which one intentionally shifts attention from one input to another), reflexive attention (in which the shift occurs in response to some external cue), selective attention (to focus on one source and to ignore another source), and divided attention (focus on more than one simultaneous source).

Theoretical Background

The word "meditation" refers to a broad variety of practices, and failure to make distinctions would be akin to the use of the term "religion" to refer to all religious ceremonies as if they were essentially the same (see Fig. 1).

Different traditions suggest different physical postures for meditation. Cross-legged sitting postures (lotus position), supine, repetitive physical movements such as swaying, standing postures, walking, dancing, and performing monotonous activities are used. The eyes may be closed (most traditions), half-open and looking slightly downward (e.g., Zen), or fully open (e.g., Brahma Kumaris). Meditation can be performed silently, or focused on an auditory input, such as a mantra (sound, syllable, word, or group of words, for example, the syllable "om" or "aum" which is central to both Hindu and Buddhist traditions) or a koan (question or statement whose meaning cannot be accessed by rational thinking, but by intuition, e.g., "Two hands clap and there is a sound; what is the sound of one hand?"). Hence, defining meditation involves the need for a precise understanding of



Attention, Memory, and Meditation. Fig. 1 Variety of meditation practices and attentional subsystems meditation as a scientific explanandum taking into account the importance of various traditions (Lutz et al. 2007).

Attentional regulation is a common cognitive function associated with divergent meditation methods. Several authors have demonstrated that meditation practice alters brain activity in areas important for sensory, cognitive, and emotional processing (e.g., Newberg and Iversen 2003). During meditation, sensory input is diminished and sustained concentration and heightened awareness can be achieved. Lutz et al. (2008) suggested a useful framework in which the diversity of different meditation techniques is grouped into two main categories:

1. *Focused attention*: directing and sustaining attention on a selected object, such as breathing, scriptural passage, mantra, religious pictures, etc. A typical example is Shamatha, a single-pointed, focusing, pacifying, and calming meditation technique. The key concept is the concentration of mind. If the mind is wandering, meditators show a disengagement of attention from distraction and a shift of attention back to the selected object.
2. *Open monitoring*: no explicit focus on objects. This meditation technique is characterized by meta-attention. Vipassana is an example of a form of meditation that includes any meditation technique that cultivates insight including contemplation, introspection, analytic meditation, and observations about experience.

All meditation practices have in common that the meditator is asked to remain in the "here and now"; the main focus of meditation is therefore the present. Tart (2001) pointed out that in different kinds of meditation, memory is largely inactive and, if it is activated, ignored. There is a very strong focus on the present time, either in terms of concentration of a specific object or the breath, etc. or on the larger range of focus in insight meditation. The meditator is interested in sensing what body sensations feels like here and now, but not in remembering what it felt like earlier or reflecting about how it might feel in the future. This stays in sharp contrast to hypnotic trance in which suppressed memories may be reexperienced and where age-regression or age-progression are used therapeutically to allow the subjects to experience all forms of inner sensory, perceptual, or emotional events.

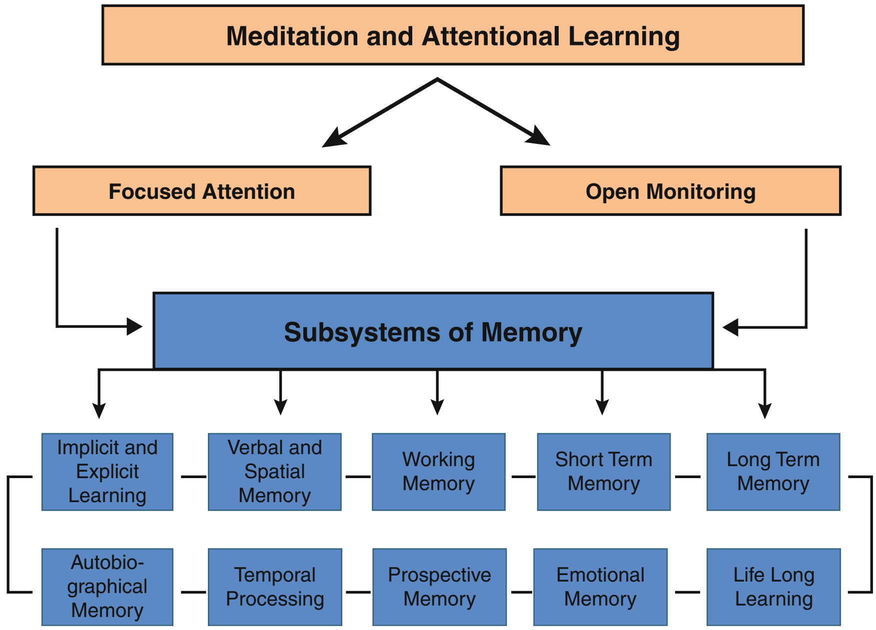
Descriptions of various meditation techniques imply that we should expect differences in attention, memory mechanisms, and brain function associated with the exercises of the different types of meditation techniques. Unfortunately, as yet there are no investigations available which systematically compared the outcome of different meditation exercises on brain plasticity chances, attention, and memory functions.

Important Scientific Research and Open Questions

Learning and memory can occur consciously (explicit) or without conscious awareness (implicit) and are characterized by the acquisition of new knowledge, behaviors, skills, and values. An important research question to be investigated is the outcome of long-term practices of different meditation techniques with focused attention versus meta-attention on implicit and explicit memory functions. There are different subcomponents which need to be systematically addressed, such as working memory (temporarily stores information for detailed analysis), short-term memory, long-term memory, prospective memory (remembering what we must do in the future), temporal processing (sequential learning), autobiographical memory, verbal and spatial memory, emotional memory, and lifelong learning (see Fig. 2). Relevant research is still in its infancy. As yet there are only few studies available that have analyzed the effect of individual meditation techniques on subsystems of memory functions.

Yoga exercises seem to improve short-term memory performance. It was found that cyclic meditation (cycles of yoga postures and supine rest) improved memory scores on a standard memory test which examines spatial and verbal memory functioning (Wechsler Memory Scale) immediately after the practice (Subramanya and Teiles 2009). However, as yet there is no information on long-term effects of yoga exercises on different aspects of learning and memory function.

From a neurobiological point of view the most extensively studied form of meditation is Buddhism. Nowadays practices of Buddhism with its emphasis on the individual's independence in learning practice are becoming more and more popular in Western countries. Buddhism offers powerful and unique learning techniques that are useful for improving lifelong



Attention, Memory, and Meditation. Fig. 2 Further research is needed to examine the effects of different meditation techniques and attentional learning on subsystems of memory functions

learning which refers to an individual's conscious learning taking place throughout his whole life span. Practices of Buddhist meditation, contemplation, and mindfulness seem to improve conscious life experience awareness.

Attentional training constitutes a fundamental aspect of mindfulness training. In the most widely used form, subjects are instructed to return to their attention to their breath whenever it wanders. Numerous studies indicate that this kind of mindfulness training improves attention known as "concentrative" and restricted to a specific focus. If attention is objectless and the goal is to keep attention in the present moment without orienting, directing, or limiting it in any way, improvements were reported in so-called receptive attention to the whole field of awareness. In the latter case, attention remains in an open state and can be directed to currently experienced sensations, thoughts, emotions, and memories (Jha et al. 2007). Since receptive attention is open to the entire field of experience, no external stimuli are considered to be distractors. However, in concentrative attention outside stimuli are considered to be interfering and distracting.

Meditation is accompanied by plasticity changes in the brain. Using functional magnetic resonance imaging (fMRI), Baron Short et al. (2010) tested subjects with at least 4 years of regular meditative practices from different meditative traditions (Tibetan Buddhists, Zen Buddhists, Yoga practitioners) and different experiences in meditation practices and durations. Results indicate that brain activities in the dorsal lateral prefrontal cortex and anterior cingulate cortex varied over the time of a meditation session and differed between long- and short-term practitioners. In the more practiced subjects, regional brain activations correlated with better sustained attention and attentional error monitoring. Using fMRI, a major restriction is that subjects may find it extremely difficult to carry out their familiar meditation exercise when confined to a narrow scanner tube.

Using electroencephalography (EEG) increases in alpha (most pronounced in the frontal cortex), gamma, and theta power were observed by several authors in different types of meditation. In long-term meditators, changes in EEG activity are dynamical and dependent on the arousal level. Increasing the arousal level desynchronized activities in theta and alpha frequency bands. Meditation techniques based on focused attention showed a high amplitude activity and a marked phase synchronization in the gamma-band (between 25 and 42 Hz), especially in lateral fronto-parietal locations. In the deepest stage of Zen meditation, an increase in the alpha band (8–13 Hz) and theta-power (4–7 Hz) was recorded at all brain locations (most prominent in the left parietal cortex) (Coromaldi et al. 2006).

In open monitoring meditation, the awareness of the subjective features of a given moment and its emotional tone are of crucial importance. Therefore, brain regions involved in focusing or sustaining attention onto a specific object are less relevant. But instead processes that rely on meta-representation in the brain are critically involved including the anterior insula, somatosensory cortex, and anterior cingulate cortex (Damasio 2000).

So far only a few studies are available that specifically compared aspects of anatomical correlates between meditators and non-meditators. Lazar et al. (2005) reported that brain regions associated with attention, interoception, and sensory processing were thicker in long-term Vipassana meditators as compared to a non-meditating control group including the prefrontal cortex and anterior insula. Differences in cortical thickness were most pronounced in the most experienced subjects. Interestingly, there is recent evidence for an increase in brain volumes of gray matter in areas which are known to be critically involved in memory functioning. In long-term meditators using different meditation techniques, larger hippocampal and frontal volumes were observed (Luders et al. 2009). Taken together, the results suggest that long-term meditation can induce changes in brain structure. But the correlation with mental functioning remains unclear. Furthermore, it remains an open question whether alterations in brain functions like enhanced attentional capacities are caused by long-term meditation training itself or by individual personality differences. Therefore, longitudinal studies are needed to follow individuals over time in response to mental training.

Taken together, the results are controversial. There are so many different kinds of meditation techniques that findings are heterogeneous. The heterogeneity is additionally caused by the great variability in the degree of experience in meditation (Halsband 2009). It is also difficult to compare recent and older studies because technology and analytical procedures have changed.

Cross-References

► Amnesia and Learning
► Association Learning
► Associative Learning
► Complex Declarative Learning
► Conditions of Learning
► Declarative Learning
► Explicit Learning
► Human Learning
► Imagery and Learning
► Implicit Learning
► Learning and Recall Under Hypnosis
► Memory Codes and Neural Plasticity of Learning
► Memory Structure
► Mental Imagery and Learning
► Mental Models Improving Learning
► Neuropsychology of Learning
► Pair-Associated Learning
► Procedural Learning

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Attentional Control of Memory Retrieval

► Attentional Modulation of Spread of Activation

Attentional Modulation of Spread of Activation

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Synonyms

Attentional control of memory retrieval

Definition

Attention refers to a cognitive process that enhances the availability of information. Depending on the type of information that it enhances and its consequences, attention can be divided into several types. For example, when the result of the process is that one information channel comes to dominate a competing channel, the type of attentional process is referred to as selective attention. Definitions of attention are rarely complete, as the term is used to describe a cognitive process or a collection of processes and is used in the colloquial meaning of the word. In Cognitive Science, spread of activation refers to a process by which knowledge concepts that are stored in semantic memory become part of the overall stream of information. For example, when a picture of a dog is presented, the conceptual knowledge of dog becomes activated and part of the stream of information. Through spread of activation, the related concept of cat becomes somewhat activated, even though no picture of a cat is presented. Attentional modulation of spread of activation refers to the influence that attention has on the flow of information among concepts.

Theoretical Background

Although the oldest theories of knowledge representation and acquisition date back to Aristotle and the associationists, the foundations of most of the contemporary knowledge we have about spread of activation can be traced to the late 1960 and early 1970s. Research on conceptual knowledge focused on how knowledge is represented in our mind. A closely related question is how knowledge accumulates in our mind. A first influential theory of how knowledge is represented is the teachable language comprehender, more commonly known as the hierarchical theory (Collins and Quillian 1969). In this theory, memory consists of three basic components: concepts, properties, and pointers that associate concepts with their properties. This theory was called hierarchical because it assumed that concepts are linked in accordance to their ordinate category. For example, *bird* and *fish* are both types of animal so they are both linked to *animal*, but they are not interconnected. This hierarchy allows for property inheritance, where any lower-level concept inherits the properties of the higher-level concepts to which it is connected. In our example, both *bird* and *fish* inherit the *animal* property that it *eats* and that it *has skin*. This feature of the theory leads to cognitive economy - every property needs to be represented only once.

The hierarchical theory was extremely powerful in accounting for empirical data and in producing new predictions. Some of these predictions soon proved the inadequacy of the model and resulted in it being abandoned as a model of human knowledge representation. The immediate successor of the theory was called the spreading activation model (Collins and Loftus 1975), which abandoned the strict hierarchical nature and allowed the links among concepts to vary in strength and type. Importantly, the model includes the process by which energy or activation spreads from one concept to the next via the links and in proportion to the strength of those links.

A commonly used experimental paradigm to test the amount of spreading of activation is the semantic priming paradigm of which there exist several variants. The basic paradigm involves the presentation of a word (or a picture) that the participant needs to read to themselves. This first word is called the *prime* (e.g., dog) and is followed by a string of letters, the *target*. In the naming version of the paradigm, this letter string is always a word and the participant reads aloud that word. The time to read aloud the word, the naming time, is faster when the prime and target are related (e.g., dog – CAT) compared to when they are unrelated (e.g., dog – PLANE). This effect is referred to as the priming effect and it is also found in the variant called the lexical decision paradigm. In this version, the letter string can either be a word or a nonword (e.g., ANEPL). The participant has to indicate whether the string of letters forms a word or not. The time to say yes to the word is taken as the relevant response time measure and it is faster when it was preceded by a related prime. The main explanation of this finding is that the activation spreads from the prime concept to related concepts. When the target is presented, related targets have their concepts already pre-activated and thus less time is needed to respond. When an unrelated target is presented, the activation of its concept will take longer.

The lexical decision and naming paradigms are standard research paradigms and their use has led to an increase in our understanding of how and when activation spreads through a semantic network (see Neely 1991). One important finding is that activation can spread in an automatic or in a controlled fashion. This was inferred from the observation that priming effects are larger after a long exposure to the prime and a long duration between the onsets of the prime and target than with shorter exposures and durations. Typically, the priming effect is calculated as the difference in naming or decision times when the target was preceded by a related or unrelated prime. When a neutral prime is used, such as a string of ampersands, the naming or decision time of the target is uncontaminated with any pre-activation that comes from the prime. The difference in primed response time against the unprimed or neutral response time can be used to look at facilitatory (related versus neutral) and inhibitory (unrelated versus neutral) effects of primes. Short exposure durations to prime only leads to facilitation, whereas with longer durations inhibitory effects are found. This is explained in term of fast automatic spread of activation, which is only facilitatory in nature, followed by anticipatory, controlled processes. Other manipulations have further supported the distinction between automatic and controlled spread of activation (Neely 1991).

A major assumption underlying the automatic/controlled dichotomy is that the priming effect reflects at least the result of a pure automatic process. To address whether facilitatory priming reflect automatic spread of activation, a distracting task needs to be conducted on the prime. This variant of the priming paradigm leads to the *prime-task effect*, which is the absence of priming when a non-semantic task is performed on the prime (Maxfield 1997). In a typical example, a prime word consisting of n letters is presented together with a string of n identical letters either above or below the prime word. The participant has to search the prime word and indicate whether the letter of the string is present in the prime. Following this prime task, the participant names a target word or makes a lexical decision to a target letter-string. The result is a complete absence of the priming effect – a null-effect. The importance of this null-effect is that priming is normally found under so many different manipulations that it is hard not to find an effect at all. The prime-task null-effect has been held to provide evidence against the obligatory nature of semantic activation and spread of activation.

The main argument against the view that concepts become automatically activated when processing the environment focuses on the absence of priming when the prime word is shown to have been processed, as shown by accurate performance on the prime task. A counterargument is that the absence of priming does not invalidate the automaticity of semantic spread of activation, as it is possible that the task itself may have prevented concepts to become activated at the appropriate semantic level. For example, to decide whether the letter L is present in the word PLANE, it is not necessary to activate the semantic concept. All that is needed to complete the prime task is to rely on visual feature processing. In this manner, from a semantic point of view, the prime is processed as if it was a neutral prime.

The prime-task null-effect shows that spread of activation is found when attention is directed at the semantic level of processing. When attention is directed to other levels (visual, phonological), the semantic concept might at best not be activated sufficiently to allow spread of activation. Therefore, attention allows spread of activation in the entire semantic system.

The implicit assumption of the allowance-principle is that when attention is directed to the semantic level, the prime does get activated automatically and hence lead, via the automatic spread of activation, to priming effects. To address this allowance-principle, a variant of the priming paradigm was used in which the prime had to be held in active state. This variant required the retention of the prime for a later memory task, and yields the *prime-retention effect*. The prime-retention effect refers to the reduction of the priming effect when the prime is maintained in active state. The prime-retention task is such that the entire string of letters needs to be remembered for either recall or recognition. The importance of this effect can be seen when it is considered that all contemporary theories of semantic priming assume that the more activation is available for processing the prime the larger the priming effect should be. Instead the priming effect decreases and for prime-target pairs that are weakly associated, the priming effect even reverses. Although there has not been as much research with this paradigm as compared to the prime-task variant, the prime-retention effect has also been held to provide evidence against the obligatory nature of semantic spread of activation.

The main argument against automatic spread of activation given the prime-retention effect is that even when attention to the prime is directed to the semantic level, spread of activation as measured by the priming effect is diminished. The effect implies that the allowance-principle is incomplete, as it assumes a monotonic relation between the level of attention allocated to the semantic level and the amount of semantic priming. When combining the prime-task and prime-retention results, the influence of attention on the spread of activation is in terms of permitting (Davelaar 2005). Thus, attention permits the spread of activation in certain parts of the semantic system, where the resulting priming effect is largest when an intermediate level of attention is focused on the semantic level of the prime.

Important Scientific Research and Open Questions

The construct of spread of activation is meaningful only in a knowledge system that has each concept represented as a single node. Despite the success of the spreading-activation models, other theories exist that are able to account for the basic findings of semantic priming paradigms (see McNamara 2005). These theories fall into two groups: feature-based or distributed models and decision-based models. Distributed models attack the assumption that knowledge is represented as a single node and instead assume that concepts are represented by a large number of nodes with each node partaking in multiple concepts. The difference among concepts lies in the difference in the distribution of activation over the nodes, so that a single node might be more active for one than another concept. The associative links in the spreading-activation models are then replaced by the similarity of the distributions of activations. Decision-based models attack the assumption that priming effects is the result of pre-activating the target concept. These models instead appeal to the complexities of decision-making in that two concepts that are "linked" are more commonly experienced together than two concepts that are not "linked." The priming effects are then a reflection of the familiarity of the pair. These models clearly attack the entire assumption of spread of activation and pre-activation.

It may come as no surprise that the three types of theories have produced hybrids that are able to explain findings that challenge either parent theory. For example, sparse-distributed models assume that a single node partakes only in a small subset of related concepts. Nevertheless, all the models addressed here share the inability to account for the influence of attention. What this tells us is that either the fundamental one-layer structure of semantic memory is false or that the associative links are not as fixed as assumed from a stable knowledge system. As the hierarchical model (Collins and Quillian 1969) has sparked much research until it was proven to be incomplete, the inclusion of attentional processes in empirical work might lead to a reinterpretation of the entire structure of conceptual knowledge. The main question then is what that structure is and how knowledge is assimilated and stabilized within this alternative structure.

Apart from gaining a theoretical understanding of the structure of conceptual knowledge, the importance of attentional modulation of spread of activation extends to the field of clinical neuropsychology. It has been found that elderly individuals, patients with damage to the prefrontal cortex, patients with certain types of dementia, and patients with schizophrenia show excessive semantic priming effects. These same individuals have been studied in relation to their decreased ability to focus attention. Understanding how attention modulates the spread of activation might lead to a reinterpretation of their neuropsychological symptoms and the development of new rehabilitation programs.

Cross-References

- ▶ ACT (Adaptive Control of Thought)
- ▶ Aristotle (384–322 B.C.)
- ▶ Associationism
- ▶ Knowledge Organization
- ▶ Knowledge Representation
- ▶ Memory Structure

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Attentiveness to Learning

▶ Interests and Learning

Attitude

▶ Learner Characteristics and Online Learning

Attitude Change

▶ Persuasion and Learning

Attitude Change Through Learning

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Synonyms

Attitudes; Beliefs; Opinions; Perceptions

Definition

The word attitude refers to an individual's orientation toward an item, person, concept, institution, social process, or situation, and is indicative of his/her web of beliefs and perceptions, based on either direct experience or observational learning, though it must be noted that, as with other widely used terms, "attitude," "belief," and "opinion" are subject to differences of interpretation, overlapping of meaning, and even interchangeability when used in the social and behavioral sciences. Being complex mental orientations, some researchers prefer to infer attitudes from observed behavior, seeing them as a tendency to act in certain ways toward persons and situations, a positive or negative attitude being evidenced in terms of the degree of like or dislike shown. Rokeach combines various perspectives, describing an attitude as "a relatively enduring organization of beliefs around an object or situation predisposing one to respond in some preferential manner" (1976, p. 112).

Attitudes can be classified according to affective, behavioral, and cognitive responses to an "attitude object" and are expressed as positive and/or negative judgments. The affective response expresses a degree of preference, the behavioral response is conveyed through words or behavioral tendencies, and the cognitive response constitutes the individual's beliefs about the object (Mantle-Bromley 1995; Zimbardo and Lieppe 1991). Attitude change through learning occurs when these "learned responses" are modified through further experience, self-observation and reflection, consciousness-raising (awareness-raising), and/or implicit/explicit instruction in learner strategies or emotional management.

Theoretical Background

Attitudes to learning and the perceptions and beliefs which determine them have a significant influence on learning behavior and on learning outcomes, since successful learners develop insightful beliefs about the learning processes, their own abilities, and the use of effective learning strategies, which together have a facilitative effect on learning. Mistaken or uninformed beliefs on the other hand may lead to dependence on less effective strategies, resulting in indifference toward learning, poor cognitive performance, classroom anxiety, and a negative attitude to autonomy (Victori and Lockhart 1995). Teachers therefore need to acknowledge and respect students' attitudes, beliefs, and expectations and help them overcome any harmful perceptions and blocks, as well as enhance students' awareness of their personal weaknesses and strengths and of their task/strategic knowledge, since beliefs differing from those of the teacher can lead to frustration, dissatisfaction with the course, unwillingness to perform activities, and lack of confidence in the teacher, as well as affecting achievement (Mantle-Bromley 1995).

Adults and children form "self-schemata" concerning capabilities and limitations, degree of personal control over academic achievement, reasons for success and failure at different tasks, and expectancies for the future. These schemata and other beliefs help to construct attitudes to language learning, and have various origins: (1) the mother culture, (2) the family, (3) classroom/social peers, (4) repetitive experiences, and (5) self-fulfilling (often negative) prophecies. Although usually related to past experiences, the resulting attitudes also contribute to future behavior, positive attitudes helping to overcome problems and thus sustaining motivation, and negative attitudes (including those of the teacher) leading to decreased motivation.

It follows that identification, analysis, and modification of students' attitudes to learning are important procedures for teachers if they are to facilitate effective learning and there has been extensive research into the measurement of attitudes (as factors in the learning process) on the part of social psychologists, sociologists, and (to a lesser extent) researchers in the field of education. Practical methodologies for actively pursuing attitude change in the classroom, based upon this research, have largely followed the recent student-centered trend, focusing on the learner as the agent of his/her own learning. From this perspective, self-awareness of and reflection on individual attitudes can provide the foundation for acquisition of learning strategies, which can lead to life-long, self-directed (autonomous) learning. Role-plays have also been identified as effective tools for promoting attitude change, since they give the participants the opportunity to investigate issues from different perspectives and hence to understand that there are various, equally valid ways of perceiving situations. The recent focus on diversity in cultural studies, international studies, and language teaching is an example of this shift toward the acknowledgment and acceptance of differing perceptions, facilitating the consequent attitude modification which accompanies such awareness. In terms of assessment, the "alternative assessment" movement has also placed the learner at the center of attitude modification through the use of learner journals, portfolios, projects, presentations, self-peer-assessment, and classroom-based assessment (CBA), all of which encourage the learner to participate in and be responsible for assessment and through awareness of the factors involved to develop sound attitudes toward learning and evaluation. The European Portfolio Project and the Common European Framework of Reference for Languages: Learning, Teaching, Assessment (CEFR), with its DIALANG self-assessment scales are examples of such an approach being applied on an international scale.

Important Scientific Research and Open Questions

Early research on the relationship between attitudes and learning found that stress and anxiety were strong (negative) contributory factors for the students and that teachers also have attitudes and beliefs about learning, which affect their teaching:

- Not until we have taken a hard critical look at the attitudes and motivation of teachers, both individually and as a profession, will we be ready to determine what obstacles lie in the way of creating the kinds of learning environments which would be most helpful to our students. (Sauvignon 1976, p. 296)

Although it has been acknowledged for some time that all students have different needs, preferences, beliefs, learning styles, and educational backgrounds and that imposition of change upon these factors can lead to negative attitudes to learning, the importance of student awareness of (and reflection on) learning beliefs (metacognitive knowledge), learning styles, learning preferences, and expectations only began to receive attention in the 1980s, when research was mostly limited to identification of those beliefs. One such research instrument was the Beliefs About Language Learning Inventory (BALLI), developed to assess teacher and student opinions on a variety of issues related to language learning (Horwitz 1985, p. 383). This was used in three quite large-scale American studies, with similar results, and Horwitz proposed that gaps between teacher and learner beliefs probably result in "negative outcomes" (Mantle-Bromley 1995, pp. 380–381). Mantle-Bromley also found that learners with realistic and informed beliefs are more likely to behave productively in class, work harder outside class, and persist longer with study (1995, pp. 373–375), and that incorrect beliefs are detrimental to language learning. Furthermore, it has also been shown that mistaken beliefs (and the resulting misinformed attitudes to learning) can result in a lack of student confidence, through lack of success being attributed to lack of aptitude. In this case, teachers need to work on and with students' representations in the classroom, focusing on a change in conceptualization.

Research on self-esteem has demonstrated a clear link between individual perception of competence and actual learning, though there is a need for further research into learner beliefs about ability, self-efficacy, and self-esteem and their contribution to the formation of attitudes. Personal variables such as intentions, attributions, expectancies, perceptions, and beliefs about learning abilities, which learners bring to the classroom, also need to be researched, on the basis of "a clear understanding of attitudes and attitude-change theory in order to address these issues" (Mantle-Bromley 1995, p. 373). Mantle-Bromley also strongly recommends that "teachers design and implement lessons on the language-learning process that incorporate attitude-change methods. Research then needs to be conducted to determine if such lessons can indeed alter students' beliefs" (1995, p. 383).

Cross-References

► Attitudes – Formation and Change
► Beliefs About Language Learning
► Beliefs About Learning
► Learning Strategies
► Perceptions of the Learning Context and Learning Outcomes

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Attitude Polarization

► Divergent Probabilistic Judgments Under Bayesian Learning with Nonadditive Beliefs

Attitudes – Formation and Change

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Synonyms

Disposition; Inclination; Mindset; Opinion; Position; Prejudice; Sentiment; View

Definition

An "attitude" is a hypothetical construct that represents the degree to which an individual likes or dislikes something. Everything, i.e., any person, place, thing, or event, can be the object of an attitude. People can be in conflict with or ambivalent toward an object if they simultaneously possess positive and negative attitudes toward it. However, social psychology speaks not only of attitudes, but also of “beliefs,” “opinions,” “prejudices,” “values,” “positions,” “views,” and so on, and it is not always clear how these concepts differ from one another.

Attitudes refer to a person’s predisposition or tendency to *evaluate* an object or its symbolic representation in a certain way. Thus, attitudes always express a person’s particular relation to objects and help to structure the person’s consciousness by furnishing the objects with a ► valence and *preference*. These factors are dependent on the centrality (i.e., the personal importance) of an object and its relevance for action in a certain context.

Attitudes are the result of either direct experience or observational learning from the environment. From the perspective of the neurosciences, attitudes can be considered as (parts of) associative networks in long-term memory. These networks consist of affective and cognitive nodes linked through associative pathways. Accordingly, most psychologists agree on the point that attitudes contain affective, cognitive, and behavioral components (Eagly and Chaiken 1995). Taking into consideration previous and current attitude research, Breckler and Wiggins (1992) define attitudes as “mental and neural representations, organized through experience, exerting a directive or dynamic influence on behavior” (p. 409).

Theoretical Background

Historically speaking, attitude is one of Jung’s 57 definitions of *psychological types*. Jung’s definition of attitude is a “readiness of the psyche to act or react in a certain way” (Jung 1921/1971, p. 687). Attitudes very often come in pairs, one conscious and the other unconscious. Within this broad definition, Jung defines several attitudes, such as extraversion and introversion, rational and irrational attitudes, individual and social attitudes.

Some decades later (i.e., in the 1950s and 1960s), it was particularly Carl Hovland who pioneered the development of a comprehensive theory of attitudes and their formation and change as a result of experience and learning with a special emphasis on the role of communication. Hovland argued that an attitude is a response to communication with messages of varying degrees of persuasiveness. The persuasiveness of communication is dependent on characteristics of the individual who processes a message and characteristics of the information sources. The first category of characteristics is named “target characteristics” and contains, for instance, intelligence and self-esteem. Other person-centered characteristics are the frame of mind and mood of the targets of persuasion. The characteristics of the communicated messages are named “source characteristics” and contain variables such as expertise, trustworthiness, and the interpersonal attraction or attractiveness of the messages. Actually, the credibility of a perceived message and the messenger seems to be a key variable for the formation and change of attitudes.

Since the 1960s, numerous theories of attitude formation and attitude change have been developed. An example is consistency theories, which imply that people tend to be consistent in their beliefs and values. One well-known consistency theory is the ► dissonance reduction theory advocated by Leon Festinger; another example is the Fritz Heider’s ► balance theory. Finally, the ► self-perception theory (Daryl Bem) is also worthy of mention in the context of consistency theories of attitude formation and change.

The various theories of attitude formation and change (through learning) are grounded on the assumption of an interplay between cognitive, affective, and behavioral components. The cognitive component of an attitude consists of *beliefs* as elementary cognitive units that cannot be broken into smaller units (Rokeach 1973). Beliefs include an evaluation of the object of an attitude as correct or false, right or wrong, or desirable or undesirable, and they differ in their degree of centrality. As a rule of thumb, the more central a belief is, the more resistant it is to change. However, when changes do happen (e.g., due to better arguments), they have a lasting effect on the person’s entire system of attitudes and values. This theoretical position rests on the assumption that there is a strong connection between a person’s beliefs and his or her entire system of attitudes and associated values. Some social psychologists (e.g., Rokeach 1973) argue that attitudes are organized in consistent and coherent structures and form more or less integrated *value systems*. These value systems may also be referred to as “ideologies” in that they constitute a strongly connected set of beliefs, opinions, and views, which are supposed to justify a group or institution. Beliefs are associated with affective responses to the object of an attitude, which also exerts a dynamic and guiding influence on human behavior. The question of how to explain the relationships between beliefs, affects, and overt behaviors has occupied social psychologists for decades. A model developed in the early 1960s, which has since become widely accepted, is the *three-component model* (cf. Triandis 1971), which, as the name suggests, is made up of three closely related components:

1. The *affective* component (indicated by responses of the sympathetic nervous system and verbal affect statements)
2. The *cognitive* component (indicated by verbal belief statements or reaction times to attitude stimuli)
3. The *behavioral* component (indicated by overt actions or verbal behavior statements)

Each attitude contains feelings, opinions, and beliefs as well as actions and particular behaviors referring to the attitude object. However, each of these three components may be more marked than the others for a particular attitude. Some attitudes are highly affective and are only related to an object as the expression of feelings, and some express themselves immediately in overt action when a need can be satisfied simply and directly (e.g., choosing players for a soccer game). Other attitudes are highly intellectualized and can thus not be used to predict a person's behavior in a concrete situation. But not only is it tough to judge the relationship between attitudes and behavior, judging the relationships between the various components of attitudes in general is also a difficult undertaking. In studying these relationships, social psychologists focus especially on two main questions: first, the type of relationship between the affective and cognitive attitude components, and second, the type of relationship between the cognitive judgment (beliefs) and consistency of people's attitudes and their overt behavior.

Many dual process models have been developed in order to explain the affective responses to and cognitive processing of messages. They include the *elaboration likelihood model (ELM)*, the *heuristic-systematic model (HSM)*, and the *extended parallel process model (EPPM)*. In the ELM (Petty and Cacioppo 1986), cognitive processing is the central route and affective processing is often associated with the peripheral route. The central route pertains to an elaborate cognitive processing of information, while the peripheral route relies on cues or feelings. A true attitude change only happens through the central processing route, which incorporates both cognitive and affective components as opposed to the more heuristics-based peripheral route. In the HSM (Eagly and Chaiken 1993), information is either processed in a high-involvement and high-effort systematic manner or through shortcuts known as heuristics. The EPPM contains both thinking and feeling in conjunction with threats and fear appeals. This model suggests that persuasive fear appeals work best when people have high involvement and high efficacy. In other words, fear appeals are most effective when an individual cares about the issue or situation and possesses – and is aware of possessing – the agency to deal with it.

Important Scientific Research and Open Questions

According to Olson and Zanna (1993), attitudes are among the best investigated constructs of twentieth century social psychology – from early work on attitude measurement in the 1920s to research on attitude change from the 1950s to the 1970s and attitude structures and their changes in the 1980s and 1990s.

The cognitive component of attitudes holds a prominent position in social psychology, not only because it "mediates" between the other two components of the model, but also because it is easier to measure by way of interviews, questionnaires, and special attitude scales (Dawes 1972). One way of doing this is with *multi-attributive attitude models*, which assume that attitudes are grounded on numerous salient attributes which immediately become the object of a subjective evaluation. These attributes may also be classified according to the way in which they are acquired (direct versus indirect experience) or what they contain. Some attitudes are grounded more on object attributes and others more on behavioral attributes. This has led to the formation of two conceptions of attitudes in social–psychological research: "object attitudes" and "behavioral attitudes."

The first main body of research investigates *object attitudes*, focusing especially on the relationship between affective evaluation and beliefs. It is generally assumed that the affective component is essential for evaluating attitude objects since people are already in possession of it before being introduced to the object domain. The cognitive component, on the other hand, takes shape only gradually in the process of attitude-specific learning experiences. This means that the less experience someone has with an attitude object, the more dependent the cognitive structure of the attitude will be on the affective component. On the other hand, it may be assumed that the affective component is closely connected with the cognitive structural characteristics of the attitude, which means that it is possible to predict whether these characteristics are known. As an attitude becomes reinforced, the affective and cognitive components become increasingly independent of one another and the subject makes the realization that an affective judgment of the object can be different than a cognitive judgment. Social psychologists have succeeded in confirming this learning-dependent "separation" of the two components as well as the initial dominance of the affective component.

The second main group of social–psychological studies investigates *behavioral attitudes* and focuses on the relationship between the cognitive component of attitudes and concrete action. This line of research is often said to go back to a "classic" study by LaPiere (1934) in which the author found a minimal correspondence between verbally expressed beliefs and observable behavior. Eckes and Six (1994) conducted a meta-analysis of 501 of these studies and concluded "that long-established and widely accepted beliefs concerning the relation between attitude and behavior . . . need to be corrected" (270) since it is clear that behavioral attitudes are related not only to a particular goal but also to a particular action, the specific context of that action, and a particular period of time. The decision to behave in one way or another in a concrete situation involves not only short-lived opinions and views but also more permanent value positions. There is also considerable research on *implicit attitudes*, which generally remain unconscious but have effects on behavior that are measurable through sophisticated methods, such as through the measurement of reaction times to attitude stimuli. Implicit and explicit attitudes seem to affect people's behavior in different ways. However, we still have a poor understanding of the relationship between them due to a lack of substantial research.

Research on attitude formation and change focuses on the way people process messages. In terms of research methodology, the challenge for researchers is measuring the affective component and its subsequent impact on beliefs and overt action. Measures may include the use of physiological cues like facial expressions, vocal changes, and other body rate measures (Breckler and Wiggins 1992). Other methods include concept or network mapping and using primes or word cues. An overview of the variety of assessment procedures traditionally applied in attitude research can be found in Dawes (1972).

Cross-References

- ▶ Attituty Change Through Learning
- ▶ Change of Values Through Learning
- ▶ Persuasion and Learning
- ▶ Value Learning

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Attitudes

▶ Attitude Change Through Learning

Attitudes Toward Learning

► Culture of Learning

Attractor Neural Network

► Associative Memory and Learning

Attribute-Treatment Interaction

► Aptitude-Treatment Interaction

Attribution Theory

Individuals' reasons for success and failure influence their future motivation in related tasks.

Attribution Theory in Communication Research

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Synonyms

Acknowledgment; Ascription

Definition

People have a strong need to understand the question "why" because it helps us to understand the world around us. Attribution theory provides one way to understand how people answer the question "why" and make sense of their worlds. Attribution theory seeks to help people make sense of their world by identifying causes for the behaviors and events they experience. Causal locus is the core of Attribution theory. The primary causes for behavior can be an internal or external locus. An internal locus is also called dispositional because it reflects a person's disposition shaping the behavior. An external locus is also called situational because it reflects environmental factors shaping the behavior. The metaphor of scientists guides Attribution theory. People are all scientists who collect information about their worlds in order to understand that world. Attributions are one form of information people use to explain their worlds (Weiner 2004).

Theoretical Background

Attribution theory was pioneered by Fritz Heider in the 1950s. Harold Kelley and Bernard Weiner have made important contributions to the development of Attribution theory. Kelley developed the idea of covariance in attributions – co-occurring factors that shape attributions. Kelley identified three factors that help to determine whether people attribute behavior to an internal or external locus. The first factor is consistency, the question is whether or not the person previously behaved in the same way in similar situations. If a person behaves the same way in similar situations, consistency is high. The second factor is distinctiveness, the question is whether or not the person behaved similarly in different situations. If a person behaves differently in different situations, distinctiveness is high. The third factor is consensus, the question is whether or not other people would act the same way in a similar situation. If others would act the same in a similar situation, consensus is high. People are more likely to make internal attributions when consistency, distinctiveness, and consensus are low and external attributions when they are high.

Weiner examined Attribution theory as a way to understand motivation. Weiner (2006) identified three factors that shaped attributions: locus, controllability, and stability. Locus is whether internal or external factors are responsible for the behavior. Controllability is the degree to which the cause of the behavior can be altered. Was the person forced into the behavior or was it done willingly? Though similar, controllability and locus are distinct. As Weiner notes (2006), an external factor can be either uncontrollable or under someone's control and some internal factors are uncontrollable. Hence, we cannot simply equate external for uncontrollable and internal for controllable. Stability is whether or not the cause is stable over time or just temporary.

The initial research in Attribution theory involved attributions as the dependent variable. Researchers tried to determine what factors influenced people making attributions that were dispositional or situational. We see search for what shapes attributions in Kelley's covariance and Weiner's early research. Attribution as an independent variable examines how attributions influence cognition, emotion, and actions. Weiner's own research reflects a shift to attributions as the independent variable. Weiner has examined the role of attributions as they relate to motivation, more recently in a theory of social motivation and justice. For instance, Weiner (2006) examined the effects of attributions on the emotions of sympathy and anger and their related behaviors.

While predominantly a psychological theory, Attribution theory has been applied to the study of communication. A wide range of communication research includes attributions as a variable. However, Attributions theory as a critical component of research and theory building is mostly strongly rooted in interpersonal communication and corporate communication. The communication-based Attribution theory research is constructed around "events." An event occurs, people make attributions, those attributions affect communication, and the communication affects the relationship between the parties. Interpersonal events focus on conflict while corporate events center on crises. Both events are negative occurrences that trigger a search for attributions. Communication research adopted Attribution theory because understanding how people create meaning can be useful when explaining communication behaviors. Attributions influence how people react, how they communicate, and attributions can even be a topic of discussion (Manusov and Spitzberg 2008).

The interpersonal communication Attribution theory research centers on conflict and is applied to the context of communication between individuals. Conflicts are the type of event that can have a significant effect on relationships. How people communicate during a conflict has serious ramifications for their relationship. Interpersonal communication is a broad domain encompassing a variety of different contexts for conflict between individuals. Attribution theory has been used extensively to study the contexts of marriage and intimate aggression and violence (Manusov and Spitzberg 2008).

Corporate communication examines the communication context within and between organizations. Attribution theory has been used extensively to examine crisis communication, a form of communication between organizational actors (management) and the organization's stakeholders. A crisis is an event that violates stakeholder expectations for organizational behavior and is potentially disruptive for an organization. A crisis is a negative event for an organization and its stakeholders creating a perfect trigger for attributions. Negative events are strong motivators for people to seek attributions. People want to make sense of events such as transportation accidents, product harm events, and management misconduct. When people learn about a crisis they will engage in the attribution process.

The attribution process can have significant, negative ramifications for crisis communication and the effect of the crisis on an organization. The attributions stakeholders make during a crisis can alter their relationships with the organization in crisis. Marketing researchers were the first to link Attribution theory to crises. Building upon this connection, Situation Crisis Communication Theory (SCCT) constructed a more detailed understanding of crisis communication premised upon Attribution theory. SCCT translated ideas from Attribution theory to the crisis context and extended upon those ideas. Instead of people, organizations are at the center of the attribution process. People (the organization's stakeholders) make attributions about how responsible the organization is for the crisis.

SCCT was developed to bridge a significant gap in the crisis communication literature. The crisis communication literature is well populated with the lists of types of crises and lists of crisis response strategies, and what management says and does in response to a crisis. However, there was no connection between the lists. A general tenet in much communication research is that the nature of the situation can determine what constitutes effective communication.

Attributions of crisis responsibility serve as the linchpin of SCCT that connected crisis types and crisis response strategies. Crisis managers adjust their communicative responses based upon how people are likely to attribute responsibility for a crisis – how people perceive the situation. Crisis response strategies vary along an accommodation continuum. The strategies vary in how much they accommodate victims of the crisis ranging from denial (no accommodation) to a full apology that accepts responsibility and asks for forgiveness (strong accommodation). Accommodation in part reflects the amount of responsibility the organization assumes with the response. Greater accommodation typically reflects a greater acceptance of responsibility by the organization.

SCCT draws upon Attribution theory to explain and to predict how people will react to crises and crisis response strategies. Crisis managers need to anticipate how stakeholders are likely to react to a crisis. More specifically, crisis managers must understand what attributions of crisis responsibility stakeholders are likely to develop from a crisis. Armed with such insight, crisis managers can select crisis response strategies that will most effectively protect their relationship with stakeholders – minimize the negative effects of a crisis (Coombs 2007). SCCT is premised on two-step process for assessing potential assessments of crisis responsibility based upon research inspired by Attribution theory. The first step is to assess the basic crisis type the organization faces. The crisis type is the frame being used to define the crisis. Each frame will be associated with a specific level of crisis responsibility.

The second step is to determine whether or not any intensifying factors exist. Intensifying factors increase attributions of crisis responsibility. When an intensifying factor exists, stakeholders should view victim crises and accidental crises as intentional. Prior reputation and crisis history are two of the intensifying factors identified by SCCT. Prior reputation is how well or poorly an organization is perceived to have treated stakeholders prior to a crisis. Crisis history is whether or not an organization has had similar crises in the past. By combining assessments of the crisis type and the intensifying factors, crisis managers have a good read on how stakeholders are likely to react to the crisis – the level of crisis responsibility stakeholders are likely to hold.

The level of crisis responsibility suggests the level of accommodation in the crisis response – how much responsibility an organization should accept from the crisis in its communication. Crisis response strategies should vary in how much the organization is perceived to accept responsibility for the crisis.

SCCT posits that as attributions of crisis responsibility increase, the crisis managers must use more accommodative strategies. Two factors mitigate against crisis managers automatically using the most accommodative strategies: (1) cost and (2) low benefit. Increases in accommodation also mean an increase in costs for the organization in crisis. Management may be unable or unwilling to accept the high cost of an accommodative strategy. Using a highly accommodative strategy in a minor (low attribution) crisis may do more harm than good. Over accommodating does not increase the benefits of crisis response and may increase the harm. When an organization overreacts, people begin to wonder if something else might be happening to warrant such an accommodative response.

It should be noted that the reputation repair efforts presented by SCCT are used after the use of a base response strategy. The base response strategy begins with public safety by providing any information stakeholders might need to protect themselves physically from the crisis. This is combined with efforts to help stakeholders cope psychologically with the crisis and include expressions of sympathy and explanations of what is being done to prevent a repeat of the crisis event.

Important Scientific Research and Open Questions

Three early topics that guided Attribution theory research was the fundamental attribution error, actor verses observer discrepancies, and hedonic bias. The fundamental attribution error states that we are more likely to attribute the behavior of others to internal factors but attribute our behavior to external factors. The actor versus observer discrepancy finds actors favor situational attributions while observers favor personal attributions for behaviors. The hedonic bias finds that people attribute success to personal factors and failure to situational factors. These topics reflect the need to understand whether people use an internal or external locus to explain an event. The implications of these three Attribution theory principles are still being explored for their utility in explaining interpersonal and corporate communication.

Attribution theory assumes a rather linear relationship between attributions (cognitions), emotion, and behavior (Weiner 2004). But research questions that linearity. Could it be that emotion precedes attributions or that emotion and behavior are simultaneous? These are important questions that are still open for study.

The research into interpersonal conflicts is interesting. There are three general communication strategies for conflict resolution: (1) avoidance, try not to communicate with one another about the conflict; (2) competitive, try to become the winner in the conflict; and (3) cooperative, try to work together to resolve the conflict. Alan Sillars has found that how people communicate during a conflict is based in part on attributions of blame for the conflict. Cooperative strategies are most likely to be used when the person sees themselves as responsible for the conflict and/or you perceive the other person as cooperative. However, attribution biases work against people seeing themselves as responsible thereby discouraging cooperation. It is unfortunate that attribution works against cooperation because ultimately it is the communication strategy that produces the greatest satisfaction with the conflict outcome and has the most positive effect on relationships. Competitive strategies create escalation and less satisfaction with the conflict outcome.

The marriage context explores the way partner attributions affect the quality of a marriage. Attribution research in relationships has found that non-distressed couples make low-impact attributions about negative partner behaviors. Low-impact attributions are not internal or stable and therefore, serve to enhance the relationship. Distressed couples, on the other hand, attribute partner behaviors to be internal and stable or a distress-maintaining response. When examining violent men, researchers found that they attribute their violence to their wives. In each interpersonal context Attribution theory sheds new light on communication issues by using attributions to better understand the communication process.

The Attribution-bases corporate communication research has found that when people attribute the cause of the crisis to internal factors, high organizational crisis responsibility, they are more likely to view the organization less positively (reputational damage), more likely to reduce purchase intentions, and more likely to engage in negative word-of-mouth. The research supports the belief that attributions of crisis responsibility can have a negative effect on the relationship between an organization and its stakeholders.

SCCT research has shown that the most common crisis types/frames cluster into three groups: (1) victim, the organization is attacked by outside forces such as product tampering, terrorism, or natural disaster; (2) accidental, some technical error created the crisis; and (3) preventable, management purposefully placed stakeholders at risk and/or violated the law. Victim crises have minimal attributions of crisis responsibility, accidental have moderate attributions of crisis responsibility, and preventable have very strong perceptions of crisis responsibility. Crisis managers can use this information to anticipate stakeholder's initial reactions to the crisis/attributions of crisis responsibility.

The SCCT research confirms that prior reputation and crisis history are intensifiers. A negative prior reputation serves to intensify attributions of crisis responsibility while a positive prior reputation has essentially no affect on attributions. A history of crises intensifies attributions of crisis responsibility in a similar fashion (Coombs 2007).

SCCT research has evaluated the primary crisis response strategies for the way stakeholders perceive the degree to which the organization accepts responsibility when using the strategy. The acceptance of responsibility is equitable to accommodation. The three primary groupings of crisis response strategies are denial, diminish, and rebuild. Denial claims there is no crisis or that the organization has no responsibility for the crisis. Diminish seeks to reduce perceptions of responsibility for the crisis and can involve justification and excuses strategies. Rebuild tries to repair the damage done to the reputation and includes both apologies and compensation strategies. Bolstering is a fourth category but is supplementary to the other three and seeks to aid the reputation through reminders of past good works or establishing the organization as a victim of the crisis too. As a supplemental strategy, bolstering should not be used without one of the other three primary strategies.

Research has confirmed the general recommendation that matching the level of crisis responsibility in the crisis response to the attributions of crisis responsibility lessens the threat from a crisis. Research suggests that matching does protect the organizational reputation, reduce anger, protect purchase intention, and reduce the likelihood of negative word-of-mouth. More detailed study of specific crisis response strategies and their effect on post-crisis attributions, reputations, affect, and behaviors is needed. The initial studies have only scratched the surface of these critically important topics.

Cross-References

- ► Attribution Theory of Motivation
- ► Communication Theory

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Attribution Theory of Motivation

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Synonyms

Attributional style; Causal attribution; Causation of behavior; Explanatory style; Locus of control

Definition

Originally, attribution theory was an area of social psychology introduced by Heider (1958). It explains how people *attribute* causes to events and how this cognitive perception affects their motivation. Another important contribution from social psychology is the ► locus of control theory, which is more concerned with individual differences in attributions. A central assumption of both theoretical approaches is the distinction between internal and external loci of causality of good or bad results of behavior. In the 1970s, Bernard Weiner made some important contributions to the attribution theory, adding the dimension of temporal *stability vs. instability* and later that of *responsibility* (or *controllability*), which indicates whether a causal factor of success or failure could be perceived as internal or external to a person.

Theoretical Background

In order to understand the importance of attribution theory for motivation it may be useful to sketch the historical development of motivational theories in the twentieth century. Until the late 1950s, the *reinforcement theory* dominated motivational psychology as well as discussions in educational psychology on possibilities for a targeted influence of learning motivation. In contrast to the mechanistic assumptions of extrinsic reinforcement, some researchers (e.g., Atkinson, McClelland) argued that the study of motivation is concerned with the emotions, cognitions, and environmental influences that cause humans to act or not act on their own behalf or on that of others.

Atkinson and McClelland introduced the construct "need for achievement" (nAch) to research on achievement motivation as an individual motive to do something better, faster, more efficiently, and with less effort. In the 1960s the "expectation × value theory" (Atkinson 1964) became popular. On the one hand, it was used to investigate the characteristics of tasks and, on the other hand, to find out which values and expectations for solving these tasks are relevant for motivation. Values were conceived as important factors of "intrinsic learning motivation." Eccles (1983) distinguished between an *intrinsic value*, consisting in the immediate pleasure one experiences in working on learning tasks, an *attainment value*, consisting in the goal of solving a task in a particular domain which coincides with the needs and expectations of the learner, and a *utility value*, consisting in the learner's estimation of the usefulness of solving a task for reaching a particular goal.

In continuation of the "expectation × value theory," some theorists argued that the level of demand individuals set for themselves in achievement situations is one of the central components of the achievement motive. Specifically, they identified two relatively stable expressions of choice of risk, which Heckhausen (1963) termed *hope of success* and *fear of failure*. The investigation of these expressions of risk was at the core of uncountable studies in the following decades.

They consistently demonstrated that success-oriented people show a clear tendency to seek situations in which they are likely to succeed, whereas failure-oriented people are more likely to avoid achievement situations. A further characteristic of people who are motivated by success is that they tend to set a level of demand which is only moderately higher than their previous achievements and is thus realistic. People who want to avoid failure, on the other hand, usually choose either especially high or especially low levels of demand. By choosing the first option, these people prepare an excuse for themselves which is particularly useful in maintaining self-worth before even having attempted the task, namely that the demands of the task were too high. The other option is even less useful for stabilizing self-worth because success in a task with a low level of demand will not bring much social recognition and failure will only lower the person's self-concept further. In addition, failure-oriented people tend to attribute failure to stable internal factors (such as their lack of ability), while success-oriented people are more likely to look for the reason for failure in variable factors (such as a lack of effort).

These differences between success-oriented and failure-oriented people form the core of the *attribution theory* of motivation developed by Weiner (1972, 1986), which attempts to identify the factors which people attribute to success and failure in achievement situations.

The causes of success and failure named most frequently include ability, effort, difficulty of task, luck, mood, and help or hindrance by others. People usually attribute their success or failure to causes which already played a role in their previous experiences with achievement (in similar situations) or to causes which correspond to social norms. For example, a person who fails an exam that other people had no trouble passing will probably attribute this failure to a lack of ability if he or she has failed similar exams in the past.

Weiner (1986) distinguishes between three causal dimensions of achievement motivation: *locus*, *stability*, and *controllability*. The first dimension has to do with whether a cause of success or failure can be localized within the person or in the particular situation, that is to say, outside of the person, and with whether this cause can be willfully changed. Aptitude and effort are considered as internal factors and difficulty of task and chance as external factors for success or failure. Attribution to internal factors leads to an increase in self-esteem in the case of success and to a decrease in self-esteem in the case of failure, a rule which does not apply in the case of attribution to external factors. The dimension of stability regulates the subjective expectation of success. Initially, it does not make any difference in this dimension whether a cause is internal or external. When a person attributes a positive event to a stable internal cause (such as aptitude), he or she will anticipate success in the future. Correspondingly, when a person attributes a negative event to a stable cause, he or she will anticipate failure in the future. Persistence in the face of failure increases when it is possible to attribute the failure to instable causes such as a lack of effort or bad luck. This statement makes it evident that the dimensions of localization and stability are interrelated in a special way. In accordance with Weiner's argumentation this relationship can be illustrated in a four-field schema (Table 1):

Included in this schema is the dimension of controllability, which is associated with numerous emotions (such as anger, guilt, compassion, shame). When someone is hindered from succeeding by factors controlled by others (e.g., noise, interruptions), it is almost inevitable that he or she will become angry. Feelings of guilt can become a factor, even in the case of self-attribution, when someone fails to fulfill a social agreement due to internal, controllable causes (e.g., a lack of effort or carelessness). Shame and embarrassment often arise when someone fails due to internal and uncontrollable causes (such as a lack of aptitude). A person who attributes success to external factors will show compassion and sympathy for a person who does not reach the same goal due to internal, uncontrollable factors (e.g., a lack of ability, physical constraints).

These emotional states also serve as attribution hints. If, for example, a teacher expresses compassion and sympathy upon the failure of a student, this

Attribution Theory of Motivation. Table 1 Schema of causal attribution (Adapted from Weiner 1972)

		Locus of control	
		Internal	*External*
Stability	*Stable*	Ability	Task difficulty
	Variable	Effort	Luck

student will tend to attribute the failure to a low level of abilities. On the other hand, if the teacher sends an emotional message of anger, the student will be encouraged in the belief that he or she did not put in enough effort. The various emotional reactions serve as motivational incentives, i.e., they suggest various actions: Compassion with others leads a person to provide help and bestow praise, whereas anger produces a lack of regard or even punishment when someone else is in need. Shy students can usually expect more help from their teacher than aggressive or hyperactive children, partly because shyness is seen as being less controllable than aggressiveness. Teachers often react to students who do not make any effort and do not try out anything by getting angry and giving them poor grades. Students who are seen as capable but fail due to a lack of effort (so-called ▶ underachievers) are often punished. On the other hand, students with low abilities who put in a lot of effort and are successful (so-called overachievers) are praised and rewarded. Guilt and shame also have motivational effects. Guilt encourages goal-directed activities, while shame tends to have a negative effect on motivation.

Important Scientific Research and Open Questions

For decades, the attribution theory has probably been the most influential theory on academic motivation and achievement motivation. Accordingly, the attribution theory of motivation has been studied in countless studies that demonstrate not only the theoretical power of the postulated explanatory styles of causal attribution: Study after study showed that the way in which people explain successes and failures in their lives is related to whether they attributed them to internal or external factors and whether these factors are stable or variable (see, for instance, Graham and Folkes 1990). A good overview of research on the attribution theory of motivation can be found in Weiner (1992) and other sources.

The attribution theory forms the basis of recent theories of motivation with relevance for school learning. Some of these theories, including the theory of self-worth, the theory of self-efficacy, and the theory of "learned helplessness," operate with constructs that refer either to the self-perception of ability or the goal orientation of learning. A second group of theories works with the constructs "task vs. ego involvement," "intrinsic vs. extrinsic motivation," and the pursuit of "cooperative vs. competitive goals."

Cross-References

▶ Achievement Motivation and Learning
▶ Confidence Judgments in Learning
▶ Learned Helplessness
▶ Motivation and Learning: Modern Theories
▶ Motivation, Volition and Performance
▶ Self-Determination and Learning
▶ Self-Esteem and Learning
▶ Self-Regulation and Motivation Strategies

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Attributional Style

▶ Attribution Theory of Motivation

Audiation

A cognitive process by which the brain gives meaning to musical sounds. Audiation takes place when a person hears and comprehends music for which the sound is no longer present or may never have been present. It is possible to audiate when listening to music, performing from notation, playing "by ear," improvising, composing, or notating music.

Audio-Video-Redundancy in Learning

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Synonyms

Auditory-visual consistency/consonance; Auditory-visual dissonance

Definition

Audio-video redundancy is a term that is applied to messages that include both audio and visual information. Usually, the audio information is spoken language information rather than natural sounds or music. Visual information runs the gamut from still pictures or text to moving pictures, scrolling text, etc. Audio-video redundancy refers to the extent to which the audio and video channels contain the same or different information.

Theoretical Background

Research in this area has focused primarily on television messages though there is also some information looking at computer-based instructional material (Drew and Grimes 1987; Grimes 1990). The question of whether and how increasing audio-video redundancy improves learning of message content is complex and to some extent depends on the context. In general, most research in this area uses some kind of limited capacity processing model. In these models, the ability to learn from the message requires that the message be selected and that sufficient resources be allocated to it for the information to be learned. Messages which are more complex require more resources to be processed. Within this context, the complexity of the audio, the video, or the combination of the two is considered.

In general, the level of redundancy is conceived to be a continuum from exact duplication, usually referred to as redundant, (e.g., in the audio channel a voice says a word, for example, "dog," and in the video channel, there is a picture (still or moving) of a dog) to conflicting, defined as there being no relationship between the information in the audio and visual channels (Grimes 1991; Lang 1995). In between these two extremes are various positions including: (1) thematic redundancy, which occurs when the information in the visual channel is only thematically related to that in the audio channel (e.g., the audio channel information is about progress moving a specific bill through congress and the audio channel shows pictures of the capitol, the American flag, and the house and senate chambers); (2) semantically related, which occurs when the audio and video channel are about the same thing but not duplicative (as in the redundant condition) (e.g., the audio channel is about that day's debate in the house and the video channel shows stock footage of the house in session – but not of that day's debate).

A great deal of research has also considered the case of "talking heads," defined as a person talking on camera (in the visual channel) and what they are saying (which could be anything from how to do algebraic equations to the latest prices to visit the pharoah's tombs in Egypt) makes up the information in the audio channel. While this is clearly an extremely natural occurrence that happens all the time – it is not clear where it stands on the audio-video redundancy continuum. Recent research, however, suggests that talking head messages require very few resources to be processed and that both the audio and the video information contained in them tend to be well-remembered – though not as well-remembered as completely redundant audio and video information.

In general, research suggests that more redundant messages require fewer resources to process than less redundant messages. Memory for information in the audio channel decreases with decreasing redundancy. Memory for video information fares somewhat better as audio-video redundancy decreases. Indeed, when audio-video redundancy is very low – or the channels actually conflict – the messages tend to be too complex for thorough processing and, as a result, only one of the channels is processed. In many cases, research suggests that, when this occurs, it is the video channel that will be better processed, perhaps because the video channel tends to be more dynamic and, when it carries unrelated information, it actually distracts viewers from the audio message.

However, several contextual variables play a role in the outcome, including whether or not the learner has control over message presentation (can they stop and start, rewind, etc.), the extent to which the learner is motivated to learn the information (are they watching the message to learn, to be entertained, etc.), and the extent to which the information relevant to the learner is contained in one or both channels. Having control over the message reduces the impact of message complexity variables on processing. If the learner can stop the message, play it over again, and pause for reflection – then learners can use these tools to allow themselves to keep up with even very complex messages. Similarly, one person's complexity is another's simplicity. Reduced audio-video redundancy can increase interest and engagement for learners who are already familiar or expert in the topic or motivated to learn by introducing more information at any given time. But, that same format will result in cognitive overload and reduced learning for the novice or unmotivated learner. Thus, when the information contained in a message is thought to be difficult for the audience, it is best to maintain a high level of audio-video redundancy. However, when information is familiar – or review – less redundancy may be a useful strategy to maintain interest.

It is also worth noting that audio-video redundancy varies over time during television and computer-based messages. At some points in time, messages may be extremely redundant while at other points in the same message, there may be little or no redundancy in information. Thus, producers of messages can increase redundancy at points in messages when they wish to maximize memory for the information and reduce redundancy at other times to increase interest or motivation. Research suggests that redundancy at a given time point primarily affects memory for the information occurring at that time and does not greatly impact the preceding and following time periods.

Finally, the impact of the level of audio-video redundancy is also greatly dependent on the structural complexity of the audio and video channels. In addition to carrying conceptual information, each channel of information can also be described in terms of the complexity of its presentation. Among the variables to be considered here are speed of presentation (audio of video), the presence of sound effects, camera techniques, and the like, as well as the sheer number of sources of information available per channel at a given time (number of voices, or audio sources in the audio, number of objects and their movement on the screen). When the individual channels are structurally complex, then reductions in redundancy severely reduce memory for the information contained in the messages.

Important Scientific Research and Open questions

Most research on audio-video redundancy has been done looking at television news and information programming – as opposed to actually looking at educational material. In general, during news programming, the important information is contained in the audio. Often the video information is complimentary at best and is chosen primarily to maintain audience interest in the message (to boost ratings) rather than being selected to improve processing of the audio message. Much less research has been done on messages that actively seek to create visuals that specifically illustrate or complete the audio messages. Some research has been done looking at how appropriate 3-D animations presented simultaneously with verbal descriptions influence message processing. In these cases, it was found that expertise of the audience and structural complexity of the message play pivotal roles. If the audience has some familiarity with the area or the structure is simpler, simultaneous redundant animation improves understanding and memory; however, if the structure is complex or the audience is not familiar with the area, it reduces memory (Fox et al. 2004).

Recent research has also begun to look more closely at channel selection in the case of cognitive overload. While a great deal of research has suggested that when the audio redundancy is very low, people tend to give up on the audio channel and shift their attention to the video channel (Grimes 1991), some research has begun to suggest that structural properties of the two channels may play a role in the direction of the shift and future research will need to be done to determine which factors influence attentional shifts toward the audio or toward the video channel.

Cross-References

► Attention, Memory, and Meditation
► Cognitive and Affective Learning Strategies
► Cognitive Learning Strategies for Digital Media
► Cognitive Load Theory

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Audio-visual (AV) Aids

Materials that use sound or vision to present information; AV aids are the building blocks of AV learning. They may take the form of presentation slides, multimedia programs, video and sound recordings, etc.

Audiovisual Learning

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Synonyms

Bi-sensory learning; Media learning; Multimedia learning

Definition

Audio-visual (AV) learning is a type of learning which is described by delivery and the use of instructional content that involves sound (auditory stimuli) and sight (visual stimuli). AV learning takes place when the instructional process is accompanied by AV learning aids such as handouts, flip charts, transparencies, whiteboards, illustrations, still and motion pictures, slide shows, television, videos, audiotapes, records, projectors, computer graphics, multimedia, physical objects, and 3D models. AV learning can appear when an instructor's verbal presentation is reinforced with a series of images or slides or as a self-standing instructional practice consisting of an instructional movie or virtual reality simulation. The above-mentioned ► Audio-visual (AV) aids have different levels of complexity and are commonly used to enhance learning and instruction by improving comprehension, retention, and transfer.

Theoretical Background

The history of AV messages goes back to 10,000–15,000 BC, when prehistoric humans painted images discovered on the walls of caves in modern-day France, or 3,500 BC, when the first roots of music were developed in Mesopotamia. Another significant achievement for AV learning is Johann Gutenberg's invention of movable type in 1450, which enabled the extensive production of documents. Several centuries later in 1658, John Amos Comenius presented to the world the first children's encyclopedia – Orbis Sensualium Pictus ("The Visible World in Pictures"). Often credited as being the first highly structured textbook, it included more than a hundred chapters covering botany, zoology, humans, religion, etc., and was illustrated with pictures, which played an important role for children's learning and instruction.

An important step for AV development in the history of modern instructional technology was the elaboration of silent visual ► media, which includes illustrations, slides, study prints, photographs, figures, charts, and so on (Dale 1969). In 1910, the first silent instructional film was adopted for instructional purposes and presented with a motion picture projector (Reiser 2002).

Driven forward by new media technologies, AV learning and education has developed rapidly since the early 1920s, when the radio was invented. Radio was often used to present various types of educational task, bringing dramatic feelings to the classroom and fostering the imagination of learners (Dale 1969). In 1926, the first full-length motion picture with a synchronized soundtrack (Don Juan) was released.

After the successful synchronization of sound and motion pictures, AV aids were in high demand. During and after World War II, there was an increased interest in media use for learning needs. Research has shown that during this period AV aids were used effectively to reinforce learning processes and strengthen retention, thinking, interest, motivation, and imagination (Allen 1956).

The benefits of motion pictures for learning were soon described by researchers, such as the ability to create reality, enhance attention, and reinforce learners' understanding of abstract concepts and relationships (Dale 1969). The advent of television followed in the 1950s. Instructional television raised much interest and expectations, as evidenced by a score of instructional TV channels in these years. Dale (1969) stresses the importance of instructional television for demonstration in a classroom setting, keeping and concentrating attention, and speeding up and enhancing learning processes in classrooms.

The development of personal computers since the late 1970s brought about a new surge in AV learning with multimedia technology. Computer-based multimedia learning consists of pictures and words in different mediums, such as text, narration, animation, sound, video, etc. (Mayer and Moreno 2002). One of the main strengths of multimedia is that it presents a potentially rich and powerful method for stimulating and improving students' understanding (see also ▶ Computer-Based Learning and ▶ Multimedia Learning in this Encyclopedia).

The development and growth of the World Wide Web (WWW) and the Internet in the 1990s marked a new era of communication, which had immediate impact on the richness of AV learning. Totally new forms of multimedia instruction like e-learning (see also ▶ E-Learning in this Encyclopedia) have created many new possibilities and opened up new horizons in education. E-learning provides new possibilities for media delivery, promotes a learner-centered environment, motivates learners, and can make learning experiences unique, convenient, and exciting.

To sum up, several important features of AV learning aids should be stressed. In modern instructional settings AV aids are used to maintain high levels of interest in learners and to promote active learning, involvement, self-control, and participation in learning activities. Another advantage of modern AV learning is that it brings realistic settings to the classroom and is at the same time easier to use and more affordable than real objects or real-life learning settings. Audio-visual devices and media can bridge the gap between socio-economic barriers, disseminate learning and instruction across large areas, expand educational possibilities, and give more people a chance to learn.

Still, the general principle and function of AV learning and education is representation: AV learning does not actually reflect the world and real-life settings but rather represents them.

Important Scientific Research and Open Questions

High-quality AV learning has a strong theoretical basis in the cognitive paradigm of learning and the ways in which people learn from words and pictures. People have two separate channels for visual/spatial and auditory/verbal information processing (Paivio 1986; Baddeley 1999). Pictures are conveyed via the eyes and are later processed in the visual/pictorial channel, while spoken words heard by our ears are processed in the auditory/verbal channel (see also ▶ Dual-Code Hypothesis in this Encyclopedia). Another notion is the limitation of the capacity of auditory and visual working memory systems (Chandler and Sweller 1991). Humans are able to actively process only a limited amount of information using each channel at any one time (Baddeley 1999). In cases in which a lot of pictures, videos, or other visual materials are presented at once, the visual/spatial channel can easily appear to be overloaded. In the same way, the auditory/verbal channel can become overloaded when a lot of spoken words, sounds, etc. are presented at the same time. Finally, meaningful learning occurs when people receive relevant information, mentally organize the information in a coherent representation, build connections between visual and verbal representations, and mentally integrate it with other prior knowledge (Mayer and Moreno 2002).

These notions lead researchers to assume that students learn more deeply through multimedia explanation than verbal explanation only. This means that it is more effective to use words and graphics together to present content than it is to use just words. This is known as the multimedia or modality principle. It was illustrated by Mayer (2005) in a series of experiments and is often used for advanced multimedia learning.

Technology has been integrated into education, and the development of AV learning follows the track and stages of technology and media development. AV learning changes its face with the progress of electronic communication systems, IT, and telecommunications. Each technological advancement leads to corresponding improvements in educational and learning capabilities and advantages. Methods and instruments used in human relations, mass media, and entertainment are transferred to the field of corporate training, K-12, higher education, and other educational settings. AV learning can appear on the TV screen, PC or notebook monitor, PDA and mobile phone display, interactive whiteboard, as a multimedia projection in the classroom, or via any other visualization tool.

It is important to realize that AV aids and AV learning are used only to supplement training and development. They are used to clarify, enrich, and strengthen instruction. Nevertheless, instructors, teachers, and tutors are still the main actors in the learning process, and the chosen instructional methods should thus dictate the type of instructional media used (AV media in particular), not vice versa.

Another open issue is the conflict between the instructor/teacher and learning media, AV learning media in particular. Currently the situation is becoming more optimistic: Mass usage of technology in society leads to its more frequent and correct use in instruction, particularly by younger teachers/instructors, for whom the new technologies are often second nature. However, there is still a gap in the "teacher–technology" relationship. This may be explained first of all by teachers' unawareness of AV technologies and their advantages. Secondly, some educators are afraid of new experiences; they are not able to master the AV technology and thus lose control of the learning process. Finally, some teachers are afraid that technologies (especially new technologies) might completely replace them and their instructional methods.

At the same time, the learners' experience and expertise, familiarity with computers, and affinity toward technologies can also influence the final effectiveness of AV media and AV learning and should always be taken into account.

Finally, the benefits and effectiveness of AV learning depend on the interrelations between the features of AV aids, the characteristics of the learners, and the demands and desired outcome of the specific learning task.

Cross-References

► Computer-Based Learning
► Dual-Processing Models of Information Processing
► e-Learning
► Multimodal Learning Through Media

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Audio-Visual Learning

► Multimedia Learning

Auditory Affective Verbal Learning

► Effects of Anxiety on Affective Learning

Auditory-Visual Consistency/ Consonance

► Audio-Video-Redundancy in Learning

Auditory-Visual Dissonance

► Audio-Video-Redundancy in Learning

Aural Learning

Of or related to the ear or to hearing. Aural learning in music takes place through listening. Aural exercises in music are designed to train the ear.

Ausubel, David P. (1918–2008)

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Life Dates

Ausubel was born on October 25, 1918 and grew up in Brooklyn, New York. He studied psychology at the University of Pennsylvania, where he graduated in 1939. He then studied medicine at Middlesex University, where he completed his degree in 1943. During his military service with the US Public Health Service, Ausubel was assigned to the United Nations Relief and Rehabilitation Administration in Stuttgart, Germany, where he worked with displaced persons. Afterward he worked with the US Public Health Service in Kentucky, the Buffalo Psychiatric Center, and Bronx Psychiatric Center. Following his military service he earned a PhD in Developmental Psychology from Columbia University in 1950. Then he served as professor for educational psychology at the University of Illinois, the University of Toronto, and in Europe at the University of Berne (Switzerland), as well as at the Salesian University at Rome and the Federal Armed Forces University at Munich, Germany.

In this time, Ausubel became one of the most influential educational psychologists. Nevertheless, in 1973, Ausubel retired from academic life and devoted himself to his psychiatric practice. At the age of 75, Ausubel retired from professional life. He published 26 textbooks on developmental and educational psychology as well as on specialized topics such as drug addiction, psychopathology, and ego development and more than 150 original articles in psychiatric and psychological journals. In 1976, he received the Thorndike Award from the American Psychological Association for Distinguished Psychological Contributions to Education. He passed away in New York on July 9, 2008 (http://keyserfuneralservice.com/obituary_view/53787).

Theoretical Background

Ausubel was widely influenced by Jean Piaget and contributed much to the development of cognitive learning theory. Ausubel's work has frequently been compared with Bruner's work (Ausubel 2000). The two held similar views about the hierarchical nature of knowledge, but Bruner was strongly oriented toward discovery processes, whereas Ausubel focused on meaningful verbal learning and the assimilation theory of information processing. He was primarily concerned with the acquisition and development of new concepts, but he also focused on transfer of learning as well as on motivational aspects of learning (see, for example, Ausubel and Robinson 1969).

Based on his subsumption theory of concept learning, Ausubel derived some prescriptions on how to design effective instruction. Sometimes this is called "expository teaching." Ausubel developed this teaching method immediately on the basis of the theory of meaningful verbal learning. In accordance with the assimilation theory of learning, Ausubel argues that it is economical to assimilate or subsume new information into already organized cognitive structures because it facilitates the retainment of stable and anchored concepts rather than isolated facts and events. This so-called obliterative assimilation contains two kinds of subsumption: a *derivative subsumption* (i.e., a deductive way of deriving subordinated concepts from superordinate concepts) and a *correlative subsumption*, which includes learning of new concepts.

In order to counter obliterative assimilation effectively through derivative or correlative subsumption, Ausubel explored various consequences for organizing teaching and learning processes for school children (Ausubel and Robinson 1969). He summarized the consequences as follows: (a) The learning tasks consist of verbal material which is organized by the teacher in such a way that obliterative assimilation is stopped. (b) The learning activity of a student consists in identifying the meanings contained in the material to be learned and integrating them permanently into the cognitive structure. (c) The existing cognitive structure must provide an adequate amount of anchors to enable the pupil to integrate new concepts in the long term. A method for ensuring that such anchors are available is the technique of providing advanced organizers. The instructional method of expository teaching remains unique today.

Contribution to the Field of Learning

Some educational psychologists believe that Ausubel's most notable contribution for classroom application was the introduction of advance organizers (Mayer 1979). However, Ausubel's contributions to the field of learning are more far-reaching than this, because not only did he contribute essentially to a new understanding of meaningful verbal learning but also to a basic understanding of learning and forgetting, discussed in terms of the *assimilation theory* of information processing in accordance with Piaget's epistemology. Furthermore, Ausubel was also centrally concerned with the various kinds of transfer of learning as well as with motivational conditions of school learning. The textbook *School Learning* by Ausubel and Robinson (1969) is still considered to be one of the most comprehensive and theoretically sound contributions to the field of school learning (and beyond).

Cross-References

► Advance Organizers
► Assimilation Theory of Learning
► History of the Science of Learning
► Meaningful Verbal Learning

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Authenticity in Learning Activities and Settings

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Synonyms

Learning through practice; Situated learning

Definition

The concept of authenticity in learning activities and settings refers to those activities that comprise the purposeful exercise of culturally derived practices in settings where they are ordinarily enacted. Most often, and contemporarily almost always, the term authentic activities refer to paid work (i.e., occupational) activities; and authentic settings refers to the workplaces in which those activities are enacted, and which act as sites for engaging in and learning the knowledge required for a specific occupational practice. However, students' classroom experiences are also authentic in terms of the cultural practice of educating through school activities and school settings.

Theoretical Background

Interest in authenticity in learning activities and settings has strengthened in the last few decades in response to at least three distinct concerns: conceptual dissatisfaction with explanations of learning emphasizing individuals' cognitive processes alone; a need to account for the situated contributions to cognition and human performance; and procedural concerns about the lack of adaptability or transfer of knowledge learnt in educational institutions. Here, these concerns are used to discuss the contributions of authenticity of learning experiences and settings.

Conceptually, accounts of the learning process need to go beyond explanations provided by cognitive psychology, which tend to privilege individuals' contributions to learning, in particular their current knowledge and the capacity to manipulate knowledge, as underpinning cognition (i.e., thinking, acting, and learning). Instead, accounts of cognition needed to include the contributions to thinking, acting, and learning provided by the physical and social settings with which individuals engage. These contributions have long been identified within early psychological accounts and anthropology, and were particularly advanced in considerations of learning through the ecological psychology and cognitive anthropology movements of the late 1960s and 1970s. Seminal work advancing the salience of the physical and social settings to cognition include Barker's (1978) account of ecological psychology, Rogoff and Lave's (1984) accounts of learning through everyday activities, and Lave and Wenger's (1991) account of learning through participation in situated practice (i.e., communities of practice). The ecological psychologist Barker (1978) proposed that setting and behaviors are linked and cannot be dismissed as being merely random (i.e., not probabilistic). He concluded that physical and social environments consist of structured, highly organized phenomena that are not passive or without causal impacts. Instead, these environments are arenas for events, and causal relations exist between the environment and human cognition. Barker went as far to suggest that in terms of cognition these settings are deterministic (i.e., they determine what individuals learn through their engagement with these socially derived environments). Rogoff and Lave (1984) captured the contributions to cognition of purposeful everyday activities in social settings by similarly suggesting that "activity structures cognition": the socially derived activities in which we engage shape how we think, act, and learn. Rather than just the internal processes of the mind, as emphasized in cognitive accounts, the socially derived goal-directed activities in which we participate shape our cognition. So, there is a cognitive legacy – learning – arising from engaging in activities, and this legacy is socially sourced. This is perhaps not surprising, because the goals for the activities in which we participate and the process we adopt to secure those goals are often social in origin, and we are assisted in that process by socially derived forms and practice. Hence, there are strong social sources to the things we do, and for what purposes and how we do them, albeit at work, in school, or when parenting, for example. These social contributions are also important because much of the knowledge we need to learn arises in the social world and we need to access that knowledge to perform socially derived roles such as when working, studying, or parenting, to reuse those instances. Hence, when seeking to secure particular kinds of learning, access to activities that are authentic in terms of the knowledge required to be learnt become important. Moreover, authentic activities and settings also support this learning process through the provision of clues and cues that assist in identifying both the goals for learning and the means by which activities progress and outcomes (i.e., learning) are secured.

The standing of authentic activities and settings was supported through Lave and Wenger's (1991) account of communities of practice in which participation in socially situated practice supports collaborative learning. More than mere participation in a social practice, learners' capacities and interests to engage effectively (i.e., to observe, listen, approximate observed tasks, and reflect upon those approximations) and the contributions and guidance of more expert partners is central to maximizing learning through engagement in authentic activities and settings. Following eras when mainstream views about learning had been dominated by behavioral and highly individualized cognitive accounts, the acknowledgment of the contribution of physical and social settings to human cognition was seen as a means of addressing limitations identified in these accounts. In particular, these new accounts granted agency to contributions to learning from beyond the person. Cognitive properties came to be regarded as being embedded in physical and social contexts, rather than just in isolated minds. Indeed, the importance of inter-psychological processes (i.e., those between the personal and social experience) came to the fore here. As a result, the process of learning has gone beyond a purely cognitive process to emphasize relations between the person thinking and acting (and learning) and the social and physical world in which they act and are located.

The potency of the authenticity of experiences for securing the knowledge or practices that are intended to be learnt is threefold. Firstly, the physical and social setting provides contributions that are not substitute or artificial; rather, they can represent genuine artifacts, informed interlocutors and situationally pertinent social forms. Through engaging with purposes, processes, and settings that are culturally authentic, it is possible for individuals to access and utilize situationally pertinent knowledge, as long proposed by anthropology (e.g., Pelissier 1991). Secondly, engagement in authentic settings and activities gives access to understand the situational requirements for performance, including the situated culture of practice and practicing. Highly abstracted forms of knowledge (i.e., canonical occupational knowledge) or problem-solving processes (i.e., general heuristics) are unlikely to be effective for responding to situationally derived problems, as the expertise literature demonstrates. Following from this and thirdly, the adaptability of the knowledge that has been learnt is premised upon its discernible applicability to particular situations. That is, situational factors shape performance requirements, which cannot be understood or responded to effectively without knowing about these requirements. However, individuals need to understand those requirements through access to them. As enacted activities and sites of enactment, authentic activities and settings furnish particular and salient contributions to human cognition. In different ways, these contributions to learning suggest that, rather than individual factors alone (i.e., capacity to manipulate knowledge), setting, activities, and artifacts also play a key role, particularly in tasks that require higher-order knowledge.

Such advances have been particularly buoyed by concerns that what is learnt in educational institutions is limited in its application in "real world" settings beyond those institutions. As links between national economic and social well-being and educational outcomes have heightened, and accountability for national investment in education has increased, so have concerns about the efficacy of learning in and through educational institutions. Concerns about the lack of applicability of domain-general knowledge (e.g., maths) and the lack of workplace-ready occupationally specific outcomes of educational programs in vocational and higher education, both of which are increasingly focusing on occupationally specific learning outcomes, have and continue to sustain broader interest in the provision of authentic experiences and settings. Specifically, the limited applicability of school-learnt knowledge has motivated much of the institutional (i.e., government and industry) interest in authentic experiences and activities. In essence, schools and schooling experiences are seen as hybrid (i.e., inauthentic) spaces whose physical and social contexts are remote from the circumstances in which the knowledge students learn would need to be applied outside schooling. To address these concerns, schooling experiences (i.e., activities and interactions) are being shaped to either find or create authentic instances of the targeted cultural practices (e.g., occupations in workplaces). Moreover, the interest in authenticity of learning experiences and settings has promoted the need for pedagogies and curriculum models that reflect the use of practice-based activities and the contributions of settings in which the practice occurs. For instance, Lave's (1990) concept of a learning curriculum and Rogoff's (1995) concept of guided participation as a pedagogical practice are examples of accounts that acknowledge the potential of learning through authentic settings and activities need to be advanced. An important outcome of the interest in situationally authentic experiences within higher and vocational education is that these experiences are now being seen more as legitimate and worthwhile settings for learning in their own terms and not just places to practice and refine what has been learnt in educational settings. In contemporary terms, this consideration of authentic settings and experiences is most noticeable in practices within higher education that aim to integrate students' experiences across both practice and educational settings.

Important Scientific Research and Open Questions

A range of scientific questions arise from this sustained interest in authentic activities and interactions. Firstly, little is understood about what kinds of learning outcomes are realized through authentic activities and settings. The usual assumption is that procedural outcomes (i.e., how to do things) are most likely realized, although this is unhelpful because conceptual and dispositional outcomes have been identified as well as procedural outcomes (Billett 2003). Secondly, there is a range of limitations as well as contributions from learning through authentic practice-based experiences. Hence, goals for and processes of effectively integrating these experiences with others (e.g., those in educational institutions) to both augment and redress the limitations need to be more clearly understood. It follows that there are important procedural questions about the extent and use of pedagogic strategies in socially authentic activities and settings. There is a tradition of providing augmenting socially authentic experiences in order to secure the kinds of knowledge that need to be learnt (i.e., the use of shells and stones to assist Micronesian fishermen learn the star patterns by which they navigate [Pelissier 1991]), and the growing use of simulators that are physically and socially inauthentic, but are experienced as authentic, and provide experiences beyond what can reasonably be advanced through authentically flying a plane, for instance. Consequently, greater scientific effort is required to understand the particular contributions to knowledge arising through engagement in authentic activities and settings; how these contributions can be maximized through appropriate models of pedagogy and curriculum; and how these contributions can be most effectively integrated with learners' experiences in educational programs and settings. The assumption is that a combination of these experiences is required, but what that combination comprises and how best it might be realized remains to be more fully understood.

Another key question is how authenticity can be understood as a personal practice. That is, in what ways is experience deemed authentic to the learner? At one level, this concern has much to do with the significance of what is experienced to the individual and the engagement of their interest, intentionality, etc., that is, is the authenticity of experiences given to, or constructed by, individuals.

Cross-References

► Guided Learning
► Workplace Learning

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Authenticity in Music

In presentation of multicultural music in music learning environments: the accuracy of the link between a music and its representative culture; the accuracy of presentation of a music according to its representative cultural tradition.

Authoring Tool

This is a software package which is to build Courseware like programming language, but easier. It also decreases the build time. It is famous for Toolbooks, Lectora, Authorware, and Director. It can be an authoring tool such as Flash and Dreamweaver which supports authoring on the web.

Authoring Tools

► E-Learning Authoring Tools

Autism Spectrum Disorder

A pervasive developmental disorder characterized by deficits in three distinct domains: communication, social interaction, and repetitive and restricted behavior.

Autistic Psychopathy

► Diagnosis of Asperger's Syndrome

Autistic Thinking

► Magical Thinking and Learning

Autoassociative Memory

► Associative Memory and Learning

Autobiographical Memory

Memory for one's own personal events or personal history. In cognitive psychology, autobiographical memory is considered as a memory system that consists of episodes of an individual's life (Williams et al. 2008). It is conceived as a combination of episodic memory (i.e., personal experiences at particular time and place) and semantic memory (i.e., the fact knowledge about the world).

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Automated Learning Assessment and Feedback

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Synonyms

Automated testing; Student modeling

Definition

Automated learning assessment measures the formative success and effectiveness of teaching by testing students' skills, opinions, values, and knowledge. Testing is often done with simple classroom quizzes and essay questions or objective forced choice instruments, but these are much weaker and less informative than assessments based on model tracing, misconception analysis, knowledge organization, or any of a broad range of statistical and neural network techniques that recent research is creating.

Theoretical Background

Effective assessment lies at the heart of effective teaching and learning, but it is all too often superficial and inadequate because, as the development of intelligent tutoring systems has clearly demonstrated, assessing students' state of knowledge so that feedback and instruction can conform to the zone of proximal development is fraught with enormous difficulties. All too often teachers simply do not have the time or resources to individualize tests or go beyond the simple assessment of facts. Furthermore, the range of misconceptions and errors students can make is so broad that it lies outside the range of knowledge and skills teachers and experts may possess. Automating assessment appears to be the only way that progress in this area can reasonably be made. Not only does automation reduce the time and resources required by teachers, it offers the benefits of repeatable, immediate individualized feedback to students and to teachers.

Important Scientific Research and Open Questions

In certain areas, automated assessment is well established and practical. In domains that are logical and unambiguous, such as programming, algebra, or geometry, a broad range of technologies from such simple stuff as mark-sensing optical readers can be used all the way to more complex technologies of model tracing tutors. Combined with large databases of reusable questions, automated assessment can be very effective. Model tracing tutors based on cognitive models such as adaptive control of thought (ACT) in unambiguous domains are based very effectively on detailed, fine-grained assessment and can cover very high proportions of all student errors. In order to do this, they monitor student actions at a keystroke level and detect errors with a very fine grain of detail. The downside of this is that students never are allowed to progress along their error paths to discover the consequences of their errors. However, on ambiguous domains such as history or English composition or criticism, this approach tests only factual and superficial aspects of instruction and fails to inspire creative thinking and imagination. For these domains, the fundamental problems of semantics and language have proven to be much more difficult stumbling blocks, but even here some real progress is being made.

Situated tutors provide scenarios that act as real problem solving situations (situated judgment tests) and so integrate assessment into the instruction. Assessment is not just a set of tests at the end of the scenario, but is instead embedded in the scenario or simulation by monitoring student actions and interactions. These tutors are required to record, track, and interpret student actions, but unlike model tracing tutors, assessment is at a coarser grain of detail and deals with higher order plans, explanations, and predictions. Situated tutors can provide the scenarios through high-fidelity simulations such as virtual reality or low-fidelity simulations such as video and pictures or even short paragraphs of text. Because of the broad character of the problem sets in these ill-defined scenarios, where no absolute measure of correct or incorrect answers exists, unique assessment tools have had to be developed, including survey – like instruments of Likert rating scales and consensus-based assessments in which the standard of measurement is either the consensus of experts or the consensus of the learning students themselves. Natural language processing and statistical analysis of written responses using tools like latent semantic analysis also can provide a kind of consensus-based assessment.

The consensus of peers can also be used in social interaction to provide student feedback and monitoring as an effective assessment tool. Social interaction tutors can provide tools that structure collaboration and make that structure visible in graphs and networks, either face to face in classrooms or distributed across the Internet. More frequently, peers and tutors are represented as technological agents that guide and structure as well as monitor inquiry, with the capability of presenting visual graphs and multimedia. These agents are often based on machine learning and natural language technologies such as Bayes classifiers that analyze students' preferences and knowledge states. Within the domain of physics, mixed initiative dialogs have proven successful in guiding and interpreting student problem solving. In these systems, formal languages are used to represent knowledge in structured ontologies. Students' written responses are analyzed for strengths, errors, and misconceptions. Statistical and knowledge-based natural language tutors are growing in power by leaps and bounds and provide the best hope of empowering teachers and students with continuous assessment and feedback in the future.

Cross-References

► Adaptive Control of Thought (ACT)
► Preconceptions and Learning

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Automated Testing

► Automated Learning Assessment and Feedback

Automatic Encoding

► Cognitive Automatisms and Routinized Learning

Automatic Information Processing

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Synonyms

Involuntary information processing

Definition

Automatic information processing refers to a mental cognitive process with the following characteristics: it is fast, parallel, efficient, requires little cognitive effort, and does not require active control or attention by the subject. This type of processing is the result of repetitive training on the same task. Once learned, an automatic response is difficult to suppress, modify, or ignore. Automatic information processing is used for skilled tasks and is considered to be the opposite process to controlled information processing.

Theoretical Background

During the 1950s the field of cognitive psychology focused on the capacity limits of human information processing, such as how the brain treats incoming information (stimuli). In 1958, the British psychologist Broadbent introduced a significant model of information processing and was one of the first to draw a distinction between automatic and controlled processes. Automatic processing was later defined by Posner and Snyder in 1975 to be an unconscious and unintentional process, whereas controlled processing requires conscious intention. This view was redefined by Schneider and Shiffrin in 1977 and has since been supported by convincing evidence, and thereby kept its relevance during the decades. In the "dual-process" information processing model of Schneider and Shiffrin, a distinction between "automatic detection" and "controlled search" emphasizes two fundamentally different human information processing operations. According to this view automatic processing is parallel, fast, and a result of repeated training on a task, whereas controlled information processing is slow, serial, limited, and effortful. When learning a new skill, such as learning to walk, controlled processing is required and becomes more automatically processed as the skill is increasingly mastered. For example, learning how to read is initially effortful and requires extensive cognitive capacity. Gradually, reading training will change the information processing to a more automatic process. A novice reader needs more time and has more errors compared to a skilled reader. Another example is when first learning how to drive a car in order to become an experienced driver, as information processing transfers from operations that require controlled processing to more automatic operations.

Important Scientific Research and Open Questions

Numerous behavioral studies have shown that repetitive training on the same task increases the speed of performance and improves response accuracy, thus changing from controlled to automatic information processing. Various experimental paradigms have been developed in order to examine the distinction between automatic and controlled information processing. The dependent variables Reaction Time/ Response Time (RT) and Accuracy (AC) are often used as indicators of processes taking place, when solving a task with increasing demands on cognitive information processing. These studies have been examining information processing within different cognitive domains, such as memory, attention, and executive functioning. Several neuropsychological studies have investigated automatic and controlled information processing in various patient groups, such as ADHD, learning disorders, patients with frontal lobe brain damage, Alzheimer´ disease, depression, etc. In cognitive neuroscience, different techniques such as ERP (event-related potentials), fMRI (functional magnetic resonance imaging), and PET (positron emission tomography), have aimed to provide evidence for the brain localization of automatic and controlled information processing. So far, the frontal lobes have been identified as the region of brain that are related to controlled information processing, whereas automatic information processing has been proved more difficult to localize.

Cross-References

► Attention and Implicit Learning
► Automaticity in Memory
► Bottom-Up- and Top-Down Learning
► Controlled Information Processing
► Dual-Process Models of Information Processing

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Automatic Learning

► Scaffolding Discovery Learning Spaces

Automatic Process

► Cognitive Automatisms and Routinized Learning

Automatic Processing

► Automaticity in Memory

Automaticity

Capacity to draw upon highly proceduralized knowledge to engage in uncontrolled information processing, e.g., in performing highly polished skill.

Automaticity in Memory

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Synonyms

Automatic processing; Effortless processing; Uncontrolled processing

Definition

Most definitions of automatic processing define automaticity in terms of a set of criteria believed to be indicative of processes that do not require effort and that are not under conscious control. Posner and Snyder (1975) set the standard for such definitions by describing an automatic process as one which (1) occurs without intention, (2) is concealed from consciousness, and (3) does not interfere with and proceeds in parallel to other ongoing mental activity. Hasher and Zacks (1984) provided further criteria by adding that automatic processes do not benefit from training, are invariant across age and individual difference, and are not affected by state, arousal, or situational factors. In contrast, controlled or effortful processes require attentional capacity such that subsequent performance is influenced by intention and/or strategy. The consensus now is that the distinction between automatic and effortful processes is not clearly bounded, but that cognitive processes lie on an automatic/effortful continuum. Additionally, some cognitive processes, such as encoding of frequency information, are believed to be inherently more automatic than effortful, while others are thought to become increasingly automatized through repeated performance and practice. With this distinction in mind, it should be noted that whereas Posner and Snyder's criteria were offered in an attempt to explain automaticity developed through practice, Hasher and Zacks' criteria were offered with respect to processes thought to be innately automatic.

Theoretical Background

Most automaticity theories hold that automatic processes require no attention and that automaticity develops from repeated performance or practice as a result of gradual withdrawal of attention from the specified task. This type of automaticity theory is inextricably linked to capacity theories of attention. Capacity theories suggest that we have a limited amount of attentional resources that must be allocated to differing tasks that compete for such resources. Tasks that require an abundance of attention leave relatively few resources available for competing tasks. Tasks that require no attention for completion are typically considered automatic.

Although attention-driven theories of automaticity are most common, alternative theories do exist. For example, Logan (1988) suggests that automatic processes are governed exclusively by the memory system. Specifically, Logan suggests that automaticity is direct retrieval of target information from memory without intermediary computational steps. Mainly addressing automaticity that develops through performance and/or practice, Logan's theory proposes that effortful tasks are typically completed using general algorithms. Over time, specific solutions to specific problems are learned and stored in memory. At that point, a response to a problem for which a solution has been stored can be generated either by using an algorithm or by retrieving a solution stored in memory. Eventually, use of an algorithm for a specific problem is abandoned and retrieval of a specific solution from memory becomes the dominant response to the problem. The development of automaticity is marked by transition from algorithm-based responses to memory-based responses such that the process is considered automatic when responses become exclusively memory based.

Although Logan's theory provides a reasonable explanation for automaticity developed through practice, it does not address the issue of inherently automatic processes. Hasher and Zacks' (1984) discussion of automaticity focused on innate automatic processes such as the encoding of attributes of events such as frequency, spatial location, and temporal order. Importantly, the authors suggest that these attributes are automatically encoded for attended events. That is, no additional attentional resources are required to encode frequency, spatial location, and temporal order of an event after the event initially receives attention. Specifically addressing automatic encoding of frequency information, Hasher and Zacks suggest that such information is represented in memory in accordance with a multiple-trace view of representation. That is, it is believed that each repetition of an event is stored as an independent memory trace.

For general memory theory, the topic of automaticity has been of interest due, in part, to its supposed relationship with attention. Most theories of memory assume that attentional capacity influences memory. Theories vary in their emphasis on automatic processes, and all theories that adopt automatic processing do so as an interdependent relation with controlled processes (dual-process theories and parallel distributed processing theories).

Important Scientific Research and Open Questions

Frequency encoding has been the most extensively studied topic related to inherent automaticity and memory. Early empirical research suggested that accurate memory for frequency information could be obtained regardless of intention to process, practice, feedback, individual differences, and age (Hasher and Zacks 1984). However, subsequent research has demonstrated that memory for frequency is affected by levels of processing, intention, and encoding strategy. An example of the influence of levels of processing on memory for frequency is provided by Maki and Ostby (1987, Experiment 1). These authors presented participants with a list of words of varying frequency, which were to be processed either structurally (by determining word length) or semantically (by rating ease of imagery). The results indicated that memory for frequency was more accurate after semantic than structural processing. Similarly, research has demonstrated that memory for frequency of information that requires additional resources simply for comprehension (e.g., bizarre or novel stimuli) is less accurate than memory for frequency of easy-to-comprehend information. Overall, the current consensus is that memory for frequency is not solely the result of automatic processes.

Research provides even less support for the notion that spatial location and temporal order information are encoded automatically. The bulk of research on these topics suggests that the accuracy of memory for both spatial location and temporal order are influenced by intention, strategy, cognitive load, individual differences, and age (see Naveh-Benjamin 1990, for an example).

Craik et al. (1996) reported an extensive study of attentional demands on memory. In a series of four experiments, attention was divided at either study or test. Dividing attention at study reduced memory substantially with little cost to the secondary task used to divide attention. Dividing attention at test produced a smaller memory deficit but a larger disruption of the secondary task. Based on the trade-off between memory and secondary-task performance, Craik et al. concluded that both encoding and retrieval processes require capacity. The data do imply that encoding requires more controlled processing than retrieval, which in the presence of proper cues seems to be obligatory. Nonetheless, the disruption of the secondary task when attention is divided at retrieval implicates controlled contributions to the output process.

In sum, current research in the area of automaticity and memory provides little evidence to suggest that memory for any type of information is solely the result of innately automatic processes. Thus, defining automatic processes in terms of a set of necessary criteria does not appear tenable. On the contrary, the existing research is in keeping with the notion that cognitive processes can be described relative to an automatic/effortful continuum and that memory is influenced by processes that lie on both ends of that continuum. As such, promising future research will focus on determining how automatic and controlled processes work in concert to create accurate memory.

Cross-References

► Attention, Memory, and Mediation
► Automatic Information Processing
► Controlled Information Processing

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Automatism

► Rote Memorization

Automatization

► Routinization of Learning

Autonoesis

A mode of consciousness that embodies an individual's awareness of continuity over time, allowing for a mental exploration of the trajectory of personal experiences in the remote or recent past.

Autonomous Agent Architectures

Autonomous agent architectures are design methodologies, i.e., collections of knowledge and strategies that are applied to create situated intelligence. The design knowledge expressed in agent architectures contains knowledge derived by reasoning and knowledge derived by experience. The design and implementation of autonomous agents includes classical, reactive and multiagent planning, and communication among autonomous agents.

Autonomous Learning

► Independent Learning

Autonomous Learning and Effective Engagement

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Synonyms

Effective learning; Self-regulated learning

Definition

The educational literature is replete with alternative interpretations of what is meant by *autonomous learning*. More extreme interpretations of this notion, which take autonomous learning to mean independent learning, are based on the idea of the individual being resistant to external influence at all stages of their learning. Consequently, it is important to stress that while autonomous learning is self-managed and self-monitored, learning, sometimes referred to collectively as *self-regulated* learning, (Entwistle and McCune 2004) such learning may also be *informed* through interaction with peers or by reflection on the views of the educator. Here, the learner uses other persons' views to sharpen their own views without compromising their personal contribution to knowledge construction with its nuances and insights, so that transmission is not their principal route to knowing. They also accept their individual accountability rather than that of the educator for setting of goals, identification and use of resources in achieving these goals and for the perspectives they develop within a knowledge domain. Thus, autonomous learning may also involve *personalized* learning. It is not, however, synonymous with student-centered learning, as the latter may tolerate higher degrees of instructor-directed learning, even where an emphasis is placed on student participation. The attribute of learner autonomy has also come to be recognized as one to be acquired through a journey of self-discovery. This is a "cultural journey" involving initial "disorientation" and "emotional turmoil" while learners' early expectations on "learning, knowledge and authority" conflict with their experiences and they progress to the stage of being comfortable with uncertainty (Taylor 1986; Baxter Magolda 2001).

Effective engagement is also a term which is open to interpretation. A more recent interpretation, influenced by Baxter Magolda's work on self-authorship, is that of a quality of participation in the learning experience which is not only supportive of knowledge retention, but also, *transformative*. Precisely, the learner is empowered to reconstruct what they already knew or believed into a system of beliefs, conceptualizations, values, and forms of reasoning which are symptomatic of a more mature state of cognitive development (MacDougall 2008).

This interpretation takes a *deep approach* to learning as a necessary but not a sufficient condition for effective engagement. Different characterizations contrasting deep and surface learning exist, including *a greater degree of semantic or cognitive analysis* versus *repetition of analyses carried out*, *intention to understand* versus *intention to reproduce* and *meaning directed* versus *reproducing directed* (Entwistle and McCune 2004). In turn, Biggs's notion of *internalizing*, reflected by an intrinsic interest in content, the intention to understand and openness to fresh perspectives on existing knowledge has at least become a part of what is recognized as integral to deep learning.

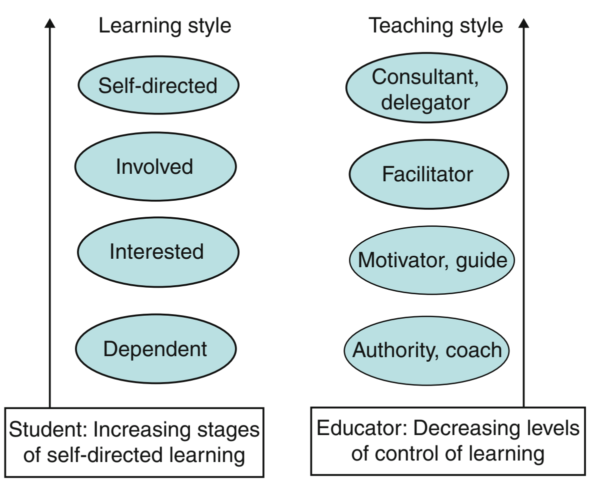
In applying these definitions to course design, it is critical to appreciate that the presentation of material and the approach of the educator can influence learner traits and that these traits may be evolutionary rather than static.

Theoretical Background

Clearly, according to the above definitions, autonomous learning and effective engagement are inextricably linked. Central to this link is the sense of *authenticity* that arises when learners acquire some degree of ownership of learning through autonomous learning. The need for such authenticity to facilitate transformative learning has been recognized. However, the role of the educator in cultivating a student's self-efficacy as an autonomous learner at an early stage is also clear. As Baxter Magolda observes (Baxter Magolda 2001), use of the learner's current knowledge and experience is perceived as a "sign of respect" and simultaneously furnishes the learner with an awareness of their capacity to enhance their own learning.

The importance of assessing preparedness of students for autonomous learning in advance of their learning experiences has been partially recognized through production of the Self-Directed Learning Readiness Scale (SDLRS). The value of such preparatory work, aimed at recognizing the individuality of the learner, is clear when one considers the evidence in the literature that considerable variability in readiness for self-directed learning may occur within any given cohort based on psychosocial and cultural factors. For example, British students from overseas have in some studies shown a tendency to assume that ownership of academic knowledge lies mainly with the host country. In turn, they have perceived their responsibility as that of becoming acquainted with British ways of thinking concerning their fields of study. Consequently, they have been less inclined to question the objectivity of beliefs and practises within their host institution and to recognize their own capacity for ownership or construction of knowledge. Moreover, in some East Asian countries, conformity to popular beliefs and practise is seen as a cultural norm, and thus the idea of autonomous learning requires some explaining. Such observations can help inform the design of personalized E-Learning resources for entrants to undergraduate courses in higher education.

The concept of *readiness for self-directed learning* itself has a firm grounding in learning theory literature, both through the multifarious studies through which the SDLRS has been validated and through Grow's Stages of Self-Directed Learning Model. The latter model (Fig. 1) highlights the various contexts in



Autonomous Learning and Effective Engagement. Fig. 1 Intended matching of learning and teaching styles in Grow's stages of self-directed learning model which mismatch can arise between teaching style in terms of control of learning and student preparedness for self-directed learning.

Such mismatch can occur when ellipses on the left and right of the figure are aligned in a different manner to that shown. Take, for example, the case of teaching statistics to students enrolled in profession-orientated courses. Here, the educator may be employed to assume the role of *facilitator* when students are still at the *dependent* stage due to their lack of preparedness specifically in statistical learning.

According to Grow's model, it is the responsibility of the educator to adapt their teaching style in such a way that the student's ability to manage their own learning increases. His underlying philosophy of education includes the doctrine that "[t]he goal of the educational process is to produce self-directed, lifelong learners." This doctrine itself rests on the seemingly paradoxical assumption that "teachers can be vigorously influential while empowering students toward greater autonomy."

In assessing potential for effective engagement, the wide range of inventories available for diagnosing learning styles or approaches can be informative (Entwistle and McCune 2004). In assessing learner predisposition to disengagement, the relevance of *volition*, defined as "students' ability to maintain the effort needed to achieve their goals, even in the face of adversity" has been recognized. This construct may be viewed as a component of self-efficacy. However, more recently, it has also been represented more specifically within the context of assessing *effort regulation*, thus illustrating further the strong connection which exists between autonomous learning and effective engagement.

Educators with an interest in promoting effective engagement through deep learning ought to be aware that there is a wealth of recent literature available providing innovative illustrations of constructive measures to ensure that short-answer question styles involve the assessment of higher orders of learning. Also, they should appreciate the relevance of the psychologist Carl Rogers's earlier work on *experiential learning* as informed by his earlier experience as a psychotherapist. Experiential learning involves constructing authentic meaning based on one's personal encounter with a relevant event which necessitates re-evaluation of personal knowledge and belief systems. Rogers recognized two learning styles, *cognitive* and *experiential*, as representative of meaningless and significant learning, respectively. Cognitive learning is typified by memorizing vocabulary and recommended facts purely for reproduction. Experiential learning, by contrast, is affective and far more pervasive. In this case, learning involves the whole person, thus influencing their behaviour and attitudes and possibly their personality. The latter form of learning might occur, for example, when participating in clinical research to gather evidence before reaching an optimal decision for patient care. These learning styles are likely to have provided some essential groundwork for conceptualizations of deep and surface learning. However, Rogers's appreciation of the importance of "evaluational interaction with others" (Rogers 1967) and an environment of empathy and unconditional positive regard for feelings, views, and ideas in allowing learners to reach their full potential and develop creativity and confidence concerning their own choices has also contributed greatly to the democratic nature of autonomous learning. Rogers's work has also informed educators of the importance of context-driven learning, including case-based inquiry learning, in facilitating effective engagement. This type of learning involves integrating the learning of new knowledge with scenarios which the learner is likely to consider important to living. Thus, for example, in Medicine, students may learn to choose appropriate methods for estimating patient risk within the context of a case scenario where it is imperative that the appropriate treatment pathway is selected for the patient.

Phenomenographic research has formed the basis for, not only the deep-surface dichotomy but also, a profusion of related conceptualizations for representing learning styles and approaches. However, in recent years, the notion of *threshold concept* has also become prominent in learning theory as a basis for evaluating teaching contexts. A threshold concept has been described "as akin to a portal, opening up a new and previously inaccessible way of thinking about something. It represents a transformed way of understanding, or interpreting, or viewing something without which the learner cannot progress . . ." (Meyer and Land 2003). Thus, the identification of threshold concepts ought to be highly relevant to any program aimed at promoting the transformative element of effective engagement.

In the current age, distance learning and the use of Web 2.0 technology to allow students to manage their use of learning resources are becoming increasingly popular. Within such contexts, particularly in higher education, instructors are typically limited in terms of both contact hours and their available support network of co-facilitators. Such developments point to the need to foster learner autonomy and effective engagement, not only as a basis for enhancing the quality of student learning but also, in developing a realizable working model for the educator in terms of student expectations.

Important Scientific Research and Open Questions

Given the very close link between the notions of autonomous learning and effective engagement, it is unsurprising that the SDLRS should already contain questions which measure self-efficacy in terms of self-concept as an effective learner. Nevertheless, since self-efficacy in this sense is so fundamental to effective engagement, it is important to explore how it may be measured more fully in preparing students for their learning tasks. Such work can be informed by consideration of the General Self-Efficacy Scale (GES) of Schwarzer and Jerusalem. The GES is the most commonly accepted measurement of self-efficacy and like the SDLRS, its construct validity has withstood scrutiny from a number of sources. Within the SDLRS, important items from the GES have been omitted, particularly those relating to the capacity to handle unforeseen difficulties, solve difficult problems, and remain focused on personal goals. As the GES comprises only ten items, with a total average response time of about 4 min, it could conveniently be merged with the SDLRS inventory. However, style of the available response categories for this add-on would need to be highlighted for the benefit of the respondent and would preclude the possibility of conveniently combining scores from the SDLRS and GES in any meaningful sense.

Low self-efficacy scores can assist in identifying the need to promote positive behavioral changes in individuals who are particularly vulnerable to discouragement and hence disengagement. The call for a revised version of the GES in assessing readiness of students for self-directed learning in subjects which they encounter as nonspecialist learners is implicit from the finding that degrees of individual autonomy are not uniform across disciplines.

Moreover, to optimize the use of such a scale in improving student learning, more work needs to be done to ensure that it is itemized to capture the specific types of task to be performed and that it is adapted accordingly as these tasks change. In making such distinctions, however, it is important that the level of specificity is not so high as to preclude its utility beyond the level of an individual institution.

The relatively recent work on threshold concepts opens the way for further case studies on subject-specific and context-specific threshold concepts. For example, in the case of learning statistics, it may be the case that distinctions need to be made between threshold concepts encountered by specialists and non-specialists.

Cross-References

► Approaches to Learning and Studying
► Case-Based Inquiry Learning
► Constructivist Learning
► Cultural Influences on Personalized E-Learning Systems
► Deep Approaches to Learning in Higher Education
► Experiential (Significant Learning)
► Phenomenography
► Rogers, Carl R. (1902–1987)
► Self-Efficacy for Self-Regulated Learning
► Statistical Learning

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Autonomous Mental Development

► Developmental Robotics

Autonomy

► Self-Determination and Learning

Autopoiesis

A term coined by Humberto Maturana (1980) to explain the process of living/cognizing. It comes from the Greek *auto* meaning *self* and *poiesis* meaning *creation* or *production*. The autopoietic (living) system is an autonomous, self-organizing system. It is operationally closed containing within it all the elements necessary for its own re/production and the maintenance of its organization, but it is open to the flow of matter and energy and hence coupled to its environment.

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Average Group Level

► Composition of Learning Groups

Aversive Conditioning

► Aversive Learning in Drosophila melanogaster
► Fear Conditioning in Animals and Humans

Aversive Learning in *Drosophila melanogaster*

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Synonyms

Aversive conditioning; Conditioned avoidance

Definition

Flies normally avoid an aversive stimulus (e.g., electric shock) and this reflex-behavioral response can be conditioned to a neutral stimulus (e.g., an odor): if the odor is paired with an electric shock, this odor by itself will induce the avoidance response. Then, the fly has associated the odor and the electric shock, and the odor is now predictive of the punishment (Tully and Quinn 1985). In this example, the odor is neutral to the fly before the learning session, but flies may also learn, for instance, to avoid a lighted area to which they are usually attracted if light is associated with a bitter gustatory stimulus (Le Bourg and Buecher 2002).

Theoretical Background

For many decades, some – if not many – neuroscientists considered that insects were unable to learn. Insects were (and are sometimes still) viewed as automata only able to perform stereotyped behaviors. This attitude has been reinforced by the writings of esteemed entomologists such as Jean-Henri Fabre who in 1879 in his famous *Souvenirs entomologiques* wrote that "Nature only endowed it (the insect) with faculties needed in ordinary circumstances... and since these blind faculties, not modifiable by experience, are sufficient to save the race, the animal is unable to go further." Textbooks now warn against the feeling that insects are unable to learn.

Numerous aversive learning paradigms have been developed in flies because reward learning is difficult to establish. By contrast, bees are known to be easily trained with positive reinforcers such as sugar. The reason for this difference between flies and bees has probably to be linked with the different constraints to which these insects are confronted. Bees have to find specialized food sources (flowers), while *Drosophila* flies can feed on various sources but need to avoid environmental threats (e.g., dryness, heat). Due to their tiny size (2 mm long), these flies cannot sustain such threats for a long time and learning to avoid them could be of adaptive significance.

Important Scientific Research and Open Questions

The first learning experiments on fruitflies were performed in the 1960s, but it happened they could not be reproduced. Many attempts were done later but only a few experiments have been successfully replicated and used in other laboratories. The first such study (Médioni and Vaysse 1975) involved the conditioned suppression of a reflex, the extension of the proboscis when a starved fly walks on sugar (legs contain chemoreceptors detecting sugar). If the fly encounters a bitter stimulus or an electric shock just after sugar, it will stop to extend its proboscis when walking on sugar. The fly will again extend its proboscis when walking on sugar if the aversive stimulus is removed (learning extinction). Later on, other procedures have been designed. For instance, contrary to virgin females, mated females strongly reject males when they court them. Following this rejection, and depending on the time spent with unreceptive females, males will not court females even if they are receptive (Siegel and Hall 1979). These two learning paradigms, as well as other ones, have been designed to train individual flies but there are procedures to train groups of flies. The most famous one is the olfactory aversive conditioning. Groups of flies are put in a closed vial where there is an odor associated with an electric shock and thereafter in a vial containing a second odor but no shock: when given the choice between two vials with the two odors, most of the flies will prefer the vial containing the odor not previously associated with electric shock (Tully and Quinn 1985). This procedure is used by many laboratories. A debate occurred in the 1980s on the use of groups of flies or of individuals to study learning. Today, it can be said that this debate is over: group procedures are best to quickly screen learning and memory mutants and to study the different memory phases, while individual paradigms provide individual scores, as in studies of mammals, allow to verify that learning mutants are impaired in other learning procedures, or are used for instance to study the effects of aging.

Nowadays, most neuroscientists are convinced that flies can learn. The challenge is now to use more thoroughly learning procedures to study for instance the effects of mutations known to have deleterious effects in human beings, or of environmental conditions which could impair (or improve) the life of organisms (e.g., Iijima et al. 2004). Both group and individual aversive learning procedures can be useful in these endeavors.

Cross-References

▶ Associative Learning
▶ Aversive Motivation and Learning
▶ Avoidance Learning
▶ Comparative Psychology and Ethology
▶ Conditioning
▶ Group Learning
▶ Individual Learning
▶ Invertebrate Learning
▶ Learning in Honeybees: Associative Processes

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Avoidance Behaviour

▶ Abnormal Avoidance Learning

A

Avoidance Learning

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Synonyms

Learning to avoid aversive outcomes

Definition

Learning to avoid aversive outcomes is crucial for survival, and it is ubiquitous in everyday life. This entry focuses on ► active avoidance, in which performing a certain behavior prevents an aversive outcome that would otherwise occur. ► Avoidance learning in that context consists of learning to perform the appropriate behaviors in the appropriate circumstances to prevent aversive outcomes. Active avoidance should be distinguished from ► passive avoidance, often called *punishment*, in which performing a behavior results in an aversive outcome, and learning therefore consists of suppressing, rather than strengthening, the behavior. Punishment is discussed in the "Punishment and Reward" entry. Henceforward, whenever the term "avoidance" is used, it is intended to mean active avoidance.

Theoretical Background

The earliest avoidance-learning experiments were conducted at the beginning of the twentieth century by Bekhterev, using what would become one of the most common paradigms in research on avoidance: the signaled avoidance procedure. In this procedure, a trial starts with the presentation of a neutral warning stimulus, often referred to as the conditioned stimulus (CS). Unless the subject performs a pre-specified response, an aversive unconditioned stimulus (US), such as a shock, occurs at a given time following the onset of the CS. If, however, the subject performs the pre-specified response – the avoidance response – after the onset of the CS but before the US occurs, the US is omitted. Subjects – both humans and nonhuman animals – typically learn to perform the avoidance response, thereby avoiding the US.

Most experiments in avoidance learning have been conducted with rats, but a wide variety of other species (e.g., monkeys, dogs, guinea pigs, pigeons, chicks, and goldfish) have also been shown to learn to avoid. Although there are some differences between species in avoidance learning – specifically, animals learn the avoidance response more easily when it is closely related to one of their species-specific defense reactions – many findings in avoidance learning have been shown to generalize across species, and theories of avoidance learning are generally assumed to apply to a wide variety of species (including humans). Henceforward, the term "subject" will be used instead of "animal," to highlight the fact that the findings and ideas discussed are generally assumed to apply to both humans and nonhuman animals.

One of the earliest explanations for avoidance learning was based on Pavlov's ► stimulus-substitution theory. In Pavlov's experiments, a neutral stimulus such as the ringing of a bell (the CS) was paired with food (the US). After a few such pairings, the CS would elicit the same response (salivation) as the US. Pavlov proposed that the CS becomes a substitute for – that is, starts eliciting the same responses as – the US. This idea also provided an elegant explanation for avoidance learning, because in the early experiments on avoidance, the avoidance response was typically a fleeing behavior that was spontaneously elicited by the shock. Avoidance learning was therefore assumed to be due to the pairings of the CS with the US early in avoidance training (before the avoidance response is learned); such pairings would make the CS elicit the same fleeing response that the US elicited. Experiments in the late 1930s, however, contradicted this Pavlovian account, suggesting that avoidance learning depends instead on instrumental learning. Explaining avoidance learning in instrumental terms raised a theoretical conundrum, though. The main account of instrumental learning was Thorndike's ► law of effect. Thorndike proposed that instrumental learning consists of learning stimulus-response (or situation-response; S-R) associations. The association between situation S and response R is strengthened when the subject is in situation S, performs response R, and that response is "accompanied or closely followed by satisfaction" (in Thorndike's own words). As Mowrer (1947) noted, however, applying the law of effect to avoidance learning raised a difficult question: "how can a shock which is *not experienced*, i.e., which is avoided, be said to provide [. . .] a source of [. . .] satisfaction" (p. 108)?

Mowrer's (1947) two-factor theory – which remains one of the main theories of avoidance learning – provided an answer to this puzzle. Mowrer was strongly influenced by Hull's ► drive-reduction theory. Hull suggested that responses are learned via drive reduction, where *drives* are states such as hunger, the reduction of which acts as a reward. Mowrer suggested that fear is an acquired drive, and that reductions in fear are therefore reinforcing. He proposed that avoidance learning involves two processes (hence the name "two-factor theory"). Early in training, before the subject consistently avoids, the CS is often followed by the US, and this produces fear of the CS via Pavlovian conditioning. Subsequently, a response that terminates the CS reduces fear, and that fear reduction reinforces the response. For Mowrer, the avoidance response is therefore reinforced by CS termination, not by the actual shock avoidance. He suggested that "the *avoidance* of the shock is a [. . .] by-product."

In experiments conducted before the development of two-factor theory, the avoidance response both terminated the CS and avoided the US, making it impossible to determine the relative contributions of these two events to learning. Following the development of two-factor theory, however, several experiments tried to disentangle the differential effects of these events. One of the most influential such experiments was the ► acquired-drive experiment of Brown and Jacobs (1949). The experiment consisted of two phases. In the first phase, rats underwent Pavlovian conditioning of a CS to a shock. In the second phase, the CS was presented and the rats could terminate it by performing a response. The US was never presented during this phase, regardless of the rats' actions, so the response did not play any role in avoiding the US. The rats learned to perform the response, suggesting that, as predicted by two-factor theory, CS termination was sufficient to support avoidance learning.

Although this finding was widely replicated, subsequent experiments demonstrated that, contrary to the predictions of two-factor theory, US avoidance also plays a role in reinforcing the avoidance response. These experiments typically used a 2 × 2 factorial design, in which the two factors were CS termination (yes or no) and US avoidance (yes or no). Generally, both factors were found to be effective in reinforcing the response, with the highest level of avoidance learning occurring when the response produced both effects.

Another prediction of two-factor theory was also found to be at odds with experimental findings. According to the theory, the avoidance response is reinforced by reduction of the fear associated with the CS; fear of the CS and the strength of the avoidance response should therefore correlate. Several studies, however, found that long after fear of the CS had virtually extinguished (due to consecutive avoidance responses that ensured that the CS was not followed by the US), the avoidance response still persisted.

These difficulties with two-factor theory prompted the development of alternative theories, the most prominent of which is the cognitive theory of Seligman and Johnston (1973). The main tenet of Seligman and Johnston's theory is that the avoidance response is driven not by S-R associations, but by expectancies about response-outcome (R-O) contingencies. The theory suggests that during avoidance learning subjects develop two R-O expectancies: (1) if they perform the avoidance response, no shock will occur; and (2) if they do not perform the avoidance response, shock will occur. Subjects perform the avoidance response because they prefer no shock to shock.

This theory naturally explains the effectiveness of US avoidance in supporting learning. It also explains the persistence of avoidance after fear is extinguished, because avoidance is assumed to be driven by R-O expectancies rather than being reinforced by fear reduction. The theory may even explain learning in acquired-drive experiments: In the first phase of such experiments, subjects may develop the expectancy that if they do not perform the avoidance response (which is typically blocked in this phase), shock will occur. In the second phase, they may develop the expectancy that if they perform the avoidance response, no shock will occur, while failing to disconfirm the expectancy that shock will occur if they do not perform the response. The theory, however, has difficulty explaining avoidance learning when the response terminates the CS but is followed by the US.

Important Scientific Research and Open Questions

The past decade has witnessed a revolution in our understanding of conditioning, brought about by the use of computational models from the field of ► reinforcement learning to explain a myriad of behavioral and neural findings in conditioning (Maia 2009).

Recent work has shown that one such model – the so-called ▶ actor-critic – explains a wide variety of findings in avoidance learning (Maia 2010). Remarkably, the model is closely related to two-factor theory (Maia 2010). The model consists of two components: the *critic* and the *actor*. The critic implements Pavlovian conditioning by learning the *values* of stimuli or situations (i.e., the future reinforcements predicted by those stimuli or situations). In fear conditioning, the critic learns a negative value for the CS, because the CS predicts an aversive US. The actor implements S-R learning. Unlike in the law of effect, however, the change in strength of the S-R association is *not* determined simply by whether the response is followed by a positive or negative outcome. Instead, it is determined by whether the response is followed by an outcome that is *better* or *worse* than expected. Specifically, a ▶ prediction error is calculated by subtracting the value that was expected from the actual outcome. If the prediction error is positive, the outcome was better than expected, and the S-R association is strengthened. If the prediction error is negative, the outcome was worse than expected, and the S-R association is weakened.

The actor-critic's explanation for many of the findings in avoidance learning is similar to the explanation of two-factor theory. Consider, for example, the learning of the avoidance response. Early in training, when the CS is often followed by the US, the CS acquires a negative value. This corresponds to Pavlovian fear learning in two-factor theory. Subsequently, when the CS is presented and the avoidance response terminates it, the model goes from a situation with a negative value to a situation with a value of 0 (because in the absence of the CS, no shock is predicted). This produces a positive prediction error, which reinforces the response. The positive prediction error is caused by a reduction in fear, so the avoidance response is reinforced by fear reduction, as in two-factor theory.

Despite these similarities between the actor-critic and two-factor theory, the fact that in the model the S-R strength is changed on the basis of prediction errors rather than on the basis of external outcomes allows the model to explain findings that two-factor theory cannot explain (Maia 2010). Consider, for example, the persistence of the avoidance response after fear of the CS has extinguished. When fear of the CS extinguishes, the value of the CS becomes 0. When the CS is subsequently presented and the model performs the avoidance response, the model goes from a situation with a value of 0 to another situation with a value of 0 (because the US is not predicted in either the presence or absence of the CS). The prediction error is therefore 0, and the strength of the S-R association remains unchanged. The response therefore persists after fear has extinguished. In fact, in the model, the response persists perpetually, unless responding has some cost (representing the effort of responding).

With certain extensions, the model can also explain the effects of US avoidance on learning (Maia 2010). Furthermore, the model explains some findings that no other theory can explain – for example, the reduction in avoidance latencies that occurs with extended training (Maia 2010). The model may therefore provide the most comprehensive theory of avoidance to date. Furthermore, two aspects of this theory seem quite satisfactory. First, the model was developed in machine learning and is independently motivated on computational grounds. The theory makes no assumptions specific to avoidance; it simply shows that this general-purpose ▶ reinforcement-learning system explains a variety of findings in avoidance. Second, the model maps closely to the brain (Maia 2009), so it offers the prospect for an integrated neurobehavioral theory of avoidance.

Despite the strengths of this approach and the appeal of explaining a broad range of findings using a simple model, the fact that the actor-critic does not implement R-O contingencies may be a weakness of this approach. Substantial evidence suggests that in other instrumental-conditioning paradigms, subjects can learn both S-R and R-O contingencies, and the same may apply to avoidance learning. Other reinforcement-learning models learn R-O contingencies (Maia 2009), and such models have been used to explain the effects of antipsychotic drugs on avoidance (Smith et al. 2004). A comprehensive theory of avoidance may have to include both S-R and R-O learning, as well as their interactions. Developing such a theory should be a major focus for future research.

Cross-References

- ▶ Abnormal Avoidance Learning
- ▶ Behaviorism and Behaviorist Learning Theories
- ▶ Conditioning
- ▶ Fear Conditioning in Animals and Humans
- ▶ Law of Effect

► Operant Behavior
► Pain-Relief Learning
► Punishment and Reward
► Reinforcement Learning
► Reinforcement Learning in Animals

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Avoidant

► Fear of Failure in Learning

Avoidant Oriented

► Fear of Failure in Learning

Aware

► Consciousness and Emotion: Attentive vs. Pre-attentive Elaboration of Face Processing

Axiom Schema

Schemas are used in formal logic to specify rules of inference, in mathematics to describe theories with infinitely many axioms, and in semantics to give adequacy conditions for definitions of truth. Accordingly, an axiom schema is a well-formulated formula in the language of an axiomatic system, in which one or more schematic variables may appear. Well-known examples of axiom schemas are the induction schema as part of Peano's axioms for the arithmetic of the natural numbers, and the axiom schema of replacement as part of the Zermelo–Fraenkel set theory.