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PAC Learning

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Synonyms

Probably approximately correct theory; Statistical learning theory

Definition

The Probably Approximately Correct (PAC) learning theory, first proposed by L. Valiant (Valiant 1984), is a statistical framework for learning a task using a set of training data. In its simplest form and for a typical modeling task, the PAC learning theory attempts to relate the accuracy and statistical confidence of the model to the number of training examples used.

Next, a more detailed formulation of the PAC learning is provided. For learning an unknown function f: $X \rightarrow [0\ 1]$ in F, where F is a family of functions, an algorithm A is used to form a hypothesis or model h_n: $X \rightarrow [0\ 1]$. The function h_n is an approximation of f formed by A using n training examples. Then, in order to assess the quality of the learning/approximation process, it is desirable to ensure with the statistical confidence of $1 - \delta$ that the true distance between f and h_n over the entire space, i.e. $d_p(f, h_n)$ is less than the accuracy factor of ε, i.e.

$$\sup_{f\, \varepsilon\, F} \Pr\{d_p(f,\ h_n) \leq \varepsilon\} \geq (1 - \delta) \qquad (1)$$

In Eq. 1 P is the probability distribution of the data. If for any ε, a δ can be found such that the above inequality is satisfied, the conditions for PAC learning are satisfied. Equation 1 describes the logic behind the naming of this theory; if the above equation is satisfied for some small ε and δ, then it is highly "probable" that h_n provides a "correct approximation" of f.

Theoretical Background

The typical outcome of the PAC learning formulation of a learning task is an equality that provides either of the following:

(a) Bounds on the number of training examples in order to provide pre-specified levels of accuracy or statistical confidence over the resulting model.
(b) Given a fixed number of training examples, the possible trade-off between the accuracy and the statistical confidence of the learning process.
(c) When comparing a set of different learning tasks, the relative complexity of these learning tasks. Such a comparison can be made assuming the same values of both accuracy and statistical confidence, and regarding the number of training examples as the complexity factor. The complexity factor is referred to as "sample complexity."

It has to be mentioned that there is no guarantee that a function f in F is even learnable in the PAC learning sense. The literature of PAC learning theory in the last few decades provides a variety of learning tasks that are PAC learnable and also some that are not PAC learnable. Furthermore, among those learning tasks that are PAC learning, the sample complexity for the algorithm used for the learning task can be very different (Vidyasagar); some algorithms applied for the same learning task can result to much higher sample complexity than others. Moreover, using the same algorithm for learning of an unknown function belonging to another family of functions results to different levels of sample complexity. While some of the original learning tasks addressed by the PAC learning were families of Boolean functions and decision trees, the PAC learning theory was soon applied to families of functions with real outputs. For instance, the literature of the PAC learning theory explores the learning properties of several families of artificial neural networks (Anthony, Hassler).

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With regards to the statistical properties of the input data, the original formulation of the PAC learning was for with independently and identically distributed (i.i.d.) data and as such the results were only applicable to "static" learning tasks. However, the majority of real learning applications violate the i.i.d. assumption. During the last two decades, the formulation of the PAC learning theory was extended to a variety of learning theories that allow non-i.i.d. data, which created frameworks to address different dynamic modeling tasks in many different applications such as signal processing, image processing, and control (Najarian et al. 2001; Najarian et al. 2000). For instance, one of the dynamic learning tasks to which the original PAC learning is not applicable is learning with Nonlinear Finite Impulse Response (NFIR) models. An extensions of the PAC learning that addresses the NFIR modeling tasks was formed by extending the PAC learning to a learning theory with m-dependent data (Najarian et al. 2001).

Important Scientific Research and Open Questions

While many existing bounds on sample complexity introduced by the PAC learning theory are rather conservative and may not reflect the exact complexity of the corresponding learning task, the order and mathematical relationship among different factors involved in the learning process such as sample complexity, accuracy, confidence, characteristics of the function family, and the statistical dependencies among the training data, provide unique insight into the level of difficulty/ease of the learning task in hand.

The PAC learning theory is a multi-disciplinary field of science that attracts mathematicians, statisticians, psychologists, engineers, physicists, and scientists in other fields of computational sciences. The main future directions of the PAC learning theory include searching for tighter upper bounds on sample complexity of learning with a variety of popular models such as support vector machines (SVMs) and some families of neural networks.

Cross-References

► Active Learning
► Activity Theories of Learning
► Formal Learning Theory
► Mathematical Models/Theories of Learning
► Probability Theory in Machine Learning
► Statistical Learning Theory and Induction
► Stochastic Models of Learning

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Pain-relief Learning

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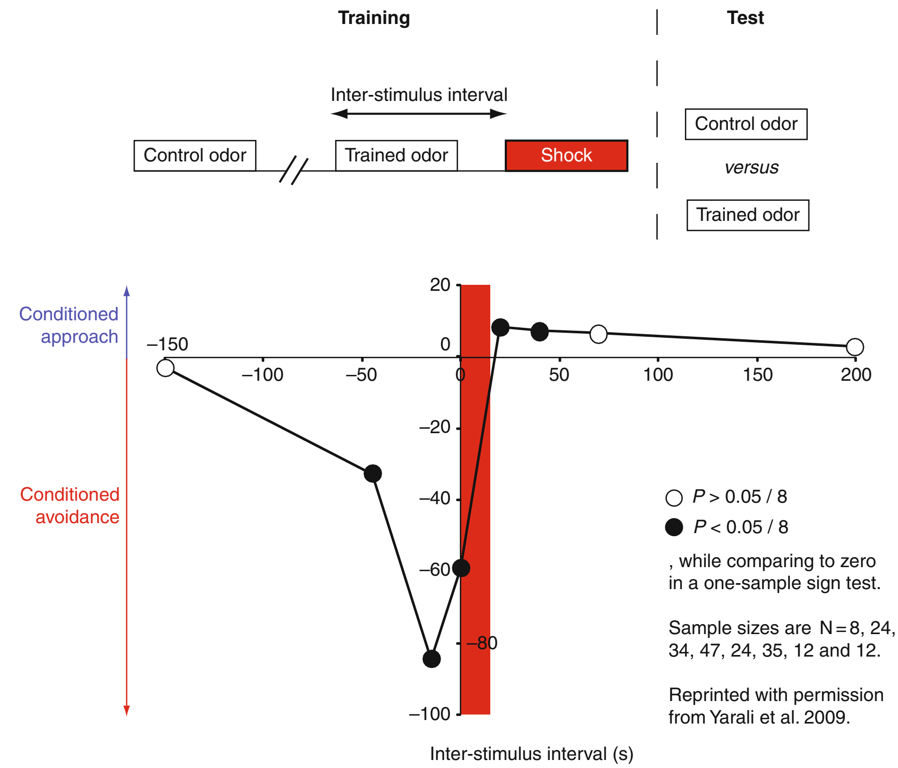
Synonyms

Backward inhibitory conditioning

Definition

If an animal experiences a stimulus *before* an aversive event, it learns this stimulus as a signal for this event and, encountering it the next time, acts anticipatively, in the simplest case by avoiding it. Such associative learning depends on the relative timing of events, namely, if timing is reversed during training such that the stimulus occurs upon the cessation of the aversive event, it can later on elicit opposite behavioral tendencies, e.g., approach, as it has been learned as a signal for what may be called *relief*.

As an example, take the situation in Fig. 1 (Yarali et al. 2009): Fruit flies were given first a control odor, and then a trained odor, which was paired with electric shock as reinforcer. After training, flies were given the



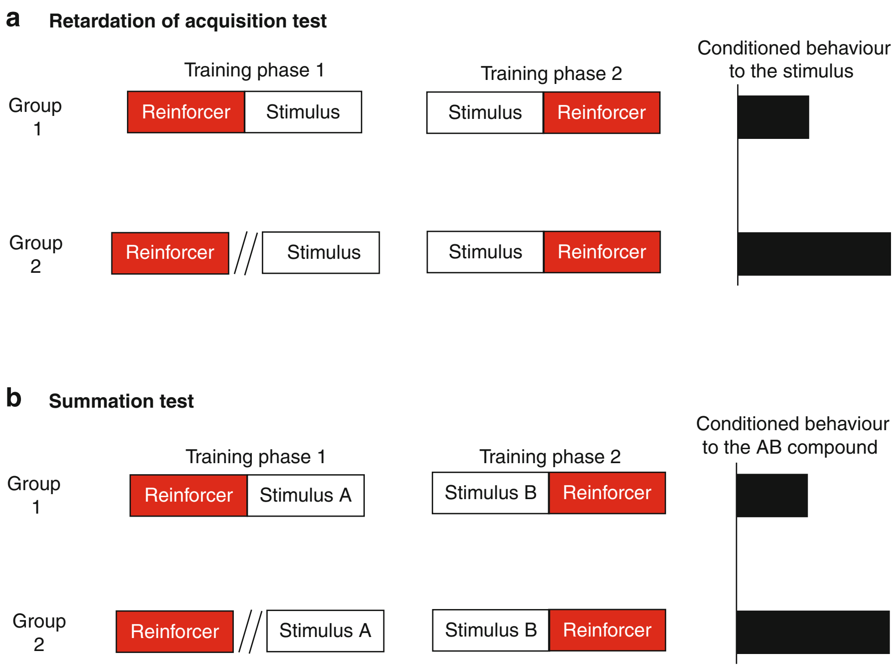
Pain-relief Learning. Fig. 1 Learning of pain versus pain-relief in fruit flies

choice between the two odors to see whether they show conditioned avoidance or approach to the trained odor (across repetitions of the experiment, the chemical identities of the odors were swapped to average-out flies' innate preference between the odors). Conditioned behavior is plotted as a function of the interval between the onset of the trained odor and the onset of the shock. If the trained odor shortly *preceded*, or overlapped with shock, flies later on *avoided* it. In turn, once trained with an opposite timing of events, i.e., first shock, and then the trained odor, flies *approached* this odor. Training with very long intervals between the trained odor and the shock supported no learning. In analogous experiments with human subjects, a visual cue that had *preceded* shock during training later on *potentiated* the subjects' startle to a sudden tone; whereas a cue that had *followed* shock subsequently *attenuated* the startle response, reflecting opposite learned valences (Andreatta et al. 2010).

Theoretical Background

The fruit fly paradigm (Fig. 1) allows for observing opposite behavioral consequences of odor–shock training on the one hand and shock–odor training on the other hand; this is because, superimposed on the flies' innate, untrained olfactory behavior, learning can establish either conditioned avoidance or conditioned approach. Similarly, in the human paradigm, the two opposing kinds of learning affect an innate behavior in two opposite ways (Anderatta et al. 2010). Contrarily, in many other paradigms, only one-way changes in the respective behavioral tendency can be measured, i.e., the dog cannot un-salivate, the rat cannot un-freeze, the rabbit cannot un-blink its eye. In such cases, relief learning needs to be assessed indirectly (reviewed by Wagner and Larew 1985).

For the *retardation of acquisition test* (Fig. 2a), two groups of animals are given two phases of training, each. In the first phase, the first group is trained such that a stimulus follows an aversive reinforcer, so as to establish it as a relief signal; whereas the second group, as control, is given unpaired presentations of the stimulus and the reinforcer. Then, in the second phase, both groups are trained with the stimulus preceding the reinforcer. Finally, conditioned behavior toward the stimulus is compared between the groups. Had the first



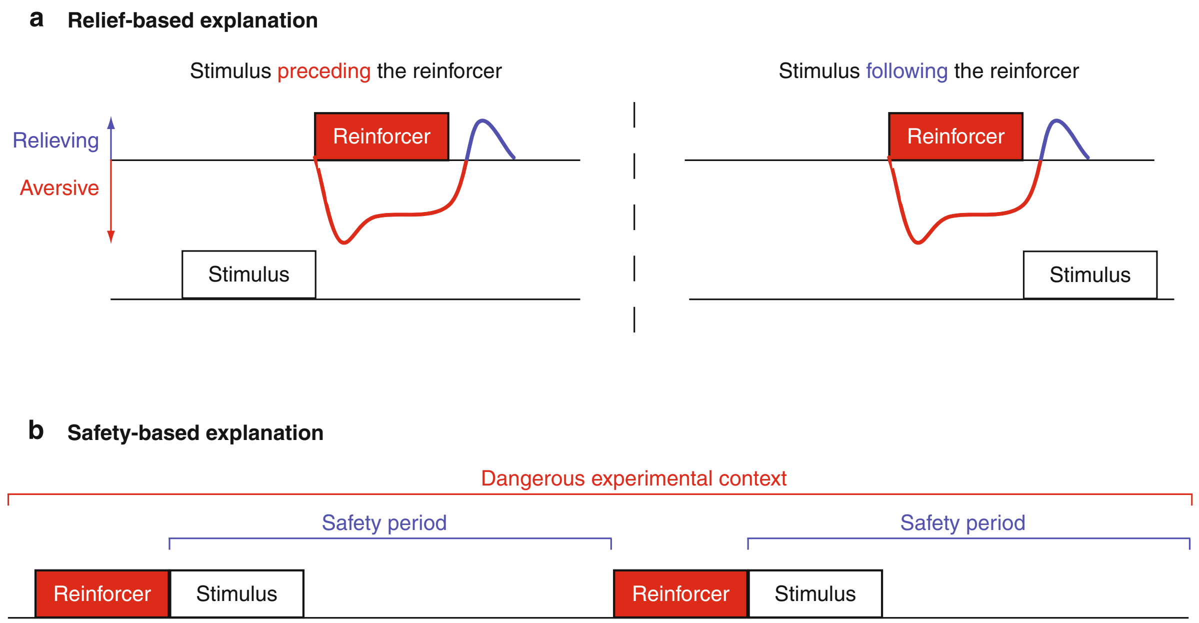
Pain-relief Learning. Fig. 2 Indirect behavioral tests for relief learning

group indeed learned the stimulus as a relief signal in the first phase, it should be retarded in establishing the opposite kind of memory about the same stimulus in the second phase, resulting in a net weaker conditioned behavior.

An additional way to assess relief learning is the so-called *summation test* (Fig. 2b), which also involves two groups and two training phases. In the first phase, the first group is trained to learn stimulus A as a signal for relief. Meanwhile, the second group is given unpaired training. In the second phase, both groups are then trained such that another stimulus, B, precedes the same reinforcer as was used in the first phase. Finally, the two groups are compared in terms of their conditioned behavior toward the compound AB. Had relief learning about stimulus A indeed occurred in the first group, it should add up with the opposite kind of learning with respect to stimulus B, resulting in a net weaker conditioned behavior. A related approach is to summate the effect of relief learning with ongoing operant conditioned behavior: In this case, animals are first trained to generate a particular behavior in order to avoid an aversive reinforcer. Afterwards, a stimulus is trained as a signal for relief from the very same reinforcer. Consequently, the frequency of the conditioned behavior should be dampened in the presence of this stimulus.

The label "*relief* learning" implies learning of an association between the trained stimulus and the offset of an aversive reinforcer (reviewed by Wagner and Larew 1985). Indeed, it has been suggested that aversive events, in addition to their primary effect, induce a delayed state of relief; the opponency of these two states is thought to govern the behavior toward such events (Solomon and Corbit 1974). Furthermore, initially neutral stimuli, depending on their timing, can be associated with either of these opponent states (reviewed by Wagner and Larew 1985): If a stimulus shortly precedes an aversive reinforcer, it will be learned as a signal for the primary, aversive state (Fig. 3a, left). A stimulus that closely follows an aversive reinforcer, on the other hand, will overlap and thus become associated with the delayed state of relief (Fig. 3a, right).

There is, however, an alternative explanation to what we call relief learning (reviewed by Wagner and Larew 1985; sketched in the present Fig. 3b). Namely, during training, through repeated exposure to the aversive reinforcer within the particular experimental context, animals might well learn this context as a signal for the reinforcer. Within this dangerous context, the



Pain-relief Learning. Fig. 3 Alternative psychological explanations for relief learning

occurrence of the trained stimulus might in turn be learned to signal a reinforcer-free period. In this case, the term "*safety* learning" would be more becoming.

How to discriminate between the relief-based explanation (Fig. 3a) and the safety-based explanation (Fig. 3b)? Three experimental strategies have been used to date (reviewed by Wagner and Larew 1985). First, safety learning (Fig. 3b) would clearly require multiple training trials, such that first the context can be learned to predict the reinforcer, and only then, within this already "charged" context, the trained stimulus can become a safety signal. Requirement for training repetition has indeed been observed in many, but not all experimental systems looked at. Second, relief learning (Fig. 3a) would clearly depend on the interval between the reinforcer and the trained stimulus, as is found to be the case in nearly all experimental systems looked at. The extent of safety learning (Fig. 3b), on the other hand, would essentially depend on the length of the safety period signaled by the trained stimulus; accordingly, in some experimental systems, the interval between subsequent reinforcer presentations seems to matter. Third, safety learning (Fig. 3b) obviously relies on the value of the experimental context as a signal for the reinforcer. Indeed in some experimental systems (e.g., rat: Chang et al. 2003), extinguishing the context–reinforcer association by extended exposure to the context without the reinforcer, diminishes the effect of reinforcer–stimulus training. Taken together, all three experimental strategies have given mixed results, thus not providing sufficient reason to generally prefer the relief-based or the safety-based explanation over the other.

Two further paradigms other than reinforcer–stimulus pairings lead to what can be called safety learning; these are left out of the scope of this article and will only be described briefly. In the first kind of paradigm, training with explicitly unpaired presentations of a stimulus and an aversive reinforcer establishes the stimulus as a signal for the absence of the reinforcer. In the second kind of paradigm, animals are first trained with stimulus A–reinforcer pairings; and then, a compound of A and another stimulus, B, is presented without any reinforcer; B, thus signals the absence of the reinforcer, which is predicted to occur, due to A.

Important Scientific Research and Open Questions

Research on relief learning has long focused on the underlying psychological mechanisms, leading to the formulation of valuable mathematical models (e.g., Wagner and Larew 1985). Only recently, also the neurobiological bases of relief learning became a research topic.

Arguably, relief learning requires a convergence of the neuronal signals induced on the one hand by the trained stimulus and on the other hand by the relieving offset of the aversive reinforcer. Three obvious questions arise: How is relief neuronally signaled? Where in the brain do such signals converge with the processing of the trained stimulus to enable the neuronal plasticity? And, what is the nature of this plasticity?

In man, combining behavioral experiments with imaging of neuronal activity can reveal the neuronal correlates of relief learning. Also in simpler organisms, behavioral assays can be combined with optical or electrophysiological methods for monitoring neuronal activity. Importantly, the experimentally more accessible brains of simpler organisms enable also going beyond correlative relationships. In rodents, the roles of various neurotransmitter systems for relief learning can be tested using pharmacological interference. The fruit fly, an even simpler system, enables not only pharmacological, but also genetic interference: It is possible to debilitate desired fly neurotransmitter systems via mutations, and to block or induce the activity of specific fly neurons using transgenic tools.

To tackle the nature of the neuronal plasticity underlying relief learning, electrophysiological methods can be combined with behavioral experiments. In addition, genetic interference can be used to uncover the critical molecular signaling cascades. Conceivably, stimulus–reinforcer training on the one hand and reinforcer–stimulus training on the other hand might modify a common neural circuit in opposite ways; such bidirectional plasticity depending on event timing is a common phenomenon (reviewed by Dan and Poo 2006).

Apart from where and how memory traces concerning relief are laid down in the brain, it is interesting to study how they interact with the corresponding aversive memory traces. The behavior toward aversive events is suggested to be governed by the opponency of the aversive and relieving memories of such events (Solomon and Corbit 1974). How is such opponency kept at the molecular and neuronal levels? In the fruit fly, a single gene coherently affects the two opposing kinds of memory about electric shock, suggesting an at least partially genetically controlled balance (Yarali et al. 2009). By combining pharmacological and genetic intervention with behavioral assays in various organisms, the pivots of such balance can be revealed.

In short, the most promising approach toward the neurobiology of relief learning seems to be a comparative one across organisms, which combines behavioral experiments with monitoring as well as pharmacological and genetic alteration of neuronal activity. For such comparative approach, it will be helpful to use comparable behavioral paradigms in different organisms. Clearly, for unambiguous interpretation of the effects of genetic and pharmacological interference, paradigms which enable direct assessment of relief learning (Yarali et al. (2009) and present Fig. 1 for the fruit fly; Andreatta et al. (2010) for man) have advantages over designs where indirect tests (Fig. 2) are required.

Cross-References

- ▶ Animal Learning and Intelligence
- ▶ Anticipatory Learning
- ▶ Associative Learning
- ▶ Conditioning
- ▶ Extinction Learning
- ▶ Formal Learning Theory
- ▶ Inhibition and Learning
- ▶ Learning Mutants
- ▶ Memory Codes and Neural Plasticity in Learning
- ▶ Neuropsychology of Learning
- ▶ Reinforcement Learning in Animals

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Paired-Associate Learning

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Synonyms

Associative learning

Definition

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 typically 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

Paired-associate learning has most commonly been used to examine and understand the mechanisms of learning and forgetting of information. Because classic paired-associate learning paradigms use unrelated items (e.g., unrelated words or number–letter combinations), paired-associate learning has been regarded as a method for examining the processes underlying human memory without the complicating forces of previous learning history that occurs when concept pairs have a preexisting association. This makes paired-associate learning a particularly useful paradigm for understanding memory processes because it places many extraneous factors in the control of experimenters, while studying concept pairs that have a preexisting association necessarily leaves a number of factors from a person's life learning history outside of experimenters' control. While paired-associate learning has been used to document numerous facets of memory processes, two particularly influential contributions paired-associate learning research has made to understanding memory is to examine *the nature of associations in memory* and understanding *forgetting*.

Regarding the nature of associations in memory, there are two primary viewpoints that have been advanced. One advocates that associations between concepts are *independent* of one another. For example, if presented with a paired associate such as *stove-letter*, people will encode associative relationships in each direction (*stove* → *letter* and *letter* → *stove*). This theory allows for each association to be separately strengthened based upon factors such as participants' attention to each association's direction, the extent to which a particular direction of association reflects the properties of the environment, and other factors that may separately strengthen an association in each direction. A second view suggests that associations are generally symmetric, such that encoding an associative relationship between two concepts produces a single association, which represents a combination of the properties of each item that forms a paired associate. In effect, this theory suggests that encoding a paired associate effectively produces a new representation that stores the combined properties of a paired associate.

Regarding forgetting, there are also two primary viewpoints that have been advanced to explain forgetting, each of which has been tested extensively with paired-associate learning. One is that memories *decay*, or weaken over time. The alternative view is that memories *interfere* with one another. The interference view suggests that rather than memories weakening and losing information over time, they instead become harder to access because we are continually encoding and storing new memories. Thus, encoding and storage of other memories creates competition among memories, rendering them more difficult to retrieve at a later point in time.

Important Scientific Research and Open Questions

There are two lines of evidence that contribute to understanding the nature of associations in memory. One line involves the use of forward and backward recall of paired associates (e.g., Kahana 2002). For example, if people study the paired associate *letter* – *stove*, forward recall requires participants to produce *stove* when given *letter* as a cue, while backward recall requires participants to produce *letter* when given *stove* as a cue. A second line of evidence comes from free association (e.g., Nelson et al. 1998), where people are provided with a single term and asked to provide the first concept that comes to mind in response to the term. While this latter task does not involve encoding and retrieval of paired associates, performance on free association tasks potentially enables understanding of the structure of associations in a task that reflects the rich lifetime experience of people. To the extent these two tasks suggest similar conclusions, the more confidence we may have in those conclusions about how associations are stored in the mind. Indeed, analyses of both of these tasks suggest that associations are bidirectional (Brainerd et al. 2008; Kahana 2002), with evidence from paired-associate learning strongly suggesting that encoding of concept pairs produces a single association between two concepts rather than strengthening of two independent associations (Kahana 2002). Thus, encoding of paired associates seems to create a new representation of the combination of features of the items in the paired associate, rather than storage of two separate associations that represent each direction of association between paired associates.

Regarding forgetting, most of the available evidence documents interference as the primary cause of forgetting and suggests little role for decay. In part, this may be because it is exceptionally difficult to conduct an adequate test of the role of decay in producing forgetting: Any increase in time between encoding and retrieval of a paired associate is likely to also include the storage of new memories, and therefore, increases interference. Although deriving a test of the role of decay in forgetting is difficult, there is ample evidence that interference can produce forgetting. Further, interference appears to create forgetting both due to memories stored prior to an experience (e.g., Underwood 1957), known as *proactive interference*, and due to memories stored following an experience (e.g., Barnes and Underwood 1959), known as *retroactive interference*. Finally, while paired-associate learning has figured prominently in discerning that forgetting occurs due to interference, there exists parallel evidence that similar principles operate when encoding and retrieving stimuli that are not paired associates (e.g., Wickens 1970).

There are, however, outstanding questions in understanding forgetting. In particular, much current research is directed toward understanding how much forgetting is under conscious control (Anderson and Green 2001), which has potential implications for how well people can suppress unwanted memories. Similarly, currently research is examining the extent to which retrieval itself functions as a cause of forgetting (Anderson et al. 1994), as well as the extent to which forgetting due to interference is the result of competition among associations between concepts in memory or is caused by inhibition of memory representations (Anderson 2003).

Cross-References

► Abilities to Learn: Cognitive Abilities
► Conditioned Inhibition
► Cued Recall
► Directed Forgetting
► Retention and Learning
► Role of Similarity in Human Associative Learning

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Paradigm

The word *paradigm* comes from the Greek word παράδειγμα (*paradeigma*) which means "pattern" or "example." From the late 1800s, the word *paradigm* has been used as an epistemological term to denote a "thought pattern" in scientific disciplines. The most popular use of the word in this context was by Thomas Kuhn (1970) who applied it to describe *a set of practices* in science.

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Paradigms of Learning Research

► Methodologies of Research on Learning (Overview Article)

Parahippocampal Gyrus

The region of the brain that surrounds the hippocampus. The parahippocampal gyrus contains regions that are critical to memory, and that communicate with the hippocampus to encode, maintain, and retrieve information.

Parallel Constraint Satisfaction Theory of Analogy

► Analogical Coherence/Correspondence

Parallel Distributed Processing (PDP)

► Connectionism

Pareto Optimal

An allocation of outcomes among individuals is Pareto optimal or Pareto efficient when there is no change that will make any of the individuals better off without hurting one of the other individuals.

Parsimony Principle for Mental Models

The mental model theory postulates that mental models are parsimonious. This means that they represent what is possible, but not what is impossible. The principle of parsimony applies at two levels. At the first level, mental models represent only what is possible. The second level has to do with individual models of possibilities.

Parsing

► Learning by Chunking

Part

► Configural Cues in Associative Learning

P

Partial Reinforcement Effect

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Synonyms

Effect of intermittent reinforcement; Partial reinforcement extinction effect

Definition

The partial reinforcement effect (PRE) is the empirical finding that resistance to extinction is greater following acquisition where some, but not all, responses are reinforced (PRF); compared to acquisition all responses are reinforced (CRF). Extinction is the experimental condition where no reinforcers are given for each response, which generally results in the response no longer being made. Thus, "resistance to extinction" refers to the relative degree that the response continues to occur during the extinction condition. Another way of stating the basic PRE is that the persistence of a response undergoing extinction is greater when training (acquisition) consisted of PRF as compared to CRF.

Theoretical Background

The first report of the PRE occurred before the middle of the last century, and it has been studied in literally hundreds of experiments under a variety of procedures. The most commonly used method for theoretically important data is the straight runway utilizing rats as the subject. The runway consists of three parts: (1) a start compartment into which the rat is placed and subsequently a door is opened allowing the rat to enter the (2) alley way, which leads to the (3) goal box where food or other reinforcing event is located. Using a CRF schedule means that food is present on every occasion, while using a PRF schedule means that food is present on some trials, but not on others. When the finding that PRF resulted in greater resistance to extinction than CRF, it was a major challenge to the then predominant stimulus-response (S-R) theories that claimed that the function of reinforcement was to strengthen behavior in a direct fashion. Since a PRF schedule resulted in fewer reinforced trials than a CRF schedule (assuming the total number of trials to be constant), then the CRF schedule should result in greater strength of response than the PRF schedule, and be reflected by greater resistance to the effects of extinction for the CRF schedule – exactly the opposite of what is found. For this reason, the PRE is sometimes characterized as representing a paradoxical effect of reinforcement. Of course, the PRE is a paradox only in the context of the S-R theories of learning from the first half of the last century. The PRE is also important because it represents a fundamental problem that must confront a forager in the real world: How long should searching for food in a particular location persist?

In more recent times two main theories (and several minor ones) have been developed by Abram Amsel, called Frustration Theory, and by E. J. Capaldi, called Sequential Theory. Recognition of the importance of these two theories is the fact that the initial volume of the prestigious book series, *The Psychology of Learning and Motivation*, contained the lead two chapters authored by these theorists (Amsel 1967; Capaldi 1967). Both theories are in the S-R tradition, but differ radically in how the S-R concepts are applied.

Amsel's Frustration Theory postulates four stages of learning with capital letters S and R representing the observable, and the small letter s and r representing internal mediating events in the tradition of the Hull—Spence theory of learning (Hull 1952). We will forgo these formal representations as they become quite intricate, in favor of words that represent what the theory postulates. The stages are: (1) an expectancy of reward is established on rewarded (R) trials (this is as far as the CRF conditions progresses during acquisition) (2) a non-rewarded (N) trial now generates frustration which (3) becomes anticipated, resulting in a conflict between the approach associated with the anticipation of food and avoidance associated with the anticipation of frustration, but (4) the reward that occurs on trials when frustration is anticipated is said to counter-condition the frustration–avoidance relationship to a frustration–approach relationship. Thus, when extinction is initiated, the PRF and CRF subjects will experience only frustration, but the PRF subjects have experienced frustration during acquisition, and been conditioned to approach the goal, while the CRF subjects have not experienced frustration previously, so the tendency to avoid the frustration location is strong, and they, therefore, rapidly stop approaching the goal.

Capaldi's Sequential Theory takes a much different approach, denying the importance of an emotion like frustration, and stressing the memory of events from one trial to the next as a basic mechanism to explain the PRE. It is interesting that in the early development of sequential theory (e.g., the 1967 chapter), the word "memory" is not used. Presumably, the strict behaviorism of the time made such words taboo, but it is clear that memory must be what was accounting for the effect of the previous trial to be present on the current one. What Capaldi proposed was that on an N trial in the PRF condition, the memory of the N trial (S^N) would be present on the next trial and if that trial ended in reinforcement, the memory would be conditioned to the instrumental response, an S^N-R_I association in the terminology of the theory. In extinction only the memories of N trials would be present and this memory, being unfamiliar to the CRF-trained subject, would cause "stimulus generalization decrement." This means that any change in stimulus conditions will result in the response only being maintained by the process of generalization. The PRF-trained subjects have had the memory of non-reward conditioned to the instrumental response and therefore do not suffer the stimulus generalization decrement of the CRF subjects, thereby accounting for the PRE.

The two theories of the PRE are strikingly different in the mechanisms proposed, but there is one similarity that is important to appreciate. Both theories stress the importance of the introduction of new, novel, stimulus conditions during extinction for the CRF-trained subjects. For Frustration Theory it is frustration itself and unconditioned tendency to avoid frustrating situations. For Sequential Theory it is the memory of non-reward that is present resulting in stimulus generalization decrement. One of the early "theories" of the PRE was called the Discrimination Hypothesis and made the intuitively appealing suggestion that the PRE is a result of the PRF subjects not being able to discriminate the start of extinction, while the CRF easily discriminate it. The Discrimination Hypothesis was rejected on empirical grounds, when it was found that following a period of PRF training with CRF training resulted in an undiminished PRE, even though the CRF training prior to extinction should have allowed an easy discrimination of the start of extinction. The Discrimination Hypothesis also suffers from a lack of ability to make unique and surprising predictions or account for most of the complex effects that have been produced by the two main theories. Discrimination clearly plays a role in the PRE, but the simplistic "failure-to-discriminate-the-start-of extinction" is not a satisfying explanation of the effect.

Another minor theory of the PRE is the application of the social psychological idea referred to as cognitive dissonance (Lawrence and Festinger 1962). The theory suggests that when the rat runs down to the goal box and finds no food, and cognitive dissonance is aroused. It is as if the rat says to itself, "I ran down here, expending energy, and there's nothing in it for me." According to the theory the goal box itself receives enhanced value to justify the run down the alley to it, thereby reducing the discomfort caused by the presence of cognitive dissonance. Humorists have characterized the explanation as the "theory of the pretty goal box." The theory has not been particularly influential and has rarely been tested.

The terms "extinction" and the "resistance to extinction" used to describe the PRE are unfortunate since they encourage a basic misunderstanding between extinction, the procedure, and extinction, a psychological phenomenon. Extinction as a procedure is the non-reinforcement of a previously reinforced behavior. The misunderstanding comes from thinking that the extinction label implies a psychological process of the disappearance of the behavior and the relationship the behavior had to the reinforcer. Neither of the major theories of the PRE imply the total destruction of the mechanisms accounting for the previously reinforced behavior. As mentioned above, both theories depend on stimulus change to bring about the decrease in the previously reinforced behavior during extinction. Indeed, the occurrence of spontaneous recovery, known for over 100 years, is evidence that extinction does not obliterate what was previously learned. Successive phases of acquisition-extinction-reacquisition-re-extinction and so on reveal that reacquisition occurs more rapidly than acquisition, again refuting the idea that extinction destroys the effects of acquisition. Researchers periodically rediscover the fact that the extinction procedure does not result in a "psychological extinction."

Some other phenomena that are important in understanding the PRE follow.

- Partial delay of reinforcement results in greater resistance to extinction than continuous immediate reinforcement (delay involves the rat entering the goal box and being required to wait before food is available).
- Partial punishment also results in greater resistance to extinction than no punishment.
- Larger magnitudes of reinforcement result in greater resistance to extinction for PRF-trained subjects, but less resistance to extinction for CRF-trained subjects.
- Lower percentages of reinforcement generally result in greater resistance to extinction, to some limiting (very low percentage) value. Percentage of reinforced trials is confounded with length of successive non-reinforced trial, and when experimentally separated, the percentage effect seems to be explained by the N-length effect.
- The effect of PRF and CRF during acquisition can be somewhat variable, with no differences, or

sometimes faster running for PRF than CRF in start and middle parts of the runway and CRF faster than PRF in the end, or goal box region, of the runway (Amsel 1967).

- Within subject procedures (PRF in one runway, CRF in another for the same subject) have resulted in a variety of outcomes, but seem best made understandable by applying Capaldi's Sequential Theory (1967).

Important Scientific Research and Open Questions

Most textbook writers on learning and conditioning have come to the conclusion that there is more support for the Sequential Theory than the Frustration Theory as an explanation of the PRE. Amsel (1967) himself acknowledged the sequential approach to have greater support, but he argued that the theory was only appropriate when the spacing of trials was very close in time. This argument comes from the older (early 1950s) arguments that stimulus traces (proprioceptive stimuli associated with no food in the mouth) remain active after a non-reinforced trial and carry over to the next trial where they would be conditioned to the response if it resulted in reinforcement. This is called the Hull–Sheffield Hypothesis, and could only be applicable if the trials were close together in time (Hull 1952). Amsel, and others who followed in the frustration theory camp, defined the sequential theory of Capaldi as dealing with these aftereffects, and therefore if trial spacing was sufficiently long, the sequential theory could be ignored as being relevant to explaining PRE phenomena. Clearly, Sequential Theory is relevant for longer inter-trial intervals, and non-reinforcement persists to the next trial by being a memory that is reinstated on a subsequent trial by contextual cues. In recent times, the study of nonhuman animal memory has revealed a rich and detailed memory system, in most ways directly analogous to human memory systems and reinstatement of memories is a well-documented phenomenon (Spear and Riccio 1994). This is not to say that frustration as an emotional response to non-reinforcement is irrelevant to the PRE. It may well be that frustration is part of what is remembered from non-reinforced trials, allowing it to be a factor in a complete theory of the PRE.

Cross-References

► Cognitive Dissonance in the Learning Process
► Extinction Learning
► Memory Persistence
► Punishment and Reward
► Reinforcement Learning
► Reinforcement Learning in Animals
► Retrieval Cues and Learning
► Sequential Learning

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Partial Reinforcement Extinction Effect

► Partial Reinforcement Effect

Participation

► Measurement of Student Engagement in Learning

Participatory Learning

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Synonyms

Cooperative learning; Interactive learning

Definition

The word *participatory* comes from *participation*, which refers to the action of taking part in activities and projects, the act of sharing in the activities of a group. The process of *participation* fosters mutual learning. The participatory learning strategy has its theoretical basis in the behaviorism as well as in cognitive and social psychology. Collaboration is a useful tool used within participatory culture as a desired educational outcome. The Partnership for twenty-first century Skills, for example, defines collaboration as working effectively and respectfully with diverse teams, exercising flexibility and a willingness to make compromises to accomplish a common goal, and assuming shared responsibility for collaborative work while valuing individual contributions.

Theoretical Background

Many authors have done research about the learning process and the way students learn better (e.g., Skinner 1953; Ausubel 1960). The ability to learn has been a key characteristic of human beings throughout history. Learning can be defined as a change in behavior resulting from experience, and it involves complex intellectual or attitudinal changes which may affect learners' behavior.

However, in the process of learning, it is necessary to follow several principles. According to Motah (2007), learning should be relevant to existing knowledge and any future tasks; it should comprise appropriate sequencing of instruction; it should involve feedback on performance; and it should have active student involvement. This last principle is essential for success, and learning can thus not be viewed just as a teacher providing information. Learning is more than that. It is an active process in which a learner learns from experience. Therefore, students must be given opportunities to practice and apply new knowledge. One way of achieving this is through involvement in participatory learning, which is closely related to "cooperation."

Cooperative learning is the best form of participatory learning. It is a successful teaching strategy that can be applied in the classroom by having groups of students with different levels of ability work together to develop tasks in small teams. In a cooperative classroom, learners support, encourage, and help each other, exchange ideas and give positive feedback to each other, follow common goals, and learn to take responsibility for their own behavior and for their academic work. As Slavin (1990) states, students learn to handle interpersonal, intergroup, and intersocietal relations in constructive and creative ways and to assume their role as responsible members of society. Furthermore, they greatly enjoy doing so. In cooperative groups, students play different roles: material person, recorder, organizer, and participation checker. Each member of the group is responsible for his own learning and the learning of his group. There is no one main leader; all participants may play a leading role. The teacher acts as an encourager and facilitator of learning. In cooperative learning, the classroom is organized so that students can learn not only from the teacher but also from the world around them as a result of interaction. Students become involved in a purposeful and meaningful topic, context, or situation. They may find out about the historical background, issues, and problems associated with the topic.

Participatory Learning Technique (PLT) is a way of organizing the classroom that motivates learners to participate in the act of teaching, a peer-based learning process. In this way, learning is focused on increased student participation, so it is basically student centered.

Student-centered learning has the following relevant characteristics:

- It is an alternative methodology.
- It involves participatory learning and a collaborative approach.
- Students interact and learn from each other.
- Teachers have a willingness and ability to learn from students: to see in the way that students see and to appreciate how students make sense of their world.
- Learning is viewed as the construction of new information.

As students become the center of tasks, participatory learning is really a good strategy by means of which learners take an active part in the learning process and have a great opportunity for meeting, interacting, and getting acquainted with other learners. The participatory learning strategy is the instructional use of small groups of three to eight members in which learners work together to achieve a common goal and to maximize their own and each other's learning (Johnson and Johnson 1994). The strategy is very advantageous at all levels, but in adult learning it plays a major role, since it provides chances for concrete experience, followed by personal reflection on that experience, abstract conceptualization derived from general rules describing the experience, and the application of known theories to it. It thus leads to active experimentation and the construction of ways of modifying the next occurrence of the experience, leading in turn to the next concrete experience (Kohle 1982). Thus, the participatory learning technique is more effective than the traditional method not only in the sense that it enhances students' achievements, but also because it leads learners to develop a more positive and favorable attitude toward any course.

Participatory approaches include various techniques to facilitate learning and information sharing. When people first take part in participatory learning, they interact with facilitators to learn different approaches. At the same time, the facilitators use certain techniques to help the people involved in activities feel comfortable with a participatory approach, to encourage them to share ideas, information, and knowledge, to support group learning, to help them use effective communication, to manage group dynamics, to keep the work practical and relevant, and to invite the group to take control of the learning and sharing process.

Some participatory learning techniques that can be adapted to different courses according to the level of learners are the following:

Games

Games can be very effective for breaking out of conventional expectations about university classrooms and the roles of academics and students. They are an enjoyable way of handing over leadership roles to students as a lead-in for the more serious topics to follow. Run well, many games and energizers provide opportunities for bringing even the shyest and most reserved students to the center and creating nonthreatening opportunities early on for them to act in the role of facilitator.

Discussion

Robert Shostak (2003) describes discussion as a method that permits open interaction between student and student as well as between teacher and student. It involves free-flowing conversation, giving students an opportunity to express their opinions and ideas and hear those of their peers and the teacher. The teacher participates more as a member of the group. When it is properly planned and structured in advance, a discussion involves participants in higher-order cognitive skills such as analysis, synthesis, and evaluation.

Brainstorming

This technique allows learners to express any ideas that come to mind and collect them all in a list without evaluation or judgment. The quantity, not the quality, is what matters. Ideas can be discussed later for practicality. Sometimes unlikely or seemingly ridiculous ideas lead to a more practical idea which would otherwise not have been considered.

Critical Incident

By means of this technique, facilitators use problem situations to analyze advantages and disadvantages and possible solutions to a given situation. Pictures or drawings can be used as aids.

Describing Visual Images

For this technique, it is suggested to choose photographs or drawings with a clear, relevant message. Before displaying the image, the teacher asks three volunteers to leave the room. Then he/she discusses with the other participants how to describe the picture and asks person A to return and listen to a description of the image (without allowing him/her to see it). Then, he/she lets person A tell B and B tell C, and asks C to draw the picture. Then the participants discuss. It is used to highlight how messages become distorted when passed from one person to another.

Good, Bad, or in Between

The facilitator shows the participants pictures, each with a scene that could be interpreted as good, bad, or in between, depending on the point of view. Then he/she asks the participants to sort the scenes into these three categories and discuss the different alternatives.

Information Collection

Members of the group are asked to collect information on relevant subjects at the local library, offices, service organizations, etc. This is useful for finding out what is needed or the likely results of an idea before trying it out in practice.

Making Something Together

The facilitator provides materials and objects and asks the participants to make something. Then the facilitator watches and uses the results to discuss communication and cooperation.

Creating Digital Videos

Learning by creating video helps participants learn something, but they may not all learn the same thing. Video production takes time and a great effort, so it is best to have learners working in groups. Then the facilitator can plan oral activities about the content of the video to be developed cooperatively, according to the subject.

Pictures, Posters, or Study Cards

The facilitator presents a story about a relevant topic using pictures, and has participants discuss the content and results in groups.

Experience Presentations

Teachers ask one participant to describe personal experiences related to daily life or work and create a favorable environment for discussion among other members of the group.

Problem Solving

A table with four columns is made. The problems of participants are listed in the first column, possible solutions in the second column, what prevents them from solving the problem in the third column, and what will help them solve it in the fourth column. When the table is finished, the participants engage in a discussion.

Project Work

Projects allow students to work independently in small groups in and outside of the classroom to gather the necessary information from books, journals, the Internet, and other sources. The learners are also expected to come up with an action plan detailing the steps to be taken to complete the project as well as the different duties and responsibilities of the members of the group.

Project work involves multi-skill activities which focus on a theme of interest rather than specific language tasks (Haines 1989). In project work, students work together to achieve a common goal, a concrete outcome, such as a brochure, a report, a video, a radio program, etc.

Spoken Messages

The facilitator thinks of a given message related to a situation, gives it to one member, and tells him/her to pass it around from one person to another by whispering. Then the facilitator asks the last person to repeat what she/he has heard. After that he/she discusses how and why the message changed, how misunderstanding can be avoided, and what can be learned from this game.

Important Scientific Research and Open Questions

The concept of participatory learning raises some questions in relation to the effectiveness of applying the techniques. Some researchers, for example Dutcher (2004), state that participatory learning techniques might have some limitations. After applying these techniques to undergraduate students, he compiled some information on potential problems related to particular techniques, including the danger of overuse, the reluctance of some learners to participate due to peer pressure or shyness, the difficulties of adequately assessing student participation, the varying levels of "social maturity" of different students, and the problem of whether to form learning groups along the lines of heterogeneity or homogeneity.

Although it has been proven that participatory learning is more effective than passive learning, it is not applied enough in university contexts. Indeed, participatory tasks are effective ways to challenge learners to analyze and apply their own knowledge and expertise in new ways and thus extend it. A basic concept related to learning and teaching participation is that individuals generate theories relevant to their own context (Taylor and Fransman 2003).

Also, there are forms of participatory learning that are sometimes disregarded by teachers. This is the case for games, which, according to Chambers (2002), energize participants and lighten their mood. Games contribute to engaging participants in the learning process and help them relate to each other. They are an enjoyable technique that provides opportunities for bringing even the shyest and most reserved students to the center of activities to act as facilitators. Games also build relationships among learners in the classroom and create a sense of collectivism and mutual support and solidarity.

Cross-References

► Collaborative Learning
► Cooperative: Learning
► Cooperative Learning Groups and Streaming
► Generic Architectures for Cooperative Learning Environments
► Interactive Learning Environments

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Parts

► Human Feature Learning

Passion

► Creative Inquiry
► Emotional Intelligence in Animals

Passive Avoidance

Not performing a behavior that would produce an aversive outcome. Contrast with active avoidance.

Passive Learning

► Receptive Learning

Path

► Trajectories of Participation; Temporality and Learning

Path Dependence

This expression indicates an outcome dependent on all the previous history experienced by an agent, rather than simply on its present situation or on the situation at t-1; all previous points of the trajectory covered by our agent matter; knowledge is constructed step by step.

Pattern

► Configural Cues in Associative Learning
► Metapatterns for Research into Complex Systems of Learning

Pattern Classification

► Statistical Learning Theory and Induction

Pattern Recognition

► Mathematical Models/Theories of Learning (TL)
► Statistical Learning Theory and Induction

Pattern Separation

A mode of processing in neural networks in which complex inputs are represented a limited number of active units. This protects potentially overlapping inputs from interference effects. It is facilitated by sparse processing.

Patterned Syllable Stream

► Infant Artificial Language Learning

Pavlov, Ivan P. (1849–1936)

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Life Dates

Pavlov grew up in a small town (Ryazan) in Russia about 250 miles southeast of Moscow. His father, a parish priest, nurtured his interest in learning and scholarship, and his early education destined him to follow his father's footsteps. He attended the Ryazan Theological Seminary in the early 1860s but his interests soon extended beyond the traditional ecclesiastical curriculum and at the age of 21 Pavlov entered the University of St. Petersburg to study natural science and physiology. His primary mentor was Sergei Botkin, who emphasized experimental physiology and the importance of the nervous system in the control and regulation of physiological functions. The emphasis on experimentation and neural control was attractive to Pavlov because it provided a more scientific evidence-based foundation for physiology and medicine than traditional notions of "bodily humors" and the imbalance of humors as the cause of disease. Experimentation and the axiom of neural control and regulation remained major features of Pavlov's work for the rest of his life. His dissertation involved studies of the neural innervation of the heart and earned him an M.D. degree from the Imperial Military Academy of St. Petersburg in 1883. As a medical student, Pavlov was appointed to serve as director of Botkin's laboratory, which gave him invaluable experience supervising and assisting numerous other students with their physiological experiments. After obtaining his M.D. degree, Pavlov went to Germany for 2 years, where he worked with Rudolf Heidenhain, the professor of physiology at Breslau and an expert surgeon with an interest in the digestive system. Pavlov gained invaluable surgical experience in Breslau's laboratory.

Pavlov had difficulty making ends meet after returning to St. Petersburg but he remained active in laboratory work. His efforts were well rewarded by an appointment as professor of pharmacology (in 1890) and then professor of physiology (in 1895) at the Imperial Military Academy in St. Petersburg. He also became Director of the Institute of Experimental Medicine in St. Petersburg, which had been created (and funded) by Prince Oldenburgski, to facilitate the conduct of experiments with greater autonomy and academic freedom than was possible at the University. Many of Pavlov's most famous research findings (including work on the conditioned response) were described in progress reports to Prince Oldenbursgski.

At the Institute of Experimental Medicine, Pavlov carried out an extensive research program on digestive physiology and digestive secretions. His book, *Lectures on the Work of the Principal Digestive Glands* was published in 1897 and brought him considerable international recognition. Much of his research was made possible by his mastery of aseptic animal surgery, which minimized postoperative infection and permitted Pavlov to study dogs over many months and sometimes years. He also developed ways to externalize digestive glands and ducts, which enabled him to directly observe digestive secretions. In recognition of the importance of his extensive research on digestion (including stomach secretions, the pancreas, the discharge of bile, and gastrointestinal motility) Pavlov received the Nobel Prize in 1904. Interestingly, the research for which he is primarily remembered till today, the conditioning of reflexes, was conducted after the work for which he received the Nobel Prize.

In addition to being an expert experimentalist, Pavlov owed much of his research productivity to his effectiveness as a laboratory manager. Medical students were required to complete an experimental thesis as a part of their degree requirements. This provided Pavlov with a steady stream of research assistants who needed experimental projects. Pavlov was happy to comply, and between 1897 and his death in 1936, he supervised the work of 146 research assistants. Most of his research findings were written up in student thesis reports. When Pavlov switched his attention to the conditioned reflex, one of his major concerns was to be sure that his new experiments had the same methodological rigor as his studies of digestive physiology and yielded similar quantitative data. He made the conditioning procedures simple enough to be easily communicated and carried out by new students entering the laboratory. He also emphasized strict experimental control so that the results would be readily replicated.

Contribution(s) to the Field of Learning

Pavlov's primary contribution to the field of learning was the development of concepts and procedures for the study of conditioned behavior. An important aspect of Pavlov's approach was that new learning is based on what the organism is already able to do by virtue of its existing repertoire or instinctive behavior. Pavlov called a stimulus that elicits responding without prior training the unconditioned or unconditional stimulus (US). Through associative learning or conditioning, responding relevant to the US comes to be elicited by other cues, called conditioned stimuli (CS). Thus, conditioning increases the range of stimuli that control behavior. The mechanisms and functional significance of this type of learning captivated Pavlov and provided the inspiration for more than a century of subsequent research on this type of learning.

Pavlov first identified a conditioning effect during the course of studying stomach secretions in dogs that were outfitted with two fistulas. One of the fistulas was used to externalize the esophagus so that food that was swallowed would not enter the stomach. The other fistula was inserted into the stomach to enable collection of stomach secretions. When the esophageal fistula was closed, the dog could eat normally. When the esophageal fistula was opened, any food the dog swallowed did not enter the stomach, thus enabling Pavlov to measure stomach secretions in the absence of having food stimulate receptors in the stomach. Observations of dogs with the double fistula technique revealed that food in the stomach is not required to stimulate gastric secretions. Food in the mouth will also trigger such sections. In fact, just about any stimulus that reliably precedes food in the mouth (the sight of food or the presence of the person who usually feeds the dog) will stimulate gastric secretions. Since such secretions occurred under circumstances in which the dog appeared to anticipate or think about the presentation of food, the effect was called "psychic secretion."

The phenomenon of "psychic secretion" was well known in Pavlov's laboratory for several years before he turned his full attention to studying the mechanisms that were responsible for anticipatory responding. Although the phenomenon of conditioning was initially discovered in connection with digestive secretions of the stomach, most of Pavlov's subsequent research involved studies of conditioned salivation. Pavlov was persuaded to focus on the mechanisms of conditioned responding not because he was interested in psychology but because he considered conditioning to be a way to study the functions of the nervous system. His most widely read book on conditioning, *Conditioned reflexes*, is subtitled "An investigation of the physiological activity of the cerebral cortex" (Pavlov 1927/1960). The book deals primarily with Pavlov's research on salivary conditioning, which he regarded as an "objective method" for "investigating the physiological activities of the cerebral hemispheres." The book includes chapters titled "The analyzing and synthesizing activity of the cerebral hemispheres" and "Irradiation and concentration of nervous processes in the cerebral hemispheres," but the experiments described are behavioral studies of salivary conditioning.

The first systematic studies of conditioned salivation were carried out by Stefan Vul'fson and Anton Snarskii in Pavlov's laboratory. Vul'fson initially measured salivation in response to various substances placed in a dog's mouth (dry food, wet food, sour water, and sand) and found that after a while the mere sight of these substances would also elicit salivation. (Contrary to popular accounts, Pavlov rarely if ever used a bell as a conditioned stimulus.) Vul'fson also found that the chemical composition of the saliva elicited by the conditioned visual cues was similar to the salivation that occurred in response to the substance in the mouth (the unconditioned stimulus). Vul'fson's results were characterized as "natural conditioned reflexes" because his procedures were similar to what occurs when dogs naturally encounter food items. Dogs first see the food that they later ingest.

Anton Snarskii extended Vul'fson's observations by experimentally manipulating the visual features of what was placed in the dog's mouth. He initially presented sour water that was colored black with a dye. The acidity of the sour water placed in the mouth elicited salivation unconditionally, and this response then came to be made to sight of plain water that had been dyed black. Snarskii's method permitted presentation of the conditioned stimulus (the sight of black water) independently of the unconditioned stimulus (sour taste in the mouth). The methodological separation of the conditioned and unconditioned stimulus opened up a large range of experimental manipulations that continue to be examined in contemporary research on Pavlovian conditioning. Snarskii also helped to move Pavlov's laboratory away from mentalistic to mechanistic interpretations of the conditioned response. The shift toward mechanistic interpretations of conditioned responding was also facilitated by I. F. Tolochinov who joined Pavlov's laboratory after having worked with V. M. Bechterev on the knee-jerk and eyelid reflexes. Tolochinov conducted the first studies of the extinction of conditioned behavior. The phenomenon of extinction helped convince Pavlov that conditioning involved a fairly mechanistic association between a conditioned and an unconditioned stimulus.

Having established a replicable methodology and a physiological/mechanistic conceptual foundation for the study of conditioned behavior, Pavlov and his students pursued a program of research that continued for more than 30 years and mapped out many of the major phenomena and concepts of Pavlovian conditioning. Because of his background in physiology, Pavlov was interested not only in processes that encouraged responding (excitatory conditioning) but also processes that served to discourage or inhibit responding (inhibitory conditioning). For Pavlov, conditioned behavior was regulated by excitatory and inhibitor processes, making inhibition just as important as excitation. However, the inhibitory aspects of Pavlovian conditioning received relatively little attention in Western psychology until the late 1960s. His research helped to identify numerous now-familiar conditioning effects, such as acquisition, extinction, spontaneous recovery, overshadowing and other compound conditioning effects, conditioned inhibition, disinhibition, inhibition of delay, higher-order conditioning, and stimulus generalization.

Throughout his investigations, Pavlov was interested in how conditioned responding helps the organism interact with its environment. Because his methods permitted observing dogs repeatedly over long periods of time, he was also able to identify systematic individual differences among his animals and became interested in "temperament" or what we would call "personality." Towards the end of his career he also became interested in how conditioning may help us better understand psychopathology and disease.

Cross-References

► Associationism
► Associative Learning
► Classical Conditioning
► Conditioned Inhibition
► Conditioning
► Pavlovian Conditioning

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Pavlovian and Operant Technologies

► Behavior Modification, Behavior Therapy, Applied Behavior Analysis and Learning

Pavlovian Conditioning

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Synonyms

Classical conditioning; Respondent conditioning

Definition

Pavlovian conditioning refers to the adjustments organisms make in response to *observing the temporal relations* among environmental or proprioceptive stimuli. It is a form of *associative learning* that allows organisms to *predict* future events. It is distinct from *instrumental learning* in that Pavlovian adjustments do not influence the likelihood of future events but rather enable organisms to *prepare* for them. Among those studying human memory, Pavlovian conditioning is considered one of the *implicit* forms of learning, distinguishing it from the *explicit* forms of learning involved in episodic and semantic memory. It is named for Ivan Pavlov, who first scientifically investigated and characterized Pavlovian phenomena (Pavlov 1927). It has been studied in numerous vertebrate and invertebrate species.

Theoretical Background

Although Pavlovian conditioning refers broadly to learning about *event co-occurrence*, it is most often studied by observing the response changes that take place to a behaviorally silent stimulus that is repeatedly followed by a response-eliciting, biologically relevant stimulus. The first stimulus is referred to as the *conditioned stimulus (CS)*, and the second is referred to as the *unconditioned stimulus (US)*. A US-elicited behavior is called an *unconditioned response (UR)* and a CS-elicited behavior that results from pairing with the US is called a *conditioned response (CR)*. Pavlovian conditioning was first envisioned as a *general learning mechanism* in which CSs and USs of equivalent salience could serve interchangeable roles. However, evidence that learning depends on *evolutionarily selected biases in CS-US compatibility* was provided in 1966 when John Garcia and Robert Koelling reported a disposition in rats to associate flavors and illness.

An *associative framework* is most often used to understand Pavlovian phenomena. Its main assumptions are that conditioned responding is an index of the underlying *associative strengths* among stimuli and that learning is the process whereby associative strengths are adjusted with experience. Within this framework, the US acts to strengthen or maintain associations with preceding stimuli, and so USs are referred to as ► *reinforcers*. The term "reinforcer" is used somewhat differently in instrumental learning, where it is limited to consequential stimuli for which an organism will work.

In addition to promoting conditioning responding, Pavlovian conditioning also involves mechanisms that oppose it. Mechanisms and stimuli that promote behavior are termed *excitatory*; those that oppose behavior are termed *inhibitory*. Similarly, an *excitor* is a CS that elicits conditioned responding, and an *inhibitor* is a CS that opposes responding.

Basic Excitatory Phenomena

Acquisition: The increase in conditioned responding that results from repeated CS-US pairings. A plot of conditioned responding over trials or time is called a *learning curve*.

Generalization: The conditioned responding to a novel stimulus that results from similarity to a previously trained CS. A plot of responding across similarity is known as a *generalization gradient*.

Summation: The conditioned responding that is generated by the simultaneous presentation of multiple stimuli. It commonly refers to observing more conditioned responding to two simultaneously presented excitors than to either alone.

Second-order conditioning: The increase in conditioned responding that develops when a CS is followed by a previously reinforced CS.

Basic Inhibitory Phenomena

Extinction: The decrease in conditioned responding that results from breaking the CS-US relationship, as when an excitor is subsequently nonreinforced.

Discrimination: The decrease in *generalized* conditioned responding that results from intermixing reinforced presentations of a stimulus with non-reinforced presentations of a similar stimulus. A result of successful discrimination training is a *modified generalization gradient* which sometimes takes the form of a *peak shift*.

Inhibition of delay: The decrease in conditioned responding that results from delaying a conditioned response until closer to the time of US presentation.

Inhibitory phenomena are thought to result from the *superimposition of an inhibitory process* on an existing excitatory process. Evidence for this comes from phenomena that unmask the excitatory process, such as *spontaneous recovery*, *reinstatement*, and ► *renewal*.

Theoretical Development

Origins: Contiguity

Psychologists originally followed philosophers such as Aristotle, David Hume, and David Hartley in accepting that the primary determinant of conditioned responding was spatiotemporal *contiguity* and that learning proceeded as a function of the *number of CS-US pairings*. While researchers agreed on what produced learning, they offered alternative ideas about what was learned. *Stimulus–response (S-R)* theorists proposed a direct connection between the CS and the CR, whereas *stimulus-stimulus (S-S)* theorists proposed that the US representation mediated the pathway between the CS and the CR. Although initial support was found for a role of S-S learning, convincing data were not collected until the 1970s, when ► *post-conditioning devaluation* of the US was shown to selectively influence the CS with which it was trained.

Early theorists realized the importance of *motivational processes* to conditioned responding, and a variety of ideas were proposed to understand their role in learning and performance (Cofer and Appley 1964). Some most strongly emphasized the role of *biological drive states*. Others focused more on the notion of *incentive*. Drive theorists tend to emphasize the *drive-reducing* aspects of reinforcers, whereas incentive theorists tend to emphasize their ability to *energize* and *direct* behavior.

In 1943, Hull presented the first *algorithmic model* of Pavlovian conditioning. Hull accepted contiguity as primary to learning and proposed an equation that specified the amount of learning generated by individual CS-US pairings. This amount was a function of the difference between maximum potential knowledge and current knowledge, where knowledge was conceptualized as the *habit strength* (now called ► *associative strength*) between a CS and a US. Other properties that influenced conditioned responding, such as US delay and magnitude, were incorporated as *learning rate parameters*. Much of the theoretical advancement that followed either incorporated or modified Hull's learning algorithm (Vogel et al. 2004).

Using a learning rule equivalent to Hull's, William Estes' *Stimulus Sampling Theory* envisioned the CS as made up of component *elements*, each with some probability of becoming activated upon CS presentation and each with the ability to form a distinct association with the US. The idea that a stimulus is reducible to component elements has been incorporated into a number of subsequent conditioning models.

Cue Competition Effects: Contingency

Important developments in Pavlovian theory came in response to findings that showed that *CS-US contiguity was neither sufficient nor necessary to produce learning*. An influential report came from Leo Kamin in 1967, who showed response impairment when a novel CS was reinforced in the presence of an excitor instead of in the presence of another novel CS. This phenomenon was referred to as ► *blocking*, and it demonstrated that CS-US contiguity is not always sufficient to produce conditioned responding. A related phenomenon, *conditioned inhibition*, refers to the decrease in conditioned responding that results from nonreinforcement of a novel CS in the presence of an excitor. It demonstrates a form of Pavlovian learning in the absence of any contiguous CS-US pairings, challenging the necessity of contiguity for the learning process. An accumulation of related findings led to the understanding that *a CS produces conditioned responding if its presence increases the likelihood of a US and opposes conditioned responding if its presence decreases the likelihood of a US.*

As a result of these and related phenomena, theories were modified and developed to incorporate *contingency* and not contiguity as the primary determinant of conditioned responding. As exemplified by the influential ► *Rescorla–Wagner model* (Rescorla and Wagner 1972), *US processing accounts* attributed failures of contiguity to the ineffectiveness of expected USs in generating associative learning. *CS processing accounts* proposed that they resulted from learned attentional shifts. *Competing response accounts* blamed the oppositional effects of better predictors that became associatively activated.

The idea that stimuli compete for control over conditioned responding is referred to as *cue competition*. Besides blocking and conditioned inhibition, other cue competition phenomena include:

Overshadowing: The decrease in conditioned responding that results from reinforcing an untrained CS in the presence of another untrained CS.

Superconditioning: The increase in conditioned responding that results from reinforcing an untrained CS in the presence of an inhibitor.

Overexpectation: The decrease in conditioned responding that results from reinforcing an excitor in the presence of another excitor.

Relative validity: The decrease in conditioned responding that results from reinforcing a novel stimulus in the presence of one CS while nonreinforcing it in the presence of another, as compared with reinforcing a novel stimulus half of the time independent of which of two other CSs is simultaneously presented.

An emphasis on cue competition necessitated assumptions about how cues combine to elicit conditioned responding. Those adopting an *elemental view* proposed that a compound stimulus could be understood as the sum of its parts. Those adopting a *configural view* treated each stimulus as a unitary whole, reducible only to the experimenter who designed it.

Important Scientific Research and Open Questions

Timing

A growing appreciation for the role of *timing* in Pavlovian processes has emerged from knowledge that:

Pavlovian preparations have optimal CS-US intervals for generating conditioned responding. If the interval is decreased such that the US precedes the CS, as in *backwards conditioning*, the CS may become an inhibitor.

Delay conditioning, in which the CS co-terminates with the US, leads to greater levels of conditioned responding than does *trace conditioning*, in which the CS terminates before US presentation.

Decreasing the CS duration often promotes conditioned responding, whereas decreasing the time between CS-US pairings (*intertrial interval*, ITI) impairs it. Under some conditions, conditioned responding is well-characterized as a function of the *ratio of CS duration to ITI duration.*

Temporal conditioning, in which time is the only reliable signal of the US, leads to appropriately timed conditioned responding.

When a long duration stimulus is a discriminatory cue that precedes and overlaps a shorter CS, it may come to *modulate* conditioned responding instead of directly eliciting it. This phenomenon is referred to as ► *occasion setting*.

To incorporate timing into Pavlovian theory, proponents of *real-time models* envision *stimulus representations* as dynamically changing in time and capable of existing as *traces*. Activation levels at the time of conditioning determine the amount of associative change (Vogel et al. 2004). Proponents of information processing models propose that durations are directly encoded and used in *computations* to determine conditioned responding (Gallistel 1990). This latter approach marks a divergence from associationism, and the success of such an approach is an important open question.

Neural Substrate

Early conceptualizations of Pavlovian conditioning were rooted in the biological understanding of the nervous system. Learning was thought to involve modifications to *reflexes*, and the notions of excitation and inhibition were adapted from understandings of neuron functioning (Konorski 1948). Although the trend in theoretical development has been away from such explicit ties to biology, much current research aims to understand the neural mechanisms involved in Pavlovian conditioning.

For the study of the neural basis of behavior, Pavlovian conditioning has the advantage of being well-characterized in nonhuman animals. It also resembles *long-term potentiation*, a process by which the *synaptic strength* between neurons is modified by patterns of co-activation. Although recent work has linked long-term potentiation to behavioral changes in several species, the nature of the link remains controversial.

Neuroscientific work on Pavlovian mechanisms has found anatomical distinctions between delay and trace conditioning, acquisition and extinction, and *contextual* and *discrete-cue conditioning*. Pharmacological manipulations have been found that selectively enhance or impair Pavlovian learning. Others have focused on the potential role of *dopamine* in representing US expectancy.

Translation of Learning into Behavior

Although much is known about the circumstances that produce learning, and advances have been made in understanding what is learned, there has been less progress in determining how this *knowledge translates into behavior*. Greater conditioned responding is thought to be indicative of greater associative strength, but this assumption is not strong enough to test some of the primary tenets of Pavlovian theory, for instance that associative change is greatest early in training and decreases throughout. Recently, Robert Rescorla developed a technique that partially circumvents this limitation, finding support for long-held assumptions as well as evidence that calls others into question. As Pavlovian methods continue to advance, it is likely that previously unaddressable questions will become answerable and that theories will be modified accordingly.

Cross-References

► Associative Learning
► Computational Models of Classical Conditioning
► Conditioning
► Contingency in Learning
► Instrumental Learning
► Mathematical Models/Theories of Learning
► Pavlow, Ivan
► Role of Similarity in Human Associative Learning
► Temporal Learning in Humans and Other Animals

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Pavlovian Context Conditioning

► Context Conditioning

Pavlovian Drug Conditioning

► Drug Conditioning

Pavlovian Reinforcer

Synonym of unconditioned stimulus (US). Reinforcer refers to stimuli with the ability to reinforce, or strengthen, associations between stimuli or between stimuli and responses. Conventionally, the term refers to biologically relevant, response-eliciting stimuli with the ability to generate responding to preceding stimuli; however, other than temporal placement, Pavlovian reinforcers do not appear to have essential unifying characteristics. They are distinct from instrumental reinforcers in that their likelihood cannot be influenced by an organism's behavior and in that they can be either appetitive or aversive.

Pedagogical Agents

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Synonyms

Animated pedagogical agents; Instructional agents; Lifelike characters

Definition

Pedagogical agents are lifelike characters presented on a computer screen that guide users through multimedia learning environments. They are defined in relation to the context of their employment as "learning partners" or "virtual tutors" in educational software. Therefore, they can be distinguished from other agent applications such as "embodied conversational agents," "anthropomorph interface agents," "virtual characters," or "non-player characters."

The term "agent" itself does also refer to different meanings that are often conflated (Erickson 1997): (a) the agent-metaphor, presenting a character on the screen; and (b) adaptive functionalities, aspects of artificial intelligence that are implemented in software applications that are not necessarily visible on the screen (e.g., intelligence, adaptively, responsiveness).

While both meanings come into play when intelligent agents are presented on the screen, the distinction is of interest when discussing pedagogical agents. The term "pedagogical agent" refers to the agent-metaphor but not in all cases to adaptive functionalities. In fact, pedagogical agents often communicate via predefined texts, incorporating no aspects of artificial intelligence. This can either be viewed as a limitation or an opportunity to investigate whether the presentation of a character on the screen – without responsiveness – yields additional learning benefits.

Further, the label "animated pedagogical agents" is frequently used synonymous to "pedagogical agents" (e.g., Moreno 2005). It does, however, disregard that pedagogical agents can also be presented as static pictures or videos of human tutors.

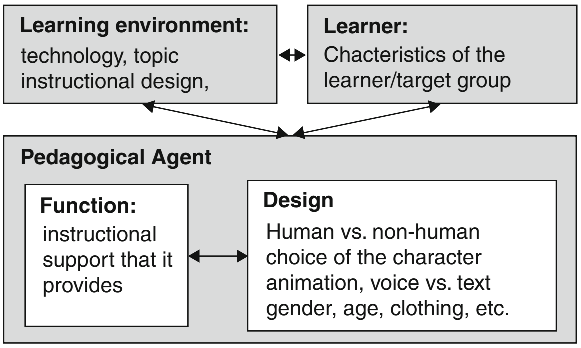
Theoretical Background

Pedagogical agents became popular in the 1990s, when first studies examined their effectiveness from an educational perspective (Clarebout et al. 2002). The goal of their use is to facilitate learner motivation and learning outcomes. Lester et al. (1997) postulated the *persona effect*, claiming that the mere presence of pedagogical agents can motivate students, and in turn promote learning. However, this assumption was derived from a pre-posttest difference, but the study did not contain a control group. Although the problem of the missing control group was pointed out previously (Clarebout et al. 2002; Moreno 2005), the persona effect is still cited.

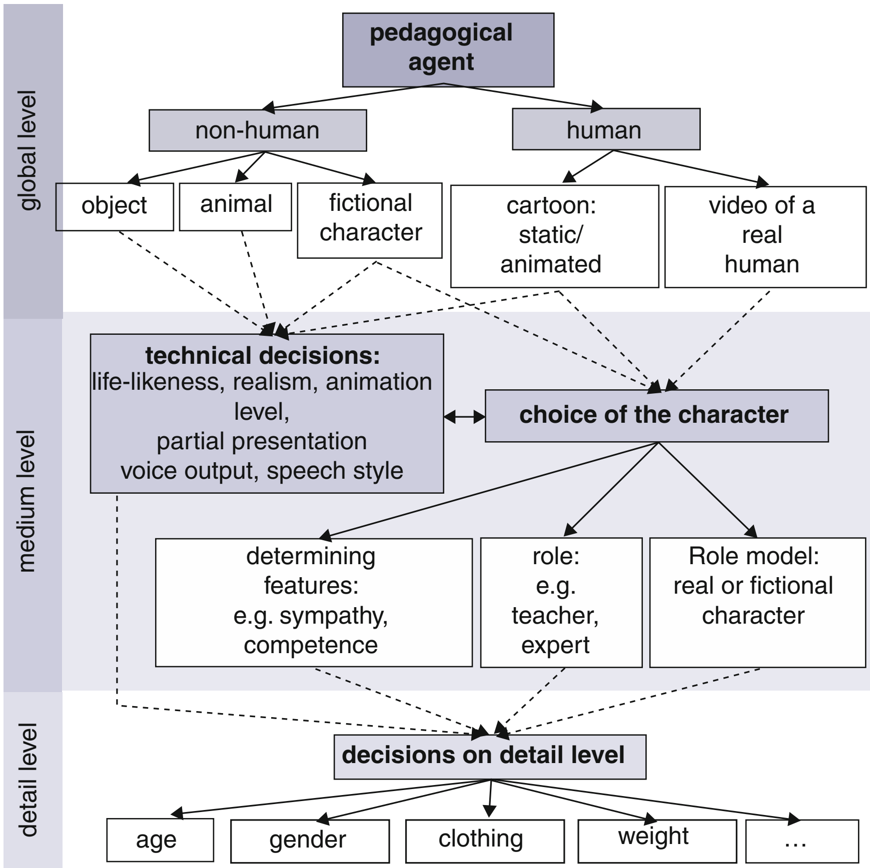
The most frequently applied theoretical framework for research on pedagogical agents is *social agency theory* (Mayer 2005), also referred to as social cues hypotheses. The main assumption of social agency theory is that the voice and the image of the pedagogical agent provide social cues that prompt social responses. Due to the priming of the social interaction schema, learners are assumed to engage in sense-making activities and, therefore, in processing the learning material more deeply. A deeper level of cognitive processing should then promote transfer performance. Social agency theory, therefore, still refers to a facilitating effect due to the mere presence of the pedagogical agent. Domagk (2010), however, claims that not the mere presence but also the valence of the social cues (e.g., sympathy toward the character) plays a decisive role.

In line with this claim, the current discussion on pedagogical agents shifts from the question "Do pedagogical agents facilitate motivation and learning?" to the more specific questions "Under what conditions are they effective?" and "How should they be designed to be effective?" (Heidig and Clarebout 2011) Research on pedagogical agents is a complex topic as different conditions apply to their implementation. In order to systemize these conditions, Heidig and Clarebout (2011) propose a multilevel framework: *Pedagogical Agents – Conditions of Use (PACU)*, that comprises (1) the characteristics of the learning environment in which the pedagogical agent is implemented, (2) the characteristics of the learner who works with the learning environment, (3) the functions that the pedagogical agent executes, and (4) the pedagogical agents design (Fig. 1).

For the design of pedagogical agents, Heidig and Clarebout (2011) further propose a subordinate model that organizes design decision on three different levels, whereas decisions on a higher level presuppose decisions on a lower level: *Pedagogical Agents – Levels of Design* (PALD) (Fig. 2). First, on a global design level, pedagogical agents can be depicted as human or nonhuman characters and either animated or static. Second, on a medium design level, technical decisions on the auditory and visual presence of the pedagogical agents have to be taken (e.g., degree of lifelikeness, animation level, spoken vs. printed text). Further, the choice of the character can be driven by referring to role models or determining features such as competence or sympathy. Finally, on a detail design level, decisions concern the age, clothing, ethnicity, or gender of the pedagogical agent and many more.



Pedagogical Agents. Fig. 1 Condition of Use Model (PACU; Heidig and Clarebout 2011)



Pedagogical Agents. Fig. 2 Levels of Design Model (PALD)

P

Important Scientific Research and Open Questions

Based on empirical studies on pedagogical agents, Moreno (2005) proposes eight principles for the design of pedagogical agents that are closely related to principles for the design of multimedia learning:

- *Modality principle.* Pedagogical agents should communicate via spoken rather than printed text.
- *Redundancy principle.* Pedagogical agents should communicate via spoken text alone rather than spoken and printed text.
- *Personalization principle.* Pedagogical agents should communicate in a personalized rather than a formal, monologue style.
- *Active-learning principle.* The function of the pedagogical agent should aim at promoting cognitive activities of the learner (e.g., guidance and reflection).
- *Interactivity principle.* The function of the pedagogical agent may also aim at promoting interactions between the learner and the agent, for instance, by allowing to ask questions or selecting answers instead of presenting them.
- *Guidance principle.* Especially for novice learners, the pedagogical agent should provide guidance, e.g., for the selection of relevant information.
- *Reflection principle.* Pedagogical agents may provoke self-explanations of learners.
- *Cost-efficient principle.* As the implementation of pedagogical agents is costly in terms of financial and personnel resources, the reasons for their use should be balanced with the expected costs.

Although these principles are derived from empirical studies on pedagogical agents, most of them are based on sparse evidence. While the modality and the redundancy principle are comparatively well grounded on studies on pedagogical agents and studies from multimedia learning, the other principles are based upon single studies only.

A current review on pedagogical agents (Heidig and Clarebout 2011) reveals that despite a large number of empirical studies on the effectiveness of pedagogical agents, a lot of open questions remain. First, research on pedagogical agents was concerned with the question whether they actually facilitate learner motivation and learning. Surprisingly, only 15 out of the 39 available studies on learning effects of pedagogical agents examine this question by comparing an agent to a no-agent group (most studies only compare different agent groups). The studies that applied a control-group design yielded mixed results for learning, mainly indicating no effect. These results challenge broad claims of a general learning facilitating effect of pedagogical agents. Although promoting learner motivation is one of the main goals of the use of pedagogical agents, it has so far rarely been assessed.

Therefore, the question arises under which conditions pedagogical agents might be effective in terms of motivation and learning. In order to answer this question, empirical studies need to compare more than one agent group to a control group without an agent. Only ten out of the 39 available studies fulfill this requirement. According to the PACU, eight of these studies concern the design of the pedagogical agent, whereas the other conditions (characteristics of the learning environment, learner variables, and function of the pedagogical agent) are only examined in single studies. Three studies on the design of pedagogical agents consistently showed no effect on retention when presenting either an animated or a static agent or no agent. Apart from that little can be said about other aspects without further empirical evidence.

The main body of research on pedagogical agents so far concerned the question how pedagogical agents should be designed. The respective studies (24 of the 39 available studies) compare different agent groups but do not comprise a control group. They can, therefore, not be considered to derive answers to the questions whether the presence of a pedagogical agent makes a difference to learner motivation and learning. Yet, they provide evidence which variables should be considered when designing a pedagogical agent. The PACU model can be applied to systematize their findings (Heidig and Clarebout 2011):

- *Characteristics of the learning environment:* Five studies consistently indicate that the implementation of pedagogical agents in technically advanced learning environments (virtual reality, interactive versions), did not benefit the learners compared to simpler versions (desktop computer, noninteractive version) (e.g., Moreno and Mayer 2002).
- *Characteristics of the learner:* Only three studies are available on learner characteristics, whereas two of these studies examined cognitive prerequisites (prior knowledge, academic competency) and one study considered self-regulation skills as metacognitive factor (e.g., Clarebout and Elen 2006).
- *Functions of the pedagogical agent:* Three studies consistently showed an advantage of explanatory compared to corrective feedback on transfer performance (e.g., Moreno 2004). Providing reflection prompts yielded advantages on far transfer tasks in two studies, but no difference in another study (Moreno and Mayer 2005). Only single studies are available on other possible functions such as motivation, information, or prequestions.
- *Design of the pedagogical agent:* As most studies (24 out of 39) concern the design of pedagogical agents, they can be reviewed according to the PALD model.
  - *Global design level:* Human vs. nonhuman characters were only compared in a single study. Presenting an animated or a static agent yielded no difference in retention in three studies (e.g., Baylor and Ryu 2003).
  - *Medium design level – technical decisions:* Five studies consistently indicate an advantage of spoken compared to printed text on retention and transfer (modality principle) (e.g., Atkinson 2002; Moreno and Mayer 2002). Two studies report an advantage of a human compared to a computer-simulated voice (Atkinson et al. 2005).
  - *Medium design level – choice of the character:* Two studies indicate no effect of the sympathy toward the pedagogical agent (likable vs. dislikable) on motivation, but on transfer performance (Domagk 2010).
  - *Detail design level:* Four studies compared a male and a female agent but yielded mixed results (e.g., Kim et al. 2007).

The provided list does only comprise variables that were investigated in more than one empirical study. Only single studies are available on other aspects. It therefore highlights, that despite a large number of studies, little is known about the effective design of pedagogical agents. This is partly due to the complexity of the topic as many variables come into play when implementing a pedagogical agent.

However, the state of the art of research on pedagogical agents points to a methodological issue: most studies on pedagogical agents do not comprise a control group. Research designs that comprise more than one agent group and a control group are needed in order to answer the still remaining question of how to design a pedagogical agent in order to promote learner motivation and learning. The comparison to a control group is further essential for reasoned decisions on whether to implement a pedagogical agent into a multimedia learning environment.

In light of the costs for their implementation, the results of empirical studies on the effectiveness of pedagogical agents draw a rather discouraging picture. Nevertheless, detrimental effects of pedagogical agents as a criterion for exclusion have so far only occurred in a single study (Domagk 2010).

Cross-References

- ▶ Design of Learning Environments
- ▶ Interactive Learning Environments
- ▶ Learner Characteristics
- ▶ Learning Agents and Agent-Based Modeling
- ▶ Modality Effect
- ▶ Motivation and Learning
- ▶ Multimedia Learning
- ▶ Open Learning Environments
- ▶ Virtual Change Agents

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Peer Learning

▶ Social Interactions and Learning

Peer Learning and Assessment

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Synonyms

Peer-assisted learning and peer assessment; Peer learning partnership; Peer-moderated marking

Definition

The term *peer learning* refers to situations where peers support each other in learning processes. There are different forms of peer learning such as peer support groups, supplemental instruction, peer tutoring, peer teaching, and peer-assisted learning. *Peer learning* emphasizes the experience of all participating students. *Peer learning* is the acquisition of knowledge and skill through active helping and support among peers who are equals in standing or matched companions. Peer learning occurs among peers from similar social groupings, who are not professional teachers, helping each other to learn and in doing so, learning themselves (Topping and Ehly 1998). On the other hand, the term *peer assessment* describes the process undertaken by students to assess each others' work in related peer group tasks. Students contribute to the evaluation procedures by having input in individual team member scores. Peer assessment refers to situations where peers formatively and qualitatively evaluate the products or outcomes of learning of others in the team or group. *Peer learning and assessment* are related with pedagogic approaches that promote *group-based learning and participative assessment, cooperative learning, collaborative learning, active learning, constructivist learning, reflective learning, and learning by doing.*

Theoretical Background

"*Peer learning* is an educational practice in which students interact with other students to attain educational goals" (O'Donnell and King 1999, p. 3). *Constructivist learning* approaches emphasize discovery learning and view knowledge acquisition as a social activity; therefore, peer learning as a collaborative work between peers has become an important means of implementing constructivist educational approaches as well as a means of enhancing teaching-learning processes (e.g. O'Donnell and King 1999).

Piaget's theory of cognitive development describes how children develop cognitive abilities, associated with the construction of internal schemas for understanding the world (Thurston et al. 2007). According to cognitive constructivism, people construct their own understanding of the world, so people create their own mental models to make sense of their experiences. In addition, Vygotsky's social constructivist theory emphasizes the importance of social context for cognitive development. Both Vygotskian and Piagetian theories require peer interaction and emphasize the role of peer learning in cognitive development (Thurston et al. 2007). Interactions in Vygotskian peer-learning contexts are cooperative with shared questioning and ideas among peers who work together to generate joint understanding (Thurston et al. 2007). In Piagetian peer learning, collaborative learning techniques and peer-tutoring techniques support the adaptation of cognitive structures which are more easily established between peers than between child and teacher (Thurston et al. 2007). Peer learning is an application of constructivist learning theory which emphasizes that learning is a social process and that learners share, compare, and reformulate ideas to restructure new understandings. Since peer learning allows learners to exchange their personal views and test them with those of others', learners can build their own understandings through peer interactions and observations (Thurston et al. 2007). Learning how to work cooperatively is a valued educational activity; therefore, peer learning supports the fundamental task that schools undertake in preparing students for life in the workplace after school (O'Donnell and King 1999). Peer learning is viewed as a way to enhance learning outcomes and as providing formative experiences necessary for transition to, and full participation in, a society that is increasingly becoming technological and multicultural.

According to Topping and Ehly (1998),

► The research on peer learning with respect to academic achievement provides strong support for a variety of methods of peer learning, including cooperative learning, collaborative learning and peer tutoring. Although these various methods show achievement benefits, the mechanisms by which these techniques accomplish these goals differ

One of the methods of peer learning mostly cited in the literature is reciprocal peer tutoring (mutual tutoring) or reciprocal peer learning. *Reciprocal peer learning* is a collaborative learning approach which embeds peer assessment in a formalized learning process to facilitate student involvement in instructional activities, to enhance learner control and peer-cooperation, and to improve academic achievement. *Reciprocal peer learning* employs same-age student pairs (dyads) of comparable ability and assigns them the task of learning together with the primary objective of keeping both tutee and tutor engaged in constructive academic activity (Topping and Ehly 1998). Dyads engaging in *reciprocal peer learning* are given instruction on how to study given course content, administrate practice tests, assess each other's work and provide feedback on course content. *Reciprocal peer learning* is designed to incorporate the most effective learning strategies informed by the literature on peer teaching, peer assessment, academic achievement motivation, and classroom group-reward strategies (Topping and Ehly 1998).

Other commonly used peer-learning methods including peer tutoring, peer modeling, peer education, peer counseling, peer monitoring, and peer assessment are defined by Topping and Ehly (1998) as follows:

- *Peer tutoring* is characterized by specific role-taking: at any point someone has the job of tutor, whereas the other (or the others) is in role as tutee(s). (p. 5)

  Peer modeling is the provision of a competent exemplar of desirable learning behavior by a member or members of a group with the intention that others in the group will imitate it. (p. 6)

  Peer education is describable as peers offering credible and reliable information about sensitive life issues and the opportunity to discuss this in an informal peer group setting. (p. 7)

  Peer counseling is people from similar groupings who are not professional teachers or line managers who help clarify general life problems and identify solutions by listening, feeding back, summarizing and being positive and supportive. (p. 7)

  Peer monitoring is about peers keeping an eye on whether their partners are going through appropriate and effective processes and procedures of learning. (p. 7)

  Peer assessment is about peers formatively and qualitatively evaluating the products or outcomes of learning of others in the group. (p. 8)

Some research (e.g., Cassidy 2006; Parr and Townsend 2002; Walker 2002) indicates that peer learning emphasizes the value of peer-to-peer interaction as a means of developing competence and lifelong learning skills. Also, as cooperative and collaborative learning activities, peer learning results in (a) team-building spirit and more supportive relationships; (b) greater psychological well-being, social competence, communication skills, and self-esteem; and (c) higher achievement and greater productivity in terms of enhanced learning outcomes (Topping and Ehly 1998; Walker 2002). Peer group activity in learning settings is acknowledged to have effects on academic achievement, affective development, and social outcomes; however, there is less certainty about how the dynamics and processes involved are related to learning (Parr and Townsend 2002). Parr and Townsend (2002) emphasize the benefits of two-way peer interactions in learning process in which knowledge is socially constructed by peers as opposed to learning occurring in a social context. Parr and Townsend (2002) state that peer tutoring is relatively low in two-way interaction and provides little opportunity for knowledge to be jointly constructed; however, collaborative learning involves high levels of reciprocity as peers interact in the search for new, shared understanding. Parr and Townsend (2002) state that explanations for the peer effects in learning are varied and may be found across a range of research disciplines. For example, socio-cognitive theory holds that cognitive conflict gives rise to cognitive restructuring; on the other hand, sociocultural approach argues that peer feedback and observational learning result in the acquisition of positive attitudes to reading (Parr and Townsend 2002). Parr and Townsend (2002) conclude that some peer effects are likely to influence achievement directly, while others are likely to have an indirect influence through proximal indicators of achievement.

Peer assessment also refers to making judgments about the work of peers to encourage responsibility for learning. Topping and Ehly (1998) define peer assesment as the determination of the amount, level, value, or worth of an equal-level peer's work. It is different from peer monitoring in that its main focus is on learning outcomes or learning products rather than the survey of peers' learning processes and procedures (Topping and Ehly 1998). Topping and Ehly (1998) further state that there are numbers of ways for peer assessment:

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- Peer assessment can operate in different curriculum areas or subjects. The product or output to be assessed can vary-writing, portfolios, oral statements, test performance, or other skilled behaviors. The peer assessment can be summative (judging a final product to be correct-incorrect, . . . or grade to the output by criterion matching). Alternatively, it can be formative (involving detailed qualitative feedback . . . to the current or subsequent products). The participant constellation can vary – the assessors may be individuals or pairs or groups; the assessed may be individuals or pairs or groups. Directionality can vary – peer assessment can be one-way, reciprocal, or mutual. Assessors and assessed may come from the same or different year of study, and be of the same or different ability. Place and time can vary – most peer assessment is formal and in class, but it can occur informally out of class. The objectives for the exercise may vary-the teacher may target cognitive or meta-cognitive gains, time saving, or other goals. (Topping and Ehly 1998, p. 257)

As a result of revising many research studies on peer assessment, Walker (2002) states the following benefits can be attributed to peer assessment: (1) peer assessment is an alternative method for assessing group work as the students often have greater knowledge of the contributions made by their fellow group members; (2) peer assessment increases the students' responsibility and autonomy and allows for the development of both personal and interpersonal skills; (3) prior knowledge of the assessment procedure can lead to greater clarity of high-quality work by providing concrete examples of the assessed; (4) the knowledge that one is to be assessed by one's peers encourage students to work harder; (5) peer assessment can be used as a means for cutting down on the time lecturers spend marking and allows feedback to be provided in greater quantity, more efficiently. In addition, Cassidy (2006) states that peer assessment is one example of educational practice likely to contribute positively toward the development of employability skills, referring to communication skills, higher-order skills such as learning skills and strategies, problem -solving, decision making, and affective skills, interpersonal skills (cooperation, teamwork), self-discipline, self-management, and ability to work without supervision. Topping and Ehly (1998) summarize the reasons for using peer assessment:

- When peers interact with the purpose of assessing one another's work, the expectation is that the quality of the work of all concerned will often improve as a result of the thinking involved and feedback provided. Students may also improve their own skills in critiquing or evaluating their own work (self-assessment) as a result of their interactions during peer assessment.. . . Also, the practice of regulating the activities of others by commenting on the quality of peers' work may help students internalize techniques for self-regulation. (Topping and Ehly 1998, p. 257)

Topping and Ehly (1998) also emphasize the role of feedback in learning as essential to the development and execution of self-regulatory skills. Peer feedback during peer assessment engages learners in a cognitively complex task that requires understanding of the goals of the task as well as the criteria for success together with the ability to make judgments about the product (Topping and Ehly 1998). Although peer feedback might be of poorer quality than that provided by the teacher, the efficacy of feedback depends on both the giver and the receiver and peer feedback can be effective to improve future performance (Topping and Ehly 1998). Topping and Ehly (1998) suggest that the organization of peer assessment should include objectives, criteria, matching and constellation, training, activity, monitoring, moderation, onward action, and evaluation.

Peer learning and assessment allow learners to play an active role in the learning and assessment processes instead of remaining passive and uninvolved with the content of the courses. According to social constructivist approach, individuals create meaning through their interactions with each other and a shared understanding among individuals is socially constructed through communication, interaction, and negotiation within team members. Thus, peer learning and assessment allow learners to involve in an active, social and reflective learning process.

Important Scientific Research and Open Questions

The concept of peer learning is important for five reasons: educational, economic, political, social, and affective (Topping and Ehly 1998). Topping and Ehly (1998) summarizes the following points about importance of peer learning:

- Peer learning promotes to raise standards in literacy, numeracy, science, and vocationally relevant transferable skills. In addition, considering the benefits of peer learning in an information technology environment, peers support each other on transmission of information technology skills as well as supporting development of cognitive skills, attitudes and self-image.
- Peer learning is important because it is effective and cost-effective as documented by research reviews and meta-analyses of evaluation research.
- Considering social benefits, peer learning is a vehicle to decrease social isolation across divides of age, gender, ethnic origin, and social class. Politically, peer learning delegates management of learning to learners in a democratic way.
- Considering affective benefits, peer learning helps improve motivation and confidence. Peer learning also helps develop sense of pride and responsibility among peers.

Research studies (e.g., Cassidy 2006; Topping and Ehly 1998; Walker 2002) draw attention to the advantages of peer assessment, which include (1) extended interaction between peers for constructive feedback based on multiple observations of performance; (2) acquisition of self-directed learning skills, critical reasoning skills, and communication skills; (3) enhanced metacognitive skills; (4) improved understanding of subject matter and deep learning; (5) increased student responsibility and autonomy; and (6) insight into assessment procedures and expectations for high-quality work. Although strong support for peer assessment is evident in the literature, difficulties and limitations have repeatedly been reported, including (1) unreliable and unfair assessment; (2) bias in peer marking due to interpersonal relationships between students; (3) feeling uncomfortable and unqualified to make the judgment; (4) task being too challenging and time-consuming; and (5) awarding marks to their peers based on dislike (Cassidy 2006; Walker 2002). On the other hand, research studies related to the issue of reliability and validity of peer assessment report conflicting results. Many studies yielded high validity, but still a few revealed low validity of peer assessment. In sum, validity of peer assessment is a concern for evaluating student learning (Topping and Ehly 1998). In a study by Cassidy (2006) on undergraduate students' attitudes toward peer assessment, students expressed a positive attitude toward peer assessment but had concerns about their capability to assess peers and the responsibility associated with assessing peers. In addition, Cassidy (2006) emphasizes that the introduction and successful implementation of peer assessment in higher education is notoriously problematic, particularly in terms of concerns regarding reliability and validity of marks, potential bias, and resistance from students. Topping and Ehly (1998) state that professional teachers should be well aware that carrying out peer assessment requires a great deal of planning and guidelines, since the purpose of peer assessment and the criteria of the assessment are key elements in determining its validity and reliability and also since when peers are placed in the role of evaluator of the work of their peers, social processes might influence the reliability and validity of the assessments.

The effect of the peer assessment is interrelated with the social nature of the appraisal process during which peers come to accept each other's assessments and learn from it. Topping and Ehly (1998) state that peer assessments are affected by friendship bonds, group popularity levels of individuals, and perception of criticism as socially uncomfortable or even socially rejecting and inviting. The development of interpersonal variables such as psychological safety, trust, value diversity, and interdependence affect the outcomes of the peer learning and peer assessment. Integrating different perspectives and developing a shared understanding are crucial for peer learning and peer assessment performing well.

Consequently, peer learning and assessment have received increased attention in both higher education and K-12 education. Peer learning and peer assessment are viewed as tools for "learning to learn" which requires a fundamental change in students' beliefs, perceptions, and habits of learning since students need to understand what their roles are as learners. Peer learning and assessment experiences help students develop an awareness of how they learn best and how to study effectively. Peer learning and assessment enhance students' metacognitive skills including reflection and a deep understanding of content by allowing students to share their understanding about what "knowledge" means in their discipline and what "learning" implies. The aims of designing and developing peer-learning and assessment activities inside or outside the classroom are to assist learners in developing a sense of leadership on learning process and develop their confidence, to encourage learners to reflect on learning experiences, to enhance their learning and performance, and to enable learners to develop an understanding of their learning process and collaborative learning partnerships. Therefore, peer learning and assessment are considered to promote lifelong learning skills.

Cross-References

- ► Assessment in Learning
- ► Collaborative Learning
- ► Constructivist Learning
- ► Cooperative Learning
- ► Group Dynamics and Learning
- ► Group Learning

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Peer Learning Partnership

► Peer Learning and Assessment

Peer Tutoring

► Learning by Teaching

Peer-Assisted Learning and Peer Assessment

► Peer Learning and Assessment

Peer-Moderated Marking

► Peer Learning and Assessment

Perceived Affordance

► Affordance

Perceived Benefits

► Posttraumatic Growth

Perception

Perception is the process by which information from the environment detected by the senses and transformed into meaningful experience in the brain. A dynamic search for useful patterns rather than a passive recording, perception is an interpretation of events, which involves the breakdown of sensory data and the assembly of information on both conscious and unconscious levels.

Cross-References

- ► Attitude Change Through Learning
- ► Beliefs About Language Learning

Perceptions of Experiences

► Phenomenography

Perceptions of the Learning Context and Learning Outcomes

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Synonyms

Learning environment; Learning context

Definition

Learning context refers to students' perceptions of the course and the teaching/learning requirements.

Learning outcomes are referred to in this entry as the extent to which students have understood knowledge that relates to the acquisition of discipline skills which represent an important measure of the quality of learning. Research has shown that the outcomes of students' learning are associated with approaches they use in learning (Entwistle and Ramsden 1983).

Deep Approaches to learning is characterized by a desire to understand underlying principles.

Surface approach to learning is characterized by a desire to cope with content or set tasks by memorizing detail.

Qualitative learning outcomes are measured by the complexity of the students' understanding of the aims of a course of study.

Quantitative learning outcomes are measured by students' academic grades.

Student perceptions refer to student views of their experiences as expressed in quantitative and/or qualitative studies.

Theoretical Background

Traditionally the interest in student learning in the 1960s and 1970s related to student selection into universities and prediction of academic performance. Research focusing on student performance, however, has been criticized for failing to suggest how student learning can be improved, having emphasized the explanation of student behavior from the viewpoint of a detached objective observer. More recently, student learning in higher education has focused on examining students' experiences of learning via student perceptions. These perceptions have been identified from both quantitative and qualitative studies of student experiences of higher education including studies of learning outcomes. The change in the research paradigm has given greater direction for the teacher in higher education, by providing a description of student learning from the student's perspective.

The change in direction of higher education research with an increased focus on student perceptions of learning, has also been linked with the need to develop a better understanding of student learning approaches and ► learning outcomes. Studies across various discipline areas have posited that deep learning approaches have been associated with positive perceptions of the ► learning context (Ramsden 2003) that result in quality learning outcomes. ► Surface approaches to learning have been associated with perceptions of high workload requirements and the view that assessment tasks require rote learning of factual material resulting in inferior learning outcomes.

In addressing learning outcomes, various studies have drawn attention to the types of learning outcomes that students derive from a course of study. For example, Trigwell and Prosser (1991) found that a deep approach to learning was related to ► qualitative learning outcomes rather than quantitative learning outcomes. Studies that have used examination results as a measure of learning outcomes when investigating the relationship between learning approach, learning context, and learning outcomes have generally produced mixed results. The inconsistency in research findings has been attributed to the inappropriateness of academic grades as a means of measuring the quality of learning outcomes. Studies that have used ► qualitative measures of learning outcomes have more consistently shown relationships between the learning context and learning approaches. For example, Jackling (2005) focused on assessing the links between learning approaches and qualitative assessment of students' conceptual understanding in a discipline area. The results demonstrated a strong association among learning context, learning approach, and quality of learning outcomes.

Researchers have emphasized aspects of the learning environment such as the nature of the learning task, and the learning context (Entwistle and Ramsden 1983) in the understanding of student approaches to learning. This component in the theory of learning approaches is particularly important as it relates to the educator's ability to change the environment to enable improvement in student learning. Features of the learning context, including good teaching, clear goals, appropriate workload, and appropriate assessment, are linked with the quality of learning approaches and subsequent learning outcomes achieved by students. Overall, the concept of learning approach has evolved as being a function of student characteristics, modified by the specific learning context.

The change in emphasis in educational research on learning has also led to a focus on understanding motivation, particularly intrinsic motivation, as an important part of the examination of the characteristics of the individual learner. Intrinsic motivation evolves from some interaction between the person and the object or task of learning. Interest in completing a task appears to be closely aligned with the theoretical notion of intrinsic motivation. A person's interests, when matched with tasks congruent to that interest, appear to activate intense involvement in the task, resembling deep learning. For example, students studying a discipline of high interest to them are more likely to adopt a deep approach to learning. This is supported by the notion that deep learning evolves from the congruence between the person who is interested in an object/field of interest and subsequently adopting a deep approach to learning based on that interest.

The various ways in which the learning context more generally affects the quality of student learning includes an examination of the ways of improving teaching so that a deep approach to learning results in greater conceptual understanding. Additionally, much of the literature has been based on students' perceptions of the learning context, as the purpose of the research has been to understand the experience of higher education from a student's perspective.

Important Scientific Research and Open Questions

The extent to which students have understood knowledge that relates to the acquisition of professional skills represents an important measure of the quality of learning. At least for a short period, students retain vast quantities of information but this can result in operating with erroneous conceptions and ultimately not developing self-critical awareness in their subjects at university level.

Many research studies have shown that the learning outcomes of students' are associated with the approaches they use in learning. ► Deep approaches to learning are related to higher-quality outcomes, whereas surface approaches are associated with poorer learning outcomes. Students who use deep approaches to study tend to retain more factual material when tested on their knowledge at a later period of time. Most students who use surface approaches view learning as a process of increasing knowledge or memorization, while students using deep approaches have views of learning associated with understanding reality and abstracting meaning.

Models of Student Learning

Theoretical models of student learning have incorporated the literature around approaches to learning integrated with student perceptions of the context of learning. The intention in formulating models is to enable educators to focus on ways of improving student learning by viewing the learning context as an interactive system, highlighting interactions between the student, the teacher, and the learning environment. Models of student learning have concentrated on the structure of the learning situation and by their nature imply relative stability, irrespective of contextual influences on learning.

Student perceptions of the qualities of good teaching, independence in learning, assessment, and workload have been shown to impact on learning approaches. Furthermore, in the arts/social science and science disciplines typically perceptions of good teaching and independence in learning, favor the development of deep approaches to learning. Student perceptions of a heavy workload result in negative attitudes and surface approaches to learning. Closely allied to workload requirements, assessment methods also influence the approach students adopt in completing tasks.

In terms of good teaching, this implies that teachers engage students in learning in ways that are appropriate to develop and advance deep approaches to learning. However, the definition of good teaching is to some extent vague. Various attempts to measure students' perceptions of good teaching as part of the context of learning have highlighted that good teaching occurs in situations where a deep approach to learning is encouraged. In these environments, the teaching is stimulating and considerate, especially teaching that demonstrates that the lecturer has personal commitment to the subject matter and stresses its meaning and relevance to students. In contrast, surface approaches to learning are typified by teaching that displays a lack of interest in and background knowledge of the subject matter.

In terms of workload requirements, deep approaches to learning are encouraged by a learning context where the workload and pace of the course is suitable. A balanced workload enables students to reflect on the content and thus enables learning behavior that leads to a deep approach to learning. Surface approaches to learning are often present in courses that have an excessive amount of material in the curriculum. Overloading students with content encourages "busy work" and students are likely to adopt minimizing strategies, such as rote learning particular aspects of course content in order to succeed. The result is likely to be learning outcomes that are inferior to situations where a more balanced approach to curriculum content is employed. Surface approaches to learning result in students having at best, a sketchy knowledge and a limited capacity to apply the discipline knowledge effectively.

Assessment regimes have a powerful impact on how students interact with the learning context. In some instances the grading system as part of the assessment process is so powerful, students employ learning strategies which enable them to earn high grades, at the cost of understanding the material. Thus high grades may not be synonymous with deep approaches to learning. More generally, unsuitable assessment methods impose pressures on students to take the wrong approaches to learning tasks. For example, assessment methods that emphasize recall or the application of trivial procedural knowledge, typically encourage a ► surface approach to learning. Similarly, assessment methods that provide conflicting messages about the rewards and provide little or no feedback on progress are also likely to encourage a surface approach to learning. In contrast, deep approaches to learning are encouraged when teaching and assessment methods foster active and long-term engagement with learning tasks and there are clearly stated academic expectations.

Students have typically adopted different learning approaches depending upon the perceived demands within the context of the learning environment. As outlined above, student perceptions of the learning context in terms of good teaching, workload, and assessment have typically impacted on their learning approach and subsequently the quality of the learning outcomes achieved.

In specific disciplines there needs to be an evaluation of student perceptions of the learning context. It is acknowledged, however, that students' perceptions are only one source of information in curriculum design and educators need to take into account the need to ensure students acquire a sufficient body of knowledge to meet the needs of all stakeholders including where appropriate, professional associations and employers.

At an institutional level, intervention strategies have been shown to impact on student perceptions of the learning context. Interactive feedback as an intervention strategy using small group discussion in university learning environments, as a means of monitoring changes in students' perceptions of the learning context may be warranted. This type of structured feedback has the potential to provide educators with insights as to ways to change the emphasis in the learning context so as to maximize the adoption of deep approaches to learning that improve the quality of learning outcomes.

Cross-References

► Assessment in Learning
► Complex Learning
► Context-Based Learning
► Deep Approaches to Learning in Higher Education
► Independent Learning
► Learning Criteria, Learning Outcomes and Assessment Criteria
► Learning Environments
► Learning Strategies
► Longitudinal Learning Research on Changes in Learning of University Students
► Outcomes of Learning
► Qualitative Learning Research

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Perceptual Adaptation

► Perceptual Learning

Perceptual Improvement

► Visual Perceptual Learning

Perceptual Learning

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Synonyms

Habituation; Perceptual adaptation; Sensitization

Definition

Perceptual learning consists of long-lasting changes to an organism's perceptual system that improve its ability to respond to its environment in specific ways. These changes persist over time; more ephemeral perceptual changes are typically considered to be adaptation, attentional processes, or strategy shifts, rather than perceptual learning. These changes are due to environmental inputs; perceptual changes not coupled to the environment are considered maturation, rather than learning. Perceptual learning benefits an organism by tailoring the processes that gather information to the organism's needs for and uses of the information.

Theoretical Background

Perceptual learning is psychologically important both because it is *perceptual* and because it is *learning*. Because the changes are ► perceptual they affect all cognitive processes that occur downstream in the flow of information processing. Accordingly, it makes sense for perceptual systems to change slowly and conservatively. However, because these changes constitute ► learning, the payoffs for perceptual flexibility are too large to forego completely. They allow an organism to respond quickly, efficiently, and effectively to stimuli without dedicating online attentional resources. Instead of strategically determining how to use unbiased perceptual representations to fit one's needs, it is often easier to work with task-relevant representations created directly by perceptual processes. Many sophisticated cognitive tasks can be solved by converting originally demanding, strategic operations into learned, automatically executed perceptual processes.

An initial suggestion that our experiences and tasks influence perception comes from a consideration of the differences between novices and experts. Experts in many domains, including radiologists, wine tasters, and Olympic judges, develop specialized perceptual tools for analyzing objects within their domains of expertise. Much of training and expertise involves not only developing a database of cases or explicit strategies for dealing with the world, but also tailoring perceptual processes to represent the world more efficiently (Gibson 1991). There is evidence that perceptual learning occurs early in both neurological and functional senses.

Neurological evidence for perceptual learning. Several sources of evidence point to the influence of expertise occurring at a relatively early stage of perceptual processing. First, electrophysiological recordings of dog and bird experts show enhanced electrical activity at 164 ms after the presentation of dog or bird pictures, but only when the experts categorized objects within their domain of expertise (Gauthier et al. 2010). Likewise, practice in discriminating small motions in different directions significantly alters electrical brain potentials occurring within 100 ms of the stimulus onset, in an area centered over the visual cortex. These neurophysiological responses implicate relatively early influences of expertise. Expertise for visual stimuli as eclectic as butterflies, cars, chess positions, dogs, and birds has been associated with an area of the temporal lobe known as the fusiform face area. The identification of a common brain area implicated in visual expertise for many domains suggests the promise of developing general theories and models of perceptual learning.

Prolonged practice with a subtle line discrimination task results in much improved discrimination, but the improvements are highly specific to the orientation of the lines shown during training (Jacobs 2010). Such high specificity of training effects is typically associated with changes to early visual cortex. There is also evidence for early effects of experience on tactile perception, where "early" is operationalized neurologically in terms of a relatively small number of intervening synapses connecting a critical brain region to input from the external world. Monkeys trained to discriminate between slightly different sound frequencies develop larger somatosensory cortex representations for the presented frequencies than do control monkeys (Recanzone et al. 1993). Similarly, monkeys learning to make a tactile discrimination with one hand develop a larger cortical representation for that hand than for the other hand. Expert violinists show greater activity in their sensory cortex when their left rather than right hand is lightly touched, consistent with the observation that violinists use their left hand fingers considerably more than their right hand fingers.

Functional evidence for perceptual learning. Experience often exerts an influence before other putatively early perceptual processes have been completed. The organization of the mental representation of a scene into figure and ground is influenced by the visual familiarity of the contours. A shape is more likely to be interpreted as the figure in an ambiguous scene if it is familiar rather than unfamiliar. Furthermore, object fragments that are not naturally grouped together can nonetheless be perceptually joined if participants have been familiarized with an object that unifies the fragments. Two complementary functional processes of perceptual learning are unitization and ► differentiation.

Via unitization, a single functional unit is constructed that combines many stimulus components useful for a task (Goldstone 1998). One source of evidence for unitization is the absence of complexity effects. People can identify a long word almost as quickly as a short word, if the words are equated for familiarity. Shape components of often-presented stimuli become processed as a single functional unit with practice, resulting in highly efficient identification of the unit being identified even in a field of similar distractors. Unitization tends to occur when a set of components to be unitized frequently co-occurs and their co-occurrence is diagnostic for an important task.

Via unitization, new perceptual representations can be created by chunking together elements that were previously psychologically separated, but the converse process of differentiation also occurs. Perceptual dimensions that were originally psychologically fused together can become separated and isolated. Wine experts can learn to isolate the tannin content in wine. Color experts (vision scientists and artists) are better able than nonexperts to selectively attend to dimensions (e.g., hue, chroma, and value) that comprise color. There is developmental evidence that dimensions that are easily isolated by adults, such as the brightness and size of a square, are treated as psychologically fused by 4-year-old children. Differentiation of objects into psychologically separated elements tends to occur when the elements appear approximately independently of each other, and when the elements are differentially relevant for an important task.

Important Scientific Research and Open Questions

One of the theoretical and empirical challenges underlying our opening definition is to distinguish between perceptual learning and higher-level, cognitive learning. In fact, Hall (1991) has persuasively argued that many results that have been explained in terms of perceptual learning are more parsimoniously described as strengthening and weakening of associations. Several strategies have been proposed for differentiating perceptual changes from higher-level changes. Under the assumption that perception involves the early stages of information processing, one can look for evidence that experience influences early processes, exactly the goal of the aforementioned neurological and functional research.

Mechanisms of perceptual learning. Perceptual learning is not a unitary process. Psychophysicists have distinguished between relatively peripheral, specific adaptations and more general, strategic ones, and between quick and slow perceptual learning processes. Cognitive scientists have distinguished between training mechanisms driven by feedback (supervised training) and those that require no feedback, instead operating on the statistical structure inherent in the environmentally supplied stimuli (unsupervised training). Identifying the major mechanisms by which perceptual learning occurs is helpful for organizing empirical results as well as informing formal models of learning. In addition to unitization and differentiation, another major mechanism is ► attention weighting. By this mechanism, perception becomes adapted to tasks and environments by increasing attention to perceptual dimensions and features that are important, and/or by decreasing attention to irrelevant dimensions and features. Attention weighting, however, is not always properly considered perceptual because attention can be selectively directed toward important stimulus aspects at several different stages in information processing, not only at the early stages.

A phenomenon of particular interest for attentional accounts of perceptual learning is categorical perception. According to this phenomenon, people are better able to distinguish between physically different stimuli when the stimuli come from different categories than when they come from the same category. This effect was originally documented for speech sounds. Observers listened to three sounds – A followed by B followed by X – and indicated whether X was identical to A or B. Subjects performed the task more accurately when syllables A and B belonged to different phonemic categories than when they were variants of the same phoneme, even when physical differences were equated. Perceptual learning is implicated because the categorical perception effects that are found depend on the listener's language. A sound difference that crosses a boundary between phonemes in a language will be more discriminable to speakers of that language than to speakers of a language in which the sound difference does not cross a phonemic boundary. Furthermore, laboratory training on the sound categories of a language can produce categorical perception among speakers of a language that does not have these categories. Categorical perception is an important phenomenon because it involves the interplay between higher-level conceptual systems and lower-level perceptual systems. Traditional information flow diagrams in cognitive science typically draw a clean division between perceptual and conceptual systems, with information moving only from perception to the conceptual system. The frequency of categorical perception effects indicates permeability and bidirectional influence between these systems. We do not simply base our categories on the outputs of perceptual systems independent of feedback. Instead, our perceptual systems become customized to the useful categories that we acquire.

Perceptual learning and education. A perceptual learning perspective can inform scientifically grounded educational reform. A credible and worthy hope for education is to teach students to re-task for new purposes their long-tuned, but still inherently dynamic perceptual systems. Systematically training perception is a highly effective method to facilitate sophisticated reasoning. Developing expertise in most scientific domains involves perceptual learning. Biology students learn to identify cell structures, geology students learn to identify rock samples, and chemistry students learn to recognize chemical compounds by their molecular structures. In mathematics, successful solution of a problem is often a matter of changing one's way of looking at it. Progress in the teaching of these fields will be well served by understanding the mechanisms by which perceptual and conceptual representations inform and influence one another.

One of the reasons why wisdom cannot be simply told, but rather must be lived, is that wisdom is frequently perceptual and thus must be built into one's neurological wiring. Doctors with years of clinical experience are often surprised to find that their verbal descriptions have little value to second-year residents. The lecturer knows what she means by "spiky" tumors or "aggravated" tissue, but the meanings of these words are not communicable in the same way that "isosceles" can be given a simple verbal gloss of "a triangle having two sides of equal length." The doctor's terminology is not easily communicated because the words are just the tip of the iceberg. The iceberg below the surface is the years of experience needed to connect perceptual information to the words. Understanding the words is largely a matter of acquiring the perceptual skills of segmentation, highlighting, categorical perception, differentiation, and unitization. While the doctor's terminology takes years to master because its perceptual basis must also be learned, the final result of this mastery is that the newly forged expert sees a new world. Philosophers of science have described how scientists, exposed to a novel theoretical paradigm, can come to see physical phenomena in new ways. A similar transformative experience accompanies students acquiring expertise and justifies the hard and long work necessary to establish this "see change" in perception.

Scientific and mathematical reasoning depend on thinking analytically, making novel and creative associations between dissimilar domains, and developing deep construals of phenomena that seem to run counter to untutored perceptions. However, an appreciation of the adaptability of perception can lead us to reevaluate the traditional position that abstract reasoning is opposed to, and must overcome, potentially misleading perceptual resemblances. The results reviewed here suggest an alternative position that even seemingly abstract cognitive tasks can be accomplished by educating perceptual processes. Sophisticated understandings do not merely trump perception. Sophisticated understandings shape perception, and vice versa.

Cross-References

- ▶ Adaptation and Learning
- ▶ Animal Perceptual Learning
- ▶ Discrimination Learning Model
- ▶ Expertise
- ▶ Generalization Versus Discrimination in Learning
- ▶ Neuropsychology of Learning
- ▶ Routinization of Learning
- ▶ Sensorimotor Adaptation
- ▶ Similarity Learning
- ▶ Simultaneous Discrimination Learning
- ▶ Visual Perception Learning

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Perceptual Learning in Speech

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Synonyms

Recalibration; Retuning

Definition

Perceptual learning in speech describes a change in the mapping from acoustic cues in the speech signal to abstract linguistic representations. Learning leads to a lasting benefit to the listener by improving speech comprehension. The change can occur as a response to a specific feature (such as a talker- or accent idiosyncrasy) or to a global degradation of the signal (such as in synthesized or compressed speech). In perceptual learning, a top-down process is involved in causing the change, whereas purely bottom-up, signal-driven phenomena are considered to be adaptation.

Theoretical Background

Perceptual learning provides listeners with a mechanism for coping with an immense amount of variability in the speech signal. The realization of acoustic cues that are associated with particular speech sounds vary considerably from talker to talker, even in the most favorable listening conditions, because of differences in the anatomy of the vocal tract, individual habits, or accents. As listeners, we often adjust to such variation without effort: the speech perception system maintains an impression of constancy by adjusting, sometimes quite rapidly, to changing listening situations. These adjustments are stored in memory so that they can be reused: for example, being familiar with a particular talker facilitates comprehension of that talker on subsequent encounters (Nygaard et al. 1994). Perceptual learning is also a means to overcome drastic degradation of the speech signal, resulting from compression, filtering, or synthesis, for example, in the use of auditory prostheses. Comprehension of such signals can often be improved through perceptual learning, although this may be more effortful and proceed relatively slowly. Understanding how perceptual learning operates has had important implications for cognitive models of human speech perception and may inform the design of artificial speech recognition systems, where dealing with variability in the input signal represents one of the major challenges to the field. How to optimize perceptual learning is also a topic of investigation in settings where explicit training on speech takes place, such as second-language learning and rehabilitation from hearing impairment.

Important Scientific Research and Open Questions

Specificity Versus Generalization

A fundamental challenge for the perceptual system is to decide under which conditions a previously learned adjustment should be applied. Generalization of learning can be beneficial: for example, when an unfamiliar talker speaks with a familiar accent, what was learned about that accent on previous occasions with other talkers can improve the intelligibility of the novel talker. In contrast, a learned adjustment to a talker's speech impediment will not benefit intelligibility when overgeneralized to the context of a different talker who does not have the impediment. One of the earliest studies on perceptual learning in speech already demonstrated that learning becomes more reliable when the exposure situation provides a representative sample of the underlying variation. If learning is based on a very restricted set of exposure materials, it does not tend to generalize to broader contexts (Greenspan et al. 1988).

Levels of Processing

While most studies on perceptual learning have simply used changes in intelligibility as an outcome measure, a few recent studies have investigated more explicitly at which point in the speech perception system learning may take place, and how the learning mechanism operates (Cutler et al. 2010; Samuel and Kraljic 2009). This research suggests that learning affects the pre-lexical level of processing. A pre-lexical locus of learning is advantageous since an adjustment to a phonemic category can generalize across the entire lexicon, and is thus beneficial whenever that sound is encountered again in novel lexical contexts. These studies have also revealed that lexical knowledge can be a driving force in perceptual learning. A speech sound that is perceptually opaque can often be disambiguated by the word context in which it occurs. Repeated exposure to the opaque sound in the context of different words leads to an adjustment of the phonemic representation of that sound, sometimes in a talker-specific manner. Other types of disambiguating context may be used as well. For example, visual information from the face of the talker is effective in inducing perceptual learning at the phoneme level (Bertelson et al. 2003), and it is likely that there are other types of contextual information which can be exploited by a perceptual-learning mechanism if they occur with sufficient reliability.

Applications

Several lines of research have investigated how best to use perceptual learning in explicit training situations. For example, adult users of cochlear implants need to learn to adjust to a considerable spectral degradation of the acoustic signal they receive from the environment. Perceptual learning under such conditions is typically slow and effortful, but can be maximized by providing explicit feedback and by introducing a realistic degree of phonetic variability in the training materials (Stacey and Summerfield 2007). In second-language learning, a high degree of variability in training materials is often beneficial for the acquisition of a novel phonemic category, for example, by hearing the critical new speech sound produced by many different talkers and in different contexts.

Cross-References

► Acoustic and Phonological Learning
► Adaptation and Learning
► Bottom-Up and Top-Down Learning
► Categorical Representation
► Perceptual Learning
► Phonetics and Speech Processing
► Phonological Representation
► Psycholinguistics and Learning

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Perceptual Learning of Animals

► Animal Perceptual Learning

Perceptual Modalities

► Adult Learning Styles

Perceptual Representation System

A form of nondeclarative memory, manifested by an improvement in the processing of a repeated stimulus, primarily studied in the context of perceptual repetition priming. Perceptual memory is independent of structures within medial temporal lobe and striatum, but rather is mediated by changes within the sensory cortices, accompanied by a reduction of activity for repeated stimuli. Perceptual memory is elicited by both identical and perceptually similar stimuli, making it suitable for an extraction of a prototype representation from a set of exemplars.

Perceptual Simulations

► Simulation and Learning: The Role of Mental Models

Perceptual Skill Learning

► Procedural Learning

Performance

► Competency-Based Learning
► Learner Characteristics and Online Learning

Performance Consulting

► Human Resource Development and Performance Improvement

Performance Criteria

► Learning Criteria, Learning Outcomes, and Assessment Criteria

Performance Gains

► Ability Determinants of Complex Skill Acquisition

Performance Improvement

► Human Resource Development and Performance Improvement

Performance Technology

► Human Resource Development and Performance Improvement

Performance Trajectories

► Ability Determinants of Complex Skill Acquisition

Performance-Approach Goal

A motivation system by which students want to do better so that they will be recognized as competent by their peers, teachers, and parents.

Performance-Avoidance Goal

A motivation system by which students do their academic work primarily because they fear appearing incompetent.

Performance-Focused Model

► Comparator Hypothesis of Associative Learning

Performing Art

► Dancing: A Nonverbal Language for Imagining and Learning

Periodic Learning Control

► Iterative Learning Control

Peripheral Information

Information, typically emotionally neutral, that is not central to the event being encoded, but which occurs in close spatial or temporal proximity. In the example given above, the face of the person pointing the gun at you (or what clothes they were wearing, or if there was a car behind them) would constitute the peripheral information of the event.

Perseveration

► Impulsivity and Reversal Learning

Perseverative Interests

Perseverative interests, like circumscribed interests, are intense preoccupations with one or more limited patterns of interest that are unusual either in intensity or focus. Perseverative interests involve highly preferred materials, activities, or objects that a child seeks out, talks about, becomes engaged with for prolonged periods of time, and resists interruption.

Cross-References

► Interest-Based Child Participation in Everyday Learning Activities

Persistence

► Memory Dynamics

Persistent Memory

► Memory Persistence

Person Life Goals

► Goals and Goalsetting: Prevention and Treatment of Depression

Personal Attributes

► Individual Differences

Personal Enrichment

► Lifelong and Worklife Learning

Personal Interests

Personal, or individual, interests are a child's likes, preferences, favorites, and so forth that influence how the child participates in activity. Personal interests can be conceptualized either as a disposition or as actualized state. Personal interests are considered to be relatively enduring across different activities and over time. Personal interests usually are associated with increased knowledge, positive feelings, and value.

Cross-References

► Interest-Based Child Participation in Everyday Learning Activities

Personal Knowledge Management

It comprises a range of concepts, methods, tools, and practices of optimizing individual processes of handling all the information you are surrounded with and developing the personal experiences and competencies. Often personal knowledge management is seen as part of organizational knowledge management, but you can realize the concept in education and informal contexts, too. There are overlapping insights and practices in personal knowledge management on the one hand and strategies of learning, metacognition, and problem solving on the other hand.

Personal Learning Environment

► Cultural Influences on Personalized e-learning Systems

Personal Projects

► Goals and Goalsetting: Prevention and Treatment of Depression

Personal Quality

► Social Interaction Learning Styles

Personal Scheme

► Emotional Mental Models

Personality

► Extraversion, Social Interaction, and Affect Repair

► Neuroticism as a Predictor of Mood Change

Personality and Learning

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Synonyms

Learning styles

Definition

Personality: The consistent high level traits associated with the way an individual interacts with other individuals and groups.

Learning: The processes by which an individual acquires new skills, behaviors, or understandings, often in a formal setting called education.

Theoretical Background

During the long history of psychology, various types of personality have been proposed, ranging from the "humors" suggested by the early Greek philosophers to the personality factors investigated by psychologists in the twentieth century. Although many personality theorists have used differing terms to describe the important (noncognitive) dimensions of personality, more recent research has isolated five broad dimensions of personality, which are often called "The Big Five." One frequently cited example of the Big Five is that set down by Goldberg and is associated with the following personality traits:

- Extraversion
- Agreeableness
- Conscientiousness
- Emotional stability
- Openness

In contrast to these formal descriptive types, the less discriminatory measures derived from the work of the twentieth century analytical psychologist Carl Jung is called the Myers-Briggs Type Inventory (MBTI).

P

The Myers-Briggs Personality Test

The Myers-Briggs Type Indicator (MBTI) is a self-report personality inventory designed to give people information about their Jungian psychological type preferences. The measure was developed by Isabel Briggs Myers and Katherine Cook Briggs in the early 1940s to try and make C. G. Jung's theory of human personality understandable and useful in everyday life. Its increasing popularity in educational settings is in part due to its nonjudgmental nature.

Within the MBTI "The Big Five" are associated with the following types:

- Extraversion vs. introversion.
- Feeling vs. thinking.
- Judging vs. perception.
- No match is made on the measures of emotional stability since an evaluation is felt to be judgmental.
- Intuition vs. sensing.

Important Scientific Research and Open Questions

The history of the use of the Myers-Briggs Type Inventory within education is relatively long, although it took some considerable time for it to gain widespread support. As early as the late 1960s, it had been proposed that the MBTI might be a suitable instrument to determine the best teachers with regard to matching teaching style and material presentation to students. Early evaluations compared the MBTI against other personality measures such as Cattell's 16PF in predicting successful learning styles and grade point averages. A large body of research in the last decade has found the MBTI to be one of the best predictors for many aspects of education including group presentation styles, learning preferences, assessment methods, and group work.

It is important to realize that the field of personality and its implications in learning is still in its early stages. Although personality theory posits fundamental traits that underlie human behavior, the reality is that people can exhibit different behaviors under different circumstances. This makes the design of fixed frameworks that can be predictive problematic. However, the field offers great potential to maximize preferred interaction styles with learning modalities.

Cross-References

► Big Five Personality and Prejudice
► Extraversion, Social Interaction and Affect Repair
► Learner Characteristics
► Personality Effects on Learning
► Person-Centered Learning

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Personality Effects on Learning

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Synonyms

Character; Disposition; Temperament; Traits

Definition

Personality describes a person's dispositional and distinctive pattern of thoughts, feelings, and behavior across various situations. In any given moment, personality traits may be poor predictors of behavior, but by comparing reactions over a wide range of contexts, consistencies are likely to appear. Personality traits thus serve as indications of likely patterns of behavior.

Theoretical Background

Individual differences in learning have long been an important topic of investigation. Not only does this field provide practically useful insight for development of instruction and learning support, it also contributes to a deeper understanding of cognitive, emotional, and behavioral mechanisms in learning processes. On a broad level cognitive differences, such as intelligence, measure maximal ability: what a person *can* do. Personality and motivation, in turn, influence typical behavior: what a person in actuality *will* do, and *how* he/she does it (Chamorro-Premuzic and Furnham 2005).

Personality traits may have a directing, framing, strengthening, or weakening impact on educational processes depending on the trait in question and on what is being learnt. Personality may influence learning indirectly through attitudes and motivation which create particular conceptions of learning, learning investment, and preferred ways to learn. Personality traits may thus be expressed in learning styles, which in turn create learning strategies and produce a certain learning outcome. For instance deep learning, which reflects intrinsic motivation and often results in a good study outcome, has been related to personality traits such as openness, conscientiousness, and emotional stability (e.g., Diseth 2003). Personality also influences how a student behaves in an educational context, which is another influential factor on learning outcome. Conscientious students, for instance, are likely to attend classes, while extraverts often have a higher degree of absence.

Personality, interest, and intelligence are all fundamentally intertwined as each part of the triad influences the development of the others (Ackerman 1996). General knowledge (crystallized intelligence) grows through investment of reasoning ability (fluid intelligence), personality, motivation, interest, and effort in learning processes. Mere cognitive ability is thus not enough for knowledge development if not supported by motivation and drive. Openness to experience, intellectual engagement, and need for cognition, for instance, are all personality traits that trigger a curiosity to find out more. Interest alone, however, is not sufficient if it is not supported by effort and dedication. Here, a personality trait such as conscientiousness may provide the determination, discipline, and persistence which would further support knowledge acquisition.

Personality

The most established model of personality to date is the five-factor model (Costa and McCrae 1992). This model describes personality as a combination of traits along five central dimensions: openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism.

Conscientiousness

Conscientiousness has consistently been found to have a strong influence on learning processes, across ages, and in various learning contexts (for a review see Chamorro-Premuzic and Furnham 2005). Inherent in conscientiousness is a motivational factor that drives educational pursuits: a strong will to succeed. In addition, the trait triggers behavior that support learning processes, such as persistence and high study morale. Conscientiousness has been linked to methodic, serial, and analytic learning as opposed to an elaborative one.

Conscientious people are reliable, dutiful, and dependable to their character. They persist even in the face of difficulties. Conscientious students in addition tend to be achievement-oriented and goal-directed. They work hard on their assignments and fulfill task requirements. They are also efficient in organizing their studies and managing their time. All these efforts usually pay off and result in good grades. Traits that seem particularly important for academic success are discipline, work drive, self-regulated learning, self-control, task commitment, and self-efficacy.

Openness

Openness to experience is a personality trait distinguished by an intrinsic motivation to explore the unknown. Openness, occasionally named intellect, also more directly influences learning processes through the traits typical cognitive fluency in divergent thinking, abstract and verbal reasoning, and critical reflection (for a review see Chamorro-Premuzic and Furnham 2005).

People with high levels of openness are typically intellectually curious and reflective. They enjoy solving cognitive puzzles and have a high need for cognition. As a result they often develop a wide general knowledge. Together with their typical unconventionality and analytical ability, this provides useful tools for creative solutions. Openness has consequently been linked to creativity, divergent thinking, cognitive flexibility, and elaborative as opposed to analytical learning. Typical for students with high openness is deep, constructive, and meaning-oriented learning, where students relate what they learn to their previous understanding (e.g., Diseth 2003). Open students additionally tend to reflect on their own thinking and learning processes which further strengthen their understanding. All these factors facilitate learning, and often result in academic success.

Extraversion

Extraverts are spontaneous and talkative, while introverts deliberate more before they act. One of the basic differences between the traits lies in the source of energy, which extraverts seek from the outside and introverts find within.

Extraverts tend to harbor an interactive as well as practical down-to-earth approach to learning (for a review see Chamorro-Premuzic and Furnham 2005). They prefer to learn through social interaction, by listening and explaining to others. This makes them actively participate in classroom discussions and thrive in collaborative settings. Extraversion may, however, also be distractive for learning processes due to the often impatient and impulsive nature of outgoing students who at times tend to be more attracted by social interaction than studies.

Introverts are generally independent, methodical, thorough, reflective, and analytical in their learning processes. They strive to integrate and connect content matter, and find out how things are related. Introverts tend to hesitate and think things through before they act and are less likely to spontaneously speak in the classroom. Online learning environments may thus be particularly suitable for them.

Neuroticism

People with high neuroticism are sensitive and reactive, and suffer from a heightened likelihood to experience negative emotions, such as worry, apprehension, and sadness. In a learning situation, the impact of neuroticism may be twofold. Worry may lead to better preparation and increased effort in an attempt to avoid an expected failure, therefore resulting in a better outcome. At too high levels, however, anxiety often becomes intrusive by consuming cognitive capacity and distracting attention away from learning processes – for a review see Chamorro-Premuzic and Furnham (2005). As a consequence, neurotic students may at times resort to a surface approach to studying distinguished by memorization and factual learning rather than reflection and analysis (e.g., Diseth 2003).

Strong feelings of anxiety may also have a more direct impact on cognitive processes and impair the ability to comprehend and integrate information with previous understanding. Specifically, anxiety interferes with the encoding of information so that a person becomes less able to sort out the most relevant part of a message and, as a consequence, will have difficulty in remembering it afterward (Wood et al. 2001). The impairing influence of neuroticism is particularly strong during demanding and stressful tasks, as well as during learning processes that require analytical and critical thinking. A quiet and serene learning environment may counteract these mechanisms.

Agreeableness

Agreeable people are caring, benevolent, and compassionate. Within the five-factor model of personality, agreeableness is the trait which is least connected to academic learning. The trait may nevertheless generate a positive impact on grades through willingness to comply, attend classes, and abide by external demands. This trait may in addition facilitate team work and other forms of collaboration. Agreeableness brings with it an aptitude for intuitive learning such as interpretation of nonverbal cues and emphatic understanding. Disagreeable adults, in turn, often have an advanced vocabulary and a high general knowledge, perhaps due to a more independent nature and non-reliance on others. A disagreeable nature may also cultivate cognitive endeavors as a compensation for social disadvantages.

Traits Outside of the Five-Factor Model

Outside of the five-factor model, traits that have a positive impact on learning are, among others, self-efficacy, internal locus of control, high need for cognition, optimism, resistance to stress, resilience, tough-mindedness, and work drive. Furthermore, drawing on the Myers-Briggs personality framework (Myers and McCauley 1985), it has been shown that sensing students are detail- and fact-oriented and like organized and structured lectures, whereas intuitives prefer discovery learning and focus on detecting patterns and relationships. Judging students are decisive, organized, and task-focused, whereas perceptive students are more flexible and spontaneous.

Important Scientific Research and Open Questions

Researchers have argued that the connection between personality and learning processes is best revealed by looking at specific facets of the five-factor model traits rather than at meta-traits. Promising findings have been revealed within this research tradition. It is furthermore essential to consider the influence of domain and subject for a deeper understanding of the connection between personality and learning as each personality trait comes with its own aptitudes and weaknesses. Various traits may facilitate or hinder learning dependent on the learning task, whether this is practical, social, analytical, or creative for instance. Some disciplines, such as mathematics, may require analytical thinking, while the learning of other topics is facilitated by creative thinking. Various traits may also be more or less influential on learning depending on age, gender, educational requirements, and grade level. For instance, self-directed learning and critical thinking become increasingly important from elementary school to university education. Although research has found that individual differences such as personality, intelligence, or motivation influence learning outcome, studies seldom explain more than 30% of the learning process. More research is therefore needed before final conclusions can be made.

Cross-References

▶ Big Five Personality and Prejudice
▶ Interpersonal Curiosity
▶ Personality and Learning
▶ Personalized Learning
▶ Person-Centered Learning
▶ Religiosity and Personality – Effects on Learning

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Personality Trait Theory

▶ Big Five Personality and Prejudice

Personality Traits

▶ Jungian Learning Styles

Personalization in e-Learning

▶ Cultural Influences on Personalized e-learning Systems

Personalized Educational Systems

▶ Personalized Learning Systems

Personalized e-Learning Systems

▶ Personalized Learning Systems

Personalized Learning

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Synonyms

Customized learning; Individualized learning

Definition

Personalized learning means tailoring education to learners' current situation, characteristics, and needs in order to help learners to achieve the best possible learning progress and outcomes. Personalized learning can appear on different levels of education, including personalizing curriculums, courses, learning material, learning activities, and other learning support. Through personalized learning, each learner is provided with education that is tailored to his/her individual characteristics and needs and learns in a way that is most suitable for him/her, resulting in different learning experiences for each learner.

Theoretical Background

Each learner has individual characteristics and needs such as different prior knowledge, cognitive abilities, learning styles, and so on. These individual differences affect the learning process and are the reason why some learners find it easy to learn in a particular course, whereas others find the same course difficult (Jonassen and Grabowski 1993). Personalized learning addresses the individual differences of learners by treating each learner as an individual person and considering his/her current situation as well as his/her characteristics and needs in the learning process. This implies that the learning experience is different for learners with different characteristics and needs due to the tailoring of the curriculum, courses, learning material, and/or support.

In the educational domain, the terms "personalized learning" and "adaptive learning" are often used in a similar context. While both terms refer to the tailoring of education to learners' current situation, characteristics, and needs, adaptive learning stresses more on the aspect of achieving this tailoring automatically (typically by a learning system) while personalized learning stresses more on the consideration of the learner as an individual person. Furthermore, adaptive learning can also be applied to groups of learners, tailoring education to those groups. On the other hand, personalized learning always focuses on the individuals, regardless of the fact whether they work alone or in groups.

Personalized learning can involve different levels in the educational process, including personalization of the curriculum, the courses, as well as the support provided within the courses. Furthermore, personalized learning can be based on different characteristics and needs of learners and can take place in traditional (face-to-face) learning settings as well as in technology-enhanced learning settings.

In traditional classes, personalized learning requires a small number of learners per teacher. The small number of learners makes it possible for teachers to become aware of the individual characteristics and needs of learners and enables teachers to tailor their lessons, activities, and support, respectively. In traditional classes, personalized learning is also related to more choices for learners in the curriculum programs, parental involvement in education (if learners are children), student-driven learning, as well as allowing learners to make decisions in the personalization process.

The use of technology in education opened up new possibilities for providing personalized learning to learners and significantly enhanced the potential of personalized learning. Through the development and usage of learning systems, large numbers of learners in a class can use and benefit from personalized learning (Graf 2007). Personalized learning through technology can range from welcoming a learner by his/her name in the online course and allowing a learner to personalize his/her learning environment, for example, through changing the language and the color schema, to more complex features such as enabling the learner to create his/her own personal learning space by adding/removing particular tools and features to/from his/her space. Furthermore, personalized learning can take place by considering learners' characteristics and needs and recommending learners personalized courses, learning material, and learning activities. Such personalization can be based on different characteristics and needs of learners such as their prior knowledge, learning styles, cognitive abilities, learning interests, learning goals, motivation, and so on (Graf et al. 2009). A learning system can detect such characteristics and needs of learners, either through asking learners explicitly or by monitoring their behavior and actions in the system, and use this information then for providing personalized learning (Brusilovsky 1996). Another aspect where technology can facilitate personalized learning is the personalization of curriculums where systems can consider various factors of learners in order to calculate the most suitable curricula as well as the best sequence of courses for each learner.

Important Scientific Research and Open Questions

Most of the current research on personalized learning is strongly related to technology-enhanced learning, enabling learning systems to provide personalized learning. When looking at learning systems that are commonly used in technology-enhanced learning, such as learning management systems, it can be seen that these systems typically provide only simple features for supporting personalized learning, allowing learners, for example, to change the language or color schema of their interfaces.

However, a lot of research has been performed and is performed on integrating more complex aspects of personalized learning into learning systems. One research direction in this context deals with making learning environments/systems more personal and providing personalized learning experiences by allowing learners to change and adjust the environment to their personal needs and preferences. A promising area in this context is the use of mash-ups for building personal learning environments (Wild et al. 2008). Such mash-up personal learning environments are based on the idea of social software and Web 2.0 technology and enable learners to create their own learning spaces with the tools and features they need and want to use through adding them to and removing them from their learning spaces.

Another approach for providing personalized learning is to develop systems that are able to identify learners' characteristics, needs, and current situation and consider them in order to provide learners with a personalized learning experience. Many systems have been developed and evaluated over the last years that implement certain learning strategies for personalized learning. Examples of such systems are given in the survey by Knutov et al. (2009), where some of the most well-known adaptive and personalized learning systems are compared with respect to their concepts, architectures, and techniques for providing adaptivity and personalization. Such learning systems are able to consider particular characteristics such as the prior knowledge or the learning styles of learners and provide personalized learning based on these characteristics. As mentioned before, many characteristics exist which are worth to be considered in such learning systems in order to tailor education best possible to learners. One of the future research topics in personalized learning, for technology-enhanced settings but also for face-to-face settings, deals with the combination of different characteristics of learners that should be considered when delivering personalized learning. In technology-enhanced learning, open issues related to the combination of characteristics include, for example, whether and how characteristics influence/compensate each other and how such effects influence the provision of personalized learning. Another open question in this context deals with the selection of characteristics that should be considered in personalized learning and whether these characteristics should be the same for all learners or might vary for each learner.

Another area of future research is the interweaving of personalized learning with other pedagogical models such as mobile learning, ubiquitous learning, game-based learning, collaborative learning, and others. For all these models, the consideration of personalization has high potential to enhance the respective model by improving the learning progress and outcome of learners through tailoring the respective activities and concepts to the learners' current situation, characteristics, and needs.

Cross-References

- ► Adaptability and Learning
- ► Adaptation and Learning
- ► Adaptive Blended Learning Environments
- ► Adaptive Learning Systems
- ► Adaptive Learning Through Variation and Selection
- ► Individual Differences in Learning
- ► Individual Learning
- ► Personalized Learning Systems

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Personalized Learning Systems

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Synonyms

Personalized educational systems; Personalized e-learning systems

Definition

Most of the learning systems typically used in educational institutions, such as learning management systems, provide the same courses, identical in structure, composition, and content, for all learners (Graf 2007). In contrast, personalized learning systems are learning systems that consider the individual differences of learners and tailor the learning experience of learners to their current situation, characteristics, and needs. By adapting courses, learning material, and/or learning activities to learners' individual situation, characteristics, and needs, personalized learning systems aim at increasing learners' progress and outcome, enabling learners to learn with less effort, for example, in terms of time required for learning, and offering higher learner satisfaction.

Theoretical Background

Each learner has individual characteristics and needs such as different prior knowledge, cognitive abilities, learning styles, and so on. These individual differences affect the learning process and are the reason why some learners find it easy to learn in a particular course, whereas others find the same course difficult (Jonassen and Grabowski 1993). Personalized learning systems address this issue by adapting courses, learning material, and/or learning activities to the learners' current situation, characteristics, and needs.

Besides the term "personalized learning systems," there exist other terms which are often used in a similar context. The term "adaptive learning system" stresses the ability of a learning system to automatically provide different courses, learning material, and/or learning activities for different learners and the term "intelligent learning (or tutoring) system" refers to systems that focus on the use of techniques from the field of artificial intelligence to provide broader and better support for learners. On the other hand, the term "personalized learning system" emphasizes the aim of the system to consider a learner's individual differences and treat each learner as an individual person. However, many of the learning systems developed based on the idea of tailoring education to learners' characteristics and needs can be considered as personalized, adaptive, and intelligent.

Personalized learning systems usually focus on personalization on the course level, meaning that such systems provide courses that fit learners' individual needs and characteristics. The personalization typically works in two steps. First, the respective characteristics and/or needs of learners have to be identified. This process is called student modeling and aims at building and updating a student model that includes information about the students' characteristics and/or needs. Brusilovsky (1996) distinguished between two different ways of student modeling: collaborative and automatic. In the collaborative approach, the learners provide explicit feedback which can be used to build and update a student model, such as filling out a questionnaire. In the automatic approach, the process of building and updating the student model is done automatically based on the behavior and actions of learners while they are using the system for learning. Furthermore, student modeling can be done statically or dynamically. Static student modeling refers to an approach where the student model is initialized only once (mostly when the students are registering for the course). In contrast, a dynamic student modeling approach frequently updates the information in the student model.

In the second step, personalized courses are composed based on the identified characteristics and/or needs of learners which are stored in the student model. Such personalized courses can differ, for example, with respect to the learning objects/activities that are presented in the course, the number of presented learning objects/activities, the sequence in which particular learning objects/activities are presented, the presentation and layout of the course itself, the amount of additional support provided to learners, the navigation within the course, and so on. Brusilovsky (2001) pointed out two distinct areas of adaptation techniques for adjusting courses to students' characteristics and/or needs, namely, adaptive presentation and adaptive navigation support. Adaptive navigation support deals with providing students different ways to navigate through a course and includes features such as direct guidance, map adaptation, as well as adaptive sorting, hiding, annotating, and generating of links. Adaptive presentation deals with how the content itself is presented to learners and includes adaptation features based on content such as adaptive multimedia presentation, adaptive text presentation, and adaptation of modality.

Many characteristics and needs of learners exist to which a personalized learning system can adapt its courses to. One of the first characteristics that has been considered in personalized learning systems is the learners' knowledge level or prior knowledge. Later on, cognitive and pedagogical aspects have been considered more and more, leading to the development of systems that tailor courses to learners' learning styles, cognitive abilities, learning interests, learning goals, motivation, and so on. In addition, personalization features have been developed and integrated in learning systems, allowing, for example, to change the language or color schema of a course in order to enhance the possibilities for personalization in these systems.

Numerous personalized learning systems have been developed over the last years. These systems differ with respect to which adaptation techniques are used, which characteristics and needs of learners are considered, why adaptation and personalization is needed, where and when adaption and personalization is applied, as well as how adaption and personalization is implemented within the systems. Knutov et al. (2009) introduced and compared some of the most well-known learning systems with respect to these issues, discussing their concepts, architectures, and techniques used for adaptivity and personalization.

Important Scientific Research and Open Questions

When looking at which systems are currently used for education, it can be seen that personalized learning systems are applied only very rarely and that most educational institutions are using so-called learning management systems. Learning management systems are developed to support teachers in creating, holding, and managing online courses and present these courses then to learners. In contrast, personalized learning systems focus particularly on supporting learners, tailoring courses to learners' characteristics and needs, but provide only basic functions for supporting teachers. An open research issue is to combine the advantages of both, personalized learning systems and learning management systems, and to create systems that have rich support for teachers and at the same time are able to tailor education to learners' characteristics and needs.

Another open issue in the area of personalized learning systems deals with the combination of different characteristics of learners that should be considered when delivering personalized learning. Open questions related to the combination of characteristics include whether and how characteristics influence/compensate each other and how such effects influence the provision of personalization strategies of the system. Another open question in this context deals with the selection of characteristics that should be considered when providing personalized courses and whether these characteristics should be the same for all learners or might vary for each learner.

Furthermore, high potential can be seen in the development of learning systems that combine personalized learning with other pedagogical models such as mobile learning, ubiquitous learning, game-based learning, collaborative learning, and others. Systems that implement respective pedagogical models can be merged with personalized learning systems, which would lead to more support for learners by improving the learning progress and outcome through tailoring the respective activities and concepts of each pedagogical model to the learners' current situation, characteristics, and needs.

Cross-References

▶ Adaptability and Learning
▶ Adaptation and Learning
▶ Adaptive Blended Learning Environments
▶ Adaptive Learning Systems
▶ Adaptive Learning Through Variation and Selection
▶ Computer-Based Learning Environments
▶ Individual Differences in Learning
▶ Individual Learning
▶ Learner Characteristics
▶ Personalized Learning
▶ Technology-Enhanced Learning Environments

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Person-Centered Instruction

▶ Learner-Centered Teaching

Person-Centered Learning

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Synonyms

Experiential learning (as used by Rogers); Learner-centered education; Significant learning; Whole-person learning

Definition

Person-centered learning refers to the facilitation of learning through an interpersonal climate characterized by empathic understanding, acceptance, and realness. While it is most coherent with the intentions and methods associated with (▶ Experiential Learning [Rogers]) such as dialogue and discussion, self-initiated projects, or working in teams and groups, research has shown that the attitudes of a facilitative interpersonal climate are more important than the specific methods involved. According to Rogers (1983, paraphrased from pp. 188–189), the Person-Centered Mode is characterized as follows:

- The precondition is: a leader or a person who is perceived as an authority figure in the situation is sufficiently secure within himself or herself and his or her relationship to others that he or she experiences an essential trust in the capacity of others to think for themselves, to learn for themselves.
- The facilitative teacher shares with the others – students and community members – the responsibility for the learning process.
- The facilitator provides learning resources, from within himself or herself and his or her experience, from books or materials or community experiences. He or she encourages the learners to add resources of which they have knowledge or in which they have experience. He or she opens doors to resources outside the experience of the group.
- The student develops his or her own program of learning, alone or in cooperation with others.

- A facilitative learning climate is provided. This climate may spring initially from the person who is the perceived leader. As the learning process continues, it is more and more often provided by the learners for each other. Learning from each other becomes as important as learning from books or films or work experiences.
- It can be seen that the focus is primarily on fostering the process of learning. The content of the learning, while significant, falls into a secondary place.
- The discipline necessary to reach the student's goal is self-discipline.
- The evaluation of the extent and significance of the student's learning is made primarily by the learner.
- In this growth-promoting climate, the learning tends to be deeper, proceeds at a more rapid rate, and is more pervasive in the life and behavior of the student than is the learning acquired in the traditional classroom.

Additionally, person-centered learning has recently been significantly influenced by the American Psychological Association's Learner-Centered Psychological Principles (APA Work Group 1997) led by Barbara McCombs and colleagues. McCombs and Miller (2006) emphasized that learner-centered learning, a notion that is more general than person-centered learning, has a twin focus on learners as persons and learning as processes, integrating the best knowledge about how learning occurs within the facilitator's approach. Person-centered learning shares with learner-centered learning that it also involves the broader learning context, including the connectivity between the teacher, the parents, and community members, and other educators and professionals concerned with fostering student development (Cornelius-White and Harbaugh 2010). Thus, rather than being referred to as "whole-person learning" a term like "whole-context learning" characterizes its essence.

Theoretical Background

Rogers (1951, 1969) proposed that the goals of person-centered education were to facilitate actualization, the ability to adapt flexibly and intelligently to new problem situations, to promote democratic unity, and help persons learn how to critically think, self-regulate learning, and cooperate respectfully.

Like many person-centered theorists after him, by midlife, Rogers began to see person-centered learning as vital and urgent to the survival of our species and world, given the expansive context of the current world. "The only man who is educated is the man who has learned how to learn; the man who has learned how to adapt and change; the man who has realized that no knowledge is secure, that only the process of seeking knowledge gives a basis for security. Changingness, a reliance on process rather than upon static knowledge, is the only thing that makes any sense as a goal for education in the modern world" (Rogers 1983, p. 120).

Person-centered teaching/learning can be characterized by the following goals. It aims toward the following:

- A climate of trust in the classroom in which curiosity and the natural desire to learn can be nourished and enhanced.
- A participatory mode of decision-making in all aspects of learning in which students, teachers, and administrators each have a part.
- Helping students to prize themselves, to build their confidence and self-esteem.
- Uncovering the excitement in intellectual and emotional discovery, which leads students to become lifelong learners.
- Developing in teachers the attitudes that research has shown to be most effective in facilitating learning.
- Helping teachers to grow as persons, finding rich satisfaction in their interactions with learners.
- Even more deeply, it aims toward awareness that, for all of us, the good life is within, not something which is dependent on outside sources (Rogers 1983, paraphrased from p. 3).

Rogers viewed a facilitative climate as more important than the methods. Such a climate is characterized by the following three core attitudes that the facilitator holds and communicates in a way that learners perceive them at least to some degree:

1. *Realness* in the facilitator means that he or she is not playing a role prescribed by the educational system nor hiding behind some professional façade but rather is genuine, authentic, honest, and open to the flow of experiencing that is going on inside. The facilitator does not feel one thing and say

something else. In expressing his or her positive or negative feelings – if deemed appropriate – the facilitator accepts them as their own, without blaming students. For example, if he or she is disappointed, he or she says: "I feel disappointed," not "You have disappointed me." Relationships with students are direct personal encounters in that the facilitator is a real person and not a "faceless embodiment of a curricular requirement" (Rogers 1983, p. 122). In learning situations, in particular, realness can be expressed for example by solving real, authentic problems, by fostering openness and transparency in expression, by encouraging different perspectives to be expressed and considered, by soliciting and giving open feedback.

2. *Acceptance, prizing, trust.* Learners are prized for their feelings, their opinions, their being persons. The attitude is a nonpossessive caring for the learner, accepting him or her as a unique person. It is a basic trust, a belief that this other person is somehow fundamentally worthy, a human being with many feelings and many potentialities. All this is unconditional, not based on any demand that the learner perform in some prescribed way. Often, respect and acceptance are expressed indirectly through behavior. For example, having students participate in determining course goals and/or grades, providing them with choices, and trusting them to self-organize their contributions allows students to feel "taken seriously" and respected as partners in their learning processes rather that puppets that are manipulated by others.
3. *Empathic understanding.* This subjective way of understanding is not the usual evaluative understanding derived from a diagnostic analysis from an external point of view. Empathy is standing in the other's shoes, viewing the world through his or her eyes. When learners are listened to empathically, their reaction is of the kind: "At least someone understands how it feels and seems to be me without wanting to analyze me or judge me. Now I can blossom and grow and learn" (Rogers 1983, p. 125). Empathic understanding in learning situations extends from actively listening to learners to deeply taking into account the whole learning situation, including the previous knowledge of learners, their family and cultural background, the particular cohort and the personal, time and material resources of the class.

With regards to methods, Rogers emphasized shared control and choice, flexible application, differentiated for each learner or learning context. The more recent learner-centered literature (e.g., McCombs and Miller 2006), has emphasized that instructional strategies should include innovative and successfully demonstrated methods, that challenge students to think critically and are adapted to cultural informed, individualized relationships.

Important Scientific Research and Open Questions

Cornelius-White (2007) and colleagues synthesized 1,450 findings from 119 quantitative studies involving over 350,000 students from multiple countries from the 1940s till the early 2000s that investigated person-centered learning. Cornelius-White and Motschnig (2010) additionally reviewed findings from qualitative and more recent quantitative studies, especially as concerns the more than 70 studies from Learning Research Center at the University of Vienna, Austria. Overall, person-centered learning, especially as defined by empathy, warmth, and/or trusting, facilitative relationships, is supported by correlational and experimental studies to improve learning outcomes in comparison to pretest levels or traditional or low facilitative climate learning contexts. Learning outcomes supported in descending order of magnitude of effects include participation, self-efficacy, dropout prevention, motivation, social skills, motivation, and disruptive behavior reduction. Teacher beliefs related to learner-centered premises did not show as strong a relationship to student success. Generally, assessed emotional, social, and behavioral outcomes appear more associated to person-centered learning success than cognitive outcomes (achievement testing) with the exception of critical thinking.

Moderator analysis showed that person-centered learning appears to be supported under most of the conditions evaluated, such as differing gender, ethnicity, geography, student ability, etc. A few moderators showed conditions more likely to have stronger support, including female gender of the teacher, and statistical control of pretest (such as starting achievement or aptitude). An additional moderator to show variation included the perspective of measurement, whereby students and observers' ratings of the learning climate were more predictive of student success than teachers' ratings. Comparison with the larger body of educational research showed that findings on person-centered learning are above average compared to most approaches or variables investigated.

Studies on person-centered e-learning (PCeL), a technology-enhanced, hybrid variant of person-centered learning (Motschnig-Pitrik 2005), are congenial to many of the results found in studies on person-centered learning (Cornelius-White and Motschnig 2010). As a consequence, a proper balance of online activities in classes that are facilitated in a person-centered way can benefit and extend the approach to innovative, hybrid forms of learning.

Major open questions include:

- Are some person-centered learning outcomes with few findings, such as dropout prevention, generalizable cross-culturally?
- To what extent do typical experiential learning methods associated with person-centered learning, improve the facilitative climate or student learning directly and for what outcomes?
- Under what circumstances should whole-person learning be replaced by empirically supported strategies (e.g., phonics for reading) given the potential benefit to specific outcomes versus the cost to the learning relationship and learner as person?
- To what extent can a facilitative learning climate foster the deeper goals of person-centered learning, such as democratic behavior, or self-regulated, life-long learning?
- What are the long-term effects of person-centered learning, e.g., on employability or satisfaction or beneficial goal choices in life histories?

Cross-References

► Experiential/Significant Learning
► Guided Discovery Learning
► Humanistic Approaches to Learning
► Learner Control
► Rogers, Carl. R. (1902–1987)

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Perspective Transformation

A fundamental transformation in the way a learner views the world and all the influences on that worldview. Perspective transformation can occur in two ways. It can be relatively seamless and occur as a series of small changes in one's meaning schemes or it can be epoch and involve a transformation in the larger meaning perspective as one engages in a comprehensive and critical reevaluation of oneself.

Cross-References

► Jack Mezirow on Transformative Learning

Perspective-Changing Task

A perspective-changing task is the ability to imagine an object from different positions. It requires the observer to understand that the object might look different when viewed from another place, as if he had moved and turned around it, looking at the display from somewhere else.

Perspectivism

The view that all interpretations and truth claims flow from particular perspectives. There is no uniquely correct vantage point accessible to human beings. Instead, there are many possible conceptual schemes – to which we are drawn by our interests, experiences, and powers – from which judgments of truth or value can be made. Thus, no particular way of seeing and evaluating the world is objectively true, but not all perspectives are equally valid.

Persuasion and Learning

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Synonyms

Attitude change; Persuasive communication; Propaganda

Definition

"Persuasion is everywhere, playing an essential role in politics, religion, psychotherapy, education, and day-to-day social interactions" (Petty and Brinol 2008, p. 137).

The term persuasion refers to any procedure with the potential to change someone's mind and attitudes. Persuasion is the basic concept in the ► persuasion therapy of Dubois (1848–1918) and *persuasive communication*, which is at the core of this entry. Although there is no unique definition of persuasive communication, it is clear that it aims at attitude changes by means of communication. In this context, persuasion is complex and conditional; it occurs if several learning conditions are satisfied, such as exposure, attention, interest, comprehension, and knowledge acquisition.

This entry will describe the social psychological perspective on persuasion in order to explain how certain variables produce attitude change, such as credibility of information sources, a person's beliefs and emotions, and persuasive communication.

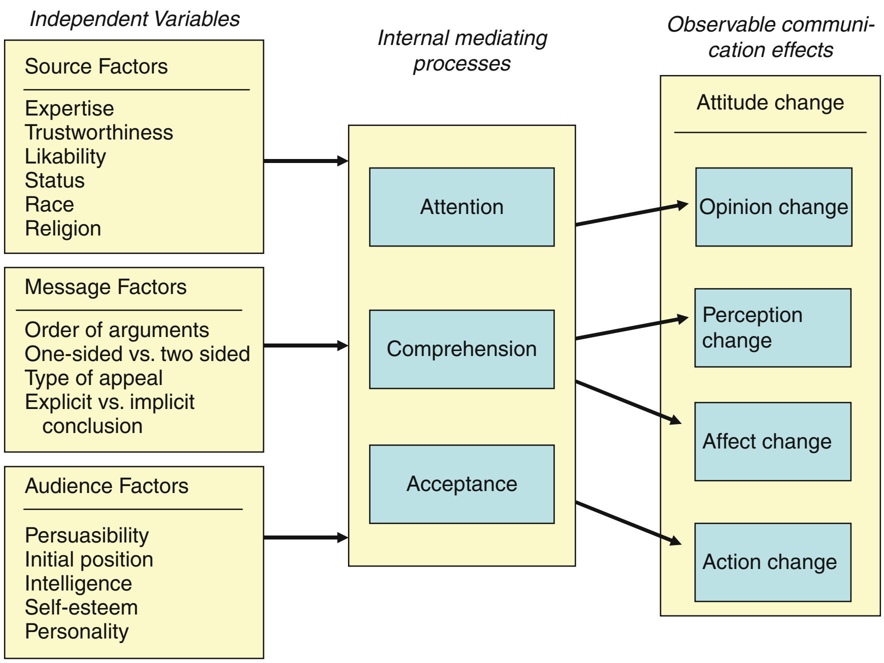
Theoretical Background

Although persuasion can be used to change many things, such as a person's specific beliefs, the most common target of persuasion in psychological literature is a person's attitudes, discussed generally in terms of the *three-component model*, including cognitive, affective, and behavioral components. There are several theories on persuasive communication that describe how attitudes can be learned and changed and what kind of influence persuasive communication might have on attitudes. Some theories focus on the systematic processing of information, whereas others also include the effects of emotions and personality traits on attitude change.

Carl Hovland, who pioneered the research on persuasive communication and its effects on attitude change, argued that an attitude is first of all an individual's response to communication with messages of varying degrees of persuasiveness. Hovland started conducting systematic research on persuasive communication and related learning experiences in the 1950s. His *message-learning approach* to attitude change focused on the question: *Who says what to whom and how and with what effect?* The message-learning theory assumes that since attitudes are learned, they can be changed by a learning process which responds to characteristics of source factors, message factors, and audience factors (see Fig. 1).

In developing the message-learning approach to persuasion, Hovland viewed persuasive communication as the process by which the communicator transmits particular, especially verbal, messages in order to change the attitudes of addressees (Hovland et al. 1953). According to this approach, the basic processes for achieving attitude change are attention, comprehension, and acceptance. These processes are dependent on the characteristics of the information sources (e.g., credibility and trustworthiness), the message itself (e.g., comprehensibility and number of arguments), and the recipient (e.g., intelligence and gender).

McGuire (1968) used the message-learning approach to develop a model of persuasion and learning that focused on information processing. More specifically, McGuire argued that the receiver must meet five preconditions in order to process persuasive messages: Attention, comprehension, acceptance of arguments and attitude change, perseverance of changed attitudes, and overt behavior in accordance with



Persuasion and Learning. Fig. 1 The message-learning approach (Adapted from Hovland et al. 1953)

a new attitude. This model shows how difficult it is to attain a change of an attitude by means of persuasive communication. If the recipient does not pass through one of the aforementioned steps, the communication was not successful. Because social psychological experiments regularly assess the effect of communication immediately after its presentation, McGuire's model can be confined to the factors attention, comprehension, and acceptance. Furthermore, the factors attention and comprehension are conceived as nonseparable components of *reception*. Thus, a simplified version of McGuire's model is called the two-factor model of persuasion. Its central assumption is that the reception of a message determines the change of attitudes. However, there are only few empirical data which support this assumption.

Alternatively, Greenwald (1968) developed a cognitive learning model of persuasion that is based on the "common assumption that the effectiveness of a persuasive communication is, at least in part, a function of the extent to which its content is learned and retained by its audience" (Greenwald 1968, p. 147). From this author's point of view, there cannot be any doubt on the fact that "cognitions bearing on attitude objects are learned. Furthermore, the most obvious source of such cognitions is the wealth of persuasive messages to which one is exposed" (p. 148). The models of McGuire and Greenwald disagree with regard to the importance of the reception of arguments, but they agree on the point that attitude change is only possible by means of meaningful processing of communicated messages which may be more or less persuasive.

One of the most influential and useful process models regarding how people are influenced by persuasive communication is the Elaboration Likelihood Method (ELM), which describes the conditions under which a person tends to think critically about a persuasive message. This model was developed in the 1980s by Petty and Cacioppo (1986) and is one of the most popular models in the area of mass media research and propaganda. The ELM basically assumes two modalities of elaborative processing of a message: A *central and a peripheral route* of information processing (or elaboration). Furthermore, the ELM assumes that the type of persuasion and the likelihood of elaboration (or thinking) depend on the recipient's motivation and ability to process messages.

The *central route to persuasion* is associated with the recipient's orientation toward arguments and the quality of the message, which will be compared with prior knowledge about the content. This conscious reference to prior knowledge results in either the acceptance or the rejection of the message. The central route to persuasion presupposes, first of all, a need for cognition and the ability to process a persuasive message. Furthermore, the recipient must be interested in the message and motivated to process it elaboratively. However, this is dependent on the subjective relevance of the message and the epistemic curiosity of the recipient. Of course, the motivation and directed attention can also be evoked by peripheral cues (as the example of advertising shows). The central route to persuasion results in a stable and persistent change of attitudes. From the perspective of cognitive theories of learning, this result can be explained as being due to a deeper level of processing of the relevant information and its subjective preferentiality. However, a prediction of behavior is only possible with regard to specific actions.

The *peripheral route to persuasion* operates with heuristic cues in which the quality of arguments is marginal. Heuristic cues refer to characteristics of the sender, his/her attractiveness, and assumed competence or publicity as well as the length of communication. Peripheral processing is probably the most frequently applied form of processing in everyday life due to its cognitive parsimony. It does not presuppose either sufficient cognitive abilities or sufficient motivation, and personal concern for the information is not relevant for the response to peripheral cues. This means that people who are less concerned with a message may refer more to peripheral cues than to the quality of arguments. Peripheral processing results in weak and unstable changes of attitudes, and a prediction of behavior is nearly impossible.

Although the two routes to persuasion are often considered to be antagonistic, an interaction is possible. Put briefly, the ELM argues that when people are sufficiently motivated, have sufficient ability, and are not distracted, they will process a persuasive message more comprehensively. When they are not motivated, have less ability, or are distracted, they may take the easy way out by allowing themselves to be influenced by unrelated factors such as the attractiveness and confidence of the presenter, rate of speech, and other associations. More specifically, Petty and Cacioppo (1986) describe some additional factors which may influence a change of attitudes. For example, *distraction* can decrease the recipient's abilities for central processing. Topics which are highly relevant to a person tend to be processed centrally, whereas irrelevant topics tend to be processed peripherally. People in a good mood will also tend to follow the peripheral route to persuasion. However, the most influential factor for choosing the central or peripheral route to persuasion is probably the *need for cognition*. People with a strong need for cognition enjoy dealing cognitively with a variety of situations and topics and focus on the quality of arguments. When processing persuasive messages, people with a strong need for cognition prefer reflective thinking and the central route of information processing. They do not respond to peripheral cues as people with a weak need for cognition do. People with a weak need for cognition are generally less motivated and/or do not have the ability to invest cognitive effort in processing information. Consequently, arguments and their quality are negligible and the topics are also less relevant to them. Instead, peripheral cues such as the attractiveness and credibility of the sender are preferred.

Central and peripheral processes can occur simultaneously (Petty and Wegener 1999), but the interplay of the conditions and mechanisms has not been explained in the ELM. What is known is the fact that purposeful reiterations of messages can increase the stability of attitude change during peripheral processing.

Important Scientific Research and Open Questions

Persuasion and learning is an issue of theoretical reflection and empirical investigation with a long history. Its roots can be traced all the way back to ancient Greek philosophy, and it was also a major characteristic of medieval scholasticism and the philosophy of Renaissance. In accordance with Aristotle, who claimed in his *Rhetoric* that the purpose of rhetoric is not to persuade but to detect the means of persuasion per se, the early approaches to persuasion distinguished between persuasion with appeals based on emotion (passion) and persuasion with appeals based on logical arguments (reason). Demirdögen (2010) has pointed out that the research of Hovland and the Yale group in the 1950s corresponds remarkably to Aristotle's view on persuasion.

Modern research on persuasion and learning started at the beginning of the twentieth century and was to a large extent guided by the idea of a single process model of persuasion, which was later contrasted with the assumption of a dualism in persuasion processes. Petty and Brinol (2008) point out that the assumption that acting or deciding is based either on a person's first impulse or a more deliberate reflection can be found in ancient Greek philosophy as well as in the psychoanalysis of Freud.

Scientific research on persuasion has exploded since the 1950s. Starting with Hovland and the Yale group, the first generation of persuasion research centered on the idea that particular variables of persuasion (e.g., distraction, emotion, and source credibility) could increase or decrease the probability of attitude changes by means of a single process. The first generation of persuasion research was guided by simple main-effect questions and produced numerous inconsistencies. As a consequence, the next generation of research focused on so-called *dual-process models* emphasizing controlled judgments that are made deliberatively with more thought vs. those made more automatically with little thought (Chaiken and Trope 1999). Undoubtedly, the Elaboration Likelihood Model of Petty and Cacioppo (1986) is one of the most popular examples of dual-process models of persuasion. With its distinction between a central and a peripheral route of information processing, the ELM refers to the traditional view of duality. Petty and Brinol (2008) argue that dual-system models also emphasize the underlying mental architecture (e.g., memory systems) and/or specific brain structures that guide processing (Smith and DeCoster 2000).

The persuasion research of the 1980s and 1990s was clearly dominated by dual-process models and shows that "multiple effects for the same variable were possible, that any one effect could be caused by different processes, and that any one variable could operate differently in different situations" (Petty and Brinol 2008, p. 144).

However, in dual-process models such as the ELM, the processes of persuasion have traditionally been investigated on the level of cognition. Therefore, they are usually characterized by a missing intrinsic emotional implication (Morris et al. 2005) as well as missing metacognitive implication. Consequently, the most recent research on persuasion focuses on metacognitive processes that may be influential factors in attitude change. Thus, some current research focuses on low-thought automatic processes that contribute to attitudes and judgments (e.g., Dijksterhuis and Nordgren 2006), while some concentrates particularly on metacognitive processes of persuasion (Petty et al. 2002; Strack, and Deutsch 2004).

Cross-References

- ► Attitude Change (Through Learning)
- ► Attitude(s) – Formation and Change
- ► Automatic Information Processing
- ► Communication Theory
- ► Controlled Information Processing
- ► Dual-Process Models of Information Processing
- ► Emotion Regulation
- ► Mood and Learning
- ► Social Construction of Learning

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Persuasion Therapy

A form of directive psychotherapy in which the client is encouraged to follow the advice of the therapist through the process of persuasion. It may be seen as an extension of the common-sense cultural practice of reasoning with people, offering advice as to how they might overcome their difficulties. It may thus be regarded as a form of cognitive therapy. Paul Dubois first introduced persuasion therapy on the basis of a psychotherapeutic methodology that was a form of Socratic dialog. Its aim was to persuade the patient to change behaviors. Dubois argued that it was necessary to appeal to a patient's intellect and reason in order to eliminate negative and self-destructive habits. Furthermore, he considered it necessary to convince the patient of the irrationality of neurotic feelings and thought processes.

Persuasive Communication

► Persuasion and Learning

Pestalozzi, Johann H. (1746–1827)

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Life Dates

Johann Heinrich Pestalozzi was born in 1746 in Zurich, Switzerland. As the son of a Protestant physician, he had a protected but isolated childhood. After performing his higher education at the Collegium Humanitatis and the Collegium Carolinum in Zurich, he studied agricultural science. Pestalozzi was influenced by Jean Jacques Bodmer, a Swiss historian and political reformist, as well as by Jean Jacques Rousseau, after whom he named his son in 1770. Rousseau's influence on Pestalozzi was strong, and he used Rousseau's *Emile* as a guide to educating his son. Inspired by Rousseau's idea of natural education, Pestalozzi started his own way of practicing new forms of education when he established his first self-supporting agricultural and handicraft school at Neuhof in 1774. However, due to financial bankruptcy, this school was closed in 1779. Two years later, Pestalozzi published *Leonard and Gertrude*, which made him popular as an educational reformer. From this point until 1799, when Pestalozzi again began to engage in active educational service as director of the orphanage at Stans, he published several educational essays and books. In these years, he developed the concept of a residential school in which children were to be educated in an emotionally satisfying setting. However, the orphanage at Stans was closed in 1780 when the French and Austrian armies fought battles in the vicinity. From 1800 to 1804, Pestalozzi conducted a residential and teacher training school at Burgdorf, where some visitors such as Herbart and Fröbel also became familiar with "Pestalozzi's idea" of education. This idea found its expression in Pestalozzi's most systematic book, *How Gertrude Teaches Her Children* (1801). In this book, Pestalozzi criticized corporal punishment, rote learning, and bookishness and argued for homelike schools where students would learn primarily through sensory experiences and engagement in activities.

In 1804, Pestalozzi relocated his pedagogical institute to Yverdon, where he worked until 1825. He died on February 17, 1827 and was buried at Neuhof, the site of his first school.

Theoretical Background

Already in his lifetime, Pestalozzi was widely considered as an important pedagogue, philanthropist, school reformer, philosopher, and also politician (Silber 1973). However, his ideas about education and learning were closely tied to his practical work as an educator. Inspired and guided by Rousseau's philosophy, Pestalozzi emphasized two important premises of education: (1) Children need an emotionally secure environment for successful learning, and (2) instruction should adapt to human conceptualization, which is based on sensation.

Accordingly, the "Pestalozzi idea" centered on *sensory learning*, with a particular emphasis on the *Anschauung* principle. This principle can be understood as a process of internal envisioning that aims at the formation of concepts from sense impressions. In accordance with the Anschauung principle, Pestalozzi designed object lessons in which students had to examine the form, shape, quantity, and weight of several physical objects and name them in association with sense experiences. The designed object lessons followed a sequence from the simple to the complex as well as from the concrete to the abstract. A consequence of the "Pestalozzi idea" was the rejection of the traditional method of recitation and the introduction of group-centered teaching and instruction.

Contribution(s) to the Field of Learning

Although Pestalozzi made significant contributions to educational philosophy and instructional methods that aimed at fostering the physical, intellectual, and moral development of students, his methodology of empirical sensory learning can be considered as his most important contribution to the field of learning. Pestalozzi's object lessons and his emphasis on sense experiences led to the introduction of the hitherto neglected areas of natural science and geography to the elementary school curriculum. Indeed, Pestalozzi's most important contribution to education was his idea of natural education, which corresponds to a large extent to Rousseau's philosophy and emphasizes both the dignity of children and the importance of engaging them in exploration of their environment (Silber 1973).

However, Pestalozzi was not a scientist but rather a charismatic practitioner with a far-reaching influence on contemporary scholars, such as Herbart, Fröbel, Fichte, and others. Herbart, for example, was attracted by the "ingenious Pestalozzi idea," by which he meant the perfect regularity of sequencing in teaching. Nevertheless, he evaluated Pestalozzi's writings as unscientific (Herbart 1812/1888).

Despite this certainly true verdict, Pestalozzi is regarded as one of the most influential educational philosophers of all time. His emphasis on empirical learning and the dignity of children and his ideas on the reform of elementary and teacher education provided the basis for the emergence of reform pedagogy at the beginning of the twentieth century.

Pestalozzianism was propagated throughout Europe and North America by people Pestalozzi had trained as teachers and by visitors who were deeply impressed with his educational philosophy. For instance, Gottlieb Fichte successfully promoted Pestalozzianism in Prussia, where it constituted the fundamental basis of the educational reform of 1809. In the United Kingdom, the Home and Colonial School Society in 1836 established a Pestalozzian teacher training school, and in the United States William Maclure and Edward Sheldon promoted Pestalozzianism (Barlow 1997).

Cross-References

► Learning in Practice and by Experience
► Openness to Experience

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Pharmacological Enhancement of Synaptic Efficacy, Spatial Learning, and Memory

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Synonyms

Spatial learning and memory enhancers; Synaptic efficacy enhancers

Definition

Enhancers of spatial learning and memory, among *cognitive enhancers*, *memory enhancers*, or *nootropics*, are compounds, including nutrients and others, that improve mental functions and performance in navigation, when taken at appropriate dosing. Processing information about one's environment and its spatial orientation in one's brain, like the formation of other types of memories, are believed to involve vastly interconnected neural networks of synapses, mostly chemical synapses, in particular brain area(s). Mammals, for instance, require a functional hippocampus in order to form and process memories about space. An enhancement of spatial learning and memory can be achieved through a more efficient operation of these existing synapses in the underlying neural network, *synaptic efficacy*, and formation of more synapses, which can be used for the learning and memory, *synaptogenesis*. *Synaptic efficacy* refers to the strength of the connection between neurons, i.e., the ability of the synaptic input arriving at a synaptic terminal of neuron A to evoke postsynaptic potentials of a postsynaptic neuron B, a sufficiency to trigger or alter spike activity of the postsynaptic neuron. High synaptic efficacy denotes a high likelihood that the firing of neuron A will cause the neuron B to fire, with all the rest remaining the same (such as the firing threshold). In this sense, synaptogenesis (or synaptic elimination) is a special but effective way to change *synaptic efficacy* between neurons (from 0, a nonexistence; or to 0). *Synaptic efficacy enhancers* in learning and memory are compounds that increase the efficiency of synaptic transmission and the number of synapses involved in the memory formation, memory consolidation and reconsolidation. Depending on the synapses affected, their impact on learning and memory may not necessarily be limited to spatial learning and memory.

Theoretical Background

Activity-dependent, bidirectional control of synaptic efficacy is thought to contribute to many forms of experience-dependent associative learning, including spatial learning and memory. In a simplest case, postsynaptic activity (or firing probability) depends on the synaptic efficacy SE_{ab} (from neuron A to neuron B) and presynaptic activity, as

$$A_b = SE_{ab} A_a$$

Changes in the efficacy of synaptic transmission of the underlying neural network lead to an altered neural activity, with everything else being equal, and are believed to represent the physiological bases of learning mechanisms. In addition, in a neural network, synapses often differ in response to the same information input. The differentiation in altered synaptic efficacy upon a set input may determine where information flows, a synaptic switch in decision making. The complicated nature of synapses in information processing and in structure guarantees numerous ways through which synaptic efficacy can be changed.

Synaptic efficacy can be typically characterized by parameters associated with specific synaptic mechanisms, such as the integrity of the synapse, the number of transmitter quanta released, the release probability, location distance of the input from the spike triggering zone, and the dynamic profile (the peak value, time integral, or rise time) of the postsynaptic potential or the synaptic conductance change. If the value of these parameters increases (except for the location distance, which has an opposite impact), the synapse should have a stronger impact on the output of the postsynaptic neuron. Synaptic efficacy between two neurons and among neuronal networks can thus be enhanced through one or more of several mechanisms, changes in the quantity of neurotransmitters released into a synapse, changes in the effectiveness of postsynaptic responses to the neurotransmitters, and changes in the types and numbers of synapses involved in the information processing. The changes in synaptic efficacy often involves both pre- and postsynaptic mechanisms, including structural plasticity. The latter includes a shift in the location of synapses. The membrane property and distribution and density of various receptors and channels are important contributors to a modulated synaptic efficacy. For instance, synapses made by Schaffer collaterals onto spines of the hippocampal CA1 pyramidal neurons contain the *N*-methyl-D-aspartate (NMDA) and/or the α-amino-3-hydroxy-5-methyl-4-isoxazole propionic acid (AMPA) receptors, the predominant ionotropic glutamate receptors mediating basal synaptic transmission. The NMDA receptors exist in every synapse, with their number proportional to the diameter of the postsynaptic density, while the AMPA receptors are found in about 75% of synapses, with their number linearly correlated with the area rather than the diameter of the postsynaptic density. Thus, small spines contain only or mainly the NMDA receptors (the so-called "silent" receptors under basal conditions), whereas large spines have a higher ratio of the AMPA to NMDA receptors. In studies with two-photon photolysis of caged glutamate, glutamate sensitivity of individual morphologically identified spines has been found to be highly correlated with spine-head volume, so that changes in spine type from small to large increases synaptic efficacy. Consistent with the observation is the evidence that increases in perforated synapses (with large spines) have been observed in learning and in enriched environments. When all others are equal, increasing synaptic density should also result in an increased synaptic efficacy. Long-term depression (LTD) induction by low-frequency stimuli has been shown to result in a retraction or collapse of spines.

Importantly, synaptic capacity is sensitive to a variety of disorders and brain injuries and can be enhanced pharmacologically. In this sense, pharmacological agents that can prevent/reverse disorder-related impact on synaptic capacity are also memory enhancers against the disease states. An enhancement of spatial learning and memory can be achieved through one or more of the following mechanisms: (1) increasing synaptic efficacy of the underlying neural network with the results of improved learning and more solid and long-lasting memory; (2) preventing/arresting the memory-impairing pathological changes associated with aging, memory disorders, and brain injuries; and (3) repairing/restoring the underlying neural networks and synapses that have been damaged by disorders and brain injuries. These are indicated and supported by the study of spatial learning and memory in nonhuman mammals, which provides valuable information about the molecular and neural mechanisms involved in the memory and memory disorders. Preclinical studies show that some agents, such as isozyme-specific activators of protein kinase C, are effective on all three, resulting in an enhancement of spatial learning and memory in healthy and diseased individuals (Alzheimer's disease transgenic mice, rodents with cerebral ischemia, brain injury, or in aging). Thus, mainly two types of enhancers are being developed: the pure enhancers in the healthy individuals and those to treat cognitive impairments such as *Alzheimer's disease*, *Parkinson's disease*, and other dementias. Currently, several spatial learning and memory enhancers and anti-dementic agents are in various stages of development.

Important Scientific Research and Open Questions

The efficacy of synaptic transmission is dynamically modulated, over a wide range of timescales and in a use-dependent manner, a property that is thought to endow the brain with the capacity for performing computations, learning, and storing information. At the core of spatial learning and memory is the correlation between the individual's capacity to express the synaptic and structural plasticity and the performance in the behavioral learning tasks. Associative learning and memory is accompanied by a variety of presynaptic and postsynaptic changes in molecular signaling cascades and in synaptic functions and structures, including an enhancement of neurotrophic activity, synaptic summation, and membrane resistance, pair-pulse facilitation, novel protein synthesis, and synaptic plasticity. The questions remain of their dynamics and determinant contribution to synaptic efficacy and learning and memory. The most popular form of synaptic plasticity, for instance, is the long-term potentiation of synaptic responses (LTP), which, as occurs in the hippocampus and other brain networks, is viewed by many as the necessary and sufficient mechanism in episodic learning and memory, including spatial learning and memory. However, dissociation of spatial learning and memory from hippocampal LTP has been observed and reported frequently. Defining the network/synaptic mechanism(s) underlying learning and memory will not only facilitate the development of memory-enhancers and anti-dementic therapeutics, but also help in answering another important question: How synaptic plasticity in an extensive network of neurons leads to the retention of specific information in the brain, especially in the long term?

Cross-References

► Associative Learning
► Cognitive Efficiency
► Episodic Learning
► Memory Consolidation and Reconsolidation
► Network Models of Learning and Memory
► Neuropsychology of Learning
► Spatial Learning

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Phenomenal Causality

► Human Causal Learning

Phenomenography

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Synonyms

Perceptions of experiences

Definition

Phenomenography is an empirical research tradition that was designed to answer questions about teaching and learning, particularly in the context of educational research. The aim of a phenomenographic study is to identify the different ways in which a group of people experience, interpret, understand, perceive or conceptualize a certain phenomenon or aspect of reality – and to do so from the perspectives of the members of the group. From its Greek etymological roots (*phainomenon*, meaning "appearance," and *graphein*, meaning "description"), phenomenography is, literally, a "description of appearances."

Theoretical Background

Focus. The central aim of a phenomenographic study is to identify the different ways in which people experience, interpret, understand, perceive, or conceptualize a certain phenomenon. According to Ference Marton (1986, 1994), one of the original developers of phenomenography, there are a limited number of qualitatively distinct ways a particular group of people can conceptualize or experience a given phenomenon; the goal of the phenomenographer is to identify and categorize these different conceptions. These conceptions are not judged for their "correctness"; rather, they are seen as interesting and useful in and of themselves.

Phenomenography adopts a non-dualist, second-order approach. The approach is non-dualist in that conceptions are viewed as being the product of an interaction between humans and the world around them. Specifically, conceptions result from a human being's *thinking* about his or her external world. The approach is second order in that phenomenographers do not examine a phenomenon itself (a first-order perspective), but people's ideas about or experiences with that phenomenon – their "conceptions" of the phenomenon.

The focus of a phenomenographic study is on the *variety* of conceptions within a *group*. Phenomenographers describe the *variation* in conceptions across the group and do not focus specifically on the commonalities in group members' conceptions. They focus on the variation in the conceptions of a particular *group* and not on individuals' conceptions. As such, detailed descriptions of the individuals in the group are not typically included in phenomenographic studies. Additionally, because the focus of a phenomenographic study is on the conceptions that a particular group of people have for a given phenomenon, researchers' conceptions of that phenomenon are not usually a focus of such a study. Instead, researchers attempt, as much as possible, to act as "neutral foils" for the ideas expressed by the participants of the study.

Ultimately, the goal of phenomenography is not only to identify people's conceptions about or "ways of experiencing" a given phenomenon, but to organize those "ways of experiencing" into conceptual categories. These categories are called "categories of description" and can be thought of as a map of the collective mind of the group being examined. Furthermore, in most cases, logical relationships will exist between the categories of description, such that a hierarchy can be established between categories of description. The ordered and related set of categories of description is called the "outcome space" of the phenomenon being studied.

Methods. There are many data sources that can reveal a person's understanding or conception of a particular phenomenon, including observations, writings, drawings, and interviews. However, as many phenomenographers agree that conceptions are most accessible through language, the method of discovery in phenomenography is usually an open and deep individual interview. "Open" indicates that there is no definite structure to the interview. While researchers may have a list of questions or concerns that they wish to discuss during the interview, they are also prepared to follow any unexpected lines of reasoning that the interviewee might address as some of these departures may lead to fruitful new reflections that could not have been anticipated by the researcher. The openness of the interview also allows the participants to express their conceptions *from their perspectives*, which is critical in phenomenographic studies. "Deep" indicates that the interview will follow a certain line of questioning until it is exhausted: until the participant has nothing else to say and until the researcher and participant have reached some kind of common understanding about the topics of discussion.

The aim of an interview is to have the participant reflect on his or her experiences and then relate those experiences to the interviewer in such a way that the two come to a mutual understanding about the meanings of the experiences (or of the account of the experiences). The process is an explorative dialogue between participant and interviewer.

▸ The experiences and understandings are jointly constituted by interviewer and interviewee. These experiences and understandings are neither there prior to the interview, ready to be "read off," nor are they only situational social constructions. They are aspects of the subject's awareness that change from being unreflected to being reflected (Marton 1994, p. 4427).

Because the aim of phenomenographic research is to identify the variation of experiences within a group, samples are chosen to maximize the possible variation. Data collection continues until no new ways of experiencing a phenomenon are revealed through additional interviews. In other words, data collection often continues until "saturation" is reached.

Because both conceptions and categories of description should emerge from the data in a phenomenographic study, analysis begins with immersion in the data. In the most common case in which interviews are the main data source, data analysis starts with a verbatim transcription of the interviews. Transcripts are read multiple times, from multiple perspectives, in order to identify the different ways of experiencing the phenomenon under study. They are first examined individually in order to contextualize participants' utterances. Then, they are examined as a group, in a more decontextualized manner, in order to identify the variety of conceptions the group has for the phenomenon under question.

Once the different conceptions or ways of experiencing the phenomenon are identified, the phenomenographer seeks to organize them into categories of description. The process of defining categories of description is an iterative one. The phenomenographer identifies attributes of a potential category of description, attempts to define the category, and supports the category with appropriate quotations from the transcripts. He or she then tests the category through additional readings of the transcripts. At this point, categories and their descriptions are modified and retested. This process of modification and data review continues until the modified categories seem to stabilize and be consistent with the interview data.

There are three main criteria for category development:

▸ That each category in the outcome space reveals something distinctive about a way of understanding the phenomenon
That the categories are logically related, typically as a hierarchy of structurally inclusive relationships
That the outcomes are parsimonious – i.e., that the critical variation in experience observed in the data be represented by a set of as few categories as possible (Akerlind 2005, p. 323)

Once the categories of description are stabilized, the phenomenographer then searches for logical relationships between them in order to create the outcome space of the study. The logical relationships between categories of description are specific to each study, but, as an example, categories of description might be ordered from more basic to more complex, where a more complex conception – correct or incorrect – might presuppose knowledge evidenced in a simpler conception. Thus, since the more complex category "includes" the simpler category, the more complex category might be ordered hierarchically "above" the simpler.

Applications of Phenomenography. As a qualitative theoretical framework, phenomenography has been used to examine three major topics:

- Students' approaches to learning
- Students' understandings of specific academic concepts/content
- People's approaches to and understandings of phenomena they experience in their day-to-day lives

As originally conceived, phenomenography was developed to answer questions about teaching and learning. Phenomenographers do not identify their results as being "true" or judge the conceptions they have identified in their studies as being "correct" or "incorrect." They do, however, claim that the results of phenomenographic studies are useful. From an educational perspective, Marton (1986) claims that "a careful account of the different ways people think about phenomena may help uncover conditions that facilitate the transition from one way of thinking to a qualitatively 'better' perception of reality" (p. 33). Thus, phenomenographic information about the different conceptions that students hold for a particular phenomenon may be useful to teachers who are developing ways of helping their students experience or understand a phenomenon from a given perspective.

Important Scientific Research and Open Questions

There have been several criticisms of phenomenography. First, phenomenography has often been criticized for its lack of specificity and explicitness concerning its methods of data collection, its methods of data analysis, and its theoretical underpinnings (Richardson 1999). Recent reports have addressed the methods of data collection and analysis in phenomenographic studies (see, for example, Akerlind 2005), but the theoretical underpinnings of phenomenography have yet to be clearly established.

A newer extension of the phenomenography described in this entry – initially called "new phenomenography" and currently known as "variation theory" – shifts to more theoretical concerns by examining the *nature* of different ways of experiencing a given phenomenon. Both classical and new phenomenography focus on the key concept of "variation." In new phenomenography, it is assumed that there are critical aspects of a given phenomenon that learners must simultaneously be aware of and focus on in order to experience that phenomenon in a particular way. Discernment of a critical aspect of a phenomenon results from experiencing variation in dimensions that correspond to that aspect. The goal of variation theory is to identify the critical aspects of a given phenomenon from a learner's perspective.

Another of the criticisms of phenomenography is its tendency to equate participants' experiences with their *accounts* of those experiences. Saljo (1997) reports that, at times, there appears to be a discrepancy between what researchers observe of a participant's experience with a particular phenomenon and how the participant describes his experience with the phenomenon. Richardson (1999) claims that phenomenographers do not skeptically examine the effects of a student's background, a student's culture, the interview environment or of socially accepted linguistic practices on what is reported by the students.

In order to avoid equating experiences with accounts of experiences, Saljo (1997) suggests that phenomenographers refer to studying people's different "accounting practices" of phenomena, which are public and accessible to study, instead of referring to studying people's "experiences." Researchers must keep in mind, however, that such accounting practices may be socially and environmentally influenced.

Finally, there have also been questions about the validity, reliability, and repeatability of phenomenographic studies. Since phenomenography makes no claims about the "truth" of its results, external measures of validity may be irrelevant. Instead, researchers suggest that phenomenographic studies should meet two other validity criteria: *communicative validity* (have appropriate research and interpretation techniques been applied?; are the results an accurate description of the data?) and *pragmatic validity* (are the results useful and meaningful to the intended audience?) (Akerlind 2005).

Akerlind also (2005) suggests three ways in which researchers can establish the reliability of their results:

1. Carrying out a *coder reliability check*, in which a second coder uses the researcher's categories of description to code the transcripts
2. Carrying out a *dialogic reliability check*, in which two researchers discuss both the data and research results, coming to a common understanding of the former and an agreement about the latter
3. Maintaining and making explicit an "interpretative awareness" (Sandberg 1997), in which researchers make their interpretive steps clear to readers by explaining their presuppositions and conceptions about the data or the phenomenon in question and outlining how they have taken a critical attitude toward their interpretations of data in order to counteract those presuppositions and conceptions

Cross-References

▶ Qualitative Research Methods
▶ Variation Theory

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Phenomenological Approach to Learning

▶ Phenomenology of Learning

Phenomenology

▶ Learning in Practice (Heidegger and Schön)

Phenomenology of Learning

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Synonyms

Embodied learning; Experiential learning; Phenomenological approach to learning

Definition

Phenomenology of Learning

Phenomenologically, learning is not only happening out of experience, but realizes itself as an experience as a life-worldly event. Through experiential processes, learning creates differences in the learner in relation to the situated environment in which learning takes place and which are embedded in more comprehensive social, cultural and systemic contexts. Basically, learning can be characterized as an ability to revise existing patterns of feeling, thinking, and acting while intentionally accommodating changes and developing new competencies and orientations. For this, processes of learning cannot merely be reduced to distinct knowledge of contents or outcomes of learning, but comprise and alter the entire learning situation. Accordingly, learning can be defined as an embodied, emotional, cognitive and responsive, individual and/or collective accomplishment, and dynamic process. In addition to acquiring knowledge, learning is also a form of making sense or abstracting meaning. This sense making involves relating parts of the subject matter to each other and to a greater whole, thereby generating a comprehension and reinterpretation of the known. Accordingly, learning creates, captures, transfers, and mobilizes as well as modifies not only knowledge of and between individuals and on a collective level, but also transforms the learner and his being-in-the-world.

From a phenomenological perspective, multidimensional processes of learning take place in a distinct way as compared to other approaches. In contrast to behaviorist and cognitive-rational orientations and approaches, learning cannot be sufficiently understood as a fixed correlation between stimuli and reactions, nor as mere adaptation process between different spheres of reality or representations. Rather, a phenomenological understanding of learning is based on sensual and embodied as well as linguistic-expressive dimensions and their interplay. Accordingly, movement perceptions, expressions processed through individual and social experiences are the original and genuine base of any learning as an event of becoming. In particular and by following Merleau-Ponty's phenomenology (1962), the living body and (social) embodiment are the presupposition, condition, and organizing media of meaningful learning. Specifically, embodied learning emerges as an interwoven relationship between bodily, emotional, and mental capacities and the resources, affordances and constraints made available in situated circumstances. This is then leading to the establishment of new body–environment connections, which transform both the learner and the situation. In an extended sense and in critique of many conventional institutional forms, learning can be interpreted phenomenologically as a *way of being and becoming*.

Relevance

▸ "The illiterate of the 21st century are not those that cannot read or write, but those that cannot learn, unlearn and relearn (Alvin Toffler)."

The relevance of a phenomenological approach to learning emerges from conditions and tendencies of our time as it corresponds to the needs of the knowledge and civic society. Learning in twenty-first century is and will increasingly be characterized by a smaller world more connected by technology and transport, more information exchange, more work in diverse project, and teams spanning languages, cultures, and geographies. Furthermore, learning is exposed to global economic and cultural influences that affect everyone's jobs and incomes; strains on basic resources; and the acute need for cooperation in relation to environmental, sociocultural, and economic challenges.

At present, rationalistic pedagogies foreground educational content and approaches amenable to quantification and itemization, which follow imperatives of performance-based funding and quality control, managerialism, and an overwhelming concern with efficiency. Correspondingly, following an instrumental and utilitarian view of education, learning is reduced to accumulation and acquisition of discrete propositional and knowledge objects or instrumental skills as part of an economic transaction of measurable in- and output. In this context and facing the requirements for a more experience-oriented theory and experimental practice of learning and exploring the inherent complexities involved, a phenomenological approach provides a valuable theoretical and practical as well as pertinent and timely contribution.

Theoretical Background

Phenomenology is a philosophy and provides a descriptive and interpretative methodology of human science, which inquires phenomena, like learning, as they present themselves in the lived world in order to find the meaning of the phenomena for itself without being obstructed by preconceptions and theoretical notions (Van Manen and Vandenberg 1996) that is irrespective of prejudices, foreknowledge, or aprioristic assumptions. As much as phenomenology is both dynamic and varied, contemporary movement, also educational phenomena and dimensions of learning, have been explored phenomenologically through diverse approaches (Dall'Alba 2009a). In terms of classical Husserlian phenomenology and its specific research methodology, especially *bracketing* as suspension of natural attitude of habitually modes of processing or culturally derived beliefs and assumptions and readymade interpretations and imaginative variation, learning can be seen and investigated as a reflexive disclosure through the structure of conscious receptive minds. It then can be interpreted as "outcome" of the connection that develops between learners' (operative) *intentional acts* and the object they are directed toward resulting in the constitution of meaning.

Following Heidegger's further development of phenomenology, learning becomes part of an *ontologization* of education (Thomson 2001) and hermeneutical interpretation of situated being-in-the-world in which, for example, the pedagogic or learning atmosphere can be disclosed and via pedagogical narratives possibilities in the world disclosed.

Phenomenologically, the main intention is to go back to learning itself that is to the present, living act of learning as embedded practice and process. With Merleau-Ponty (1962), this requires to consider the pre-reflexive and pre-symbolic, embodied modes of being its corresponding learning. To return to learning and to its life-worldly situatedness is according to Merleau-Ponty to re-turn to that world that *embodies* the act of knowing and learning and in relation to which every scientific schematization is an abstract and derivative sign language (Merleau-Ponty 1962, p. ix). Returning to such *life-worldly learning* is to relate to a meaningful world, in which embodied learners meet and cocreate and mediate the likewise bodily learnt. We learn and find the life-world meaningful primarily with respect to the ways in which we act bodily and move minds within it and in which it acts upon or moves us (Bresler 2004). Thus, embodiment does not simply mean physical manifestation or an epiphenomen in relation to learning. Rather, embodied learning means being grounded in everyday, mundane experience and integrally connected to the environment, including the very presence of the learner, but also a social community and infrastructural embeddings in an ongoing interrelation. The incarnate status of the bodily subject and collective embodiment opens the way to a specific phenomenological description of the learner and his, her, or their learning. Phenomenologically, embodied learning subjects are situated in their environment in a tactile, visual, olfactory, or auditory way and exposed to a synchronized field of interrelated senses (Merleau-Ponty 1962, p. 207). From an advanced phenomenological perspective, not only are the learner and learning embodied, but *being embodied is always already a way of learning* and acting through lived situations. Within this situatedness, the living body mediates between internal and external, the "subjective" and "objective," active and passive, intentional and responsive, as well as individual and collective experiences, dimensions, and meanings of learning. This body-mediated process coordinates the responsive relations between individual behavior, social relations and artefacts, and institutions, including through language and communication as expressive media of interrelation (Merleau-Ponty 1962, p. 197).

Such corporeal orientation suggests that the sociality and historicity of learning are incorporated in the body (rather than in social rules and norms), and that these are articulated in the skilful deployment of the body. Accordingly, from a phenomenological perspective, learning is seen as a function and emergent process of bodily subjects within an embodied context, in which a learning person is embedded passively and in which he or she takes part actively in a responsive practice. With an intentional and responsive orientation of the bodily organs and consciousness, the agent within the sphere of knowing and learning not only feels 'I think', but also 'I relate to' or 'I do'. In other words, the atmosphere in which learning is situated is not only what people think about it, but primarily what they live through with their operative intentionality (Merleau-Ponty 1962: xviii) and within a responsive order (Gendlin 1997). This implies that the 'I can' (or 'can not') precedes and conditions the possibility of the 'I know' (Merleau-Ponty 1962: 137), hence the 'I learn'. With this understanding of embodied-based knowing and learning there is a close link between what is intended and what is actually given, between intention, and the learning situation and corresponding responses. Furthermore, a relationally responsive learning is a dialogical and dialectical process encompassing self- and critical-reflexivity as part of being embodied. As living bodies, the intentional learners not only intends but also responds to meaningful questions, problems or claims put to them through situational contexts and embodied conditions in which they takes part as embodied beings. Studying and getting engaged in processes of learning requires capturing a sense of phenomenological presence and considering life-worldly practices both as a source, field, or realization and result of human learning. These presence and practices are constituted by *micro-dynamics of learning-in-use* (or learning-as-doing) and refer to an ongoing individual and social execution in specific local ways. As such, they are part of material, historical, social, and cultural contexts in which learning manifests in a variety of forms by use of different media while generating specific effects.

Effects of Learning

Based on Merleau-Pontyian phenomenology, learning as corporeal practice can be interpreted as a process of incorporating and absorbing new competencies and understandings into our body schema, which in turn transforms our ways of perceiving and acting. Phenomenologically, learning opens up a horizon of understanding by which it is a guiding pre-knowledge, and pre-understanding allows to perceive, reflect, and act. In this sense, learning is a process of structuring and modifying horizons of experiences of historical concrete ways of Being-in-the-world. Accordingly, learning is always a kind of learning to be different.

In this regard, learning is not only acquiring new elements of knowing or skills, but modifying the entire horizon of experience and expertise. In other words, learning unfolds and transforms previous understanding as horizon of actual and possible knowledge in social contexts and structural systems. As a transformational process learners, while being entwined with their world and traditions, are embodying routines, interrogate what is taken for granted and challenges and reshape assumptions about and relating to the world in more reflexive ways and by this generating new ways of being and becoming. Part of the responsibilities of effectuating education is cultivating a democratic multivocality and ethically reflective humanity, thus questions related to civic dimensions, well-being, moral and political agency, etc., which implies understanding educational processes, policies, and practices "*beyond learning*" (Biesta 2006).

Important Scientific Research and Open Questions

Increasingly, there is the need to see learning as an integral process. This integration concerns affects, feeling, thinking, and acting, as well as social and systemic dimensions and their interplay. Furthermore, integration involves creating and organizing opportunities for a more inclusive and holistic learning, while making use of various learning settings, whether in-school or out-of-school, formal or informal, and across a broad and relevant range of learning content and using supportive equipment as well as information and communication technologies. Further research could focus on how learners are integrators of their learning and exploring the interplay of emotional, cognitive, and social competencies, as well as capacities to coordinate various contents. In terms of learning practice, one important question concerns how the disembodiment, displacement, disembedding, and decontextualizing of conventional forms of learning can be overcome, toward more embodied, situated, and embedded and authentic, as well cocreative and relational ways of learning. This also includes developing, corresponding curricula and didactical and pedagogical reconstruction, and rethinking the role of the disclosing life-worldly learning environment and of teachers.

Phenomenologically, learning demands to be investigated and practiced as an embodied relational and responsive event of transformation. For further investigating this transformational dimension, developmental individual and collective levels and lines may be considered within an integral cycle of *inter-learning* (Küpers 2008).

Methodologically, there is a need for more inter- and transdisciplinary as well as real-time longitudinal research to uncover process dynamics of learning, instead of retrospective studies, which tend to highlight continuity and linear development. Future phenomenological research and corresponding empirical investigation may also focus on processes of lifelong learning and intercultural learning.

Promising perspectives are those of linking a phenomenological approach of learning to *ecopedagogies* or forms of sustainable educations. Particularly the so-called *slow pedagogy or ecopedagogy* appears as an innovative approach and form of phenomenological deconstruction at the personal, social, cultural, and ecological layers of experience (Payne and Wattchow 2009). This post-phenomenological orientation contributes for a shift in emphasis from focusing primarily on the "learning mind" to reengaging the active, perceiving, and sensuous corporeality of the body with other bodies (human and more-than-human) in making meaning in, about, and for the various environments and places in which those bodies interact.

One important challenge for a phenomenology-based research on learning concerns investigating the opportunities and limits as well as impact of information and communication technologies on learning

A challenging research field is related to further exploring how to situate learning in the social, cultural, economic, and political realities of our time and relating this nexus of relationships transformatively to a future to come. This also involves investigating how professional ways of being can be learned and reconfiguring or developing new professional and continuing education programs. This concerns especially how to integrate, attending to, and dwelling with ambiguity during and the learning, which may open up possible ways to know, to act, and to be that interrelate with the stands we take on our being (Dall'Alba 2009b).

The challenging realities of our contemporary world and the need to develop possibilities for a more sustainable way of living can use a phenomenological understanding of "Gestalts" of mindful and concernful practices of learning for cultivating more integral transformations, theoretically and practically, and to promote other and more integral ways of "becoming-in-the-world."

Cross-References

▶ Adaptation and Anticipation: Learning from Experience
▶ Emotional Learning
▶ Experiential Learning Theory
▶ Flow Experience and Learning
▶ Learning Human Emotion from Body Gesture
▶ Learning in Practice and by Experience
▶ Openness to Experience
▶ Phenomenography
▶ Science, Art and Learning Experiences

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Philosophy of Learning

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Synonyms

Epistemology and learning

Definition

In philosophy, there is no such thing as a noncontroversial definition. However, when it comes to learning, the problem is not with disagreement, but with a lack of debate. While there are many philosophical discussions that are relevant for developing a theory of learning, no such theory is at the forefront of philosophical consciousness.

As such, we propose the following minimal definition as the starting point for our discussion:

▶ Learning is a process of knowledge acquisition, where "knowledge" is construed broadly.

Next, we delineate five major questions that should govern an area of philosophy properly called "philosophy of learning." Those questions are: (1) Is learning possible?; (2) Is all knowledge acquired through learning?; (3) Where do we draw the boundaries of learning?; (4) Are there different kinds of knowledge that can be learned?; and finally, (5) What are the prerequisites of learning? In this context, we will review several philosophical debates that are essential for establishing a theory of learning.

Theoretical Background

Is Learning Possible?

Though the question "is learning possible?" seems preposterous, it is critical to note that at the beginning of philosophy, for reasons that continue to plague modern epistemologists, Plato insists that the answer to this question is "no." We should note that this paradoxical claim follows from Plato's narrow conception of knowledge. As we shall see, knowledge, for Plato, does not include skills, abilities, or beliefs concerning contingent truths.

In the *Meno*, Plato denies that learning is possible and argues that what we commonly call learning is actually recollection (*anamnesis*). In this dialogue, Socrates proposes that the soul is immortal and has learned all there is to know before its birth. Socrates demonstrates his theory by leading Meno's slave through a series of geometry questions. Socrates shows that without having to "teach" the boy anything, that is, without relating any facts or explaining any principles to him, the boy grasps some basic rules of geometry. This is meant to be a proof of the theory of recollection because the slave did not pick up knowledge externally, but found it in himself. Socrates concludes that the boy must have already had the knowledge within himself and was simply induced to recollect it.

A crucial aspect of the theory of recollection is its connection to Plato's theory of the Forms. It follows from the fact that knowledge is of the Forms that recollection is of those things that cannot be learned through sense experience. Socrates illustrates this in the *Phaedo* with the concept of "Equal." His argument is grounded in the fact that any particular instance of two things being equal will never be an instance of perfect equality. All particular instances will be deficient in some way because there is no such thing as perfect equality in the natural world. However, we do have the concept of Equal – perfectly and exactly equal. Socrates concludes that since we have never encountered absolute equality in experience, the concept must come from somewhere else. Hence, again we are led to the theory of recollection: that which cannot be learned through experience is already in us at birth.

Is All Knowledge Acquired Through Learning?

Taking as its starting point the issues that Plato raises, the question of what can and cannot be learned through experience has constituted a major debate in modern epistemology and is at the heart of the disagreement between the rationalists (Descartes, Spinoza, and Leibniz) and the empiricists (Locke, Berkeley, and Hume). The rationalists, following Plato, claim that not all knowledge can be acquired through experience and, thus, not all knowledge can be learned. Knowledge that does not come from experience is called *a priori* knowledge. Two paradigm instances of a priori knowledge are the necessary truths of mathematics and logic, and concepts or universals. Since our knowledge of universals and necessary truths cannot be the result of experience (recall the example of "Equal" above), rationalists claim that it must come from innate ideas and/or the reasoning that allows us to move from one innate idea to another.

In contemporary debates, an example of rationalism can be found in Noam Chomsky's theory of universal grammar. Though Chomsky does not posit innate propositional knowledge or concepts, he is committed to the existence of innate organizing principles that are necessary to account for our ability to acquire language. In this way, Chomsky claims that what we can learn from experience is not sufficient to explain what we come to know.

The empiricists, on the other hand, are committed to the idea that all knowledge comes from experience. The empiricists claim that everything we know, we learn as a result of contact with the world and with our awareness of that contact. Importantly, empiricists do not hold that knowledge of universals or necessary truths can be acquired through experience but, rather, they deny that the nature of universals and necessary truths are as the rationalists describe. For example, Hume argues that our concept of causation is not really of one thing causing another (since we never perceive causes) but only of constant conjunction – of one thing regularly following another. In this way, Hume reinterprets the concept of causation so that it does not go beyond that which we can learn empirically. Likewise, W.V. Quine, a few hundred years later, has insisted that the truths of math and logic are not about the world, but rather, about our ideas. It would follow that there is nothing that we can know about the world that does not begin with our experience of it.

Notoriously, Kant has tried to split the difference between empiricism and rationalism by arguing that we need both experience and innate concepts for a satisfactory epistemology. This is best exhibited by Kant's famous dictum, "Thoughts without content are empty, intuitions without concepts are blind." Kant argues that neither innate concepts nor raw experience can account for what we know. As such, learning requires innate ideas to order our empirical experiences.

Where Do We Draw the Boundaries of Learning?

Issues concerning *a priori* knowledge place limits on learning by claiming that we have in our possession knowledge that cannot be learned through experience. However, there are also important theoretical considerations regarding the boundaries of a learning event. That is, there are important considerations concerning which changes in behavior are legitimate instances of learning.

If we grant that not every goal-related change in behavior is an instance of learning, then this issue becomes critical. For instance, it is important to consider whether sensitization, classical conditioning, associative learning, or the adaptive changes that occur through evolution qualify as learning. After all, in these instances, we observe changes in behavior that are goal-directed and sensitive to environmental features. Even plants exhibit such behavioral changes, but do these qualify as instances of learning?

This issue has been advanced by Fred Dretske and developed in his exchange with Daniel Dennett. While Dretske and Dennett both consider learning to be an essential indicator of minimally rational behavior, they disagree on which behavioral changes qualify as legitimate instances of learning. Significantly, for both, learning plays a crucial role in determining the behaviors that qualify as cognitive or intelligent.

Dretske argues that behavior is minimally rational when it is properly connected to reasons. Importantly, it is learning that transforms bare informational states into reasons for action. This is because learning requires that a creature is able to pick out relevant environmental features and, given its goals, respond appropriately to those features. Learning illuminates that a creature is responding with some degree of flexibility to states that have acquired meaning for it. These qualities of flexibility and meaningfulness, Dretske holds, are the hallmarks of intelligent behavior.

Further, Dretske insists that learning must take place during the course of a lifetime if it is to give rise to minimally rational behavior. In response, Dennett has argued that the time frame of a lifetime forwards an arbitrary limit on learning. Dennett claims that changes in behavior that amass over generations, that is, those that are realized through evolution, exhibit the necessary logical relations to shifting environmental conditions such that they ought to qualify as learning. As such, species-wide changes that occur through evolution would provide the grounds for minimally rational behaviors.

Are There Different Kinds of Knowledge?

The fourth question that ought to frame a philosophy of learning concerns the categorization of various knowledge kinds. After all, the learning process and the knowledge that results from that process presumably have an intimate connection. As such, the kind of knowledge that we possess may tell us something about the kind of learning that is required for its acquisition. Additionally, as we have seen above, what qualifies as knowledge largely determines what can properly be called learning.

There are important philosophical discussions concerning introspective knowledge, knowledge by testimony, conceptual and nonconceptual content, analogical reasoning, implicit and tacit knowledge, perceptual expertise, causal knowledge, and knowledge-how. Since it is beyond the scope of this entry to evaluate every philosophical discussion concerning knowledge types, we will use the knowing-how/knowing-that debate as our paradigm example. The distinction between knowing-how and knowing-that is largely parallel to the distinction between procedural and declarative knowledge found in psychology. When it comes to the philosophical debate, an opposition emerges between the intellectualists who argue that knowledge-how is reducible to knowledge-that and the anti-intellectualists who claim that knowledge-how comprises a unique and irreducible knowledge kind.

The distinction between knowledge-how and knowledge-that is first forwarded by Gilbert Ryle in *The Concept of Mind* in 1949. Here, Ryle argues against the "intellectualist legend," which he describes as the position that the intelligence of an action comes from the thoughts that we entertain about it. Ryle argues that if propositional knowledge were responsible for the intelligent or stupid application of knowledge in action then an infinite regress would ensue. Ryle claims that it is impossible that knowing how to do something requires first thinking of the rule that governs the behavior of how to do it. For, if knowing-how required contemplating a proposition in order to know how to apply it, then one would also need to contemplate another proposition in order to know how to properly contemplate the first proposition, and so on ad infinitum.

The distinction between propositional thought and ability became standard fare in philosophy until Jason Stanley and Timothy Williamson forcefully challenged it in their 2001 article, "Knowing How." In that article, Stanley and Williamson object to Ryle's regress argument and forward their own positive, intellectualist account of knowing-how.

Stanley and Williamson claim that Ryle's regress does not comprise a threat because, in order for it to get off the ground, it must apply to intentional actions. Further, since not every contemplation of a proposition is intentional, explaining knowing-how through appeal to propositional thoughts will not necessarily spawn the feared regress. As an alternative account, Stanley and Williamson propose that knowing how to do something is a matter of entertaining a proposition about how to do it under a practical mode of presentation.

Responses to the proposal that knowledge-how is reducible to knowledge-that come in two general varieties: (1) criticism of Stanley and Williamson's positive thesis, on behalf of the anti-intellectualists, and (2) criticisms of Ryle's equation of knowledge-how with an ability or disposition, on behalf of the intellectualists. The details of this debate are critical for determining not only what we learn, but also for understanding the nature of the relationship between learning and knowledge.

Alva Noë, Tobias Rosefeldt, Michael Devitt, John Koethe, and John Williams forward arguments that fall into the first, anti-intellectualist category. Noë, Rosefeldt, and Koethe all claim that "practical mode of presentation" talk is really disguised talk of abilities or dispositions. As such, they argue that Stanley and Williamson do not solve the problem of knowing-how, but rather, incorporate it into their own intellectualist story. This is because it is not the content of the propositional knowledge that does the heavy lifting for Stanley and Williamson, but rather, the way that this knowledge is represented. However, the details of how knowledge is represented under a practical mode of presentation are missing from Stanley and Williamson's account.

Further, Devitt argues that it is implausible that all agents that know how to do something possess a corresponding singular concept that identifies *w* as the way to do it. Devitt questions whether it is reasonable to suppose that everyone who knows how to ride a bike, catch a ball, think rationally, or speak meaningfully is in possession of a sophisticated concept of how this is done. Lastly, as both Williams and Koethe argue, Stanley and Williamson's positive account of knowing-how starts the very regress that they claim knowing-how does not begin. This is because for Stanley and Williamson, knowing-how is cashed out in terms of intentionally entertaining a proposition.

In contrast, the intellectualists attempt to cleave knowledge-how from its manifestation in action in order to show that knowing-how is simply another version of knowing-that. To do this, intellectualists such as Paul Snowdon, John Bengson, Marc Moffett, and Jennifer Wright challenge Ryle's assertion that knowing-how implies ability. Snowdon offers several examples that suggest that ability is neither necessary nor sufficient for knowing-how attributions. To show that ability is not necessary for knowing-how, Snowdon appeals to examples where agents lack the opportunity to put their knowledge into practice. For instance, Snowdon knows how to make Christmas pudding but he does not have the ability to make Christmas pudding since the world's supply of sugar has been destroyed. To illustrate ability's insufficiency to generate knowledge-how, Snowdon appeals to cases where one exercises an ability but only by fluke or accident. In such a case, it would be highly inappropriate to make a knowledge attribution. Further, using experimental philosophy, Bengson, Moffett, and Wright provide data indicating that ordinary people do not require agents to have an ability in order to attribute to them the corresponding knowledge-how.

The debate about knowing-how and knowing-that is just one example of a philosophical discussion about knowledge kinds, which has implications for a theory of learning. We should notice that if knowledge-how is reducible to knowledge-that, then any nonpropositional aspect of ability will not qualify as knowledge and, as such, will not be the result of learning.

What Are the Prerequisites of Learning?

In order to develop an adequate account of learning, we must examine the requirements that the systems and processes that perform learning have to fulfill. As such, we must ask about the nature of systems that are responsible for the input, processing, storage, and output stages of learning. In this entry, we focus on the problem of representation because this issue is relevant to all stages of learning: It is relevant to the input stage of learning because the features that are detected by an organism must be represented by a system if it is going to be able to adjust or respond to them. Further, representation is relevant to the processing stage of learning since we must understand how the transformations of learning occur. When it comes to the memory or storage stage of learning, we are once again forced to ask how the products of learning are represented.

Representation is a central topic in philosophy of mind and cognitive science. The classical view regarding the nature of representation and information processing is called computationalism. Computationalism is rooted in a metaphor between the mind and a digital computer. Accordingly, computationalism is committed to the idea that the mind processes symbols and produces meaningful states that are entirely determined by those symbols and their relations. Crucially, the syntax of a state wholly determines its semantics. Computationalism is famously championed by Jerry Fodor, who claims that mental representations have a language-like structure. Fodor insists that the constituents of a representation are structurally and compositionally just like the sentences of a natural language except that they do not occur in natural language, but rather, in the Language of Thought (LOT).

In opposition to computationalism, connectionism has forwarded a theory of mental modeling where mental representations are identical to the emergent processes of interconnected networks composed of simple units. Using neural networks where representations are stored nonsymbolically in the weights between units, mental states are seen as a dynamic evolution of activity in a neural net. At the heart of connectionist models is the idea that representations are distributed throughout the network. Prominent philosophical exponents of this position are David Rumelhart, James McClelland, Paul Churchland, and Andy Clark.

Importantly, both types of representational systems realized by cognitive modeling have advantages and disadvantages. The subsymbolic architectures of connectionist models are considered to be better at learning associations, detecting simple grammatical structures, and recognizing patterns. In contrast, symbolic architectures are traditionally considered better at realizing higher-level cognitive abilities such as those related to language, reasoning, and problem solving. However, neither approach addresses how such information processes are implemented in an actual human brain.

In an attempt to merge the strengths and avoid the weaknesses of computationalism and connectionism, a third hybrid view has emerged. This theory, often called implementational connectionism, is committed to the idea that neural networks implement symbolic processing at a higher level of description. As such, neural networks can retain the strengths associated with distributed processing and also account for mental processes that require a symbolic or compositional structure.

Important Scientific Research and Open Questions

As always, in philosophy, we are left with more questions than answers. These unresolved issues, however, are instructive for elucidating the conceptual landscape that we must traverse in order to develop an adequate theory of learning. In this section, we will end by exploring four questions that follow from the above discussions.

Is Knowledge That Is Not Acquired Through Experience Not Learned?

In the previous discussion, we followed tradition by claiming that knowledge that is not learned through sense experience is not learned at all. It is important, however, to distinguish between innate ideas, such as propositional knowledge or concepts, and innate mechanisms. Once we make this distinction, the question becomes: is it possible that the innate mechanisms that structure propositional knowledge and concepts ought to be considered mechanisms of learning themselves?

Further, if we are committed to the notion that necessary truths or concepts are innate, we must consider whether the experiences that "trigger" a priori knowledge count as learning. After all, the necessity that innate ideas are manifest as the result of some sort of experience may give us reason to conclude that that which stimulates those ideas is itself a kind of learning. As such, even if knowledge is not necessarily the direct result of experience, this does not mean that it is not, in any meaningful way, related to a learning process.

Is There a Connection Between the Method Through Which Knowledge Is Learned and the Knowledge That Results from the Learning Process?

In order to learn the capitals of the South American nations, one must sit down and memorize them. In order to learn to play the piano, one must sit down and practice. Is the knowledge that results from the first method of learning necessarily different from the knowledge that results from the second? It seems plausible that the way something is learned can tell us something about the nature of the resultant knowledge, but must this always be the case? When I learn the alphabet through singing and when I learn it through reading, are the alphabets that I learn different in kind?

There seems to be compelling evidence in favor of opposing answers to this question. It appears that there are various methods for learning the same knowledge (think innovative pedagogy). However, there also seem to be particular methods that are exclusively suited for other kinds of learning (think playing the piano). As such, the questions remain: (1) Can examining the method of learning tell us about the nature of knowledge acquired as a result of that method? and (2) Is it possible that learning may affect but not dictate the nature of knowledge, and, if so, then what features of learning might affect the said knowledge?

Is There Some Foundational Type of Learning on Which All Other Learning Processes Are Based?

Some psychological theories suggest that particular areas of learning are reducible to other foundational types of learning. However, it is an open question as to whether we should consider learning to be a monolithic or a heterogeneous phenomenon. We should ask whether various knowledge kinds and the various learning processes that lead to them can be combined into a unified theory. We should ask whether it is possible that what we ordinarily call learning may actually refer to various independent processes. We should ask whether the mechanisms involved in, for example, learning to play soccer are really identical to the mechanisms involved in learning a multiplication table.

Is Learning a Success Term? That Is, Can We Learn Things Other Than Knowledge?

Is it possible that learning is not simply a matter of knowledge acquisition? Can one learn a false belief? Can one learn a bad habit? The answers to these questions will depend on whether we treat learning as a success term. We should consider whether learning must be defined by its results or whether the learning process can be defined independently of them. Importantly, as we saw above, if learning is knowledge acquisition then that which qualifies as knowledge will determine what may qualify as learning. If the scope of knowledge is narrow, then what counts as learning will likewise be narrow. As such, we must ask whether all learning ought to be defined by its results and, if so, then how narrow or wide these results should be.

Cross-References

- ▶ Folk Psychology About Others' Learning
- ▶ History of the Sciences of Learning
- ▶ Human Information Processing
- ▶ Knowledge Creation Metaphor
- ▶ Knowledge Representation
- ▶ Locke, John (1632–1704)
- ▶ Naturalistic Epistemology
- ▶ Plato (429–347 BC)

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Phonetics and Speech Processing

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Synonyms

Speech science; Speech coding; Signal processing

Definition

Phonetics is the science which studies speech production, acoustics, and perception.

Speech processing is the branch of digital signal processing that deals in particular with speech signals.

Theoretical Background

Phonetics

The process of human speech production relies foremost on breathing out. The lungs expel air during speech at a controlled rate (called *speech breathing*). The air passes through the larynx, which contains the *vocal folds* (often called "vocal cords"), whose positioning can be finely tuned by a panoply of laryngeal muscles. The term *glottis* refers to the space between the vocal folds. When the vocal folds are adducted (closed) somewhat gently, a certain amount of air pressure from the lungs (*subglottal pressure*) can set the folds into a self-sustaining oscillation called *phonation* or *voicing*. The time taken by one complete phonation cycle is the fundamental period of phonation; the reciprocal of this is called the *fundamental frequency* of phonation, and generally determines the perceived pitch of the voice. Acoustic frequency is measured in cycles per second, or Hertz (Hz).

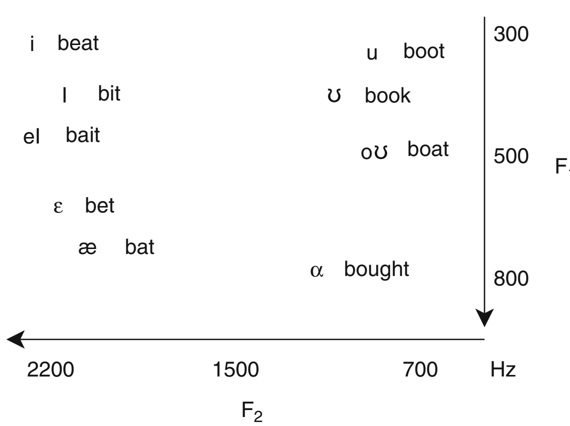
In modern phonetics, speech production is usually conceived in the *source-filter* paradigm that grew out of twentieth-century work by Martin Joos, and later Gunnar Fant. A speech sound can generally be described as created from a sound source whose output is modified by the vocal tract, viewed as a resonant filter. Vowels and many other voiced sounds chiefly rely on the vocal cords as a source, and the phonation output is then filtered through the prominent vocal tract resonances called formant frequencies.

Although fluent speech presents a continuous stream of sound, it is naturally divided into *syllables*. There has been no rigorous accepted definition, but a syllable is approximately a speech gesture that involves a movement of or within the mouth from a more closed to a more open posture (and possibly a return to a more closed posture). The most open or resonant part of a syllable is called the *nucleus*. Syllables can be further subdivided into their component gestures which make up *onset* (initial) and *coda* (final) portions surrounding the nucleus. A component of a syllable which can be contrasted or swapped with other speech gestures at particular linear positions in the speech output (e.g., syllables *bee* vs. *pea* contrast in their onsets) is called a *segment*; equivalent terms are *speech sound* and *phone*.

Phonetics has traditionally classified the segments of speech into the *vowels* and *consonants*. A vowel is defined as a *vocoid* that occupies a syllable nucleus. A segment is a vocoid when its articulation permits the relatively free passage of air through the center of the mouth. A consonant is then defined as a nonvocoid, no matter what syllable position it occupies. This imperfect dichotomy leaves room for the middle category of the *semivowel*, defined as a vocoid found in the onset or coda.

Vowels are traditionally classified using a number of phonetic features which have been determined to have a largely auditory basis. The feature of *height* is chiefly measured by the frequency of the lowest resonance of the vowel, known as F_1, the first *formant frequency*. The feature of *front-back* or "backness" is chiefly measured from the frequency of F_2, the second formant, and its distance from F_1. F_2 is also the chief auditory correlate of the degree of *lip rounding* in a vowel, which is the last of the three major vowel features (Fig. 1).

The consonants of a language are traditionally classified using articulatory features – chiefly the *places* and *manners* of articulation. The key terms of manner classify consonants according to how the airflow is modulated. *Stops* (e.g., [p, t, k]) are those consonants whose oral airflow is completely occluded for a brief period; stops which have the airflow redirected through the nasal sinus (and are thus quite resonant) are called *nasals* (e.g., [m, n]). *Fricatives* (e.g., [f, s, z]) are consonants whose oral airflow passes through a constriction which is sufficiently narrow to yield an aeroacoustic noise source. *Approximants* (e.g., [l]) are quite resonant, being slightly more open than fricatives and thus free of noise. The place of articulation for a consonant is described using the anatomical term for the location of the primary constriction point within the vocal tract; e.g., the [b] of *beat* is termed a *bilabial*, while the [k] of *keep* is termed a *velar* because of the tongue's contact with the velum behind the palate. In addition to the place and manner, consonants are identified as either *voiced* or *voiceless*; the first term applies when phonation takes place during the segment (as in [m, z, b]), and the second term otherwise (as in [f, s, p]).



Phonetics and Speech Processing. Fig. 1 Nine vowels of American English, showing typical formant ranges for an adult male speaker in the traditional "reversed axis" layout. International Phonetic Alphabet symbols mark the locations of the vowels in the formant space

Speech Processing

Speech is an acoustic *signal*, a time-varying sound wave. In order to analyze or encode (process) a speech signal, it first has to be converted into an electrical signal by a microphone, after which it is normally sampled by computer hardware to yield a *digital signal*. Speech signals are generally comprised of both periodic and aperiodic components. *A periodic* signal is one that repeats a pattern at regular time intervals, as typified by the phonation in voiced sounds such as vowels. A signal that does not have a recurrent period is an *aperiodic* signal, as typified by the noisy sounds of most consonants.

Being a function of time, a signal $s(n)$ is said to exist in the *time domain*, where n is an integer time index used for digital signals. A useful quantity that is computable from a signal in the time domain is its *autocorrelation*, which is, roughly speaking, a function obtained by multiplying the signal $s(n)$ by a time-shifted copy of itself $s(n-l)$. The time shift l is called the *lag*, and the autocorrelation is really a function of the lag defined as follows for a digital signal consisting of N samples:

$$r(l) = \sum_{n=j}^{N-|k|-1} s(n)s(n-l)$$

in which $j = 1$, $k = 0$ for nonnegative lags and $j = 0$, $k = l$ for negative lags. A graph of the autocorrelation called a *correlogram* can be used to find the main period in a periodic signal – it is equal to the first positive lag where there is a large autocorrelation value.

The most important arena for speech signal processing is the frequency domain, wherein a signal is transformed using Fourier's Integral Theorem into a function of frequency. For a continuous function of time (i.e., an analog signal) $s(t)$, the *Fourier transform* $S(f)$ defined by the Fourier Integral Theorem as follows is often taken to provide a mathematical definition of the physical concept of "frequency":

$$S(f) = \int_{-\infty}^{\infty} s(t) e^{-2\pi fti} dt$$

$$s(t) = \int_{-\infty}^{\infty} S(f) e^{2\pi fti} df$$

The second equation shows that the signal can in turn be expressed as an inverse Fourier transform of its own Fourier transform. In dealing with digital signals in practice, a discrete form of the Fourier transform is used, which is commonly called a *fast Fourier transform* (FFT) after the special class of algorithms generally used in its calculation. The magnitude of $S(f)$ provides an energy density function of frequency, commonly called the *power spectrum* or *periodogram*.

The Fourier transform, and therefore the spectrum, is formally defined only for a signal of infinite extent in time, which is not physically realistic. In practice it is desired to compute (or in reality, estimate) the spectra of short portions of a signal called *analysis windows*. A Fourier power spectrum of a 10 ms window containing one vocal fold cycle in a vowel is shown in Fig. 2; the energy is graphed using logarithmic *decibel* units. The main peaks correspond to the formant frequencies of the vowel. Spectra of a sequence of analysis windows can be strung together to provide a kind of "time-varying spectrum" of a speech signal. One representation of this which is often applied in speech science is the *spectrogram*. In the example in Fig. 2, formant frequencies appear as horizontal bands, while the vertical lines show the pressure pulses generated by the vocal folds during phonation. Consonant noise appears as random "fuzz."

Fourier spectral representations have the disadvantage of large data content relative to the amount of information provided. For practical applications of speech processing, it has been necessary to develop spectral estimation and other coding technologies with a lower data rate and greater potential for automatic analysis. A very important example of such a *parametric representation* of speech uses the technique called *linear prediction*. Linear prediction exploits the possibility of representing a digital signal $s(n)$ obeying certain constraints as a linear combination of a finite number p of its past values, to within an error term ε_n:

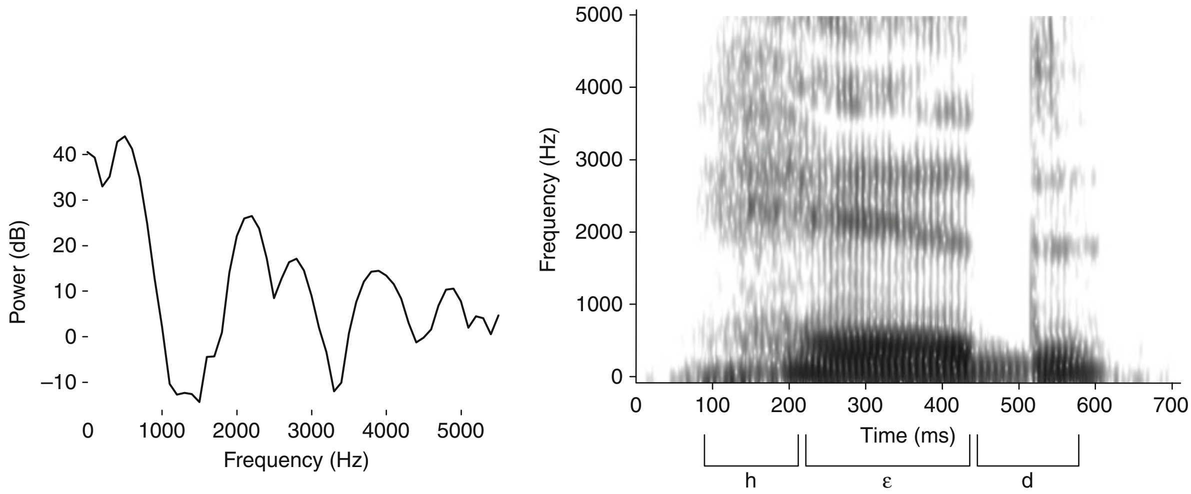
$$s(n) - a_1 s(n-1) - \cdots - a_p s(n-p) = \varepsilon_n$$

From this, a speech signal can be represented by the small set of parameters $\{p, a_1, \cdots, a_p\}$ for a typical $p = 14$, and a power spectrum which estimates the formant frequencies assuming a restricted source-filter speech model can also be computed. A spectrum estimated from linear prediction of a vowel is shown in Fig. 3. A major drawback of this technology is the dependence of the results on the parameter p, which is input by the user.

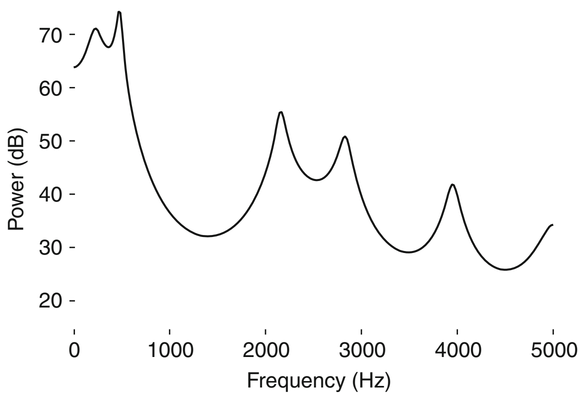
Another important speech transformation involves computing the inverse Fourier transform of the logarithmic magnitude spectrum (similar to the power spectrum). The resulting representation is called the *cepstrum*, and it is useful for estimating the fundamental frequency of speech, as well as providing a low data rate coding of the speech using approximately 24 numbers from the digital cepstrum sequence called the *cepstral coefficients*. A common modification for speech recognition applications called the *mel-frequency cepstral coefficients* (MFCC) uses a nonlinear frequency scale derived from the auditory perceptual scale for the log magnitude spectrum, before computing the inverse Fourier transform. Most modern-day speech recognition implementations represent speech segments as vectors of MFCCs, which are then used in the ubiquitous paradigm of hidden Markov models for recognizing sequences of speech sounds, and ultimately words and sentences.

Important Scientific Research and Open Questions

Current research in phonetics endeavors to describe all extant and possible sounds of the world's languages in a coherent theoretical paradigm. Research efforts are



Phonetics and Speech Processing. Fig. 2 Power spectrum of one vocal fold cycle taken from the vowel in "head" shown on left; spectrogram of the entire word shown on right, with portions labeled by the segments. In a spectrogram the energy is displayed in grayscale with the darkest areas having the greatest energy



Phonetics and Speech Processing. Fig. 3 Power spectrum computed from linear prediction of the vowel in *head* (cf. Fig. 2), by setting $p = 14$

also devoted to understanding how speech is heard and perceived by the auditory system and brain, and to how linguistic systems of sounds can be learned naturally by the child. Recent findings have called into question whether source-filter theory is a sufficiently accurate speech production paradigm; in particular it is being recognized that phonation is an aeroacoustic process, although source-filter theory neglects air flow (Fulop 2011).

Technical challenges which still plague phonetics involve speech processing endeavors such as accurate speech spectrum estimation and linear prediction methods. Current research in spectrum analysis is directed toward moving beyond Fourier power spectra and the spectrogram (a 65-year-old technology) to the application of more recent methods such as quadratic time-frequency representations and reassigned time-frequency representations (Fulop 2011). While linear prediction modeling may be sufficiently accurate for some purposes, many applications may be better served by applying autoregressive-moving average (ARMA) models which generalize linear prediction (Quatieri 2002). The way is thus paved for the development and testing of new speech analysis technologies, including their application in the service of speech recognition and synthesis.

Cross-References

- ► Acoustic and Phonological Learning
- ► Perceptual Learning in Speech
- ► Phonological Representation
- ► Signal Detection Models

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Phonological Awareness

An understanding that labels are constructed from bits of sound (phonemes; e.g.,/s/,/u/,/t/) and that these bits can be recombined in various ways to construct new utterances.

Phonological Representation

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Synonyms

Lexical representation; Phonological word form

Definition

A phonological representation is the mental representation of the sounds and combinations of sounds that comprise words in a particular spoken language. Phonological representations can be described at the acoustic level, the linguistic level, or the cognitive level. At the acoustic level, the phonological representation for a word form is analyzed in terms of the raw signal, for example, in terms of pitch, loudness, and duration. At the linguistic level, the word form is described in terms of the vocal tract and the ways that it constrains the production of speech sounds, for example, the manner of production and the place of articulation. At the cognitive level, the phonological representation is described in terms of its assumed constituent elements, namely consonant phonemes and vowel phonemes. The phoneme is an abstract unit that does not correspond in a simple way to the acoustic signal. Essentially, a phoneme is the smallest unit of sound that changes meaning. For example, "cat" and "hat" differ in their initial phoneme, and "cat" and "kit" differ in their medial phoneme. The field to date has not been able to demonstrate reliable links between the acoustic and linguistic/cognitive levels.

Theoretical Background

Most psychological research on the development of phonological representation has been at the cognitive level, and a cognitive focus will be adopted here. Early cognitive research explored when infants learn the phonemes that make up words in the spoken language. There are around 600 consonant phonemes and 200 vowel phonemes that are distinctive to the human brain. However, most languages use a smaller set of these possible phonemes. English uses about 40 phonemes. Learning the phonemes or speech sounds of their native language is an important task for the infant language learner.

Phoneme perception is usually described as "categorical," meaning that sounds that may be very similar acoustically can indicate quite different phonemes. The classic example is "p" versus "b." Different speakers will produce the physical sound corresponding to "b" in quite different ways, so there are many similar but non-identical sounds that adults recognize as the phoneme/ b/. There are also many other similar but non-identical sounds that adults would recognize as the phoneme/p/. For any speaker, there is a measurable point at which sounds that are highly similar physically stop being perceived as/b/, and begin being perceived as/p/. This is called categorical perception. In essence, the brain imposes a category of/b/sounds and a category of/p/ sounds onto a physical continuum.

In a classic study, researchers investigated the categorical perception of phonemes by infants aged 1 and 4 months (Eimas et al. 1971). In infant studies, the baby sucks a dummy to a background sound, for example, the syllable "ba" being repeated over and over again. The classic finding is that infants habituate to the sound, that is, suck rate declines as the sound becomes familiar. If a new syllable "pa" is introduced and is perceived as categorically different from "ba," suck rate should increase. Both the 1-month-old and the 4-month-old infants showed sucking rates suggestive of categorical perception.

More recent experiments with other species have established that the physical changes where languages place phonetic boundaries are not random (Kuhl 2004). The positioning of phoneme boundaries or the basic "cuts" to the physical continua is influenced by general auditory perceptual abilities. For example, other mammals such as chinchillas seem to partition physical continua for speech sounds in the same ways as humans with categorical perception. It is therefore unsurprising that infants are sensitive to the acoustic boundaries that separate phonetic categories in all human languages from birth. However, as these basic cuts are rather rough, further learning is required. During development, infants need to become specialized in the locations of the phonetic boundaries that are important for *their* language. At birth, infants can distinguish the phonemes used by all of the world's languages. By the age of around a year, language-specific patterns of listening have developed, and infants lose the ability to discriminate phonemes in other languages.

However, words are composed of sequences of phonemes. Therefore, to develop phonological representations of words, the infant needs to learn where word boundaries fall in continuous speech. There are a number of statistical or probabilistic cues that group together the phonemes that comprise particular words. These statistical patterns help infants to learn which phonemes belong to one word and which phonemes belong to the next word. For example, some sequences of phonemes are more frequent than others, and some sequences of phonemes cannot occur at all. The rules that govern the sequences of phonemes that are used to make words in a particular language are called *phonotactics*. For example, English syllables can end in "ant," but English syllables cannot end in "atn." In terms of statistical probability, if a sequence like "atn" is heard, it is likely to cross a word boundary (as in "at night"). Infants become able to extract words from continuous speech by about 7 months of age, and phonotactic probability is an important contributor (Jusczyk and Aslin 1995).

Another important contributor is infant-directed speech or "Motherese." Motherese is the singsong intonation that we use when speaking to infants. Phrases are spoken in a higher pitch, and certain words are exaggerated, for example, by using increased duration and stress. The human tendency to talk to babies using infant-directed speech across cultures suggests that this special prosodic patterning has a developmental purpose. Although it is still unclear exactly how Motherese helps infants to segment words from continuous speech, there is extensive evidence that babies prefer to listen to Motherese, and that cues such as duration and stress help them to identify words.

Changes in duration and stress also carry important information about how sounds are ordered into *multisyllabic* words. Hence prosodic information is an important part of the phonological representations for individual words. It is estimated that 90% of English bisyllabic content words follow a *strong-weak* syllable pattern. The strong syllable is stressed, and the weak syllable is unstressed. Words like mummy, daddy, bottle, baby, and sister are all examples of words that babies hear frequently that follow this typical pattern. Psychology experiments have been carried out to determine when infants can use prosodic strategies to segment words from speech. For example, learning that word onsets are aligned with strong (stressed) syllables would be one useful strategy. Jusczyk, Houston, and Newsome (1999) reported that infants aged 7.5 months could segment words with strong-weak patterns from fluent speech. These same infants appeared to mis-segment words following an atypical *weak-strong* pattern, like "guitar." Sensitivity to the predominant stress patterns of English words is clearly important for segmentation.

Infants' high sensitivity to general prosodic and rhythmic patterning in language is also shown by their own linguistic productions. Infant babbling reflects the rhythmic properties of the adult language. This was demonstrated by de Boysson-Bardies, Sagart, and Durand (1984), who recorded samples of babbling from 6-month-old babies who were learning either French, Cantonese, or Arabic. French-speaking adults who listened to the babble were able to identify the babbling of the French babies. They apparently relied on the prosodic patterning of the babble. Cross-language work has also shown that, across cultures, infants typically babble the same kinds of sounds in the same order. For example, stops like/b/and/p/and nasals like/m/are easier to produce than fricatives like/f/and liquids like/l/. The most frequent sounds found in early babble are/d/,/b/,/m/,/n/,/g/and/t/. At the same time, the relative frequency of easily produced sounds in children's babbling depends on the frequency of those sounds in the ambient language. As with statistical perceptual learning, the production of language sounds also reflects statistical probabilities.

By around 3–4 years, children's phonological representations of words are well-developed, so that words can be both produced and comprehended rapidly. The phonological representations are characterized at a sufficient level of detail to ensure that the child produces the correct sound elements for a given word in the correct order and with the typical intonation pattern. When a child's spoken output remains difficult to understand and displays jumbled and atypical sound sequencing, the child is considered to have a phonological disorder. In the typically developing child, the representation of more and more phonological word forms enables reflection on the internal sound patterning of words. By the age of 4 years, children across cultures can count the number of syllables in a spoken word, and can decide whether a spoken word rhymes with another word. By the age of 6, the average child has a spoken vocabulary of around 6,000 words and a comprehension vocabulary of around 14,000 words. At around this age, most children are at school and are learning to read. The acquisition of an alphabetic script enables children to also become aware of phonemes (Ziegler and Goswami 2005). Adults who have never learned to read do not develop phoneme awareness.

Important Scientific Research and Open Questions

The most pressing question in current research is whether the cognitive concept of a phoneme is useful in understanding the development of phonological representations. As acoustic science has developed, it has become clear that there is no simple acoustic correlate of any individual phoneme. Rather, the phoneme as an elemental unit of language is a product of the literate brain. Although rapid changes in frequency and intensity (formants) were originally assumed to be the acoustic correlates of phonemes, it is now understood that the human brain can interpret speech quite well from a reduced form of the signal that has no formant structure. More recent scientific research has thus focused on syllables and on amplitude modulation (the overall envelope shape of the sound pressure hitting the ear as speech is produced). Much of this research is driven by speech technology, as devices are invented that can either produce or recognize speech. Similarly, brain imaging methods are having an important impact on our understanding of phonological representation. For example, motor representations (stored knowledge about how to make and produce speech sounds) appear to play a central role in the *perception* of speech sounds. It seems likely that the neural phonological representation is multisensory and contains multiple levels of temporal and acoustic information.

Cross-References

► Acoustic and Phonological Learning
► Infant Language Learning
► Perceptual Learning in Speech
► Phonetics and Speech Processing

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Phonological Word Form

► Phonological Representation

Physical Activity

► Effects of Exercising During Learning

Physical Aggression

► Learned Aggression in Humans

Physiological Equilibrium

► Physiological Homeostasis and Learning

Physiological Homeostasis and Learning

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Synonyms

Internal balance; *La fixité du milieu intérieur* or stability of the internal environment; Learning; Physiological equilibrium; Physiological regulation; Physiological steady state; Self-maintenance; Self-regulation

Definition

Physiological homeostasis is the tendency of the body to maintain critical physiological parameters (e.g., blood glucose level, blood salinity, blood pressure, core body temperature) of its internal environment within specific ranges of values. The word *homeostasis* comes from the Greek *homoios* (ὅμοιος), meaning "similar," and *histēmi* (ἵστημι), meaning "standing still" – implying that the internal state is maintained not identically from one instance to the next but within a narrow range of critical values.

Theoretical Background

The concept of physiological homeostasis appears to have originated with the ancient Greeks, who believed that the body maintained a balance of four basic bodily fluids called humors: blood, phlegm, back bile, and yellow bile. Imbalances in these humors were thought to be the causes of various illnesses. Remnants of this idea persisted until the middle of the nineteenth century when bleeding was still used to treat a wide range of illnesses. As physiological knowledge and knowledge of the actual causes of diseases advanced in the nineteenth century, the term *milieu intérieur* – "internal environment" – was coined to replace the Greek concept of humors. Claude Bernard, who is widely recognized as the founder of the science of physiology, adopted the term and wrote of the stability of the *milieu intérieur* as an important physiological concept.

The physiologist Walter B. Cannon extended Bernard's concept and coined the term "homeostasis" (Cooper 2008). While Cannon's concept of homeostasis was essentially Bernard's concept of the *milieu intérieur*, Cannon "shifted attention away from the state of the internal environment . . . to a more detailed study of those control factors which intervene to ensure the maintenance of the steady conditions of the body" (Cooper 2008, p. 424). Thus, since the introduction of the concept physiologists interested in homeostasis have focused on the physiological mechanisms involved. They have also applied concepts from control theory in engineering. The most important of these concepts are *set point* and *feedback*. The standard model for these concepts is a simple temperature-control system consisting of a furnace, an air conditioner, and a thermostat. In this model when the temperature around the thermostat drops below the setting on the thermostat, or set point, the air conditioner turns off and the furnace turns on, causing the temperature to increase. When the temperature around the thermostat exceeds the set point the furnace turns off and the air conditioner turns on. Similarly, proponents of the set point or feedback theory of physiological homeostatic temperature control maintain that the temperature of warm-blooded animals, for example, is maintained at a fairly constant level by a feedback system. When the animal's body temperature drops significantly below the ideal temperature represented by a set point, there is an activation of physiological warming and warmth conservation mechanisms such as redirection of the blood away from the exterior of the body, shivering, piloerection, and physical movement to a warmer location. Conversely, when the animal's body temperature increases above the set point, there is an activation of physiological cooling mechanisms, such as redirection of the blood toward the exterior of the body, promotion of evaporation (e.g., panting in dogs, sweating in humans), and physical movement toward a cooler location.

Another control theory concept that has been applied to physiological homeostasis is *feedforward*. Whereas feedback is the correction of a current deviation from the set point, feedforward acts to prevent or minimize a pending deviation from the set point. Feedforward, in other words, "anticipates" a future deviation" and "corrects" for it in advance. An example is mammalian growth of thicker fur in advance of the cold of winter and the shedding of fur in advance of summer heat. In both cases, the animal's body is acting to prevent a pending disruption of its internal temperature.

Despite the close connections of early physiological homeostasis researchers with leading behavioral scientists – e.g., Cannon was a close friend of Pavlov, and Curt Richter studied under John B. Watson – physiologists have shown reluctance to apply learning concepts to homeostasis (Booth 2008; Cooper 2008). Nevertheless, many learning theorists through the 1930s to the 1950s attempted to derive basic learning principles from the concept of physiological homeostasis. For example, in Clark L. Hull's influential learning theory, reinforcement consisted of the reduction of a motivational or drive state that was correlated with a tissue need, where a tissue need was a homeostatic imbalance in the cells of a tissue. However, these efforts were largely abandoned when it appeared that many instances of respondent (also called classical or Pavlovian) and operant (also called instrumental) conditioning do not conform neatly to homeostasis.

More recently, the concept of physiological homeostasis has again become prevalent in the literature on learning. It is now recognized that much of respondent conditioning can be seen as the acquisition of feedforward mechanisms. For example, the secretion of saliva and other gastric juices after the presentation of a bell that has been paired with food prepares the organism to digest food more readily than if this feedforward mechanism were not operating. The conditioned aversive reaction to the appearance or taste of a food that has been paired with illness acts to prevent the disruption of homeostasis that would potentially be caused by the ingestion of a toxic substance (Garcia et al. 1974).

Some of the most striking work on the role of respondent conditioning in physiological homeostasis has been done in the area of drug addictions. Any drug taken into the body disrupts the physiological homeostasis of that body. Since the body tends to maintain physiological homeostasis, a drug will elicit an unconditioned response – called a compensatory response – that counteracts the effects of the drug, thus restoring physiological homeostasis. According to a theory that has strong empirical support, stimuli that have been paired with taking the drug will come to elicit the compensatory response for that drug as a conditioned response (Siegel 2008). This theory of compensatory conditioned responses explains why a recovering addict tends to relapse in situations where the addictive drug was taken; why increasing amounts of an addictive drug are needed in order to get the same physiological and subjective effects of an addictive drug; and why an addict is more likely to get a stronger effect (even in some cases to the point of overdosing) when the drug is taken in a different setting from the one in which it is usually taken.

While many instances of respondent conditioning can be seen as feedforward mechanisms that act in anticipation of a deviation from physiological homeostasis, there are a number of instances of respondent conditioning that cannot readily be seen in that way. These include instances in which under certain conditions a stimulus paired with a particular color will elicit the after image of that color (the McCollough effect), instances in which a stimulus paired with a reinforcing stimulus such as food or a conspecific of the opposite sex will elicit an approach response toward and interaction (e.g., pecking in the case of food) with the formerly neutral stimulus (sign tracking or autoshaping), and instances in which a stimulus paired with another will elicit visual responses or sensations elicited by the latter stimulus (conditioned seeing or conditioned sensory responses) (see Pear 2001).

Operant conditioning is also involved in some instances of homeostasis. This is particularly obvious in cases of specific hungers. For examples, evidence suggests that in at least some cases animals will learn to emit a response that has been reinforced with a specific nutrient that has been removed from their diets (Pear 2001, pp. 285–286). Responding for food in general would seem to be an example of behavior reinforced by the maintenance of homeostasis. However, there are problems with this interpretation in that the immediate effect of eating is not maintenance of homeostasis but disruption of it, to which the body's response is analogous to the compensatory drug responses mentioned above (Woods 2001).

Conditioned compensatory responses elicited by stimuli paired with a drug or food result in a reduction of homeostasis until these responses are counteracted by the drug or food, respectively. Thus, some operant responding reinforced with food or a drug could be seen as behavior reinforced by physiological homeostasis. In other words, in the theory of compensatory responses, this would be operant behavior that is reinforced by the removal or avoidance of withdrawal symptoms. This, however, leaves unanswered the question of why drugs or food would be reinforcing in the first place. Thus, while respondent conditioning on the whole serves to maintain physiological homeostasis, operant conditioning, at least on a short-term basis for food and drug reinforcement, disrupts it.

Other types of learning not mentioned above due to space limitations include sensitization, habituation, and imprinting. The possible connections of these types of learning with physiological homeostasis have not been researched.

Important Scientific Research and Open Questions

Research has clearly established that there is a balance (called physiological homeostasis) of a number of critical parameters in the body, and that sizable deviations of any of those parameters from certain critical values can lead to illness and death. Research also shows that learning is involved in maintaining these parameters within their critical values through anticipation of deviations from those values (respondent conditioning) and through acquiring new responses that provide nutrients that contribute to maintaining those values (operant conditioning).

Two critical questions arise regarding physiological homeostasis and learning:

1. Is the application of control theory to physiological homeostasis useful or valid? It has been argued that set-point theory is a misleading analogy, in that there is no neurological basis for a set point to be represented in the brain or for comparisons to be made with that set point. It has been suggested (e.g., Booth 2008) that a more realistic way to account for homeostasis is in terms of opposing processes that provide feedback to each other. For example, glucose and insulin levels in the blood can be seen as two such opposing processes. A high glucose level in the blood causes insulin to be secreted by the pancreas, resulting in absorption of the glucose by the cells. The removal of glucose from the blood leads to insulin being taken back into the pancreas.
2. Is homeostasis suitable as a general physiological principle? There is no doubt that it works reasonably well as a general principle when dealing with the internal environment. However, the label leads to treating it as a single process, whereas in fact the internal balance that occurs may be more accurately viewed as the result of a wide variety of different processes. Moreover, extension of the concept to account for external behavior is problematic, since much of an animal's external behavior does not contribute directly to homeostasis in any obvious way. This may be why earlier homeostasis researchers were reluctant to incorporate learning principles into homeostasis (Booth 2008; Cooper 2008), since research on learning generally involves the investigation of external behavior.

It has been stated that "[t]he learning researcher is a homeostasis researcher" (Siegel 2008, p. 242). However, there is much evidence that learning often does not accord well with physiological homeostasis (e.g., humans engage in a great deal of learned behavior that is detrimental to homeostasis). Another way to look at learning is that it consists of mechanisms that evolved because, like the mechanisms of homeostasis, they helped organisms remain alive long enough to perpetuate their genetic material. Moreover, learning is involved in the act of procreating and behaving in ways that ensure the survival of the individual's genetic material (Pear 2001). These functions seem unrelated to maintaining the stability of the internal environment; indeed the behaviors involved in procreating and protecting offspring can be detrimental to the organism's own physiological homeostasis (e.g., by exposing the organism to attack by a conspecific or predator). Future research directions relating physiological homeostasis and learning include identifying homeostatic feedback signals, the compensatory responses (both unconditioned and conditioned) that occur to those signals, and the type of reinforcement (if any) of responses that maintain or destabilize short- or long-term homeostasis and how the laws governing these responses compare with those governing other types of responses (also see Booth 2008).

Cross-References

► Adaptation and Learning
► Anticipatory Learning
► Behavior Modification, Behavior Therapy, Applied Behavior Analysis and Learning
► Evolution of Learning
► Feedback and Learning
► Motivation and Learning: Modern Theories
► Neurophysiology of Motivated Learning

▶ Operant Behavior
▶ Pavlovian Conditioning
▶ Reinforcement Learning

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Physiological Measures

Physiological measures are based on the assumption that there is a physiological response to increases in expenditure of effort. The difference between a leamer's baseline measurement of the physiological process and a measurement taken while the learner is performing some task is assumed to be reflective of the amount of effort the learner is investing in the task. Physiological measures that have been used to investigate learners' expenditures of mental effort include heart rate, electroencephalogram (EEG) measures, and eye fixations.

Physiological Psychology

▶ Neuropsychology of Learning

Physiological Regulation

▶ Physiological Homeostasis and Learning

Physiological Steady State

▶ Physiological Homeostasis and Learning

Piaget, Jean (1896–1980)

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Life Dates

Jean Piaget was born on August 9, 1896, in Neuchatel, Switzerland, and died on September 16, 1980, in Geneva, Switzerland. Usually he is regarded as a developmental psychologist, but he also had a strong interest in epistemology, labeling himself as a *genetic epistemologist*. But at first, Piaget studied biology with a focus on zoology and especially on mollusks. He acquired a Ph.D. in biology at the University of Neuchatel in 1918.

An early important station in his scientific work was in Paris (1919–1921), where he contributed to the research in the standardization of intelligence tests of children. However, Piaget became unsatisfied with only counting the wrong answers of the children. Asking why they answered "wrong" he found that children created their own answers following a distinct logic not given by the adults. So they did not just learn only by imitation or by rote learning, as elsewhere supposed. This is why Piaget can be regarded as an early representative of constructivism, and he surely is one of the most influential. He delivered strong arguments against the behaviorist psychology, such as represented by Watson (*Psychology as the Behaviorist Views It*, 1913) or Skinner (*The Behavior of Organisms*, 1938). Piaget's first contribution hereby was *The Language and Thought of the Child* (*Le Langage et la pensèe chez l'enfant*, 1923). However, it lasted four decades until this research was noticed in the United States.

Major stations in Piaget's academic career were Neuchatel, Geneva, and Paris. He held several professorships: in psychology, especially in experimental psychology and in genetic psychology, but also in sociology and in philosophy of science. Mostly, he lived in Geneva, where he held a professorship for Experimental Psychology, from 1940 to 1971. His lifelong study focused on children and adolescents. Many of his writings have been written in collaboration with his long-time assistant and successor in Geneva, Bärbel Inhelder.

Contribution(s) to the Field of Learning

Piaget's most influential contribution to the field of learning is his theory of four *stages of intellectual development*. These stages are the *sensorimotor stage* (from birth until approximately 2 years), the *preoperational stage* (from then to 7 years), the *concrete operational stage* (from then to 12), and the *formal operational stage* (from 12 onward). The theory shows that there is a specific and *consecutive* order in the intellectual development. This development starts with the coordination of the senses with the motoric system and is followed by a progressive development of the semantic world; beginning with a mere duplication of the world by language (the word *is* the thing) up to the disentanglement of the intellectual world from the concrete (the word *symbolizes* a thing and is finally even an *idea*). Every one of these stages is an enlargement of the former ones, for example, the *concrete* operational thinking subsists beneath the *formal* operations. None of these stages is possible before the elaboration of the precedent ones. It also has to be mentioned that the age specifications of the stages are not fixed. Development is individually different, and the later the stage, the more the variance. Important for the theoretical insight are the *order* and the *structure* of the stages and not their specific length or the time of their beginning.

Core terms for Piaget's theory are: *adaptation*, *accommodation*, *assimilation*, *causality*, *decentrification*, *egocentrism*, *equilibration*, *schema*, and *self-regulation*. These terms will be explained in the following. As a whole, Piaget's theory is the result of a long ranged series of observations and learning experiments with children, resulting in a comprehensive work, counting more than 60 books and several hundred articles, and constituting the field of *genetic epistemology*, that is, the way how knowledge is acquired during childhood.

Describing this in detail, corresponding to the stages there is also a differentiation *inside* of all of the four stages. Piaget shows that every stage begins with a phase of *egocentrism* (which is not to be meddled with *egoism*). Egocentrism stands for a complete reference of the world to oneself, caused by the inability to perceive other motivations and viewpoints. The childish learner creates hypotheses about the supposed *causal structures* of the observed phenomena, almost like a scientist. These hypotheses are often preliminary or even wrong, so Piaget recognizes at the beginning a stage of a pre-causal, of a *magic* causality. In this way the childish learner initiates his successive comprehension of simple functioning causal structures. But this understanding is also preliminary, because the child links this causal structure first only with himself (egocentrism) and later just with his parents or with other agents. It is only with further learning that the child succeeds in the comprehension of more elaborated causal structures and especially with disconnecting them from individual agents. This process is called *decentrification*, and it repeats itself on all the stages. So every stage is marked by an egocentric beginning and by a decentrificated end. But there is an important exception, which Piaget emphasized in his late writings: The fourth stage does not end anymore with a full decentrification of the intellectual world, but only with a domain specific (Piaget 1970). So the adult thinking is a mixture of decentrificated abstractions with a broad area of a still egocentrified and therefore quite simple causal and sometimes even magical thinking.

Piaget understands the structure of the learning process as an act of *adaptation*. Adaptation is to be seen as double-sided. Crudely spoken, it can be the adaptation of oneself *to the environment*, called *accommodation*, or the other way round, the adaptation of the environment *to oneself*, called *assimilation*. More formally, accommodation is the transformation of mental structures to meet the demands of the environment, and assimilation is the transformation of objects following the private mental structures. Piaget uses the term of *schema* to define this. Schema stands for an acquired way of the organization of behavior. It is the mental structure by which individuals adapt to the environment. Schemata are expanded by learning and therefore they also can be part of even more elaborated schemata.

Finally, Piaget stresses the importance of *equilibration* in his theory. The cognitive development is a process of equilibration, so there is an inner tendency to achieve a balance between the inside and the outside of oneself. In Piaget's early work the term of equilibration was adopted of natural sciences and in the sense of a kind of chemical or mechanical balance. With the concept of equilibration Piaget anticipated the idea of *negative feedback* of cybernetics. Piaget later utilized the cybernetic insights and reformulated his previously, somehow, static idea in the sense of *self-regulation*.

There are several major shifts in the development of Piaget's theory. Harry Beilin discerns five periods, thereby expanding a four-period model of Jacques Montanero (Montanero, *Genetic Epistemology: Yesterday and Today*, 1985). At the beginning he recognizes a double period of early functionalism, at first with focus on a social explanation (1923–1932), then with a shift to the theory of adaptation (1932–1937). The third period is characterized by structuralism and is from the 1940s to the early 1960s. The 1960s constitute the fourth period and are marked by a somehow revised functionalism. All in all, Beilin notices an overall occupation with structuralism and functionalism, sometimes with one dominant, sometimes the other. The last period, in the 1970s, is described as a "new theory" with two major shifts: from extension and truth testing to intension and meaning, and from the emphasis on logical necessity to that of possibility, including the consequences for constructivist theory (see Beilin and Pufall 1992).

Important Scientific Research and Open Questions

Piaget's theory of learning ends with the adolescence. This triggered a widespread discussion about the possibility and the characteristics of a fifth stage in the intellectual development. But Piaget himself tends in his late writings rather to a reduction of his four stages to only three, combining the second and the third to a longer stage, containing the constitution of the semiotic functions (Piaget and Inhelder 1966). He also stresses the openness of the fourth stage: there is no conclusion of the fourth stage (Piaget 1970) and therefore it remains highly speculative to suggest a fifth.

There is also a whole bunch of publications which "refute" Piaget's theory by the "finding" that phenomena described by him are to be seen *earlier* than assumed by Piaget. But this kind of interpretation is misleading and basically it is wrong. Piaget does not assume that a certain behavior has to be at a special age, all his dates are just of a pure observational character and therefore somehow contingent. To contradict his findings one would have to show another *order* of development, so for example, from abstraction to concreteness or from decentrification to egocentrism (for further reading on misinterpretations of Piaget's theory see Wadsworth 2004).

There is a widespread scientific research on Piaget. So here only two examples can be given: Lawrence Kohlberg expands Piaget's theory to a six-staged theory of *moral* development (Kohlberg, *The Development of Modes of Thinking and Choices in Years 10 to 16*, 1958). These six stages are grouped in three levels: the *preconventional* level (obedience, self-interest), the *conventional* level (social norms, law), and the *postconventional* level (social contract, universal ethical principles). Furthermore, Robbie Case delivers a neo-Piagetian theory with two major achievements: He succeeds in the construction of a single experimental environment for the testing of intellectual development of children and youths. This is consisting in a balance beam and cumulatively challenging tests. Secondly, he breaks every one of the four stages into four substages, creating at the same time a combination of the stages: so the stages are not just following each other anymore, every last one of the substages is simultaneous to the first substage of the following stage (Case 1985).

Other important researchers on Piaget are Kurt W. Fischer (*A Theory of Cognitive Development: The Control and Construction of Hierarchies of Skills*, 1980), John H. Flavell (*The Developmental Psychology of Jean Piaget*, 1963), Marvin Minsky (*The Society of Mind*, 1988), and Juan Pascual-Leone (*A Mathematical Model for the Transition Rule in Piaget's Developmental Stages*, 1970), to give at least a preliminary list of some of the classics. An overview on Piagetian thinking is delivered by Beilin and Pufall (Beilin and Pufall 1992).

Cross-References

- ► Behaviorism and Behaviorist Learning Theories
- ► Constructivist Learning
- ► Kohlberg, Lawrence
- ► Learning Stages
- ► Piaget's Learning Theory

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Piaget's Learning Theory

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Synonyms

Genetic epistemology; Genevan school

Definition

Jean Piaget's genetic (developmental) epistemology (study of knowledge) attempts to answer the question, "How does understanding of the world develop over the life span?" Then, Piaget's learning theory does not exist as a discrete set of propositions or principles but must be derived from the larger developmental theory. This causes problems because much of his key work remains untranslated from French even today and many commentators rely on only a very small portion of Piaget's own writing (Bond and Tryphon 2007). Piaget's constructivist account of learning sees the learner as actively making sense of the world by reflecting on the consequences of the learner's own thoughts and actions on the physical and social environment. Then, what is learned is as much a consequence of the learner's current understanding of the world, as it is of what the world is actually like. Famously, children's learning/understanding is qualitatively different during different stages of cognitive development.

Theoretical Background

Jean Piaget is more accurately seen as a philosopher than as a cognitive developmentalist or a learning theorist. His genetic epistemology is an empirically based philosophy which is, at once, too philosophical for most psychologists and too psychological for most philosophers. As a consequence, most undergraduate exposure to Piaget's theory is to a small portion of his epistemology, which usually goes by the name, Piaget's theory of cognitive development – from which some principles of learning are often drawn to contrast (almost completely) with behaviorist theory or, more recently (and almost not so completely), with Vygotskian theory. The motivation for deriving a Piagetian theory of learning from his epistemology appears to be driven at least in part by the needs of educational psychologists who, in the post-Sputnik era, looked to Piaget's theory of cognitive development [*sic*] to inform the revolution in pedagogy which seemed needed in light of the United States having been beaten to launch the first satellite.

Very importantly, the principles of learning are derived from Piaget's much broader developmental theory: genetic means developmental – not implied by genes or inheritance. The development of knowledge is an active, internal constructive process where the child builds its own understanding of the world. The fundamental building block of intelligence is the scheme – a mental representation of a mode of (either physical or cognitive) action in response to perceived environmental demand. The process of enacting schema is adaptation – an attempt to reestablish equilibrium with the environment. Both of the complementary adaptive processes – assimilation and accommodation – are brought into play with every activity. When the response to the environmental demands can be rather routine, assimilation – treating that aspect of the environment as if already mastered – predominates. Accommodation of schemes to challenging or new environmental demands predominates when the learner realizes the inadequacy of the existing cognitive or behavioral repertoire and creates new intellectual structures for dealing with these.

While the human learning organism is in a perpetual state of minor dis/equilibrium and adaptation processes are continually in play, Piaget described four major equilibrium periods during ontogeny: a sensorimotor period during infancy, a preoperational period during the years before formal schooling usually occurs, followed by a stage of concrete operational thinking, and then of formal operational thinking which roughly parallel the years spent in grade and high school respectively. The developmental sequence is the essence of Piaget's description and here the age ascriptions are left broad and ambiguous deliberately to reflect that.

Physical knowledge (about objects) is the product of empirical abstraction while reflective abstraction produces logico-mathematical knowledge about the relationships between objects. Fittingly, one of Piaget's long-term endeavors was to represent the learner's operational thinking processes as functions of logico-mathematical structures. Then, what can be learned at any time is a function of what the learner already knows – and that is a product of that learner's cognitive development. In a high school physics class where the teacher attempts to teach the principle governing the oscillation of a simple pendulum, what each student learns is more likely to be a consequence of that individual learner's cognitive capacity rather than of the common reality provided by the teacher's demonstrations and instruction; concrete operational thinking is limited to the relationships between objects: classifying materials, seriating bob weights, string lengths, and angles of amplitude. Only so-called formal operational thinking is up to the task of constructing the relationships between those relationships and abstracting the inverse proportional relationship between pendulum period and string length.

Important Scientific Research and Open Questions

While Piaget might have intended to impact upon the field of philosophy directly and on that of psychology indirectly, the main influence of the Genevan school has been in child or developmental psychology, and the application of those ideas to classroom learning. But even in the field of educational psychology, Piaget's work often appears as a special section on cognitive development – the four stages and the like. The track of remarkable favor, then disfavor of Piagetian theory is aptly portrayed in the extent to which his work is dealt with in a key reference in the field, *The Handbook of Child Psychology* (Bond and Tryphon 2007). Piaget's prodigious output is listed in the definitive *Bibliographie Jean Piaget* published by the Jean Piaget Archives Foundation in 1989 as more than 50 monographs and 520 articles along with publication information for the originals and all of the subsequent translations. Generally speaking, researchers have been selectively attentive to Genevan research. Piagetian references usually represent only a small subset of Piaget's books, and very few of his published research papers. What appears relevant to psychologists covers only a restricted period in Piaget's work, and generally does not do justice to Piaget's own explicitly epistemological perspective. While almost any Piagetian learning principle might have suffered a negative empirical evaluation in isolation from its epistemological grounding, a more balanced view of the empirical research evidence might be ascertained from the four-volume series *Jean Piaget: Critical Assessments* (Smith 1992).

Psychologists might have been alerted in advance of taking/ testing/applying Piaget's learning principles out of their epistemological context: Piaget's own foreword in what was regarded for a long time as being a definitive English language compendium of the Genevan school's work (Flavell 1963) warned that "the differences between us stem from the fact that [Flavell's] approach is perhaps too exclusively psychological and insufficiently epistemological while the converse is true for me" (p. viii). So, at the same time as Piaget is accused of underestimating the apparently almost limitless cognitive capacities of infants, he is also guilty of describing adolescent and adult thinking as being more powerful and logical than it generally is. Lourenço and Machado (1996) make a cogent defense of Piaget's theory by replying to ten common criticisms found repeatedly in the literature, and although the authors do not claim "that the problems with his theory vanish when it is better understood, they do claim that important aspects of Piaget's work have not been assimilated by developmental psychologists" (p. 143).

Moreover, psychologists' general disenchantment with grand theory, or the idea of a universal model of cognitive developmental competences seems to result in a predisposition toward mini-theories based on more local knowledge and more empirically tractable micro-problems. Would a fairer evaluation of the validity and utility of Piagetian theory look at a grand-scale application of Piagetian learning principles in ordinary school classrooms to enhance the cognitive development of young learners and their consequent learning outcomes?

In a remarkably persistent attempt to so do, Shayer and Adey (1981) described in impressive detail the cognitive developmental demands of the science curricula of English secondary schooling and argued the remarkable mismatch of those demands with the profile cognitive developmental abilities of a representative national sample of more than 10,000 school students. They then went on to develop the suite of *Thinking Science* learning experiences, teaching materials, and in-service teacher workshops (Adey et al. 1989). Adey and Shayer (1994) reported the success of these Piagetian-based interventions in raising learning achievement levels in English and Mathematics as well as Science on the UK national examinations for 15- and 16-year-olds. Almost three decades later they demonstrate meaningful decreases in levels of cognitive development with another $N >$ 10,000 sample (Shayer et al. 2007; Shayer and

Ginsburg 2009). Does such a three-decade record of Piagetian-based research demonstrating the robust impact of the quasi-experimental application of Genevan school learning principles stand in sufficient counter-balance to the myriad of much more minor failures by which Piaget's theory is now often discounted as *passé*?

Cross-References

- ► Development and Learning
- ► History of the Sciences and Learning
- ► Piaget, Jean (1896–1980)
- ► Schema(s)

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Pictorial Representations and Learning

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Synonyms

Graphical representations; Iconic representations; Images; Pictures; Visual representations

Definition

According to Peirce (1906), objects can be represented by symbolic, iconic, and indexical signs. While a symbol is related to a represented object by convention, an icon is related to a represented object by structural commonalities. An index is related to a represented object by a connection of fact, such as a causal effect. Pictorial representations are often interpreted as icons; however, they can also constitute symbols or indices. A general distinction of pictorial representations is between realistic pictures and logical pictures. Realistic pictures, such as photographs, paintings, and sketches, share concrete attributes and structures with the objects they represent. A photograph, for instance, might share colors and spatial relations with the objects it represents. In contrast, logical pictures, such as schematic illustrations and diagrams, share abstract attributes and structures with the objects they represent. For example, a line diagram might share a functional relationship between two attributes with the objects it represents. A more fine-grained classification of pictorial representations has been developed by Lohse et al. (1994).

Theoretical Background

Two fundamental research questions arise with regard to pictorial representations and learning. (1) How do people learn from pictorial representations? (2) How can learning from pictorial representations be supported? According to Paivio's dual coding theory (1986), cognition occurs in two different but interrelated cognitive systems: a verbal system and a nonverbal system. While the verbal system processes linguistic information, the nonverbal system processes auditory, haptic, olfactory, and visual information in specific sensorimotor subsystems. The verbal system is made up of symbolic representations that are organized in a sequential way and are processed serially. The visual subsystem, in contrast, encompasses analog representations that are organized in a hierarchical and nested way and are processed synchronously. In his theory of working memory, Baddeley (1991) draws a similar distinction in that he assumes a phonological loop to process linguistic information as well as a visuospatial sketchpad to process visual and spatial information. Most of the current theories of multimedia learning, e.g., Mayer (2001) and Schnotz and Bannert (2003), draw upon the theories of Paivio (1986) and Baddeley (1991).

With respect to learning from pictorial representations, Weidenmann (1988) distinguishes between two different modi of understanding: ecological understanding and indicatorial understanding. Ecological understanding aims at recognizing objects and scenes in a picture. In order to accomplish this task, Weidenmann (1988) assumes that a learner applies the same processes to the picture as they do to visual perceptions of the natural environment. Depicting codes in the picture assist the learner in constructing the appropriate surface structures. Examples of depicting codes are the use of perspectives and colors. Indicatorial understanding, in contrast, aims at identifying visual arguments in a picture. In order to achieve this goal, the learner needs to interpret directing codes in the picture as indicators for arguments. Examples of directing codes are the use of accentuations, comparisons, enlargements, and directing symbols such as arrows. Numerous principles for the design of visual arguments have been developed (e.g., Tufte 2005). Because instructional pictures almost always require the learner to reconstruct visual arguments, they demand both ecological and indicatorial understanding. Weidenmann (1988) further assumes that two different types of processes are essential for the understanding of instructional pictures: pre-attentive processes and attentive processes. While pre-attentive processes are made up of procedures that are automatically executed within fractions of a second and without cautious control, attentive processes encompass procedures that are cautiously and intentionally executed over longer periods of time. By means of attentive processes, learners systematically search for information and draw conclusions from the acquired information. Whereas ecological understanding might be accomplished through pre-attentive processes, indicatorial understanding often requires additional attentive processes.

Pinker (1990) proposed a model of how learners understand certain logical pictures, namely diagrams. In accord with Weidenmann (1988), Pinker (1990) distinguishes between pre-attentive and attentive processes when learning from a diagram. Perceptual and pre-attentive processes enable learners to first identify the basic elements of a diagram such as forms, positions, inclines, and angles. These elements are organized as perceptual groups. The perceptual groups form an analog representation known as a visual array. The visual arrays are subsequently encoded as symbolic representations in working memory. The perceived elements and their spatial relations are described by means of propositions within these representations. In the next step, the propositional representation is matched against schemata of diagrams in long-term memory. The schema that corresponds best to the propositional representation becomes instantiated with the information contained in the propositional representation. A schema is composed of both declarative and procedural knowledge about a specific type of diagram. While declarative knowledge encodes information about the geometrical features of a diagram, procedural knowledge represents how certain information can be inferred from a diagram. Finally, the instantiated schema is drawn upon in order to form conceptual relations, to initiate the retrieval of additional information from the diagram, and to infer information not explicitly represented in the diagram. Pinker's (1990) model puts emphasis on the fact that learners need to acquire schemata of diagrams in order to be able to process diagrams effectively and efficiently.

Important Scientific Research and Open Questions

Although pictures are frequently included in learning material in order to improve understanding, students often fail to successfully learn from them. This deficiency is commonly attributed to two interrelated factors.

First, it is often the case that students are simply not taught the learning techniques and strategies that would enable them to process instructional pictures systematically and deeply. In contrast, students are taught – from the elementary to the university level – reading and learning strategies which focus primarily on the specific characteristics of texts. These strategies involve both internal learning activities (e.g., paraphrasing text segments, recalling previously learned information) and external learning activities (e.g., highlighting text segments, annotating text segments). Thus, after many years of education, the students have acquired and exercised a number of internal and external techniques which help them to systematically approach particularly complex and difficult texts, but they have not acquired the techniques necessary for understanding pictures.

Secondly, and presumably related to the first factor, students often seem to underestimate the informational value of instructional pictures for learning. While written texts are perceived as representations that demand mental effort in order to be understood (cf. Salomon 1983), pictures are perceived as representations that can be effortlessly processed. As a consequence, students invest no mental effort beyond ecological understanding and therefore miss the visual argument. This, in turn, can result in illusions of understanding.

During the last 15 years, various learning techniques have been developed and empirically evaluated in order to improve students' learning from instructional pictures. For instance, in order to initiate deep processing of pictures, Peeck (1993) suggests allowing students to locate specific elements in pictures, label pictures, compare pictures, and complete pictures. While the teaching of such isolated learning techniques improves learning, the learning gains remain limited. On the other hand, if several learning techniques are employed in a coordinated and goal-oriented way, they form a learning strategy.

Schlag and Ploetzner (in press) have developed a learning strategy in order to support learning from illustrated texts. In accord with Mayer's (2001) theory of multimedia learning, the strategy aims at stimulating and sustaining the processes of information selection, organization, integration, and transformation when learning from texts and pictures. Two different experimental studies demonstrated that the students who employed the strategy attained significantly better learning results than the students who learned without the study. The effect sizes are medium to large.

Although the fundamental learning effectiveness of the proposed strategy was demonstrated by these studies, it remains unclear as to what extent or for how long would the students benefit from the strategy. It seems unlikely that the students would be in the position to employ the strategy outside of the experimental setting. Intensive training is required if a learning strategy is to be used in a self-employed and flexible way. Furthermore, students need to learn how to transfer an acquired learning strategy to new learning contexts. Up until now, it has not been well understood whether different pictorial representations demand the use of different learning techniques and strategies: Do realistic pictures demand other learning techniques than logical pictures? Do pictures combined with text require different learning techniques than isolated pictures? While research on strategies for learning from texts has a long tradition in the educational and psychological sciences, research on strategies for learning from pictorial representations is still in its infancy.

Cross-References

► AIME (Amount of Invested Mental Effort)
► Cognitive Learning
► Knowledge Acquisition: Constructing Meaning from Multiple Information Sources
► Learning Strategies
► Mental Effort
► Multimedia Learning
► Representational Learning

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Pictures

► Pictorial Representations and Learning

Pigeon Classification Behavior

► Categorical Learning in Pigeons

PISA

PISA is the acronym for the OECD Program for International Student Assessment. Every 3 years, it assesses how far students near the end of compulsory education have acquired some of the knowledge and skills essential for full participation in society.

Place and Object Recognition

► Model-Based Scene Interpretation by Multilayered Context Information

Place Learning

► Learning Spatial Orientation

Place Learning and Spatial Navigation

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Synonyms

Spatial learning in animals; Spatial memory

Definition

Spatial navigation is the process by which organisms use multiple cue sources such as path integration, magnetic cues, landmarks, and beacons to determine the route to a goal and then travel that route.

Theoretical Background

Any animal that moves must "plan" where it is going and how to get there.

Most animals face the problem of resources, such as food or mates, being separate from the organism's place of refuge (home, nest, etc.). The animal must then acquire a *cognitive map* of its surroundings and use the information in that representation of the real world to navigate most efficiently, and safely, to and from the resource.

The demands of a spatial navigation problem are quite different than those of an animal associating two stimuli as in classical (Pavlovian) conditioning or in instrumental conditioning. It seems likely then that navigation is served by a different set of systems or modules than those used in associative learning. Indeed, such explanations have been tested in place-learning situations and found wanting. For example, on an *eight-arm radial maze* individual arms could be associated with individual stimuli, in a sort of tagging fashion, or the relationship of each stimulus around the maze to each spatial location (and to all of the other stimuli) could control behavior. The latter is the case (Suzuki et al. 1980).

Typically, multiple sources and modalities of information are used to solve navigation problems. An animal can use proprioceptive cues such as distance and direction traveled to a goal to calculate an optimal path back home. The position of the sun, or alternatively the stars, in the sky and the time of day can be used to pinpoint the spatial position an organism occupies in the same way a sailor uses a sextant (Gallistel 1993). The solar or stellar positions can also simply be used as a compass. The organism could take a sort of "snapshot" of the goal or home and store it in memory. When the animal's retinal image matches the snapshot it would be at the goal. Subtle differences in the magnetic field of the earth can be used to accurately locate a position in space (Bingman et al. 2006). The goal itself, if visible, could be a *beacon*, which the animal could direct its behavior toward. Nearby *landmarks* can indicate direction and distance to a goal. Depending on the animal, and its sensory and perceptual systems, all or some of these sources of information could be used for navigation (Shettleworth 2010).

Important Scientific Research and Open Questions

Effective navigation involves the use of a number of redundant sources of information. These sources of information are redundant because they all indicate that the goal that the organism is navigating toward, is in the same place. If you were traveling to the CN Tower (which sits at the south end of the city) in Toronto, Canada, the tower itself could act as a beacon, your sun compass would tell you what direction south is and the nearby Hockey Hall of Fame could act as a landmark, as it is across the street, just north of the tower. All of these cue types point to the same position. On a cloudy day, you can still reach the tower, even though your sun compass is not available. If you did not know about the relationship between the Hockey Hall of Fame and the tower, you could still reach the tower, due to the beacon and sun compass being available and so on.

The idea that animals rely on a number of different cue modalities makes a great deal of evolutionary sense as the above example illustrates. Certain cues will be more useful in certain situations, and differences between species should be expected based on life history and evolutionary history (Shettleworth 2010).

The most basic and perhaps most common type of cue that an animal can use for navigation is *path integration* or *dead reckoning*. This involves the animal keeping track of the distance and direction that it has traveled in any one trip. So each time the animal makes a turn it then would have to keep track of that and then reset the count of the distance traveled. This type of navigation has been demonstrated in a wide variety of vertebrates and invertebrates (Gallistel 1993). One of the problems with relying solely on such a cue is that any error that the organism makes is cumulative.

Many species as diverse as insects and birds clearly use a sun compass or stellar compass for navigation. Stars and the sun reliably indicate compass direction and can then be used for navigation. Indeed, the dance language of the honey bee, so elegantly demonstrated by von Frisch, relies on a sun compass. When honey bees find a source of food they travel back to the hive to tell their sisters (all worker bees are female) about the find. Other bees gather around as the dancer begins what is called the waggle dance. She dances in a sort of figure eight with a straight portion called the waggle and then a turn (alternatively to the left or the right) where she circles back and begins again to waggle. The angular difference between a perpendicular line drawn from the ground and the waggle portion of the dance indicates the direction of the food source. For example if the difference was 20° in the dance then the other workers would "know" that the food source's direction was 20° off from the sun. The length of the waggle phase is proportional to the distance to the food source.

Once a bee has navigated to a food source and uses cues such as solar position to return to the hive, it can precisely return to the hive by comparing its memory of the entrance to the hive (a snapshot if you will) with the image on its retina. Use of such a cue can allow rather precise short-range navigation (Shettleworth 2010).

Many species are sensitive to the ambient magnetic field of the earth. In such animals (for example, homing pigeons), it is possible to navigate over unfamiliar terrain by "knowing" what direction they are traveling in using their magnetic sense (Bingman et al. 2006).

Landmark use has been extensively studied over the past 40 years or so in a variety of species. A landmark gives both distance and direction information to a goal as noted above. Landmarks should not be confused with beacons. An animal will weight a landmark more heavily when navigating when the landmark is more salient. Salience may be determined by such factors as distance to the goal, color, brightness, size, and so on. Weightings of various landmarks may be combined in a Bayesian fashion leading to a more or less accurate navigational path (Cheng et al. 2007).

The use of the many different kinds of cues and their importance can be assessed using *dissociation* or cue competition experiments. In such experiments, the subject learns to navigate to a goal and many sources of information are available, beacons, landmarks, path integration, etc. The demands of the experiment do not include which source is to be used or is the most useful; that is left up to the subject. Once the subject has learned to successfully navigate to the goal, test trials begin. In such tests the various cues are played off against one another. So, for example, distal landmarks may indicate that the goal is in position "A" the goal itself, acting as a beacon may be in position "B," and so on. The subject then chooses where to visit and these visits are recorded. When such tests are done with no reinforcement present, it is possible to determine a rank ordering of cue use and preference in a subject. These cue preference experiments show that life history variables such as dependence on spatial memory have an effect on preferences. For example, food-storing birds, which use memory to find their cached seeds, tend to use landmarks more readily than local cues such as color when navigating to a food source (Brodbeck 1994). Species that rely on landmarks tend to have a larger hippocampus than species that rely less on spatial cues for survival.

Normally all or some (depending on the species) of these cues are used to allow accurate navigation.

Cross-References

- ▶ Animal Learning and Intelligence
- ▶ Associative Learning
- ▶ Cognitive Models of Learning
- ▶ Comparative Psychology and Ethology
- ▶ Spatial Learning

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Place-Based Education

▶ Place-Based Teaching and Learning

Place-Based Teaching and Learning

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Synonyms

Place-based education; Place-conscious education

Definition

Place-based teaching and learning are by design ▶ situated in *places*, which are spatial or physical localities that are given meaning by human experience in them or relating to them. Place-based teaching is ▶ cross-disciplinary and ▶ intercultural, informed and contextualized by the natural, cultural, and socioeconomic attributes of the places that are studied. Place-based curriculum and instruction is primarily intended to motivate students through humanistic and scientific engagement with surroundings and to promote sustainability of local environments and communities (Gruenewald and Smith 2008), and only secondarily to meet specific disciplinary standards or achievement tests (Ault 2008; Smith and Sobel 2010). To this end, place-based pedagogies commonly integrate various combinations of outdoor, field-based, ▶ community-based, or ▶ experiential learning; ▶ case-based learning, ▶ problem-based learning, service learning; and ▶ action research.

Theoretical Background

Place-based educational philosophy emerges from Indigenous (Kawagley and Barnhardt 1999) and civics education (▶ Dewey John), although the term "place-based" does not appear to have been used before the 1990s. Over the past three decades, place-based education has evolved toward an emphasis on ways to dwell sustainably in places and by extension to safeguard their sociocultural and environmental viability. The scholarship of place-based teaching and learning has primarily advanced through dissemination and comparison of empirical case studies of specific place-based educational programs, most of which have been conducted in elementary or secondary schools (Gruenewald and Smith 2008; Smith and Sobel 2010).

P

Recent work (Semken and Butler Freeman 2008; Ault 2008) links empirical studies of place-based teaching and learning to *sense of place* a construct well characterized in environmental psychology and geography theories. Sense of place comprises the set of all *meanings* affixed to and all personal or group *attachments* or bonds formed to a given place (Brandenburg and Carroll 1995). It thus encapsulates the cognitive and affective human relationships to place, and enrichment of student's and teacher's senses of place constitutes an authentic learning outcome of place-based teaching.

Important Scientific Research and Open Questions

Place-based teaching and learning is a comparatively new field; research on its efficacy and broader impacts (summarized in Smith and Sobel 2010, Chaps. 6 and 7; and Semken and Butler Freeman 2008) is still preliminary and has yielded only indirect, though affirmative, results. Relevant inferences have been drawn from studies of related pedagogical approaches, including environmental education and service learning. Preliminary findings on the outcomes of place-based or environmentally based teaching and learning include enhanced student motivation and critical thinking, more collaborative and interdisciplinary practice by teachers, more active participation by students and teachers in community-based or regional problem solving, and improved performance by students on some standardized tests (Smith and Sobel 2010).

Although these initial results are positive, they do not directly address the breadth and depth of student and teacher engagement with their natural and cultural environments. Such engagement is at once the defining characteristic of place-based teaching and learning, and a primary motivation for using it. Comprehensive and authentic evidence for the efficacy of place-based teaching should encompass both significant gain in locally situated knowledge and skills and significant enhancement of the sense of place (Semken and Butler Freeman 2008). Individual senses of place can be measured with respect to places in which a curriculum or program is situated, in terms of the fundamental components place meaning and place attachment, using published psychometric instruments. However, currently available instruments may not be fully generalizable to all places and learning contexts, so additional instrument development and validation work is needed for broader quantitative study of sense of place in place-based education. Further, some preliminary work indicates that enhancement of sense of place – as evidenced by preferential attention to place-based curriculum elements and instruction, stronger attachment to places studied, and more interaction with surrounding environments or communities – can also be coded, characterized, and assessed by means of ethnographic methods in learning environments.

Cross-References

► Case-Based Learning
► Community-Based Learning
► Cross-disciplinary Learning
► Environmental Influences on Learning
► Experiential/Significant Learning
► Intercultural Learning
► Place Learning and Spatial Navigation
► Problem-Based Learning
► Situated Learning

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Place-Conscious Education

► Place-Based Teaching and Learning

Plan

► Schema-Based Problem Solving
► Schema(s)

Plan for Learning

► Curriculum and Learning

Planning in Birds

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Synonyms

Episodic future thinking in birds; Future thinking in birds; Prospective cognition

Definition

An action taken by a bird to intentionally meet a future need independent of current needs.

Theoretical Background

Future-oriented behaviors are observed in many animals but not all of them involve future planning. Nest building and provisioning, hibernation and migration are all examples of future-oriented behaviors in which there is no evidence of planning or even of future-awareness, but rather these behaviors are controlled by changes in photoperiod, temperature, and hormones. They are fixed action patterns which are demonstrated by all members of a species. Evidence that such behaviors are heritable comes from the studies of migratory restlessness in the black-capped warbler; when a southwest migrating population were interbred with a southeast migrating population, the resulting offspring migrated due south (Berthold et al. 1992). Fixed action patterns are relatively inflexible, often extremely elaborate behaviors that have consequences in the future but for which no sense of the future by the organism demonstrating the behavior is necessary.

Exactly what constitutes evidence for future planning is much debated. Planning is a mental process that can be expressed by humans in language but which in birds must be deduced from their behavior. It has been argued that to show mental time travel into the future, an animal must confound the Bischof-Köhler hypothesis which states that animals are unable to dissociate another mental state from their present one and so are incapable of anticipating future needs or drive states (Suddendorf and Corballis 1997). The corollary of the Bischof-Köhler hypothesis is often taken to be that if an animal is being driven by a current motivational state then it cannot be said to be exercising future thinking. This is clearly not the case. As human beings, we are perfectly capable of exercising future thinking when driven by a current motivational state (e.g., I am hungry and I am going to go to the café to buy some lunch). However, it is true that if an animal can be shown to be acting for a future motivational state, then it is reasonable to deduce that this must be future planning, while if an animal shows future-oriented behavior driven by a current motivational state, then the behavior may be future planning but it may not.

Similarly, it is argued that if an animal is responding to a cue this is an associative response which does not constitute planning. However, a cued response does not exclude cognitive planning. Episodic retrieval and future planning in humans are highly dependent on cueing. Once again, if the behavior is cued, the problem is how it is possible to distinguish a cognitive from an associative response based on the behavior alone.

Important Scientific Research and Open Questions

To date, there has been very little research into the planning abilities of birds. In humans, planning for the personal future is closely linked to episodic memory. Patients with brain damage that causes loss of episodic memory are also unable to imagine anything that they personally may do in the future, although they may be capable of discussing events set in the future semantically. There is an argument that the key function of episodic memory is to direct future events, people recollect specific memories and use them to guide their behavior. Western scrub-jays have the ability to act on information provided by specific past events which could be explained by episodic memory. This raised the question of whether these birds could also plan for the future based on past experiences.

Raby and colleagues (2007) gave western scrub-jays food to cache when they were not hungry in the evening, and they cached significantly more food in a place in which they might experience hunger the following morning relative to a place in which they never experienced hunger in the morning. They also preferentially store a food in a place in which they are not given that food for breakfast relative to a food that they are given in that place for breakfast when given these foods the evening before. This behavior is both a novel action (i.e., that no associative learning can have occurred) and is appropriate to a motivational state other than the one the animal is in at that moment which meets the requirements for future planning. On the other hand, the jays may simply be caching according to a general heuristic to balance food sources, but even if the birds are operating within such a heuristic, this does not exclude the possibility that the cognitive processes that allow them to implement this heuristic involve some form of foresight.

Correia and colleagues (2007) have showed that given two foods, A and B, western scrub-jays will cache more of food A relative to food B, even if they are satiated on food A at the time of caching, and once they have learned that when they get an opportunity to recover their caches they will be satiated on food B. Scrub-jays will also re-cache significantly more cached items in new sites at recovery if they have been observed caching by other jays but not if they have cached in private, suggesting some understanding of the prospect of their caches being pilfered in the future (Emery and Clayton 2001).

These studies are suggestive that some birds have the ability to take actions for the future. As with studies of episodic-like memory in birds, however, other possible explanations for the behaviors must be eliminated before concluding that birds are capable of planning.

Cross-References

► Animal Intelligence
► Episodic Learning
► Episodic-Like Memory in Food-Caching Birds

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Planning to Learn

► Meta-learning

Plato (429–347 BC)

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Life Dates

Plato, born to wealth and trained as a soldier, devoted his life to learning. Alfred North Whitehead described all of Western Philosophy as a footnote to Plato because of the range and depth of Plato's study. Plato left behind 26 dialogues and still others have been attributed to him over the centuries. In addition some of Plato's letters are available. As a whole Plato's works fall into three distinct periods. The first period includes the *Apology* (The Death of Socrates) and *Crito*, and others that directly reflect Socrates's influence and teaching style. The middle period includes the *Theatetus* the *Phaedo*, and the *Symposium* in which Plato explored a variety of subjects beyond the beliefs attributed directly to Socrates. Plato's *Republic* is normally located in the middle period but probably includes some of Socrates' own ideas, as do other works by Plato in this most prolific period. There is a third period that includes the *Laws* and the *Statesman* produced near the end of his life that extend Plato's arguments further and involve more complicated treatments of philosophical issues. There is good reason to believe that the first book of *The Republic* presents Socrates very much as he was, questioning, paradoxical, discursive, and elliptic all at once, while the remainder of the book is much more expository. Socrates is a character in all of the dialogues save for the last major work, *The Laws*, where the role of Socrates as an interlocutor is replaced by an Athenian stranger. The fact the *Laws* lacks Socrates and contains a lengthy exposition led to the conclusion for centuries that it was not by Plato. However, close textual analysis in the nineteenth and twentieth centuries affirmed the conclusion that it is by Plato when he was in his 70s. Some scholars dispute the chronology of Plato's texts.

Theoretical Background

- "Plato's *Republic* is… the most beautiful educational treatise ever written."Jean-Jacques Rousseau (1979 [1762], p. 40)

Plato and Socrates (469–399 BCE) are bound together in the Platonic dialogues where Plato recorded Socrates' cross-examining (*elenchus*) experts in the so-called Socratic Method. In the *elenchus* Socrates shows that an apparent expert on courage, piety, love, justice, or virtue in general cannot give a definitive account of these concepts. The *elenchus* reveals that conventional wisdom and the so-called wisdom of experts lacks a solid foundation. In turn, that creates a puzzle (*aporia*), a pause for thought. Socrates may be the wisest of men because he knows that he does not know and governs himself accordingly. Plato's *Phaedo* explains the theory of the forms (*eidos*), which offers a foundation for knowledge in the unchanging, invisible, abstract concepts. We know chairs because we have the *eidos* of chair in our minds which unites the changing variety of chairs we see. The idea of chair, *eidos*, logically precedes any specimen of chair. Plato is an idealist in the sense that he regards truth as based on unchanging ideas rather than the changing and often bewildering ephemera of the empirical world. The straight line does not exist in the world of experience; it is *edios* and it exists only in the world of ideas. The *eidos* of more important and more complex matters like justice are much more difficult to grasp, all the more so in the experienced world in which we live, as illustrated in the "Allegory of the Cave" in the *Republic* wherein shadows, echoes, and reflections constitute apparent realities. We must transcend these illusions and our experiences of the physical world in order to find unchanging realities.

The theory of the forms is mentioned in many of Plato's dialogues but nowhere is it given systematic exposition, and at times he warns auditors not to take it too literally (*Theaetetus*), and he says there is no *eidos* of dirt (*Timaeus*). Plato's most famous student was Aristotle who spent much of his adult life in Athens at Plato's Academy. Though Aristotle had a detailed knowledge of Plato's approach to knowledge, Aristotle forged his own empirical approach in contrast to Plato's idealism.

The Republic offers what may be the first curriculum in Western Europe. It maps the education for guardians to protect the city in a dangerous world and to nurture philosophers to rule it. To found the ideal polity, Plato posits that any children who show promise should be taken from their parents and raised together in common. "Promise" means the most potential for the tasks of guardians and philosophers. There would be an assessment of talents very early in life, perhaps before the age of 10 years, to identify suitable guardians and philosophers. While some school systems stream students into academic, vocation, or artistic channels in the early teens, this assessment in the *Republic* would seem to occur much earlier. Plato's ambition in the rigorous education he prescribes for guardians and philosophers is to root out the unworthy before they obtain office.

The curriculum includes physical exercise, music, and mathematics. These pursuits train the body, discipline the mind, and enlighten the soul. Those who have the physical spirit (*thymos*) but who accept discipline become guardians. Those who obtain those goals but go beyond them in music and mathematics are on the road to philosophy. Music and mathematics take the mind to unchanging reality of the forms (*eidos*). Philosophers see through the illusions of the world to the eternal forms. By age 50 the education of the philosopher is complete.

The curriculum for future leaders is general education without any specific attention to constitutions, government, or politics. It is consonant with the education of the gentleman that evolved from the European Renaissance (see, for example, Locke's *Some Thoughts Concerning Education* published in 1690). In the eighteenth and nineteenth centuries the education of gentlemen as social leaders became a purpose of early universities in some parts of the world, like England and Scotland. In this context, schools taught

Greek not because it was useful, not because reading Thucydides in Greek brought the reader closer to that great mind, but rather because Greek was difficult. Precisely because it was not useful, those motivated by instrumental gains will not learn it. Only those who pursue it as an end in itself could master it and so master themselves.

Plato censors poetry and drama to protect learners from bad examples. The popular culture of drama, story, myth and legend, and poetry should be controlled so that only uplifting, positive examples exist in the curriculum. Stories that show great heroes like Achilles as lascivious, greedy, or frightened would be eliminated. This emphasis on moral content explains Plato's recommendation of censorship. This impulse for censorship remains with us in spite of a lack of convincing evidence that such examples detract from the development of moral character or leadership ability.

However, Plato returns to the ban on poets a second time, late in the pages of the *Republic*. There he says poetry "cripples the mind" (595b5) and that it is "mental poison" (608b4). Why? Consider this interpretation (Havelock 1963). Epic poems of the *Iliad* and *Odyssey* were long works to be recited to passive audiences. Memory works best when our critical faculties are still. The performer is also passive, ingesting and regurgitating the text. A recitation of the *Iliad* might take five hours. The performer who says Achilles treated his friends in such a way cannot stop to discuss the merits of that treatment nor wait while the audience does so. The memory of the performer depends on the *mnemonic* devices in the flow of the story and so must continue. Auditors do not take notes but listen with concentration to take in the story with its rich descriptions and details. An oral culture transmits the past without criticism. Because Plato rejected the past as corrupt, he also rejects the passivity it required from auditors and performers in favor of the cross-examinations of Socrates and the debates practiced at his Academy. The goal is to rearrange our thoughts in logical patterns and not in narratives.

The life of discipline of philosopher candidates is complete. Their lives are dedicated to the good of the whole in the state (Nettleship 2003 [1906]). They live in communal organizations without private property or private families. Since only the guardians and philosophers are expected to dedicate themselves completely to the state, only they need to be shorn of the distractions of private family, private life, and the private property that support the family and life, though some commentators on Plato, starting with Aristotle, have supposed the communism was general. The 50-year training and development for philosophers would eliminate the vain, ambitious, impatient candidates who would drop out along the way and find satisfaction as Guardians in a military career, or in the world of business where there is money to be made, or through the free gratification of sexual appetite.

There are several implications of the communism of the guardians and philosophers. One is that their heterosexual relations are regulated. The opportunities for procreation (sexual intercourse) are arranged and controlled. That takes the form of marriage festivals where the organizer pair-off couples for sex, matching the best with the best. Since the stability Plato prizes suggests zero population growth, the occasions for sex would be few over a lifetime. It is this management of eugenics that Plato says is most likely to fail and condemn even the best state to ruin.

Plato explicitly and repeatedly includes women among the best in the guardians and the philosophers. He says, as did Socrates, that women possess talents no less than men. He says that those women who show promise of gold or silver should be incorporated into all aspects of the education he proposes, including physical exercise. This inclusion seems out of time and place in ancient Athens. None of this fits with the social role of Greek women. That discrepancy has led some to speculate that the references to women are comic relief to distract auditors from other propositions in the *Republic*. Others have accepted the text at face value but condemn Plato for lacking the sensibility of the twenty-first century to empower women.

There can be no doubt that Plato says repeatedly that women comprise half of the talent of a people and that the talent they possess should be directed to the common good in service as guardians or philosophers. We know that the historic Socrates likewise made that case. Moreover, Plato repeated the inclusion of women in the highest offices in the last book he wrote, the *Laws*. Accordingly, we have to conclude that Plato meant what he said about women. Aristotle took the role of women seriously enough in the *Republic* to denounce it.

Contribution(s) to the Field of Learning

Plato's understanding of learning rests on many assumptions that few of his contemporaries accepted, and still fewer accept today:

- First and foremost that truths are immutable (*eidos*).
- Learning is essentially remembering from previous lives.
- Temperaments and talents are fixed in individuals to be revealed through education.
- Teaching is reminding pupils of immutable truths.

Leading students to learn means then reminding them of immutable truths they once knew but have lost sight of in the confusion and corruption of daily life. Education has several forms, starting with the elenchus to free the mind from the illusions of reality. Learning is then recovering (*anamnesis*) what is within us but which is distorted and tainted by the corruption of society. In the *Meno* a slave boy exhibits the rudiments of plane geometry; it is drawn out of him as though it were a distant, suppressed memory from a previous life. The Socratic method of questioning is intended to purge interlocutors of mistaken views, preparing then to retrieve wisdom. It is the first step into a metaphysical realm. If Socrates was satisfied to confound conventional wisdom, Plato went on to offer alternatives to it. In so doing he founded the Academy which was very successful in attracting talented individuals to it. It was perhaps the first institution of higher education in Europe. A systematic approach to curriculum emerged in the Academy some of which we see in the *Republic*. These foundations were taken further by his most talented student, Aristotle.

Cross-References

► Aristotle
► History of the Sciences of Learning
► Locke, John
► Mill, John-Stuart
► Rousseau, Jean-Jacques
► Socratic Questioning

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Play

► Learning at Play

Play and Its Role in Learning

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Synonyms

Play, development, and learning; Pretend play and learning; Role-play and learning

Definition

Play cannot be forced; it is a natural, pleasurable, and spontaneous pursuit. Primarily a creative and process-orientated expression, participants in play are carried along in an unfolding flow. It is an activity engaging intense concentration, enabling a structured interaction between an individual's inner and social worlds. The agility and abstract capacity of the mind is often evident in play; for example, when we use selected objects at hand to play out an imagined story. Often a cooperative, social endeavor, rich in momentarily shared meaning, play may be framed within structured rules and goals, although never fully constructed by conscious design.

The role of play in learning has been most striking in early childhood education. In this formal educational context, play, learning, and development form an intimate nexus. Educators harness the playing child's qualities (intense concentration, motivating pleasure, and creative aptitude for generating meaning) to engage in activities intended to achieve implicit learning outcomes. With designed materials and targeted guidance, educators facilitate play as an unfolding process. As a result, the learning outcomes associated with play in early childhood range across: the physical (motor skills, particularly in infant repetitive play), the social-emotional (interaction skills, increasing range, and control of emotions), the linguistic (language building and symbolization), the cognitive (problem solving, divergent and flexible thinking), as well as the personality structure as a whole. In the play process, learning across domains is often synchronous and interrelated.

The role of play in adolescent and lifelong learning has also recently attained substantial interest. As reproductive vocations give way to creative, design-oriented vocations in the twenty-first century, creativity and imagination are now recognized as key learning outcomes. Increasingly acknowledged as an essential psychological quality active throughout the life span, play is being incorporated to target these learning outcomes across subject domains at secondary and tertiary levels.

Theoretical Background

The recognition of the role of play in learning has its roots in antiquity. The Greeks and Romans keenly observed that play was no idle effort, but the beginnings of learning. Since then, many writers on education, such as John Locke, Jean Jacques Rousseau, Johann Heinrich Pestalozzi, and Friederich Froebel, have extolled the beneficial role of play in learning. They advised channeling the spontaneous playful interest expressed by the child into educative interests through targeted materials and guidance. With the advent of psychology, the process of child's play became an object of scientific study. The behaviorists soon realized the universality of play amongst the higher primates (including humans), but it was the psychodynamic and particularly the cognitive schools who have had the greater impact influencing educators use of play as a means of learning. We will briefly summarize some of the more notable influences and mark their contribution by developmental domain.

Sigmund Freud, a psychodynamic pioneer, maintained that play was driven by primary process thinking (pleasure-seeking or wish-fulfilling thoughts) in the infant and early child. As secondary process thinking (reality-adapted thought) takes over, play activity recedes from conscious occupation to the distance of our fantasies or nightly slumber, where it awakens in the adult's dream activity. Play is a temporary outlet for frustrated demands (often originating from thwarted desires in social interactions) in the child and an avenue for negative emotions to find cathartic release. Carl Jung expanded the Freudian notion of the personal, wish-fulfilling unconscious, arguing it was also the source of creative symbolization. He maintained that play is the concretizing of the creative symbolic process. These symbols are spontaneous images whose sequence forms an inspiring flow guiding the child in the play activity. As the language and abstraction capacity of the child develops, creative symbols may be held and "played out" within one's mind without the reliance on external expression. Play does not recede into only dreams, but rather becomes allied to the bourgeoning abstracting capacities. For Jung (1977), play extends into the design and creative abilities in adulthood. He advocated that whenever one is creatively stuck, they should return to this earlier developmental act of concrete play and reenergize psychologically. Play is part of the innate creative capacity carried through the life span and should be supported as such by education.

It is the cognitive theorists who ventured furthest in examining the developmental states of the child to more fully explicate the play process within the nexus of learning and development. Jean Piaget's ideas influenced a generation of researchers and educators. He understood play as an early activity in the sequence of cognitive development. Following Freud, Piaget (1951) saw the child's playful satisfying of inner wishes as a temporary bridge to the world; a stop-gap awaiting the capacity for realistic thought to emerge. The latter increasingly takes over to the diminishment of play activity. Educators are to offer learning environments which support this transition. Cognitive play is of only partial learning use as it operates in an overbalance of assimilation over accommodation (the two should be roughly balanced for maximized learning). Piaget identified three types of play, each broadly situated within a cognitive stage of increasing sophistication: Practice play, where body movements are repeated (0–2 years, sensorimotor stage), symbolic play, where objects can carry the symbolic meanings placed upon them by the child (2–7 years, preoperational stage), and games with rules, where logical structure and play meet (7–11 years, concrete operational stage).

The Piagetian view has come under criticism originally from Vygotsky (1987) and, more recently, for example, by Russell Meares (2005) and Paul Harris (2000). Vygotsky maintained that the psychological qualities expressed during play were not shed and replaced as realistic abilities emerged, but rather they became integrated with existent realistic thought processes culminating in our ability for creative imagination and higher order thinking. His often-cited example is that of a horse being represented by a stick in a pretend play scenario, demonstrating how children use external objects as pivot points to lever the mind into higher abstraction. When the child no longer needs the stick to hold the abstraction of the horse in mind, a higher level of functioning has been attained. Assisted by increasing faculties of symbolization and language, what was external and social has become internalized at a higher level of functionality. Abstract thinking does not develop from the disappearance of play and pretence but is enabled and mediated by them.

Vygotksy also acknowledged the important role of joint attention in play between children or between the child and the participating adult. Through verbal and nonverbal communication in shared engagement, a rich social, developmental field is generated. Such mutual engagement and interaction encourage social awareness in children and models communication of their inner thoughts.

Psychodynamic and cognitive researchers have highlighted the role of play in children's development and learning across a range of domains. In Freud's perspective, play, allowing the release of frustrated energy and imaginary wish-fulfillment, assists with social-emotional development. Influenced by Freud, Piaget views play as a necessary transition in the development from unrealistic, irrational to realistic and logical thinking. Piaget's stage theory of play outlines its functions in sensorimotor, linguistic, and cognitive development. Contrary to Freud and Piaget's stances, Jung and Vygotsky argue for play's essential role in the emergence of the creative imagination as part of overall personality development. According to Jung, play and creativity are both expressions of inner symbolic contents, the former is a concrete acting out, whilst the latter is more a product of the mind. Both are valid expressions throughout the life span. According to Vygotsky, the use of external tools or signs in pretend play mediates their internalization into becoming tools of abstract thought. It is from the synthesis of these internalized tools (which allow us to hold the outer world in mind) with unrealistic thought that the creative imagination arises.

The explication of specific developmental functions of play in the physical, social-emotional, linguistic, cognitive, and personality traits drawn from the above developmental articulations (and many others) have assisted educators in the design of curriculum, materials, activities, and environments, and to refine their guidance to the playing child in the attainment of specific learning and developmental outcomes. Play-based activities are routinely used by educators as a window onto attainment of learning and development, giving them confidence to distinguish when their students are learning, rather than merely being entertained.

More recent research in early-child education has moved to include a praxis orientation, collecting data from direct observation of and involvement in education contexts (early-child centers, kindergarten, and classroom). Educators are increasingly participating as codevelopers and explicators as they trial evidence-based research into the design of curriculum, materials, and classroom environment. This has seen an emergence of descriptive accounts of play-based characteristics in contrast to the developmental explications above. A commonly examined design type is that of the emergent curriculum. The emergent curriculum uses a broad curriculum outline, within which sits the path of play as a fluid process, contained by the guidance from adults, the environment, and the materials available. The actual learning sequence itself is not predetermined as the child is not yet receptive to complex learning instructions; instead, it emerges as the process plays out. The setting up of the environment, design of materials, and the planning, monitoring, and responding by the educator all come together to assist the learner toward a meaningful emergent process.

The usefulness of play has also become recognized as an essential element of lifelong learning. As can be drawn from the theoretical discussion above, there are two competing strands in the question as to the trajectory of play in lifelong learning. The Freud–Piaget strand understands play to be a temporary, all be it useful, phenomenon belonging to childhood. In contrast, the Jung–Vygotsky strand advocates for play as an outward expression of the creative act and an essential phenomenon throughout the life span. In the traditional education paradigm, play has had acceptance beyond early childhood in only the performative disciplines such as drama, music, and sport, and was largely excluded from most other disciplines. The link between creativity and play evident in the Jung–Vygotsky strand is increasingly espoused by the very active research fields of creativity and imagination. For example, Harris (2000) and Robinson (2001) advocate play as a necessary ingredient to adult creativity, and they lament the wastage present in education, particularly in high schools, where creative adolescents are daily frustrated by curricula and practices alien to their abilities and needs.

Important Scientific Research and Open Questions

There is growing interest in the implications for education from the rapidly advancing field of cognitive neuroscience. Infant and early-child brain studies (and animal studies) have suggested the existence of sensitive windows of development. Although these implications are yet to reach consensus, there is a growing voice arguing that the design of educational contexts and materials should explicitly support the biological developments being detected. The hypothesis being that a child needs exposure to a conducive environment to attain proper brain development. Assessing the validity of these implications is complex for neuroscience detects on a cellular level and any explication to the social-mental level is not straightforward (Wood and Attfield 2005, pp. 64–65).

Cross-References

▶ Cross-cultural Learning Styles
▶ Developmental Cognitive Neuroscience and Learning
▶ Imaginative Learning
▶ Learning at Play
▶ Learning Environments
▶ Learning with Games
▶ Play, Exploration and Learning
▶ Playful Learning Environments – Effects on Children's Learning

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Play, Development, and Learning

▶ Play and Its Role in Learning

Play, Exploration, and Learning

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Synonyms

Curiosity; Diversive exploration; Ludic behavior; Specific exploration

Definitions

Play and exploration have been defined in various and contradictory ways, sometimes not even distinguished from one another. Here we will view exploration as information gathering about environments and objects within them involving orientation and sensory/perceptual sampling. Play is viewed as interaction with environments, objects, and other animals in which repeated, incompletely functional behavior differing from more serious versions structurally, contextually, or ontogenetically, are initiated voluntarily when the animal is a low stress setting. Typically, exploration is considered to be a precursor of play. Both play and exploration have been considered to be important means for animals to learn in ways not tied to traditional reinforcement or reward mechanisms utilized in instrumental and Pavlovian conditioning.

Theoretical Background

Exploration and play can certainly provide contexts in which learning occurs in the natural world of animals as well as in the laboratory, where learning is more typically studied. But the role of both these phenomena in the science of learning has been problematic and controversial. Let us start with exploration. Today we realize that exploration as a means to gain information about the environment and objects within it is ubiquitous among animals of all types from cockroaches to cockatiels. Even amoeba and bacteria can be described as engaging in exploration. Does not most movement by an organism potentially provide opportunities to gain information on potential food, danger, safe retreats, mates, and so forth? And if any of this information is retained and used subsequently, some changes in the organism, including learning, had to take place.

For early learning theorists focused on the importance of primary drive reduction in virtually all learning, exploration did not fit the conceptual scheme, however. It was not until the classic experimental demonstrations of Montgomery, Harlow, Robert Butler, William Dember, and others, beginning about 1950, on curiosity and exploratory based learning in monkeys and rats that the primary (food, water, sex) and secondary drive/reinforcer analysis of all animal learning became untenable. The earlier latent learning experiments of Tolman, whereby rats allowed to explore a maze without any food or water reinforcement later learned to run the maze for food much more efficiently than rats not given such experience also helped fuel this reassessment. While initially the explanations of exploratory behavior used concepts borrowed from traditional learning theory such as exploratory drive or stimulus hunger, currently more cognitive approaches hold sway. Thus, discrepancy reduction is viewed as important as any biological exploratory drive or need (Power 2000). As well, optimal stimulation, arousal, and stimulus satiation may be involved. Thus, experiments have documented that rats will learn a novel task or "work" just to change the level of ambient illumination in their cages. In any event, it is now clear that many animals across the phylogenetic spectrum will learn merely to have access to novel environments, objects, odors, and so forth as a "reward." In fact, in strange environments even very deprived animals will explore prior to eating or engaging in other primary biological behaviors, such as nest building.

A number of theorists discussed this major transition in the concept of motivation induced by such demonstrations, including Hebb and Leuba, but perhaps the most seminal theorist from this early period was Berlyne. In a series of books and papers in the 1950s and 1960s (e.g., Berlyne 1960), he attempted to both integrate the field and set the stage for much research. One of his main points was to classify exploration and play into the single category of *ludic* behavior. Exploratory behavior was called *specific* exploration whereas play was *diversive* exploration. For Berlyne and some others, play and exploration were too difficult to distinguish. Others disagreed. Unlike theorists, however, most students of play behavior are reluctant to combine exploration and play, as by doing that one may be prone to neglect some essential differences. However, early in life, as with human infants, it is often difficult to clearly distinguish one from the other (Burghardt 1984).

Play has had a much more checkered and diverse history. While early writers on play in the nineteenth century, for example, had little problem labeling behavior as play in all sorts of vertebrate and invertebrate animals, by the mid-twentieth century play was considered the domain of "higher" animals such as warm-blooded mammals. Even birds were dismissed as playing by many comparative psychologists and ethologists even into the 1970s! Play was the prerogative of large-brained intelligent animals and a primary means of learning, practicing behaviors in infant and juvenile periods that would be important in survival as adults. Prolonged parental care then was needed for animals to have the chance to learn survival skills given that instincts, if they did exist at all, were certainly of minimal importance to advanced mammals, especially human beings.

Today we know that this view is suspect on both grounds. First, there is increasing evidence that play can occur, albeit spottily, in all vertebrate classes (e.g., fish, reptiles) and also many invertebrates (cephalopods, insects). Second, the view that play functions in fostering survival through learning specific skills is actually very difficult to document. To reach these newer conclusions it was necessary to have improved means to identify play wherever it occurred. For the first, this meant being able to free oneself from the assumption that play was only to be looked for in mammals and perhaps birds and identified by loose criteria that were more anthropocentric than objective. For example, identifying play with "fun" is easier to apply to a dog than a turtle or fish. And of course, everything that may be pleasurable is certainly not play (Burghardt 2005).

For the second, that play is a means of learning, the story is a bit more complex. Although the current view among many developmental psychologists is that play facilitates learning and may even be the main way by which many animals, including human children, gain, maintain, and hone various cognitive and social skills (Pellegrini 2011), research is actually quite thin (Power 2000; Burghardt 2005). Part of the problem is the lack of clarity on the meaning of play and the need to recognize that play occurs in different contexts, many of them not necessarily related to learning or other types of functional benefit. Or, it could be said, the benefits of play may not be related to learning in any traditional sense. Thus, play could indirectly benefit animals by providing exercise benefits, enhance perceptual-motor skills, or social competence, rather than provide specific skill enhancement as early theorists claimed. For example, kittens who engage in predatory play with toy mice are not better mousers than those deprived of such experiences. Similarly, the widely studied play fighting in laboratory rats may enhance social skills involved in mating and courtship more than increase serious fighting abilities. A close look at the dynamics of the movements involved in play reveal rather subtle experiential effects. Given the wide variety of play types and play contexts within and between species, it is unlikely that general principles of play and learning will be found. Rather, the way learning enters in specific types of play, such as sociodramatic, construction, climbing, video games, etc., needs to be evaluated with empirical research. Thus, claims that play is the best avenue for learning, or that play is a waste of time or inefficient in promoting learning, are both suspect.

One way to conceptually resolve the issue of play and learning is to recognize that within the same species and individual, play may operate with different "rules" and outcomes. For example, primary process play is play which is the by-product of other processes and has not been "designed" for any function whatsoever. Lack of sensory stimulation, immature behavior, low levels of motivation, and so on can lead to behavior with no clear adaptive function. This could lead to some types of play being necessary for normal development or maintenance of physiological, behavioral, and neural systems. This is termed secondary process play. Tertiary process play is that in which play is an important facilitator of enhanced behavioral functioning and even in the creation of novel behavior. Thus, a prediction would be that animals that can perform more actions, and more complex actions, would be more likely to develop more complex cognitive and behavioral capacities. Similarly, endothermic animals that are capable of prolonged vigorous behavior would be more likely to, through play, combine motor actions in novel ways in interacting with objects and social stimuli. However, systematic research on such topics is in its infancy.

Important Scientific Research and Open Questions

One of the most current and topical aspects of research into both exploration and play in vertebrate animals is the role of the brain. We now know that neither overall brain size nor "intelligence" is needed for either phenomenon. The recent work of Jaak Panksepp, Sergio Pellis, and others on the neural mechanisms underlying play, learning, and addictions is untangling the complex, but illuminating threads, especially with social play (Pellis and Pellis 2009).

In past years a primary means to test the importance of play was to deprive animals of play, either social or object, and then test their competence later in life. Most play-deprivation studies led to equivocal results, since it is hard to deprive an animal just of play without affecting other aspects of behavior. Today, more sophisticated methods are starting to be employed where the goal is not to have animals play or not play but to target and control the specific play experiences and assess the effects experimentally. For example, one can raise a target animal with another one which is itself more or less playful.

Cross-References

- ▶ Anticipatory Learning
- ▶ Creative Inquiry
- ▶ Curiosity and Exploration
- ▶ Epistemic Curiosity
- ▶ Innovation and Learning Facilitated by Play
- ▶ Play and Its Role in Learning
- ▶ Playful Learning Environments

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Playful Learning Environments: Effects on Children's Learning

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Synonyms

Innovative learning environment(s); Technology-enriched playground(s)

Definition

The term "playful learning environment(s)" (PLE) denotes ▶ an innovative, technology-enriched play and learning environment whose components are located indoors as well as outdoors. Learning in such an environment takes the form of content creation and engagement in physical games and play. As a theoretical construct, the PLE embraces a ▶ technology-enriched playground complex that serves education and affords multiple forms of mind-on, hands-on, and body-on learning activities. *Playful* describes the attitude toward learning in the PLE as well as the nature of participation in that environment. Learning activities in the PLE encompass designing content for playground activities, playing games on the playground, and engagement both indoors and outdoors in other creative and playful learning activities enhanced by technological tools.

Theoretical Background

Although the term "playful learning environment" has been used in some scholarly studies, particularly in the context of technology-related learning environments (e.g., Price and Rogers 2004), it is comparatively rare in the scientific literature. Resnick (2003) uses the term "playful learning" in contrast to "edutainment," which usually refers to the sugarcoating of unpleasant learning tasks. The pedagogical conception of the PLE as including a technology-enriched playground derives from a collaborative effort of Finnish researchers from different disciplines such as education, physical exercise, technology, and industrial design during the years 2003–2006 to develop an innovative outdoor playground complex for the children of the twenty-first century (e.g., Hyvönen 2008; Kangas 2010b). Pilot playful learning environments consisted of a novel playground facility located in the schoolyard and enhanced with RFID (radio frequency identification device) technology. The affordances of the environment were subsequently extended to the classroom, providing tools, including the Internet, through which students could themselves create content and design games (Fig. 1).

Today, the PLE is understood as a physical, pedagogical, intellectual, socio-emotional, cultural, and media-rich learning environment (Kangas 2010b). This view adheres to the definition of a learning environment by Barab and Roth (2006) in that the PLE is regarded as an entity that evolves in educational practices within affordance networks, facts, concepts, cultural tools, methods, people, commitments, and goals. As a physical environment, the PLE is an indoor as well as an outdoor complex that integrates not only modern technology with outdoor spaces, but also outdoor spaces, such as playgrounds, with computers in the classrooms. In this respect, the PLE extends the classroom and school — as a formal education setting — to include outdoor, technology-enriched playgrounds situated in the schoolyards. As a pedagogical environment, the PLE is a theoretically and pedagogically defined learning

Playful Learning Environments: Effects on Children's Learning. Fig. 1 A playful learning environment

site that can be used in curriculum-based education. Pedagogical models elaborated for the PLE provide tools that enable teachers to design and use playful learning environments in educational practices (e.g., Hyvönen 2008; Kangas 2010a, b).

The value of the PLE as an intellectual learning environment lies in its support for cognitive and academic achievement. Mathematical games on the playground are one example of game-based learning that serves cognitive efforts and academic goals. As a social learning environment, the PLE accommodates all of the participants involved in the play, design, and learning processes; that is, children, teachers, and parents. Where emotional learning is concerned, the primary aim of the PLE is to produce joy associated with activity, play, and learning; it also advances the aims of overall satisfaction and well-being. As a rich media environment, the PLE provides technology, software, and Internet-connected spaces that together constitute a forum for sharing and cocreating knowledge and game content on virtual networks. The PLE is seen as an entity that enables learners to actively take part and use technological tools in learning; they may play ready-made game applications using the whole body, use game creation tools for designing curriculum-related playground activities, and integrate media elements such as digital pictures into the game design process. The PLE is continually transformative in terms of technology and media resources in that it provides affordances for users' own content design and creation of global learning network. It meets the challenges of the future school, because it affords learners a meaningful learning environment that integrates academic subject matter, technological tools, pedagogies, and learning communities. The environment also serves informal learning and provides affordances for crossing the boundaries between formal and informal learning.

The nature of learning in the playful learning environment is multifaceted. Learning in the context of the PLE is based on thinking, doing, and physical activities; in other words, mind-on, hands-on, and body-on activities (Kangas 2010b). Creative learning and playful learning — two key components of learning in the PLE — provide a way to define learning activities in what is a complex learning context (Kangas 2010b). Creative learning (CL) describes any learning where knowledge is built, applied, and used creatively. It refers to learning and design activities whose aim is to cocreate knowledge, content, and artifacts, such as media products or games, for play and gameplay on a playground. Playful learning (PL) encompasses learning activities that are based on play and physical game playing; it encourages physical activities and embodiment. New technology and its affordances are essential in the PLE: technology is not only harnessed for play and games but is increasingly seen as a tool to tap the creative potential of learners, who actively construct knowledge and develop artifacts, that is, external representations of the created knowledge (Krajcik and Blumenfeld 2006). By designing artifacts such as curriculum-based play and game content, children can create and recreate their understanding and find a meaningful way to take part in their learning activities. It is anticipated that learning outcomes in playful learning environments will be as multifaceted as the environment itself: they are expected to contribute to academic achievement, thinking skills, physical skills, participative skills, media skills, and knowledge cocreation skills (Kangas 2010a, b).

Important Scientific Research and Open Questions

The development of the PLE is contingent on commercial innovations, physical playground products, and advancements in that sector. SmartUs, a technology-enriched playground entity pioneered by Finnish playground manufacturer Lappset Group Ltd. (www.lappset.com), represents the first step in playful learning environments of the future. SmartUs has evolved in step with multidisciplinary research and development work on playful learning environments. Although theory and practice are still far from each other in practical PLE development, the experiences are encouraging (Kangas et al. 2010). The studies have shown that the PLE not only enables the integration of physical activity, play, and learning, but also creates a meaningful context for integrating creativity and informal learning with curriculum-based learning (Hyvönen 2008; Kangas 2010a, b). Thus far, research findings on playful learning environments and their effects on children's learning are scanty due to the novelty of innovation-oriented educational practices. Further research is needed to better understand learning in playful learning environments where learning has many values alongside academic achievement.

Cross-References

► Creative Inquiry
► Innovation and Learning Facilitated by Play
► Learning with Games
► Play and Its Role in Learning
► Play, Exploration, and Learning
► Technology-Enhanced Learning Environments

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Polarization

► Social Influence and the Emergence of Cultural Norms

Policy Search

A general approach to finding optimal actions in a decision problem (the policy) that directly looks for better policies by gradually altering the current policy. For instance, raising the probability that an agent executes an action because that action gives better results is a way to implement policy search.

Population Learning

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Synonyms

Genetic algorithms

Definition

Population learning refers to the process whereby a population of organisms evolves, or learns, by genetic means through a Darwinian process of iterated selection and reproduction of fit individuals. In this model, the learning process is strictly confined to each organism's genetic material: The organism itself does not contribute to its survival through any learning or adaptation process. Typical implementations of population learning, including the one outlined in this work, employ genetic algorithms.

Theoretical Background

In the natural world, a large number of organisms are born with innate abilities embodied in their genetic makeup. An accepted process for the development of these abilities is that of natural selection, as proposed by Darwin (1859I). Individuals that are well adapted to their environment are more likely to survive to reproduce and impart these abilities to the next generation through the transmission of genetic material. Over time, traits that are useful to a species become established in the population.

The process of natural selection can be seen as a learning mechanism applied to a species as a whole and is often dubbed population learning. While individuals within the species do not explicitly learn to adapt to their environment, the emergent properties of natural selection ensure that future generations are better suited to their environment than previous ones. The process of natural selection is, however, extremely slow, requiring many generations to react to environmental changes.

Genetic predisposition, or innate behaviors acquired through inheritance of genetic material, is not the only form of learning that takes place in the natural world. In order to survive, many organisms acquire the ability to alter their behavior over time to take advantage of, or to adapt to, environmental factors. This ability, identified as lifetime learning, allows an organism to build on previous experience in order to react appropriately to a particular situation it encounters in its environment. If certain behavior leads to an unfavorable outcome, the organism will alter its behavior so that the next time it encounters similar circumstances it is capable of responding differently. Thus, an organism's behavior during its lifetime (its phenotype) can be altered over time such that at the end of its life, its responses do not necessarily correspond to the inherited innate behavior derived from its genetic material (its genotype).

The relationship between population and lifetime learning has been the focus of interest even before Darwin's theories were published. Jean Baptiste Lamarck developed an evolutionary theory (now referred to as Lamarckianism) that proposed that an individual's lifetime adaptations were re-assimilated into that individual's genetic material (Lamarck 1809). In other words, an individual's genotype could be altered by its lifetime experiences. The consequences of this are that any lifetime adaptations are directly inheritable by the next generation. Lamarck's theories have since been largely discredited, although a large body of work exists examining Lamarckian evolution in populations of artificial organisms (Grefenstette 1991; Ackely and Littman 1994; Yoshii et al. 1995).

Important Scientific Research and Open Questions

Although it has been shown that individuals do not directly inherit lifetime experiences from their parents, an alternative theory posits that lifetime adaptation has nevertheless a significant effect on genetic evolution. A phenomenon related to lifetime learning, first reported by Baldwin (1896), occurs when certain behavior discovered through lifetime learning becomes imprinted onto an individual's genetic material through the evolutionary processes of crossover and mutation. To quote Hinton and Nowlan (1987) whose model was the first to demonstrate this effect through simulation, "learning can provide an easy evolutionary path towards co-adapted alleles in environments that have no good evolutionary path for non-learning organisms." This does not mean that abilities developed during an individual's lifetime are directly encoded onto its genome, as in Lamarckian theory. Rather, these abilities are eventually genetically encoded through the ordinary Darwinian process of natural selection.

The process works in two steps: firstly, lifetime adaptability allows an individual to adapt to its environment by developing a particular behavior. However, lifetime learning is typically associated with a certain cost (the consumption of time and energy). Therefore, a second step is required where, given enough time, the evolutionary process may find a rigid mechanism to replace the plastic adaptive one. In other words, the adaptive behavior becomes genetically innate. Individuals born with an innate ability do not need to acquire it during their lifetime, economizing on time and energy, and are therefore more likely to be reproductively successful, leading to a dissemination of the trait across the population. The Baldwin effect relies on the existence of lifetime adaptability and indeed, lifetime learning can be said to be guiding the evolutionary process.

Cross-References

► Adaptability and Learning
► Adaptive Learning Through Variation and Selection
► Biological and Evolutionary Constraints of Learning
► Evolution of Learning
► Evolutionary Learning and Stochastic Process Algebra
► Lifelong Learning

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Populations, Learners, or Students Who Are Disadvantaged, Educationally Disadvantaged, Low Achieving, and Underachievement

► At-Risk Learners

Port Number

A port number is a 16-bit unsigned integer, ranging from 0 to 65535. Ports are used to send and receive data from one computer to another. For example, HTTP protocol usually uses port number 80 or 8080 to send and receive data, RTSP uses port number 554, MMS uses port number 1755, and RTMP uses port number 1935 to send and receive data.

Portfolio

► Self-Reflecting Methods of Learning Research

Position

► Attitudes – Formation and Change

Positive Emotions and Learning in School

► Well-Being and Learning in School

Positive Evidence

Positive evidence is the well-formed sentences or "models" which learners are exposed to.

Positive Punishment

► Punishment and Reward

Positive Reinforcement

When this stimulus appears repeatedly after the performance of a behavior it increases or maintains the frequency with which this behavior takes place and, if it disappears, then the response reduces the frequency of its appearance. For example, the money of our salary maintains our working behavior.

Cross-References

► Punishment and Reward
► Schedules of Reinforcement

Post-conditioning Devaluation

Reducing the value of a stimulus after it has been used to generate a Pavlovian or instrumental response. Most often, the stimulus is food, and it is devalued by pairing it with illness, although satiation has also been used for this purpose. Effects of post-conditioning devaluation demonstrate a mediating role for the devalued stimulus in generating behavior. The procedure has been used to demonstrate Pavlovian stimulus-stimulus learning and instrumental response-outcome learning.

Posttraumatic Growth

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Synonyms

Adversarial growth; Benefit finding; Perceived benefits; Stress-related growth; Thriving

Definition

Posttraumatic growth is defined as a positive change in people that occurs in the aftermath of traumatic events. Posttraumatic growth has also been described as a process that may occur not only in individuals, but in larger groups or even societies. Richard Tedeschi and Lawrence Calhoun introduced the term "posttraumatic growth" in a 1995 book entitled "Trauma and Transformation: Growing in the Aftermath of Suffering," and in a 1996 article that described a quantitative measure called the Posttraumatic Growth Inventory (PTGI).

Theoretical Background

Posttraumatic growth has been described as both a process and an outcome, referring to the fact that although specific changes in the aftermath of trauma can be specified, they occur over a period of time, as people respond to the challenges to their system of core beliefs due to a traumatic experience. This traumatic event has been described as psychologically "seismic," in that it creates havoc in the set of assumptions people have relied upon to guide their lives, and upon which a life narrative has been based. The idea that this "assumptive world" of trauma survivors has been shattered is found in the work of Ronnie Janoff-Bulman.

Posttraumatic growth is comprised of five general domains of positive change: relating to others, appreciation of life, personal strength, new opportunities, and spiritual change. These five domains were derived from the original factor analysis of the PTGI and have since been confirmed. Relating to others represents the tendency to develop closer and emotionally deeper relationships. Appreciation of life refers to a tendency to value living life and the recognition of the importance of the fundamentals of living. Personal strength involves a recognition that in enduring trauma, one has exhibited more strength than was previously appreciated. New opportunities involve the opening up of life pathways that were not previously considered, perhaps because other opportunities were lost. Spiritual change involves development of new perspectives on religious and spiritual matters.

The modeling of the process of posttraumatic growth was first attempted by Tedeschi and Calhoun (1995). Various iterations of the model of posttraumatic growth have produced the most recently published model (Calhoun et al. 2010). This model describes the interplay of several variables as central to the likelihood of PTG developing post trauma. These variables include (1) cognitive processing, engagement or rumination; (2) expressing or disclosure of concerns surrounding traumatic events; (3) the reactions of others to self-disclosures; (4) the sociocultural context in which traumas occur and the attempts to process, disclose, and resolve trauma take place; (5) the individual dispositions of the trauma survivor and the degree to which they are resilient. The process of posttraumatic growth also has been described by Janoff-Bulman (2006), who has proposed three kinds of posttraumatic growth processes: strength through suffering, existential reevaluation, and psychological preparedness. The latter emphasizes the strength of the rebuilt assumptive world to withstand future shocks to the system, an inoculation of sorts that can be understood using a metaphor of how communities rebuild more resilient structures in the aftermath of earthquakes. Andreas Maercker has described a "Janus-faced" or two-component process of posttraumatic growth that includes an initial coping function to produce psychological comfort and a later constructive or transcendent function. Work by Lykins and colleagues suggests that processing that elicits posttraumatic growth may vary according to qualities of the goals individuals have, e.g., intrinsic goals (building interpersonal relationships, improving the world), as opposed to extrinsic goals (making money, improving one's appearance). Movement toward growth appears to be an interaction between tendencies toward more mature existential approaches to living and kinds of emotional-cognitive processing.

Posttraumatic growth is distinctive from resilience in that very resilient persons are unlikely to experience much challenge to their assumptive worlds or core beliefs, and therefore show little growth as they recover well or resist the influences of traumatic events. Posttraumatic growth may produce cognitive structures that are more resilient to future traumas. Posttraumatic growth is similar to "benefit finding," a construct that is commonly discussed in the health psychology literature, although posttraumatic growth focuses more on personal transformations of beliefs than benefits that might not represent more global change, such as certain health behaviors such as reducing sugar intake or stopping tobacco use.

Important Scientific Research and Open Questions

The PTGI is a 21-item Likert-format scale that was developed out of reviews of previous reports of these growth experiences that had appeared from time to time in the literature (Tedeschi and Calhoun 1995, 1996). The traumatic events that have produced reports of posttraumatic growth include natural disaster, serious illness, accidents, combat, and other crises or threatening events (Calhoun and Tedeschi 2006). The PTGI is the most commonly used measure of posttraumatic growth. It has been used in investigations of many different kinds of traumas, yielding some variation in mean scores depending on type of trauma and the culture of respondents. Women report somewhat more growth than men. There have been few studies of posttraumatic growth in children, and measures for use with children have only recently appeared (Calhoun and Tedeschi 2006).

The PTGI (Tedeschi and Calhoun 1996) and some similar instruments that measure growth in the aftermath of negative events (e.g., the Stress-Related Growth Inventory of Park) have been challenged as perhaps biasing respondents to exaggerate growth by asking only about positive changes. In response, researchers have created versions of the PTGI that also include items that ask about negative changes in the aftermath of events. In two such reports, positive changes were reported much more often than negative changes. Another challenge to the concept and its measurement has come from those who assert that there are difficulties involved in remembering oneself and comparing the present version of oneself with a past version, as required in self-reports of posttraumatic growth. A response to these issues can be found in Aspinwall and Tedeschi (2010). They point out that studies have demonstrated that family members can corroborate posttraumatic growth in others, that social desirability is unrelated to reports of growth, that people who report growth also report negative events, and that trauma can be a clear temporal marker for people, allowing them to make contrasts about life before and after such an event.

Posttraumatic growth interventions are being developed. Tedeschi & Calhoun have described a general clinical stance called "expert companionship" that they assert is constructive in facilitating posttraumatic growth (Calhoun and Tedeschi 2006). More structured approaches for larger populations may be possible, and such approaches may have common elements that follow the model of posttraumatic growth process while varying the content of intervention to account for the particulars of traumatic events.

Cross-References

► Altruism and Health
► Experiencing Wisdom Across the Lifespan
► Metacognitive Processes in Change and Therapy
► Schema Therapy

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Postural Synchrony

► Mimicry in Social Interaction: Its Effect on Learning

Potential Affordances

Potential affordances are environmental dispositions that are used to realize the former under certain conditions.

Potential Opportunities

► Affordance and Second Language Learning

Practical Learning

► Laboratory Learning

Practice

► Deliberate Practice and Its Role in Expertise Development

Practice and Play in Developing Expertise

► Expert Perceptual and Decision-Making Skills: Effects of Structured Activities and Play

Practice-Based Learning

► Workplace Learning

Practicum

► Learning in Practice and by Experience

Practitioner Research

► Action Research on Learning

Practitioner-Based Research

► Action Research on Learning

Practitioner-Led Research

► Action Research on Learning

Pragmatic Reasoning Schemas

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Synonyms

Deductive schemas; Deontic reasoning; Linguistic-based reasoning

Definition

Pragmatic reasoning schemas are linguistically based contextual schemas that have an underlying structure that is determined by people's interpretations of classes of events. This structure determines the kinds of inferences that people make with different schemas corresponding to different logical patterns.

Theoretical Background

The notion of pragmatic reasoning schemas was first proposed by Cheng and Holyoak in 1985 as a way of synthesizing research into the Wason selection task. This is a reasoning task proposed by Peter Wason in 1965 as a way of showing the difficulty many educated adults have in reasoning according to the rules of logic. The standard task presents people with a conditional rule, of the form "If there is a vowel on one side of the card, then there will be an even number on the other side". They are then shown four cards which have (1) a vowel, (2) a consonant, (3) an even number, (4) an odd number on the visible part of the card. People are then asked which cards they need to choose in order to potentially confirm or disconfirm the conditional rule. The logically correct response would be to choose card (1) and (4) since this allows the possibility of disconfirming the conditional rule by finding a card which has a vowel on one side but does not have an even number on the other side. Even very highly educated adults get the logically correct response very seldom, with success rates often close to 10%. Initial research into this task focused on the potential facilitating effect of using familiar conditional rules. However, in some studies, use of familiar rules resulted in significantly higher rates of logical responses, while in others it had no effect. For example, a rule such as "if you want to drink alcohol in a club, then you must be more than 20 years of age" leads to very high rates of logical responses, while a rule such as "if you throw a rock at a window, then the window will break" does not. Cheng and Holyoak proposed that the conditional rules that produced facilitation effects on the selection task were subclasses of pragmatic reasoning schemas. These are defined as a more or less abstract set of rules that guide people's expectations about probable outcomes in well-defined categories of situations involving classes of goals and conditions to action. These schemas are learned through experience and possibly social transmission, and allow people to make specific inferences about expected outcomes that reflect the social dynamic involved in specific situations. Each specific form of pragmatic reasoning schema leads to a corresponding pattern of deductions. For example, conditional promises such as "if you do P, then I will give you Q" are commonly interpreted in a way that is consistent with the logic of Biconditionals. Thus, people will commonly infer that if Q is given, then P was done and vice versa. In addition, people will infer that if P was not done, then Q was not given and vice versa. The key class of pragmatic schema is referred to as permission rules. These are sets of rules that govern people's expectations of outcomes in situations that describe required preconditions in order to perform a given action, that is, "if you want to do P, then you must satisfy condition Q". A classic example of such a permission rules is the previously cited one that states that in order to drink alcohol, one must be more than 20 years of age. Cheng and Holyoak specifically claimed that the internal logic of permission schemas was identical to the formal logic of if–then conditionals. For example, using the rule relating drinking to age would allow someone to confirm that "if one does not want to drink alcohol, then one may or may not be over 20 years of age," which is the same inference that can be made by a logician using the formal rule called the negation of the antecedent. Thus, selection task problems that are phrased in terms of permission schemas result in a relatively high level of logically correct responses, while problems phrased in terms of different sorts of pragmatic schemas can generate low levels of correct responses since their internal logic is not appropriate. According to this general framework, people learn to make implicit inferences about classes of pragmatically defined situations. Subsequently, when making inferences with relatively familiar content, people will activate a specific pragmatic reasoning schema. If an appropriate schema is activated, it will give logically appropriate responses, while activation of an inappropriate schema will result in incorrect responses. This approach thus claims that people's understanding of deductive logic issues directly from their ability to abstract patterns from real-world social interactions. More formal logic would result from the increasing ability to represent the internal logic of pragmatic rules in a content-free way. Thus, adults who understand the general logic of permissions will be able to use this in order to generate logically correct responses to abstract conditional reasoning problems.

Important Scientific Research and Open Questions

The relation between pragmatic reasoning schemas and performance on the Wason selection task was examined in several studies and was generally found to be robust. However, there is no real evidence that schemas are used in more generalized forms of inference. Thus, while the idea of pragmatic reasoning schemas as a synthesis of expectations about classes of events remains robust, the relationship between these and formal reasoning has been abandoned in favor of other approaches. One particularly interesting direction that has evolved from the basic idea of pragmatic reasoning schemas is the notion of a cheater detection module first proposed by Cosmides in 1989. Cosmides remarked that one of the important characteristics of permission rules is that it naturally makes people think in terms of what it takes to violate such a rule. For example, when people are given a rule about drinking alcohol and age and asked to think about conditions that would lead to violations of this rule, they will easily examine people drinking alcohol to see if they are underage, and they will examine people who are underage to see if they are drinking. These are the choices required to give logically correct answers to the selection task. Cosmides then claimed that people are biologically programmed to detect cheaters who break social rules since cheater detection is an important component of any tendency toward reciprocal, non-kin forms of altruism.

Cross-References

- ▶ Analogical Reasoning
- ▶ Logical Reasoning and Learning
- ▶ Model-Based Reasoning
- ▶ Schema-Based Reasoning
- ▶ Schemas and Decision Making

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Prayer

▶ Mindfulness and Meditation

Preconceptions and Learning

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Synonyms

Misconceptions; Alternative/commonsense conceptions; Naïve representations/knowledge; Spontaneous/commonsense ways of reasoning

Definition

Preconceptions are generally defined as opinions or conceptions formed in advance of "true" knowledge or experience. Thus, preconceptions can be considered also as prejudices or biases in forming scientific concepts. From the perspective of cognitive psychology, preconceptions can be defined as learner's biased schemas of objects and phenomena.

Theoretical Background

From a constructivist point of view, learning science consists, to a large extent, in developing mental models and schemas of the world of objects and phenomena. Various theoretical approaches were developed that start from a common point of argumentation: solving any problem supposes to build a mental representation of the elements of this problem, and learners' representations can be quite different of expected ones. di Sessa (1993), for instance, argues that learners build representations from phenomenological primitives (*p-prims*). In accordance with this argumentation, Galili and Hazan (2000) analyzed manifestations of general p-prims in specific facets of knowledge produced by learners to solve various tasks in optics. They found some coherence between these facets and concluded that learners develop "common core explanatory patterns [. . .] for addressing different settings" in a specific domain. Furthermore, they studied the evolution of these schemes and concluded that conceptual change is a very progressive process, consisting in disparition, addition, change of facets of knowledge.

Other researchers adopt an ontological approach and study the ontology of objects and events, using declarative rather than solving problems methodologies. In such an approach, ontological categories can be considered as stable, and learning as a jump of objects and events from one ontological category to another one. However, it should be noticed that this approach has been refuted by some research results which showed the evolution of preconceptions appearing a slow and gradual process and not as a sudden jump (Mazens and Lautrey 2003).

Finally, other researchers are more interested in general structures of reasoning. For example, Viennot (2003) studied manifestations of causal reasoning in various contexts and suggested experimental designs and questions to help students to get conscious of the limits of their ways of reasoning.

Important Scientific Research and Open Questions

With regard to the empirical research on preconceptions and their role in learning and reasoning, two major approaches of research can be distinguished. They differ in their aims and their methodologies.

In the first approach, representations are considered as tools of resolution of problems (i.e., to explain, to predict phenomena, to modify them). Researchers infer preconceptions from learners' explanations, predictions, and actions. For instance, if one is interested in preconceptions in optics, one can ask learners to explain how shadows are formed, how to modify the size of a shadow, what would happen when using several lamps of different colors ... without the word "light." The other approach, more linguistic oriented, would study "preconceptions of light," exploring the meaning of this word, the properties attributed to this concept, asking learners if there is light in a room, on a wall, between a lamp and a wall, etc.

Indeed, numerous studies have shown that many adults explain physical phenomena in everyday life with arguments from Aristotelian physics rather than from the Newtonian physics they learned in school. By the time children enter elementary school, they have relatively stable preconceptions of themselves and the world. These preconceptions are not isolated units of knowledge, but rather components of comprehensive conceptual structures which provide a sensitive and coherent understanding of the physical (and social) world. Preconceptions are even more persistent when the explanations provided, for example, in classrooms contradict or are not directly verifiable by perceptual evidence. In an effort to account for this fact, many researchers have attempted to explain why many students in physics class stick to erroneous preconceptions and what qualities instruction needs to have in order to change these preconceptions. These researchers concentrated on a particular "corpus of organized knowledge" (e.g., Newtonian physics, the physics of photosynthesis, light, and heat). Each of these domains is supported by a comprehensive and coherent knowledge construct which requires much time and effort to learn and which even seems to contradict intuitive experiences and everyday beliefs.

Studies on the everyday understanding of physics and the preconceptions of learners of various ages reveal that learners often fail to gain an adequate conceptual understanding of physical phenomena and that they sometimes even stick to erroneous or inadequate conceptions even if they have been given instruction geared toward bringing about conceptual changes (see Chinn and Brewer 1993).

Research on the impact of preconceptions on learning produced a large amount of empirical results about learners' misconceptions in various domains, such as in physics (electrokinetics, optics, mechanics, etc.), chemistry, and biology. These results have been used to elaborate instructional strategies in a perspective of creating *cognitive conflicts* (contradictions between predictions and empirical observations) or *socio-cognitive conflicts* (contradictions between different learners' predictions) with expectation that such conflicts could facilitate learning. Wittrock's approach of generative teaching, for instance, grounds on the assumption that school children should be instructed explicitly to apply the learning tasks and their content to their previous knowledge and preconceptions. Kourilsky and Wittrock (1992) stressed the effectiveness of pointing out and explaining notorious and typical misconceptions to school children in order to enable them to compare these misconceptions with their own conceptions and those of their co-learners and to modify them accordingly.

Generally, findings of research on the impact of preconceptions on learning indicate that the following conditions are decisive for conceptual changes:

1. Knowledge structures, which are concrete, coherent, and solidly anchored, are resistant to change. Changing deeply rooted structures involves a great deal of cognitive effort. If people do not believe that a change in conceptual structures is necessary or effective, they will not put in this effort. Thus, some authors are convinced that a change in cognitive structures can only occur if a *cognitive conflict* is triggered. In order for learners to put in the necessary effort, they must become sufficiently dissatisfied with their current conception.
2. Willingness to change conceptual structures increases when a person realizes that a new conception is reasonable and understandable. This means that the new conception must "fit" with existing ideas. If this is not the case, the person immediately "distorts" it until it is again reconciled with his or her previous knowledge.
3. Learners must deem a new conception to be fruitful. This means that it must lead them to new insight or enable them to formulate more profound hypotheses.
4. When teachers want to teach something new, they always need to take the previous knowledge of their students into account and consider that preconceptions – even those that are completely false – are astoundingly resistant to change since they create subjective plausibility.

Important theoretical questions remain for future research: Can preconceptions be considered as stable or are they produced instantaneously, when solving a problem? And in this last case, do learners use stable principles to build such representations? Are such principles organized in "naïve theories" or are they "in pieces"? Are they innate? Do preconceptions change suddenly, or do they change very progressively, continuously?

Cross-References

► Cognitive Conflict and Learning
► Conceptual Change
► Mental Model
► Schema

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Prediction

► Contingency in Learning

Prediction Error

The quantitative difference between the outcome that is received and the outcome that was expected. Prediction errors are used in the Rescorla-Wagner model and in several reinforcement-learning models, including the actor-critic. Prediction errors seem to be reported in the brain by the phasic responses of midbrain dopamine neurons.

Predictive Accuracy

In *regression* or *prediction models* this term refers to the extent to which variables can be predicted accurately. Variables used to predict other variables are referred to as *independent* or *predictor variables.* Predicted variables are called *criterion variables.* In *regression analysis* predicting a variable is equivalent to explaining the variability or *variance* of a criterion variable.

Predictive Inference

Predictive or forward inferences use *General World Knowledge* to build predictions of the consequences of what is currently happening in a situation model. This involves the following stages: (a) Recognize the problem, (b) construct a model, (c) find a solution, (d) establish the procedure, (e) implement the solution, and (f) test the model for success.

Predictive Model Learning Algorithms

► Anticipatory Learning Mechanisms

Predictive Versus Diagnostic Causal Learning

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Synonyms

Cause-effect learning versus effect-cause learning

Definition

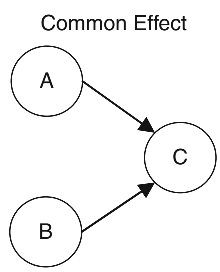
One of the most basic features of causal relations is the asymmetry between causes and effects. Causes generate effects, but not vice versa. This asymmetry has important statistical implications for the events taking part in a causal model. For example, multiple causes of a common effect compete for explaining the effect, whereas multiple effects of a common cause independently provide evidence for the cause. Despite the centrality of causal asymmetry, many psychological (e.g., associative) theories or statistical models (multiple regression) have neglected this aspect of causal relations. Waldmann and Holyoak (1992) have introduced a paradigm to test sensitivity for causal asymmetry. Participants either learned to predict a common effect from information about multiple causes (i.e., predictive learning of a common effect model), or they learned to diagnose the common cause from information about multiple effects (i.e., diagnostic learning of a common cause model). The learning input was identical, only the instructions varied. This paradigm provided clear evidence against associative theories, and showed that learners use causal intuitions to guide their learning.

Theoretical Background

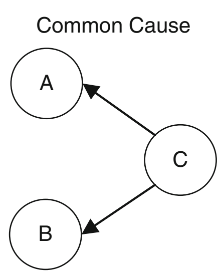
Causal reasoning belongs to one of our most central cognitive competencies. Causal knowledge allows us to predict future events, or diagnose the causes for observed facts. One of the most fundamental properties distinguishing causal relations from mere covariations is the directionality of the causal arrow. Regardless of the order in which causal events are experienced, causal relations are directed from causes to their effects. Causes generate their effects but not vice versa.

It is important to be aware of the asymmetry between causes and effects in reasoning and learning. *Predictive learning* refers to learning scenarios in which participants receive information about potential causes first, and then learn to predict their effects. For example, learners might be confronted with the task to learn which of several potential food items are causally responsible for an allergy in a group of patients. In this scenario, learners might first receive information about whether specific patients have or have not eaten various food items (e.g., peanuts, chicken, milk) (i.e., causes), and then, after their prediction, receive feedback about whether the particular patient suffered from an allergy (i.e., effect) or not. In contrast, in *diagnostic learning* learners first receive information about potential effects, and then, after their diagnosis of the most likely cause, receive feedback about the actual cause. For example, learners might be asked to pretend that they are physicians who encounter various patients. Each patient has a number of symptoms (i.e., effects) that are potentially caused by a novel disease (i.e., cause). Thus, in this task learners receive effect information first before they receive feedback about the cause. Predictive and diagnostic learning refers to the ordering of the learning events (cause information first vs. effect information first), which needs to be distinguished from predictive and diagnostic *reasoning*. If, for example, a participant learns in a predictive learning context that peanuts cause allergies, she might later nevertheless be presented with a patient who suffers from the allergy and be asked about the most likely cause. In this case, learning was predictive, but reasoning diagnostic. Thus, the direction of learning and reasoning need not necessarily match (although they often do).

Causal asymmetry has important statistical implications for the covariations between the causally linked events. Consider, for example, the two causal models depicted in Figs. 1 and 2. A traditional strategy to analyze such scenarios in multivariate statistics is to use multiple regression analysis with A and B as predictors of C. However, this statistical approach neglects the statistical implications entailed by the underlying causal model, and is insensitive to the differences between the common effect and the common cause model (see Pearl 2000). On the left side, two causes A and B generate a joint effect C (common effect model). The default assumption for common effect models is that the two causes independently influence effect C. This pattern entails *explaining away*: Thus, if C and B are known to be present, for example, A becomes less likely. In psychology this phenomenon is known as *discounting*. The model on the right side, a common cause model, has different implications.



Predictive Versus Diagnostic Causal Learning. Fig. 1 Common effect model



Predictive Versus Diagnostic Causal Learning. Fig. 2 Common cause model

A and B represent effects which should be correlated due to the common cause C. A typical assumption for such models, the *Markov* condition, implies that A and B become independent, once C is held constant. A is *screened off* from B by C.

Although causal asymmetry is a basic feature of our causal world, it has been neglected by numerous theories of causal learning and reasoning. For example, associative theories divide learning events into two classes, cues (e.g., A, B) and outcomes (e.g., C), which are distinguished on the basis of temporal order of the presentation of the learning events. Learning involves associating cues with outcomes regardless of whether cues represent causes or effects. These models are formally similar to multiple regression analysis, which also ignores the direction of the causal arrow.

Waldmann and Holyoak (1992) have introduced causal model theory in cognitive psychology, hypothesizing that learners use abstract causal knowledge about causal networks guiding their processing of the learning input (see Waldmann et al. 2006, for an overview of recent research). The general idea of their experimental paradigm was to present participants in different conditions with identical learning events but manipulate the intuitions about which events represent causes and which effects. To be able to test causal model theory against associative accounts, a paradigm was used in which learners either were confronted with predictive learning of a common effect model or diagnostic learning of a common cause model (see above). This way learners received the same cues and outcomes as learning input, the only difference was how they represented the causal role of the cues and the outcome. For example, Waldmann in a number of recent studies presented learners first with cues that represented substances in hypothetical patients' blood and then gave feedback about fictitious blood diseases (see Waldmann et al. 2006). Two conditions manipulated – through initial instructions – whether learners interpreted the substances (i.e., cues) as effects of the diseases (common cause model) or as causes (common effect model). Thus, learners represented identical cues either as causes which they used to predict a common effect (i.e., predictive learning) or as effects to diagnose a common cause (i.e., diagnostic learning). The results showed that causal models guided how the learning input was processed. Learners treated the substances as potentially competing explanations of the disease in the common effect condition, whereas the substances were treated as collateral correlated evidence for a common cause in the contrasting condition. These inferences are consistent with the structural implications of causal models, and demonstrate that people do not simply associate cues with outcomes but represent the learning events within causal model structures.

Important Scientific Research and Open Questions

Although people demonstrate a sophisticated ability to reason with causal models, there is also evidence that their competence to form adequate causal model representations may break down in predictable ways when the task becomes too complex. For example, Waldmann and Walker (2005) have shown that people have difficulties with transforming the learning input into causal model representations when the task is complex or when the learner operates at her information processing limit (see also López et al. 2005). One important goal for future research is to pinpoint the boundary conditions that limit people's capacity to reason causally.

Cross-References

- ► Abductive Reasoning
- ► Association Learning
- ► Causal Learning
- ► Causal Learning and Illusions of Control
- ► Cognitive Learning
- ► Computational Models of Human Learning
- ► Contingency in Learning
- ► Inductive Reasoning
- ► Role of Prior Knowledge in Learning Processes

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Preexisting Knowledge

► Schema-Dependent Neocortical Connectivity During Information Processing

Pre-exposure Effects on Spatial Learning

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Synonyms

Latent inhibition; Latent learning; Previous experience

Definition

Spatial learning refers to the complex ability of animals (including humans) to extract information from the environment to guide their navigation toward hidden goals. Animals (at least mammals and birds with well-developed visual systems) take advantage of the landmarks and the geometric cues (for example, the shapes of enclosures) available in a given environment. Previous experience (or ► pre-exposure) in the absence of reward with spatial cues relevant for solving subsequent spatial tasks has been found to both enhance and hinder learning.

Theoretical Background

Allowing animals to explore a maze in the absence of reward has been shown to facilitate subsequent learning of a route through the maze to the location of food, an instance of ► latent learning. It has been said that by exposing an animal to a new environment, a ► cognitive map containing useful information about the spatial arrangements in this environment is stored in the mind of the animal for future usage (Tolman 1948). The concept of a cognitive map has been supported by the findings of cells within the hippocampus which fire maximally when the animal is in a particular location (O'Keefe and Nadel 1978). The nature of the learning mechanisms responsible for the building up and usage of spatial representations has been widely discussed.

During the first half of the twentieth century learning was widely assumed to depend upon the establishment of stimulus-response (S-R) associations by means of reinforcement – the law of effect. Spatial learning, however, was shown not to depend upon obtaining a reward. In a pioneering experiment, Blodgett (1929) found that animals that were given non-reinforced exposure to a maze, learnt to proficiently navigate toward a goal after being rewarded once in the goal location; animals that were not pre-exposed to the maze took 7 days of rewarded trials to accurately navigate toward the goal location.

Early attempts to characterize spatial learning suggested it depends upon gestaltic processes: cognitive maps were suggested to be established in an all-or-none manner in response to novelty (O'Keefe and Nadel 1978). Once formed, a cognitive map was theorized to be automatically updated whenever novel information appears in a known environment. This highly flexible spatial representation would allow animals to make novel shortcuts between two points even through unexplored areas of a familiar environment – ► instantaneous transfer.

One limitation of the cognitive map theories is that experience with the environment can only benefit subsequent navigation. Recent studies, however, have provided evidence that pre-exposure can result in retarding subsequent learning (e.g., Prados et al. 2007). Such studies have suggested that associative learning mechanisms play an important role in the building up and usage of spatial representations. According to that view, spatial learning is gradual, and similar to the learning that takes place in Pavlovian and instrumental conditioning. The associative view of spatial learning can account for improved and impaired performance in spatial tasks as a result of pre-exposure. In tasks supposed to be ruled by associative principles, exposure to two stimuli sharing a common element, AX and BX, can facilitate subsequent discrimination between them – an instance of ► perceptual learning. Sometimes, however, the opposite outcome can be observed: non-reinforced exposure to the to-be-conditioned stimulus in a Pavlovian preparation typically retards subsequent conditioning – an instance of ► latent inhibition.

Important Scientific Research and Open Questions

Enhancement and impairment of subsequent learning have been observed in experiments using spatial tasks. In a series of studies, Prados et al. (2007) pre-exposed animals to configurations of landmarks and they showed impaired learning of a navigation task when both pre-exposure and training took place in the same context. When trained in a different context, however, animals showed enhanced spatial performance. According to the authors' analysis, impaired learning was the consequence of latent inhibition, a reduction in the associability of the landmarks. Latent inhibition was severely disrupted after a change of context, and the enhanced spatial learning observed was attributed to an independent perceptual learning mechanism. What these studies strongly suggest is that, at least to a certain extent, spatial learning is ruled by associative processes similar to those known to rule Pavlovian and instrumental conditioning.

Recent studies by Doeller and Burgess (2008), have provided evidence that while landmark cues, such as those used in the Prados et al. (2007) study, are learnt via associative processes, spatial cues provided by the boundaries of the arena may be learnt through a non-reward-based incidental learning process more akin to that described by O'Keefe and Nadel (1978) in the production of a cognitive map. Similar results have also been found by Redhead and Hamilton (2009) where pre-exposure to a landmark with a stable spatial relationship to a goal inhibits learning about the spatial relationship between the goal and a second landmark. This inhibition is not found if the second spatial cue is provided by the boundary of the arena suggesting learning the position of the platform in terms of the boundary is not governed by associative rules. In a second study, however, Redhead and Hamilton (2009) found that learning about the relationship between boundary cues and the goal was inhibited if it followed pre-exposure to similar geometric cues with a stable spatial relationship to the goal, suggesting the type of cue was critical as to whether pre-exposure resulted in inhibition of learning. Thus the debate regarding the rules governing pre-exposure and spatial learning is still very current.

Cross-References

- ▶ Associative Learning
- ▶ Discrimination Learning Model
- ▶ Law of Effect
- ▶ Perceptual Learning
- ▶ Spatial Learning
- ▶ Tolman, Edward C. (1886–1959)

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Preference Learning

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Definition

Preference learning refers to the induction of preference models from empirical data. Typically, these models are used for the purpose of prediction, that is, to predict the preferences of an individual (e.g., the user of a search engine) or a group of individuals with regard to a set of alternatives (e.g., websites that might be relevant for a given user query).

In the literature on choice and decision theory, two main approaches to modeling preferences can be found, namely, in terms of ▶ utility functions and in terms of ▶ preference relations. From a machine learning point of view, these two approaches give rise to two kinds of learning problems: learning utility functions and learning preference relations. The latter deviates more strongly than the former from conventional problem tasks like classification and regression, as it involves the prediction of complex structures, such as rankings or partial order relations, rather than single values. Moreover, training input in preference learning will not, as it is usually the case in ▶ supervised learning, be offered in the form of complete examples but may comprise more general types of information, such as relative preferences or different kinds of indirect feedback and implicit preference information.

Theoretical Background

Data for learning preference models can be collected in different ways. In the simplest case, users are queried about their preferences and provide explicit feedback. For example, users can inform about the result of a search engine query by labeling the retrieved pages with their degree of relevance. Normally, however, they are willing to do this for only a limited number of pages. Alternatively, one can try to infer user preferences indirectly, namely, by observing their behavior, for example, which results of a search engine are clicked on and which are not. It is also possible to present results in a way that allows for controlled, implicit gathering of information, through interleaving two different result sets in a single view (Radlinski et al. 2010).

Observed preference information can be formalized in different ways. In particular, referring to the above distinction between utility functions and preference relations as formal frameworks for preference modeling, one can distinguish between *evaluating single alternatives* and *comparing pairs of alternatives*. In the first case, a value or score $u(x)$, interpreted as a degree of utility, is attached to a single alternative x. Typically, such degrees are taken from a numerical (e.g., the nonnegative reals) or an ordinal scale (comprised of a finite number of elements, such as {`bad`, `fair`, `good`}). In the second case, preferences are expressed in a qualitative way, namely, in the form of *binary* *relations* : $x \succ y$ means that x is preferred to y. Obviously, information about (numerical) utility degrees is stronger than information about pairwise order relations, since the latter can be derived from the former but not the other way around. Besides, the order relation induced by a utility function is always complete, a property that does not necessarily hold for a binary relation. On the other hand, the acquisition of qualitative preference information is often much easier than the elicitation of numerical utility degrees.

Learning Tasks

Preference learning covers a wide spectrum of learning tasks, ranging from learning special types of preference models, such as lexicographic orders, over collaborative filtering techniques for recommender systems (estimating a customer's preference from the preferences of other customers) to utility approximation and preference elicitation (approximation of the utility function of a single agent on the basis of an as effective as possible question–answer process). In fact, problems of preference learning can be formalized within various settings, depending on the underlying type of preference model or the type of information provided as an input to the learning system.

Among the problems in the realm of preference learning, the task of "learning to rank" has probably received the most attention in the literature so far. Here, the goal is to infer a model that is able to predict preference models in the form of total order relations. More specifically, depending on the type of information provided and the prediction sought, one can distinguish between the following learning tasks:

- *Label ranking*: Like in conventional classification, we assume to be given an instance space $\mathcal{X}$ and a finite set of labels $\mathcal{Y} = \{y_1, y_2, \ldots, y_k\}$. However, instead of learning a classifier that maps instances to single labels, the goal is to learn a "label ranker" in the form of an $\mathcal{X} \rightarrow S_{\mathcal{Y}}$ mapping, where the output space $S_{\mathcal{Y}}$ is given by the set of all total orders (permutations) of the set of labels $\mathcal{Y}$. Training data consists of instances $x \in \mathcal{X}$ associated with rankings $\pi_{\boldsymbol{x}} \in S_{\mathcal{Y}}$ or, more generally, partial information about such rankings in the form of pairwise preferences on a subset of the labels. A survey of work on this problem can be found in Vembu and Gärtner (2010).
- *Instance ranking:* This setting proceeds from the setting of *ordinal classification* where the classes have a natural order: $y_1 < y_2 < \ldots < y_k$. Training data consists of a set of labeled instances $(x, y) \in \mathcal{X} \times \mathcal{Y}$, and the goal is to learn a ranking function $f(\cdot)$ on $\mathcal{X}$. Given a subset $X \subset \mathcal{X}$ of instances as an input, the function produces a ranking of these instances as an output (typically by assigning a score to each instance and then sorting by scores). Ideally, this ranking is in agreement with the class information, in the sense that instances from higher classes precede instances from lower classes.
- *Object ranking*: Like in instance ranking, the goal in object ranking is to learn a ranking function $f(\cdot)$ which, given a subset Z of an underlying referential set $\mathcal{Z}$ of objects as an input, produces a ranking of these objects as an output. However, the training information is of a different kind. Instead of revealing preference information by labeling single objects, the learner is offered qualitative preference information in the form of pairwise comparisons $z_1 \succ z_2$. For a good overview of approaches in this scenario we refer to (Kamishima et al. 2010).

All three tasks – object, instance, and label ranking – can be addressed in the two ways mentioned above: directly, by learning a utility function (Sariel et al. 2002; Herbrich et al. 2000; Joachims 2002), or indirectly, by learning binary preference models (Cohen et al. 1999; Fürnkranz et al. 2009; Hüllermeier et al. 2008). In general, the second approach is more flexible and often less difficult from a learning point of view. However, since a binary preference relation does normally not determine a unique ranking, it requires an additional step, namely, a ranking procedure that turns a (possibly non-transitive) binary relation into a total order (Hüllermeier et al. 2008).

Important Scientific Research and Open Questions

Despite the existence of several well-established learning tasks and problem settings, notably related to ranking, preference learning is still an emerging field and, as such, does not possess a precise demarcation yet, neither in terms of a formal definition nor as an exhaustive list of relevant topics. Consequently, there are still a lot of open problems, and more will probably arise in the near future. Here, we just mention a few general directions for future research:

- As mentioned above, there are two principle ways of approaching preference learning, either by learning utility functions or by learning preference relations. The relationships between these two approaches, including differences, advantages, and disadvantages from a machine learning point of view, are still not well understood.
- Despite some technical differences between the ranking problems studied so far, these problems are of course closely related. A unified framework for "learning to rank" would therefore be desirable.
- Such a framework should also include generalizations of existing ranking problems, which are mostly focused on total orders. In fact, more general types of preference relations, such as weak or partial orders, are not only of theoretical interest but also of practical relevance.
- In decision theory, and nowadays also in artificial intelligence, different types of preference models are developed and analyzed. These models rely on specific assumptions (e.g., that a preference relation can be represented in terms of a lexicographic order over a finite set of ordered domains), which are closely related to what is known as a *learning bias* in machine learning. Learning algorithms exploiting these assumptions in a systematic way have been developed only for a very few models so far.
- Preference learning algorithms deal with complex types of predictions, and a number of novel performance metrics have been developed to evaluate the predictive accuracy of models produced by these algorithms. In many cases, however, learning algorithms specifically tailored toward a certain loss function (in the sense of producing models that minimize risk with respect to this loss) do not exist.
- A number of problems from other parts of machine learning, such as ordinal, hierarchical, and multilabel classification, do have a close connection to preference learning. Exploring these connections and maybe embedding these learning problems in the preference learning framework is clearly of interest.
- Last but not least, preference learning is an interdisciplinary field with connections to other research areas, such as decision theory, operations research, (non-parametric) statistics, and social choice theory. These connections should be explored in depth, and preference learning should take advantage of existing theories and methods in the areas.

Finally, preference learning is of great interest from an application point of view. In fact, preference learning problems in general, and ranking problems in particular, arise quite naturally in many application areas. For example, products can be ranked according to a customer's preference on characteristics that discriminate different brands, or keywords can be ranked according to their relevance for an article. In particular, ranking applications occur quite naturally in the field of information retrieval. As examples of two especially interesting problems, we mention learning to rank the results of a query to a search engine (Joachims 2002; Liu 2009) and learning to rank possible recommendations for new products (de Gemmis et al. 2010).

A snapshot of the state-of-the-art research in all areas of preference learning, as well as selected applications can be found in (Fürnkranz and Hüllermeier 2010). For a selection of research on the use of preferences in ► artificial intelligence in general, we refer to (Goldsmith and Junker 2008).

Cross-References

► Learning Algorithms
► Supervised Learning

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Preference Relation

A *preference relation* is a binary relation $\succeq$ on a set of alternatives $\mathcal{A}$. For $a, b \in \mathcal{A}$, $a \succeq b$ indicates that alternative a is at least as preferable as b (weak preference). The relation $\succeq$ is assumed to be *reflexive* ($a \succeq b$), *transitive* ($a \succeq b$ and $b \succeq c$ implies $a \succeq c$), and *complete* (for all pairs of alternatives (a, b), either $a \succeq b$ or $b \succeq a$). The weak preference $\succeq$ can be decomposed into a *strict* preference relation $\succ$ ($a \succ b$ if $a \succeq b$ but not $b \succeq a$) and an indifference relation $\sim$ ($a \sim b$ if $a \succeq b$ and $b \succeq a$). In preference learning, a typical problem is to learn (weak or strict) preference relations from observed pairwise preferences.

Preferences in Learning and Achievement

▶ Learner Preferences and Achievement

Prejudice

▶ Attitudes – Formation and Change

Prejudice: Intolerance

▶ Big Five Personality and Prejudice

Premonition Effect

▶ Revelation Effect

Preparation of Teacher Educators

▶ Education of Teacher Educators

Pre-reflexive Self-Consciousness

▶ Development of Self-consciousness

Prerequisite Analysis Technique

▶ Learning Hierarchy Technique

Prescription

▶ Competency-Based Learning

Preserved Implicit Learning in Autism

▶ Intact Implicit Learning in Autism

Pretend Play and Learning

▶ Play and Its Role in Learning

Previous Experience

▶ Pre-exposure Effects on Spatial Learning

Primary Abilities

▶ Folk Knowledge and Academic Learning

Primary Memory

▶ Working Memory and Information Processing

Prime

▶ Reinstatement of Learning

Primed Recall

▶ Cued Recall

Priming

▶ Cueing

Priming, Response Learning, and Repetition Suppression

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Synonyms

fMR-adaptation; Implicit memory; Stimulus–response binding

Definition

Priming refers to a change in behavioral response to a stimulus following prior exposure to that stimulus. This behavioral change can manifest as a change in reaction time (RT), response accuracy, or response bias, and can be either positive or negative in direction. For example, responses could be faster and more accurate for a repeated relative to a novel stimulus (positive priming) or slower and less accurate (negative priming). *Repetition Suppression* (RS), as measured by *functional magnetic resonance imaging* (fMRI), refers to a decreased response for repeated relative to novel stimuli within certain brain regions, and often coincides with positive priming. Several types of learning have been associated with priming and RS. One such type is *response learning*, whereby, when a stimulus is first encountered and a response enacted, a direct *stimulus–response* (S-R) binding is formed between them. When the stimulus is repeated, this S-R binding can be retrieved. If the task performed on the repeated stimulus requires a similar response to when it was first encountered, the retrieved S-R binding can facilitate processes relating to the selection of an appropriate response. Such response retrieval is thought to lead to a decreased brain response in cortical regions that perform response-selection processes (RS) and accelerate behavioral responses (positive RT priming). Conversely, negative priming, and possibly increased responses in brain regions that perform response-selection, can be seen when the retrieved response is incongruent with the response currently required.

Theoretical Background

Multiple forms of learning have been hypothesized to underlie priming and RS. One of the dominant views within the cognitive neuroscience literature is the proposal that positive priming reflects the facilitation of specific mental processes recruited during the first and any subsequent presentation of a stimulus (Witherspoon and Moscovitch 1989). For example, following the presentation of a visual object in the context of a semantic categorization task (e.g., is the object man-made?), specific mental processes will be recruited. These processes are likely to include, at a minimum, the perceptual identification of the visual object – a *perceptual process* – as well as the retrieval of semantic information relating to the task – a *conceptual process*. If the same processes are reengaged on a subsequent presentation, these processes are thought to be facilitated. The first presentation of a stimulus therefore "greases the tracks," setting the stage for future facilitation. If a subsequent presentation of the stimulus uses the same tracks (same component processes), then facilitation will occur. If a subsequent presentation of the stimulus uses different tracks, facilitation will not occur. The amount of facilitation is therefore thought to be related to the amount of overlap in processing between the first and subsequent encounter with the stimulus. Under this *component process* view, RS reflects the facilitation of these processes (i.e., faster processing or fewer neurons involved, resulting in less brain activity). Therefore, it is argued that RS occurs within the brain regions that perform these specific mental processes. This neural facilitation is thought to lead to faster and more accurate behavioral responses, in other words positive priming.

An alternative to this view is that priming and RS result from the encoding and retrieval of direct stimulus–response (S-R) bindings (Logan 1990). Here, each encounter with a stimulus is thought to entail the formation of an S-R binding. Assuming that the repeated stimulus is encountered in a similar context to a previous presentation (e.g., in the same experimental task), the retrieval of a previously encoded S-R binding provides predictive information about the response that should be made. As such, S-R retrieval allows for the facilitation of processes relating to the selection of a response. This facilitation of response-selection processes should result in RS within the brain regions that perform these processes, leading to faster response times – positive priming. However, such S-R retrieval may not always facilitate response-selection. In a situation where the retrieved S-R binding is no longer appropriate, for example, in the context of a new experimental task, the retrieved response might interfere with response-selection. This is a situation in which negative priming can occur (i.e., slower or less accurate responses for repeated stimuli) and may relate to increases in neural activity for repeated stimuli in brain regions that perform response-selection processes, so-called *repetition enhancement (RE)*. As such, response learning effects can be positive or negative depending on the match between the retrieved response and the response currently required.

Ultimately, priming is likely to result from a combination of multiple independent sources. For example, if an object is repeated in the context of the same experimental task, it is likely that facilitation of multiple perceptual and conceptual processes will occur, in addition to facilitation of response-selection by S-R retrieval. Therefore, when considering a behavioral measure like RT, it should be remembered that it reflects the outcome of all these contributions. Priming should therefore reflect the sum total of these facilitatory and possible interference effects. In contrast, at the neural level, RS and RE can be seen across multiple cortical regions, from relatively low-level visual regions in the occipital lobe to semantic and premotor regions in the frontal lobe. As such, fMRI offers a means to spatially separate these multiple contributions to priming.

Important Scientific Research and Open Questions

Much of the fMRI literature on RS has focused on the specific brain regions and component processes that might be facilitated. In more recent years, however, there has been a renewal of interest in response learning contributions to RS. Logan (1990) was one of the first to propose that priming may stem from the rapid encoding and retrieval of S-R bindings. When a stimulus is first presented, Logan proposed that a response is generated by recruiting specific component processes, which he referred to as an *algorithmic route*. Each subsequent encounter with the stimulus however can benefit from an additional S-R, or *instance*, retrieval route, such that the final response is based on a "race" between these routes. In fact, he proposed that multiple races occur between the algorithmic route and each independently encoded S-R binding. Thus, as the number of available S-R bindings increases, so should the amount of priming. In support of this idea, Logan showed that, when the same response was required across presentations, the mean and variance of RTs decreased as a function of number of presentations in the manner predicted by an independent race. When a switch in response occurred between presentations, however, priming was reduced. In these situations, Logan proposed that S-R retrieval was effectively ignored and only the algorithmic route could enter the race, thereby removing priming completely.

Just as Logan (1990) showed that priming is reduced when a response is switched between presentations of a stimulus, Dobbins et al. (2004) showed that the RS in most brain regions decreases when the response is switched between presentations. Here, when the categorization task performed on visual objects (e.g., is it "bigger than a shoe box?") was kept constant, repeated objects produced RS in several brain regions within the occipital, temporal, and frontal lobes. Importantly, when the task was reversed between presentations (e.g., is it "smaller than a shoe box?"), RS was reduced in these regions, or even abolished in some occipital and temporal regions normally associated with perceptual processing. The importance of this finding was that RS in these regions, even relatively early visual-processing regions, may not reflect more efficient component processes (greased tracks), but rather a bypassing or curtailing of activity in those regions owing to rapid, independent retrieval of S-R bindings. This alternative S-R interpretation therefore questioned previous fMRI experiments that had used RS to infer the presence of specific component processes in specific brain regions.

As previously stated, however, priming and RS are likely the result of multiple independent forms of learning. In support of this, Horner and Henson (2008) recently revealed a dissociation between RS in the temporal and frontal lobes. Contrary to Dobbins et al., they found that RS in occipitotemporal cortex was *not* affected by any switches in response between repeated presentations, an effect confirmed by subsequent studies. In other words, RS in this brain region did not care whether a response was repeated or reversed between presentations. These data suggest that RS in this region is not driven by the retrieval of S-R bindings, but rather is likely to reflect the traditional interpretation in terms of facilitated perceptual (or conceptual) component processes. On the other hand, RS in regions of the frontal lobe was shown to be sensitive to switches in response between presentations (consistent with Dobbins et al. 2004). They therefore suggested that it is RS in these regions that reflects the facilitation of response-selection processes from the retrieval of S-R bindings. These data therefore provided evidence that RS can result from multiple forms of learning.

So far, we have discussed evidence for the facilitation of response-selection processes when an appropriate S-R binding is retrieved. To what extent are response-selection processes affected by the retrieval of an inappropriate S-R binding? In Logan's theory, previous S-R bindings are simply ignored if the task has changed, in which case, neither positive nor negative priming should be seen. In other words, these stimuli should be treated as if they were being presented for the first time. Alternatively, it may not be possible to ignore an inappropriate response, such that it could actively interfere with response-selection. If this were the case, then one would expect to see negative priming, and greater neural activity in the frontal lobe (i.e., RE), as neural activity is required to overcome the interference caused by retrieving an inappropriate response.

In fact, evidence has shown that negative priming can occur when a response is switched between presentations (Hommel 1998). Furthermore, this negative priming effect has also been seen despite stimuli being unattended on their first presentation. In such "negative priming" paradigms, two stimuli are presented at the same time and participants are required to attend and respond to only one, ignoring the other. When the previously ignored stimulus is then repeated and the participant asked to attend and respond to it, negative priming can be seen. Although this negative priming effect is likely to result from multiple forms of learning (as with positive priming), response learning has again been shown to play a role (Rothermund et al. 2005). It is thought that when the two stimuli are first presented, the response made to the attended stimulus also becomes automatically bound to any concurrent stimuli, even if they are to be ignored. In other words, the response becomes bound to all stimuli that are present at the time the response is made. When the previously ignored stimulus is presented again and participants are required to attend to it, the response previously bound to it can be retrieved and interfere with the current response required, causing negative priming.

Although priming data clearly point to interference and negative priming following the retrieval of inappropriate S-R bindings, conclusive fMRI evidence for RE following the retrieval of an inappropriate S-R binding has not yet been found. If the retrieval of an inappropriate S-R binding does lead to interference of response-selection processes, it would be predicted that this RE should occur in the same frontal lobe regions that show RS when responses are repeated. Future testing on this prediction would strengthen the claim that repetition effects in the frontal lobe reflect facilitation or interference following the retrieval of an S-R binding.

Cross-References

- ► Affective Priming and Learning
- ► Attention and Implicit Learning
- ► Explicit and Procedural-Learning-Based Systems of Perceptual Category Learning

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Primitives

► Human Feature Learning

Print-Based Learning

► Literacy and Learning

Prior Knowledge Principle

► Role of Prior Knowledge in Learning Processes

Private Schooling

► Homeschooling and Teaching

Private Speech

Self-directed talk, in other words, utterances produced to self and not others. Vygotskyan psycholinguistic theory and research link private speech to the sociocognitive processes of language learning, more specifically to the internalization of social speech for individual cognitive purposes. Private speech is used by children and adults for purposes of maintaining or regaining self-regulation (e.g., to aid in focusing attention or problem solving).

Proactive Learning

► Adaptive Proactive Learning with Cost-Reliability Trade-off

Probabilistic Approaches

► Bayesian Learning

Probabilistic Categorization

► Multiple-Cue Probability Learning

Probabilistic Learning

► Functional Learning

Probabilistic Models

► Stochastic Models of Learning

Probability Theory in Machine Learning

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Definition

Probability theory provides a useful framework in which to model machine learning algorithms and make precise statements about their effectiveness.

Theoretical Background

The language and tools of probability theory are prevalent in the analysis of machine learning. Machine learning, in general terms, concerns the inference of patterns or relationships from a limited amount of data, and this necessarily involves probability theory and statistics. For one thing, the relationships we may be trying to detect may be stochastic, or non-deterministic. Furthermore, even when they are deterministic, the information provided by a limited set of data reveals only partial information about the underlying relationship, so the best that can generally be hoped for is that the underlying relationship or pattern is detected to a good approximation, an idea that can be formalized in the language of probability theory.

Much of (supervised) machine learning concerns the selection, on the basis of a training sample of data, of a *hypothesis* that it is hoped is a good description of a relationship between *inputs* and *outputs*. Broadly speaking, there are two key distinct approaches to hypothesis selection: the Bayesian approach and the "frequentist" approach. In both cases, we have a set of possible hypotheses, $\mathcal{H}$, from which a hypothesis is to be selected.

In a Bayesian approach, there is a *prior distribution* on the set $\mathcal{H}$. Informally speaking, the prior probability of a particular hypothesis might reflect the degree of belief that the underlying relationship between inputs and outputs is described by that hypothesis. Bayesian learning proceeds by updating the prior on the basis of data seen, resulting in a *posterior* distribution over the hypotheses. This is achieved using Bayes rule, which uses the fact that the conditional probability of a hypothesis, given the data seen, can be expressed in terms of two known quantities: the conditional probability of the data, given the hypothesis, and the prior probability of the hypothesis. In practical terms, the computation of the probabilities involved can be challenging (since this often involves the calculation of high-dimensional integrals) and a number of approximation techniques are used.

In the "frequentist" approach to supervised learning, which will be the main focus in what follows, a range of probabilistic techniques is employed. In contrast to the Bayesian approach, there is no prior distribution on the set $\mathcal{H}$ of hypotheses. The choice of the class $\mathcal{H}$ may be determined by the learning system, such as a neural network, being employed; or it may be thought of as indicating a belief that the underlying relationship can be described by a particular type of hypothesis, but beyond this there is no information or assumptions about the degrees of belief in particular hypotheses. Frequentist supervised machine learning models (in contrast to Bayesian models) make some probabilistic assumptions about the way in which training data is selected, so that, informally speaking, the "fit" of a given hypothesis to a set of training data reliably indicates, to some extent, its appropriateness as a model of the true underlying relationship between inputs and outputs. To formalize this requires probability theory. Of key importance, as shall be explained, are *uniform laws of large numbers* (or "uniform convergence results").

We have drawn a distinction between Bayesian and frequentist models of learning, but we should note that, recently, new models of machine learning (known as "PAC-Bayesian" models) have been developed that combine aspects of the Bayesian and the frequentist approaches.

Important Scientific Research and Open Questions

Standard models of supervised machine learning use a probability measure (or distribution) to describe the relationship between a set of inputs, X, and outputs, Y. In the simplest case, $Y = \{0, 1\}$, there is a probability measure μ on X, and there is a deterministic *target concept* $t : X \to Y$. This is the set-up used in the standard model of learning, due to Valiant (1984), that has become known as the "PAC" (probably, approximately, correct) model. A more general formulation assumes that the relationship between X and Y is given by a probability measure P on the set $Z = X \times Y$ of all ordered pairs (x, y). This includes, as a special case, the previous setting, but is more general, permitting a stochastic – rather than deterministic – connection between X and Y. The aim is to find a (deterministic) hypothesis $h : X \to Y$ which comes close to describing the relationship P as well as is possible.

For any hypothesis h, the *(generalization) error* of h is defined as

$$\mathrm{er}_P(h) = P\{(x, y) \ : \ h(x) \ \neq y\}.$$

If h is chosen from a hypothesis class $\mathcal{H}$, then the optimal error is

$$\mathrm{opt}_P(\mathcal{H}) = \inf_{h \in \mathcal{H}} \ \mathrm{er}_P(h).$$

If P is deterministic (i.e., it corresponds to a distribution μ on X and a target concept $t : X \to Y$), and if the target concept belongs to $\mathcal{H}$, then the optimal error is 0. Generally, however, the optimal error will be positive, either because the hypothesis space $\mathcal{H}$ is limited in scope, or because P is genuinely stochastic. In general, the minimum possible value of $\mathrm{er}_P(h)$ among *all possible* functions $h : X \to Y$ is called the *Bayes error* and the optimal such h is the *Bayes classifier* h^*. For the case where $Y = \{0, 1\}$, for instance, the Bayes classifier h^* is given by

$$h^*(x) = \begin{cases} 1 & \text{if } P(Y = 1 \,|X = x) \geq 1/2 \\ 0 & \text{otherwise,} \end{cases}$$

Supervised learning is the selection of a hypothesis on the basis of a *training sample*

$$\mathbf{z} = ((x_1, y_1), (x_2, y_2), \ \ldots, \ (x_m, y_m)),$$

an (ordered) list of input–output pairs. We shall assume, for now, that Y is finite. A *learning rule* is a mapping L from all such samples to the set $\mathcal{H}$, and $L(\mathbf{z})$ denotes the hypothesis selected by the rule. In the PAC framework and its variants, it is assumed that each training sample pair (x_i, y_i) is generated independently according to the distribution P, so that the sample $\mathbf{z}$ is distributed according to the product measure P^m. One can estimate how well a given hypothesis fits the training sample by calculating its *sample error*,

$$\mathrm{er}_{\mathbf{z}}(h) = \frac{1}{m}|\{i : h(x_i) \ \neq \ y_i\}|$$

The quantity $\mathrm{er}_{\mathbf{z}}(h)$ is an empirical estimate of $\mathrm{er}_P(h)$ based on the sample $\mathbf{z}$. It would appear, intuitively, that it might be sensible to select a hypothesis which has small sample error. However, it should be realized that there is some possibility that the training sample may somehow be "unrepresentative" or potentially misleading, so we cannot expect, with certainty, that this will result in a hypothesis with small error. Considerations such as these motivate the "PAC" definition of learning. In the present context, this is as follows: We say that the learning rule L succeeds (in the PAC-sense) if, given any ε and δ strictly between 0 and 1, there is some integer $m_L(\varepsilon, \delta)$ such that, whatever the distribution P is, for $m \geq m_L(\varepsilon, \delta)$, if $\mathbf{z}$ is a training sample of length m, then with probability at least $1 - \delta$ (with respect to P^m), we have

$$\mathrm{er}_P(L(\mathbf{z})) < opt_P(\mathcal{H}) + \varepsilon.$$

It can be shown (see, for instance, Anthony and Bartlett [1999]) that if $\mathcal{H}$ is finite, and if L is a "sample error minimization algorithm," which selects a hypothesis from $\mathcal{H}$ minimizing the sample error on $\mathbf{z}$, then L succeeds. More generally, this same conclusion is true (whether or not $\mathcal{H}$ is finite) if $\mathcal{H}$ satisfies a "uniform law of large numbers." By this, we mean the following: given any ε and δ strictly between 0 and 1, there is some integer $m_0(\varepsilon, \delta)$ such that, for all measures P on $Z = X \times Y$, if $m \geq m_0(\varepsilon, \delta)$, then

$$P^m\left\{\mathbf{z} \ : \ \sup_{h \in \mathcal{H}} |\mathrm{er}_P(h) - \mathrm{er}_{\mathbf{z}}(h)| \ > \ \varepsilon\right\} < \ \delta.$$

This would follow from a bound of the form

$$P^m\left\{\mathbf{z} \ : \ \sup_{h \in \mathcal{H}} |\mathrm{er}_P(h) - \mathrm{er}_{\mathbf{z}}(h)| \ > \ \varepsilon\right\} < \ g(m, \ \varepsilon), \tag{1}$$

where $g(m, \varepsilon)$ tends to 0 as $m \to \infty$, for each $\varepsilon \in (0, 1)$. Much effort has gone into obtaining bounds of this type. Informally speaking, what such bounds provide is a guarantee that, with high probability, on a random training sample, the sample error of *any* hypothesis in the class will not be far from its (true, underlying) error. The simplest case is that in which $\mathcal{H}$ is finite. Here, one can simply observe that

$$P^m \left\{ z : \sup_{h \in \mathcal{H}} |\mathrm{er}_P(h) - \mathrm{er}_z(h)| > \varepsilon \right\} < \sum_{h \in \mathcal{H}} P^m \quad \{z : |\mathrm{er}_P(h) - \mathrm{er}_z(h)| > \varepsilon\} < 2|H|e^{-2\varepsilon^2 m},$$

using the standard Hoeffding bound.

The crucial breakthrough in this field was the extension to the situation in which $\mathcal{H}$ is not finite but is, in some other way, of limited expressive power. The pioneering work in this area was due to Vapnik and Chervonenkis (1971). Their work provides, among other things, uniform laws of large numbers in which the quantity denoted by $g(m, \varepsilon)$ above depends on the "growth function" of $\mathcal{H}$, which in turn depends on a combinatorial parameter characterizing the complexity of $\mathcal{H}$. This parameter subsequently became known as the Vapnik–Chervonenkis (or VC-) dimension and it has played a pivotal role in supervised learning theory, its importance in that context having been explicitly highlighted by Vapnik (1982) and Blumer et al. (1989).

Subsequent work addressed the case in which the set Y is infinite, and, in particular, the case where $Y = \mathbb{R}$. The definitions given above can suitably be modified to apply in this case, so that, in one possible formulation, the error becomes the expectation $\mathrm{er}_P(h) = \mathbb{E}_P((h(x) - y)^2)$ rather than the probability $P\{h(x) \neq y\}$, and the sample error is replaced by the empirical estimate $\mathrm{er}_z(h) = \frac{1}{m}\sum_{i=1}^{m} (h(x_i) - y_i)^2$. In this context, uniform laws of large numbers have been obtained, where f depends on a generalization of the growth function known as the covering number. (Such results were first expounded in the machine learning literature by Haussler (1992).)

In a different vein, returning to the case where $Y = \{0, 1\}$, there has been extensive analysis of the use of real-valued functions as classifiers. Given a function f: $X \to \mathbb{R}$, f may be used for binary classification by defining a corresponding hypothesis $h_f : X \to \{0, 1\}$ by $h_f(x) = \mathrm{sgn}(f(x))$, where $\mathrm{sgn}(z) = 1$ if $z \geq 0$ and $\mathrm{sgn}(z) = 0$ otherwise. It has been shown that using such hypotheses that achieve "large margins" on training samples can be a good strategy. Specifically, suppose we have a set $\mathcal{F}$ of functions from X to $[-1, 1]$ and suppose (with the other notations as before) that we define the (classification) error of $f \in \mathcal{F}$ to be $\mathrm{er}_P(f) = \mathrm{er}_P(h_f) = P\{\mathrm{sgn}(f(x)) \neq y\}$. Given a sample z (as before, with $\{0, 1\}$-labels y_i), and $\gamma > 0$, the γ-margin error of $f \in \mathcal{F}$ on z is

$$\mathrm{er}_z^{\gamma}(f) = \frac{1}{m}|\{i : y_i f(x_i) < \gamma\}|.$$

This counts the proportion of sample points (x_i, y_i) such that either $f(x_i)$ has a different sign than y_i (so that, as a binary classifier, f is incorrect) *or* $f(x_i)$ has the same sign as y_i, but its absolute value is less than γ (so that, although f gives the correct classification, it does not achieve this with a "margin" of at least γ). The standard type of uniform law of large numbers mentioned earlier (the sort of bound given in (1)) enables one to conclude that, given δ, then with probability at least $1 - \delta$, one has, for all $h \in \mathcal{H}$,

$$\mathrm{er}_P(h) < \mathrm{er}_z(h) + \varepsilon(m, \delta),$$

where $\varepsilon(m, \delta) \to 0$ as $m \to \infty$ if $\mathcal{H}$ has finite VC-dimension. The corresponding results relating to margin error yield bounds of the form

$$\mathrm{er}_P(f) < \mathrm{er}_z^{\gamma}(f) + \varepsilon'(m, \delta)$$

where, in many cases, ε', which depends on the covering numbers of $\mathcal{F}$, is much smaller than ε.

Covering numbers can be bounded by generalizations of the VC-dimension known as the pseudo-dimension and fat-shattering dimension; see Anthony and Bartlett (1999), for instance, for a survey of this work. More recent work has involved "Rademacher averages."

Cross-References

► Bayesian Learning
► PAC Learning
► Supervised Learning in Spiking Neural Networks

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Probably Approximately Correct Theory

► PAC Learning

Problem Solving

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Synonyms

Cognition; Problem typology; Problem-based learning; Problems; Reasoning

Definition

Problem solving is the process of constructing and applying mental representations of problems to finding solutions to those problems that are encountered in nearly every context.

Theoretical Background

Problem solving is the process of articulating solutions to problems. Problems have two critical attributes. First, a problem is an unknown in some context. That is, there is a situation in which there is something that is unknown (the difference between a goal state and a current state). Those situations vary from algorithmic math problems to vexing and complex social problems, such as violence in society (see ► Problem Typology). Second, finding or solving for the unknown must have some social, cultural, or intellectual value. That is, someone believes that it is worth finding the unknown. If no one perceives an unknown or a need to determine an unknown, there is no perceived problem. Finding the unknown is the process of problem solving.

Problem solving as a process also has two critical attributes. First, problem solving requires the construction of a mental representation of the problem situation from that which was presented. This mental representation describes the problem solver's understanding of the problem along with the ability to identify what kind of problem it is. It also informs the problem solver as to what needs to be further investigated in order to depict a better picture of the problem, in order to devise a most viable solution to the problem. This mental representation of the problem is also known as problem space (Newell and Simon 1972).

Second, problem solving often involves retrieving problem schemas from the problem solver's memory to assist the process. A person's problem-solving experiences are accumulated and stored in his or her memories. These memories are organized in forms of mental models, also known as schemas (Rumelhart and Norman 1988). These problem schemas consist of semantic representations of the entities or sets in a problem and their structural relationships, as well as the process for finding the solution to the unknown in that situation. Thus, a complete problem schema is a mental representation resulting from induction of those sets, relationships, and processes based on previous experience in solving particular types of problems. An existing problem schema enables learners to proceed directly to the implementation stage of problem solving (Gick and Holyoak 1983) and try out the solution process included on the problem schema. On the other hand, problem schemas may be externalized as formal models using language, visualizations, equations, or other kinds of modeling tools. Instruction often attempts to map an external representation of problem-solving processes onto learners' memories. Although instruction may facilitate learners in forming the basics of problem schemas with external representations, it is the learners' active and mindful mental construction of the problem space that is most critical to effective problem solving.

Several normative models have been proposed to define the problem-solving process, for example, the classic General Problem Solver (Newell and Simon 1972). The General Problem Solver specifies two sets of thinking processes associated with the problem-solving processes, understanding processes and search processes. Another popular problem-solving model, the IDEAL problem solver (Bransford and Stein 1984) describes problem solving as a uniform process of *I*dentifying potential problems, *D*efining and representing the problem, *E*xploring possible strategies, *A*cting on those strategies, and *L*ooking back and evaluating the effects of those activities. Gick and Holyoak (1983) synthesized these and other problem-solving models into a simplified model of the problem-solving process, including the processes of constructing a problem representation, searching for solutions, and implementing and monitoring solutions. Although descriptively useful, these problem-solving models treat all problems in the same way, assuming that different kinds of problems in different contexts are solved similarly.

Important Scientific Research and Open Questions

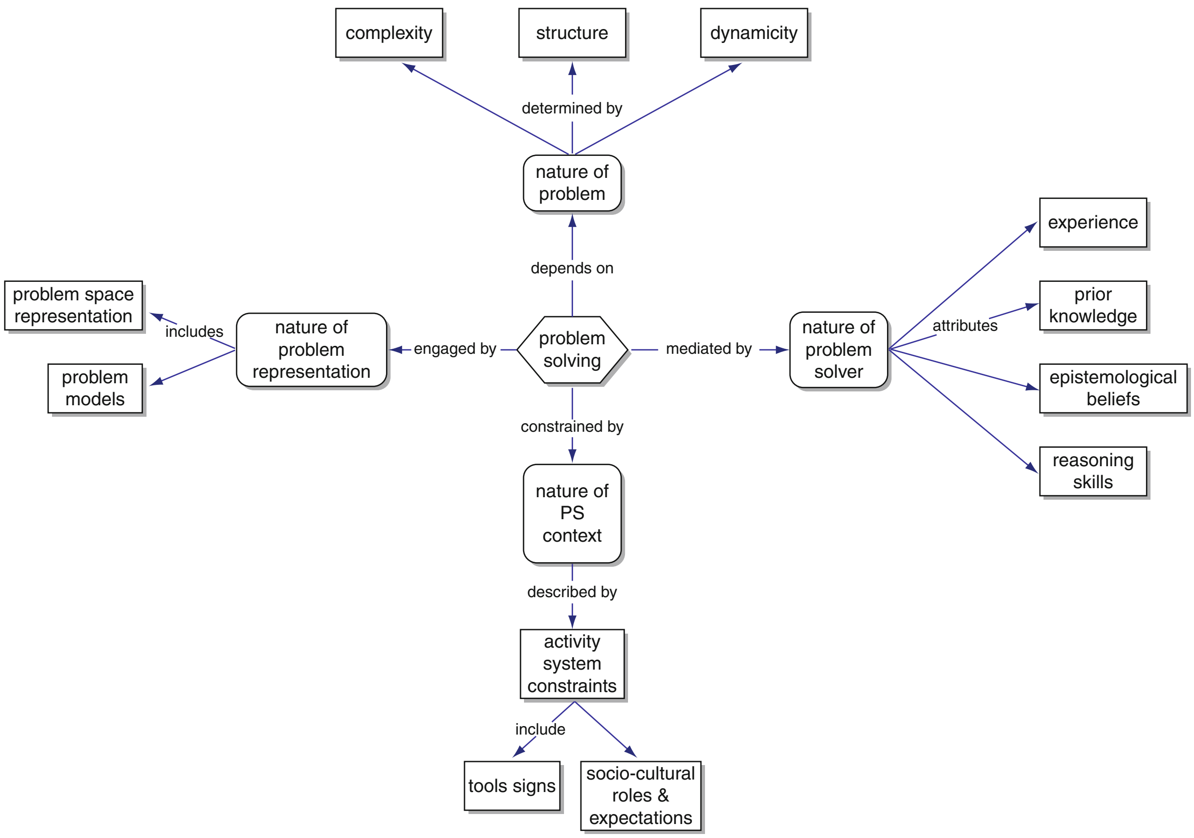
Problem solving is an incredibly complex process about which we know very little. In early problem-solving research, problem solving was treated as a unidimensional and linear solution-seeking process. In more recent years, the view of problem-solving research has shifted to a multidimensional model of problem solving, which provides researchers with more lenses for speculating upon the complex nature of problem solving. As illustrated in Fig. 1, the research on the nature of problem solving can be divided into four main aspects: problem, problem representation, problem solver, and context.

Nature of Problem

Problem solving has many meanings from many different perspectives. From an information-processing perspective, problem solving consists of sets of initial states, goals states, and path constraints (Wood 1983). Solving a problem is finding a path through the problem space that starts with initial states passing along paths that satisfy the path constraints and ends in the goal state. Most early research on problem solving has been based on this linear definition and therefore focused on simple, static, well-structured problems (see ► Problem Typology). Logic problems (e.g., tower of Hanoi) or story (word) problems in schools are examples of well-structured problem solving. This linear definition may be sufficient for describing well-structured problems; however, it is difficult to apply to ill-structured problems, where the goal states and path constraints are often unknown or are open to negotiation. Therefore, for ill-structured problems, no established routes through path constraints toward the goal state can be clearly defined. Most problems with which we deal in everyday personal or professional lives are ill structured and complex. Jonassen (2000) articulated three major dimensions in further differentiating the nature of ill-structured problems as well as the processes of solving them. As indicated in Fig. 1, the nature of problems and problem-solving process varies along at least three dimensions: structuredness, complexity, and dynamicity. All problems vary in the degrees of these three dimensions, which determine the difficulty level and the resources required for solving the problem. These three dimensions in the nature of problems have been discussed by a number of researchers (e.g., Frensch and Funke 1995; Jonassen and Hung 2008). However, the research in these areas is still in its infancy. Moreover, of these three dimensions, dynamicity could be deemed as the most difficult dimension to manage in the problem-solving process. In fact, dynamicity could amplify the degrees of structuredness and complexity (Jonassen and Hung 2008). The major research paradigm that has addressed dynamic problems is naturalistic decision making (Klein 1998). Given that many or most everyday problems are dynamic and possess the power to influence the other two dimensions, more research on the dimension of dynamicity is needed.

Nature of Problem Representation

How problems are represented to learners and how learners represent those problems both internally and externally encompass numerous research issues. Some research has examined how story problems are represented. That research has focused on worked examples and problem representations such as matrix representations. Jonassen has identified instructional components for problem-based learning environments, including worked examples, case studies, prior experiences, alternative perspectives, and problem



Problem Solving. Fig. 1 Dimensions of problems and issues needing resolution

analogues. Much more research is needed on the effects of these elements on problem representation and solution. Also, students' abilities in constructing problem space internally and externally largely determine their problem-solving competence. A number of cognitive tools have been used to facilitate students to construct problem space, such as concept mapping, schematic diagrams, influencing diagrams, and system modeling. The specific effects of these cognitive tools on various aspects and stages of problem solving are still not fully understood.

Nature of Problem Solver

Problem solving is affected by the characteristics of the problem solver. Researchers have argued that the characteristics of a person result from cognitive and social processes and consequently dictate the problem-solving process and solution. Thus, the problem solver's prior knowledge, previous experience, epistemological beliefs, reasoning skills, and a host of other individual differences have significant impact on not only the person's problem-solving competence, but also his or her primary focus, concerns, and perspective when solving different kinds of problems in different contexts. Additionally, the kinds of social interactions and the affordances of different social environments may also play a role in facilitating or hindering problem solving. These social factors could affect a person's development of problem-solving competence and effectiveness. The social interactions and environments that foster multiple perspectives could help problem solvers broaden their views when seeking solutions to problems. This habit of mind may also lead to enhancing creativity in problem solving. The research on the effects of problem solver's individual cognitive and sociocultural differences in problem solving remains scarce.

Nature of Problem-Solving Context

Problems also vary by context. In different situations and disciplines, people solve different kinds of problems. For example, Lehman et al. (1988) found students in different graduate disciplines develop different kinds of reasoning based on the kinds of problems they solve. Psychology and medical students perform better on statistical, methodological, and conditional reasoning problems than students in law and chemistry, which do not learn such forms of reasoning. The same personnel in different organizations solve different kinds of problems that emerge from the social, historical, and cultural aspects that define the organization. Relatively little research has addressed complex, ill-structured problems in everyday contexts (Sinnott 1989) and how context affects learners' development of problem-solving competence.

Cross-References

► Action-Based Learning
► Complex Problem Solving
► Mental Models and Lifelong Learning
► Problem Representation
► Problem Typology
► Problems: Definition, Types, and Evidence
► Schema-Based Instruction
► Task Sequencing and Learning

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Problem Solving in Dynamic Microworlds

► Complex Problem Solving

Problem Typology

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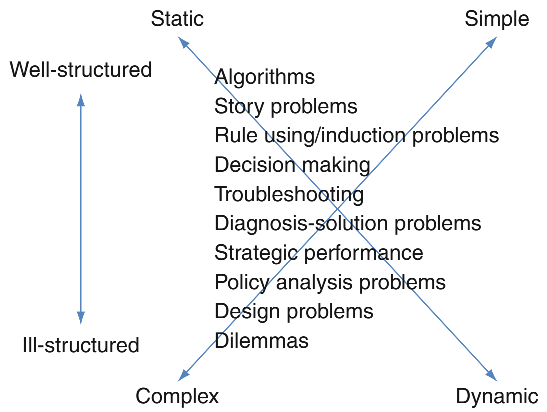
Synonyms

Learning outcomes; Learning taxonomy; Problem solving

Definition

Traditional models of problem solving, known as phase models (e.g., Bransford and Stein 1984), suggest that all problems can be solved if we (1) identify the problem, (2) generate alternative solutions, (3) evaluate those solutions, (4) implement the chosen solution, and (5) evaluate the effectiveness of the solution. However, problems and problem solving vary in several ways, including the skills and abilities of the problem solver, the nature of the problem itself, the context in which the problem occurs, and the way the problem is represented to the problem solver (Jonassen 2007). In this chapter, I describe how problems themselves vary.

Foremost among these differences is the continuum (see Fig. 1) between well-structured and ill-structured problems (Jonassen 1997, 2000; Voss and Post 1988). Most problems encountered in formal education are well-structured problems. Well-structured problems typically present all elements of the problem; engage a limited number of rules and principles that are organized in a predictive and prescriptive arrangement;



Problem Typology. Fig. 1 How problems differ

possess correct, convergent answers; and have a preferred, prescribed solution processes.

Ill-structured problems, on the other hand, are the kinds of problems that are encountered in everyday practice. Ill-structured problems have many alternative solutions to problems; vaguely defined or unclear goals and constraints; multiple solution paths; and multiple criteria for evaluating solutions; so they are more difficult to solve. Learning to troubleshoot complex systems, learning how to make policy decisions, and learning to adapt accounting techniques are ill-structured problems.

Problems also vary in complexity (see Fig. 1). The complexity of a problem is a function of the breadth of knowledge required to solve the problem, the level of prior knowledge, the intricacy for the problem-solution procedures, and the relational complexity of the problem (number of relations that need to be processed in parallel during a problem-solving process) (Jonassen and Hung 2008). Ill-structuredproblems tend to be more complex; however, there are a number of highly complex well-structured problems, such as playing chess or writing computer programs.

Problems also vary along a continuum from static to dynamic (see Fig. 1). In static problems, such as those in textbooks, the elements and conditions of the problem do not change. In dynamic problems, the relationships among variables or factors often change over time. Changes in one factor may cause variable changes in other factors that often substantively changes the nature of the problem making dynamic problems more difficult. The more intricate these interactions, the more difficult it is to ascertain a solution. Ill-structured problems tend to be more dynamic than well-structured problems.

What Kinds of Problems Exist?

Jonassen (2000) identified 10 kinds of problems, including algorithms, story problems, rule-using problems, decision making, troubleshooting, diagnosis-solution problems, strategic performance, policy analysis problems, design problems, and dilemmas. The different kinds of problems vary primarily along the well-structured/ill-structured continuum. As indicated in Fig. 1, they also vary along related continua of simple/complex and static/dynamic. This typology represents an evolving theory of problem solving. How discrete each kind of problem is and whether additional kinds of problems exist has not been validated.

Story Problems

Found at the end of chapters in virtually every science, mathematics, and engineering textbook, story problems consist of a limited number of problem elements that are usually related to each other mathematically and embedded in a thin story structure. Solving story problems requires learners to (1) represent the unknowns by letters; (2) translate relationships about unknowns into equations; (3) solve the equations to find the value of the unknowns; and (4) verify values found to see if they fit the original problem (Rich 1960). Unfortunately, it is the unsuccessful problem solvers who base their solution plans on the numbers and keywords that they select from problem (Hegarty et al. 1995). This linear process implies that solving problems is a procedure to be memorized, practiced, and habituated and that emphasizes answer getting, not meaning making (Wilson et al. 2005), so transferring that process to new contexts is very difficult for learners because they focus too closely on surface features or recall familiar solutions from previously solved problems (Woods et al. 1997). They fail to understand the principles and the conceptual applications underlying the performance, so they are unable to transfer the ability to solve one kind of problem to problems with the same structure but dissimilar features.

Rule-Using/Rule Induction Problems

Many problems have correct solutions but multiple solution paths or multiple rules governing the process.

They tend to a have clear purpose or goal that is constrained but not restricted to a specific procedure or method. Using an online search system to locate scientific literature or using a search engine to find scientific information on the World Wide Web are examples of rule-using problems. The purpose is clear: find the most relevant information sources in the least amount of time. That requires selection of search terms, constructing effective search arguments, implementing the search strategy, and evaluating the utility and credibility of information found. This is the rule-oriented essence of searching. Given that there are multiple search strategies that are possible, rule-using problems can become decidedly more ill-structured.

Many problems require that learner induce rules in order to solve problems. Figuring out how a new device works requires that users induce rules for its operation. Doing so requires that they induce rules that describe the behavior of the device.

Decision-Making Problems

Normative theories of decision-making specify that problem solvers select maximal solutions from a set of alternative solutions based on a number of weighted selection criteria. This involves comparing and contrasting the advantages and disadvantages of alternate solutions. Those criteria may be provided the problem solver(s), or the solver(s) may have to identify the most relevant criteria. Scientific businesses daily solve many decision-making problems, such as selecting a material to be used for a mechanical design; determining appropriate inventory levels; or selecting applicants for admission. Recent research has challenged this normative conception of decision making, preferring instead the construction of stories to frame decisions (see Jonassen 2011).

Troubleshooting Problems

Although troubleshooting is most commonly associated with technician-level jobs (maintaining complex communications and avionics equipment, repairing computer equipment), professionals also engage in troubleshooting faulty systems (e.g., engineers identify faults in chemical processes, physicians or psychotherapists diagnosing medical or psychological problems). Troubleshooting requires a combination of domain and system knowledge (conceptual models of the system including system components and interactions, flow control, fault states (fault characteristics, symptoms, contextual information, and probabilities of occurrence); troubleshooting strategies such as search-and-replace, serial elimination, and space splitting; and fault testing procedures. These skills are integrated and organized by the troubleshooter's experiences. As troubleshooters gain experience, their knowledge becomes indexed by those experiences rather than by any conceptual models of domain knowledge. Jonassen and Hung (2006) have articulated a research-based model for designing troubleshooting learning environments that include a multilayered conceptual model of the system, a simulator for hypothesis generation and testing, and a case library of stories from other troubleshooters.

Policy Problems

Policy problems are complex, leisure-time, ill-structured decision-making problems. They usually involve a host of city planners, policy analysts, community managers, local, state, and national legislators, citizens, agency leaders, and many other stakeholders, most of whom assume fundamentally different positions that are supported by very different beliefs. They are more contextually bound than any kind of problem considered so far. Classical situated case problems also exist in international relations, such as ".... given low crop productivity in the Soviet Union, how would the solver go about improving crop productivity if he or she served as Director of the Ministry of Agriculture in the Soviet Union" (Voss and Post 1988, p. 273).

Design Problems

Perhaps the most ill-structured kind of problem is design. Whether it be an electronic circuit, a mechanical part, or a new manufacturing system, a painting or song, design requires applying a great deal of domain knowledge with a lot of strategic knowledge resulting in an original design.

Design problems are among the most complex and ill-structured of all problems (Jonassen 2000). Despite the apparent goal of finding an optimal solution within determined constraints, design problems usually have vaguely defined or unclear goals with unstated constraints. They possess multiple solutions, with solution paths. Perhaps the most vexing part of design problems is that they possess multiple criteria for evaluating solutions, and these criteria are often unknown. Ultimately, the designer must please the client; however the criteria for an acceptable design are often unstated.

Design problems often require the designer to make judgments about the problem and defend them or express personal opinions or beliefs about the problem, so ill-structured problems are uniquely human interpersonal activities (Meacham and Emont 1989).

Dilemmas

Scientists and engineers often become embroiled in social or ethical dilemmas. Creating a biochemical product that is profitable but environmentally injurious represents a dilemma. Dilemmas may be the most ill-structured and unpredictable, often because there is no solution that will ever be acceptable to a significant portion of the people affected by the problem. Usually there are many valuable perspectives on the situation (economic, political, social, ethical, etc.); however, none compels an acceptable solution to the crisis. The situation is so complex and unpredictable that no best solution can ever be known. That does not mean that there are not many solutions, which can be attempted with variable degrees of success, however, none will ever meet the needs of the majority of people or escape the prospects of catastrophe.

Theoretical Background

The primary reason for distinguishing among different kinds of problems is the assumption that solving different kinds of problems calls on distinctly different sets of skills (Greeno 1980). Solving different kinds of problems entails different levels of certainty and risk (Wood 1983). Jonassen (2011) provides a set of design models for solving different kinds of problems.

Important Scientific Research and Open Questions

- What are the skills and processes required for solving different kinds of problems?
- Are specific kinds of problems found more commonly in different contexts?
- Is context or kind of problem more important for learning to solve problems?
- How likely is transfer across different kinds of problems?
- What are the instructional components that will best facilitate learning to solve different kinds of problems?
- To what degree do students in different disciplines learn to solve different kinds of problems?

Cross-References

► Problem-Based Learning
► Problems: Definitions, Types and Evidence

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Problem-Based Learning

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Synonyms

Inquiry-based learning; Project-based learning

Definition

Problem-based learning (PBL) is an instructional method aimed at preparing students for real-world settings. By requiring students to solve problems, PBL enhances students' learning outcomes by promoting their abilities and skills in applying knowledge, solving problems, practicing higher order thinking, and self-directing their own learning. PBL was originally conceived and implemented in the 1950s in response to medical students' unsatisfactory clinical performances. This under-desired performance was attributed to the emphasis on memorization of fragmented biomedical knowledge in traditional health science education (Barrows and Tamblyn 1980). The format and processes of PBL seen today were first developed in the medical school at McMaster University in the 1960s and 1970s (Barrows 1996). Since then, PBL has become a prominent instructional method in medical and health science education throughout the world, such as North America, Netherlands, England, Germany, Australia, New Zealand, and India. With the success of implementation in medical education, PBL has also been widely adopted by various disciplines in higher education as well as K-12 education settings. Its popularity continues to steadily rise.

The Characteristics of PBL

- Problem-focused. The students begin learning by simulating the process of solving an authentic, ill-structured problem.
- Problem-structured content. The content and skills to be learned are organized around problems, rather than as a hierarchical list of topics, so there is a reciprocal relationship between knowledge and the problem. Knowledge building is stimulated by the problem and applied back to the problem.
- Student-centered, self-directed learning. Students individually and collaboratively assume responsibility for generating learning objectives and processes through self-regulating their own learning processes, self-assessment and peer assessment, and accessing their own learning materials.
- Self-reflective. Students monitor their understanding and learn to adjust strategies for learning.
- Tutors/instructors as facilitators. Instructors are not knowledge disseminators. Rather, they support and model reasoning processes, facilitate group processes and interpersonal dynamics, probe students' knowledge deeply, and never interject content or provide direct answers to questions (Hung et al. 2008).

The Process of PBL

1. Students in groups of 5–8 encounter and reason through the problem.
2. Students define the problem and set learning objectives by identifying what they need to learn in order to solve the problem and generate hypotheses to the cause of the problem.
3. During self-directed study, individual students complete their learning assignments, which may include collecting related information, studying resources, and preparing reports to the group.
4. Students share their research results with the group, revisit the problem, and generate additional hypotheses and reject others based on their learning.
5. Students generate or select a most viable solution to the problem.
6. At the end of the learning period, students summarize and integrate their learning (Hung et al. 2008).

Theoretical Background

PBL researchers contended that PBL is conceptually based upon the information processing process model of cognition, cognitive theories, and constructivist theories. The specific applications of these theories utilized in PBL include connecting new information with prior knowledge and schemas, elaboration and construction of information learned, collaborative learning, and social negotiation. According to Barrows (1996), four fundamental components comprise PBL: problem-driven, contextualized, student-centered/self-directed, and collaborative learning processes. First of all, in PBL, the students' learning is initiated by a need to solve an authentic problem. Thus, the learning of content and its applications in PBL, as Barrows and Tamblyn (1980, p. 1) explained, "results from the process of working toward the understanding or resolution of a problem so it is important that the problem is encountered first in the learning process." In PBL, students are no longer receiving the learning content from the instructor in a "textbook" logical sequence. Rather, the knowledge needed for solving the problem formulates the scope of the content. Moreover, PBL learners have to engage in inquiry processes in which critical and creative thinking skills are the key for the learners to accomplish the problem-solving tasks imposed upon them. These cognitive processes and abilities promote the learner's higher-level thinking skills, and consequently, result in deeper understanding and better application and transfer of the knowledge in the future. Also, problem solving is inherently challenging and motivating. This intrinsic motivational component helps increase students' desire to learn and sustains their interest throughout the course of the learning.

Secondly, through the process of solving the problem, students are not only acquiring the domain knowledge, but also constructing appropriate knowledge schemata and contextualizing the knowledge learned. The approach of utilizing authentic problems naturally contextualizes the content, knowledge, and skills learned throughout the course. Traditional instruction usually presents content information and assesses students with context-free problems. The failure of traditional method in helping students link the knowledge learned to real life practice is a long discussed instructional issue. In PBL, the tasks of solving authentic problems help students establish the situational knowledge for not only structuring but also indexing their domain content knowledge.

Thirdly, self-directed learning is a critical component in PBL. Savery and Duffy (1996) asserted that in problem-based learning environments, the learner must develop his or her own learning skills and strategies to successfully fulfill the learning tasks. The learning activities embedded in the learning process encourage and elevate the learner's self-regulation and metacognition during and/or after the learning process. By observing and emulating the instructor's reasoning and problem-solving processes and being required to solve the problem independently (with appropriate amount of guidance from the instructor), the students are practicing and developing their own problem solving, self-directed learning, and metacognitive skills.

Lastly, in PBL, students work in small groups. By working collaboratively, PBL students decide what the "problem" is and collectively generate learning issues/objectives for their self-directed learning. The requirement of working in groups helps students exercise their collaboration, cooperation, interpersonal, and communication skills. Thus, through the steps of the PBL process, students engage in necessary cognitive processes that help them actively and self-directedly construct, apply, integrate, and reflect on the intended content knowledge within a relevant context.

Important Scientific Research and Open Questions

Enormous amounts of research, including more than a dozen meta-analyses (e.g., Albanese and Mitchell 1993), have been conducted to answer a question – that is, is PBL effective? A general conclusion from these empirical studies was that PBL is effective in alleviating students' problems of inert knowledge as well as enhancing students' problem solving, higher order thinking, self-directed learning skills, and motivation to learn. Also, PBL students consistently outperformed traditional students on long-term retention assessments.

Tutoring/facilitation is a critical area for the success of PBL. Donaldson and Caplow's (1996) research on the role expectations of PBL tutors revealed two major dilemmas perceived by PBL tutors: the conceptualization of facilitator and the tensions that arose as tutors tried to redefine their role in PBL as compared to their previous role as medical teacher. Because of the drastic changes in their roles in PBL, many tutors experienced difficulty in assuming their new roles. Some instructors are threatened by losing control of the learning environment. In addition, teachers who deem knowledge as a body of information to be transmitted from the knowledgeable teacher to the unknowing student could also feel troubled by the PBL process. Thus, the PBL tutor must balance a degree of participation in students' learning processes and refrain from the temptation to lecture.

Group processing plays a key role in the success of PBL implementation. However, Achilles and Hoover (1996) reported a concern in their study that the students had difficulty working in groups. In fact, the need for effective guidance of group processing was not only perceived by K-12 students, but also by the medical students. Tutor's facilitation skills are essential to effective group processing. Four consequential facilitation skills that are critical to facilitating group processing include: (1) helping the group be aware of how group processing works, (2) encouraging feedback within the group, (3) guiding the group to set appropriate learning objectives; and (4) assisting the group to integrate learning issues. Furthermore, group size is also a factor that potentially affects students' learning processes and outcomes. Six to eight students are considered an ideal group size.

The assessment used in the early implementation of PBL largely relied on traditional standardized tests. In more recent years, the emphasis of assessment has shifted from testing factual knowledge to assessing application of the knowledge. A number of different methodologies have been developed to assess students' problem solving skills, reasoning skills, and personal progress. For example, according to Swanson, Case, and van der Vleuten's (1998) classification, there are outcome-oriented instruments, such as the progress test, essay exams, oral and structured oral examinations, patient-management problems, clinical reasoning exercises, problem-analysis questions, and standardized patient-based tests, as well as process-oriented instruments, such as the triple jump–based exercises, Medical Independent Learning Exercise (MILE), the four step assessment test (4SAT), formative assessment, and tutor, peer, and self-assessment.

A number of issues and challenges also exist in the field of PBL. First, as PBL migrates to other disciplines, such as engineering, biology, or education, research needs to be focused on the nature of the problems being solved and how efficacious PBL methodologies are for different kinds of problems. Along the continuum from well-structured to ill-structured problems (Jonassen 2000), which kinds of problems can be effectively supported using PBL? Also, PBL was originally developed for training medical students. In those contexts, educators assume that students are cognitively ready for solving ill-structured problems and engaging in self-directed learning. As more PBL curricula are being implemented in K-12 schools, younger students may not be ready to solve complex and ill-structured problems and self-direct their own learning. The question of learner characteristics (developmental level, epistemological beliefs, cognitive controls, maturity, reading ability, etc.) related to PBL has not been sufficiently addressed. Lastly, the intense demand on resources presents a challenge for PBL implementation. To achieve an ideal group size (6–8) in order for the group to function effectively and efficiently, administrators face a great financial and resource challenge. Oftentimes, the quality of tutoring is compromised due to the administration's inability to resolve this issue. Another issue is workload. Both students and instructors have complained about the workload and demand on time. To investigate a problem in depth requires a substantial amount of time to complete all the required tasks. At the same time, to provide quality facilitation, the tutors have to allocate more time to prepare as well as guide students and give feedback than they do in traditional teaching methods. These are the unresolved challenges faced by PBL researchers and educators today.

Cross-References

► Action-Based Learning
► Guided Discovery Learning
► Learning by Doing
► Problem Solving
► Problem Typology
► Self-regulated Learning

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Problem-Centered Learning

► Model-Facilitated Learning

Problems

► Problem Solving

Problems: Definition, Types, and Evidence

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Synonyms

Problem solving

Definition

A distinction can be made between "task" and "problem." Generally, a *task* is a well-defined piece of work that is usually imposed by another person and may be burdensome. A *problem* is generally considered to be a task, a situation, or person which is difficult to deal with or control due to complexity and intransparency. In everyday language, a problem is a question proposed for solution, a matter stated for examination or proof. In each case, a problem is considered to be a matter which is difficult to solve or settle, a doubtful case, or a complex task involving doubt and uncertainty.

Theoretical Background

The nature of human problem solving has been studied by psychologists over the past hundred years. Beginning with the early experimental work of the Gestalt psychologists in Germany, and continuing through the 1960s and early 1970s, research on problem solving typically operated with relatively simple laboratory problems, such as Duncker's famous "X-ray" problem and Ewert and Lambert's "disk" problem (later known as "Tower of Hanoi"). Various factors account for the choice of simple problems: They have clearly defined optimal solutions, they are solvable within a relatively short time frame, researchers can trace learners' problem-solving steps, and so on. Furthermore, it can be argued that that simple problems, such as the Tower of Hanoi problem, capture the main properties of "real world" problems, and that the cognitive processes underlying attempts to solve simple problems are representative of "real world" problems.

Thus, researchers used simple problems for reasons of convenience and thought it would be possible to generalize their findings to explain how people solve more complex problems. Perhaps the best-known and most impressive example of this line of research is the work by Newell and Simon (1972). Whereas Gestalt psychologists maintained that problem solving is based on "restructuring" a problem in order to gain "insight" into its solution, cognitive psychologists agreed on the point that problem solving should be considered as information processing.

Cognitive psychologists propose that the first thing a person does when confronted with a problem is to construct a mental representation of its relevant features. This internal representation of a problem is termed a *problem space*. When its construction has been successful the problem space consists of information about the initial and goal state of the problem as well as information about the operators which can be applied to solve it. Generally, a problem occurs if a person does not know how to proceed from a given state to a desired goal state. Thus, a problem is described by three components: (1) a given initial state s_α; (2) a desired final state s_ω; and (3) a barrier which hinders the solution of the problem, that is, to come from s_α to s_ω. A helpful classification of problems and the barriers involved in them has been provided by Dörner (1976), who argues that the type of a problem depends on the transparency of the goal criteria and how familiar the means of solving it are (see Table 1).

In the case of a problem with an *interpolation barrier*, both s_α and s_ω are known – for example, if you want to travel from New York City to Sydney. The problem consists in the interpolation, that is, the effective order of the necessary transformations of states of time and space. The solution requires the correct combination or order of known operations. In the case of a problem with a *synthetic barrier* the set of operations aiming at the transformation from s_α and s_ω is not closed. That means that the individual knows after several problem-solving trials that the available means and operations are insufficient. A good example is the task of producing gold from straw: s_α and s_ω are known, but both the effective combination of operations and the necessary operations themselves are unknown. Therefore, the problem consists in finding the effective operations and their correct combination. Accordingly, the major task consists in synthesizing an inventory of effective operations. With reference to our example, we know that such an inventory does not exist because we can produce all sorts of things from straw but not gold. In the case of problems with a *dialectic barrier* the problem solver knows that a given situation s_α must be changed, but only the global criteria for the desired change are known. For example, a young lady wants to have an apartment which is more attractive than her current one, but she does not know how this can be achieved (combination of colors, style of furniture, etc.). Although it may be easy to find comparative

Problems: Definition, Types, and Evidence. Table 1 Classification of problems in accordance with both the clarity of objectives and certainty of resources (Dörner 1976)

		Clarity of objectives	
		High	*Low*
Certainty of resources	*High*	Interpolation barrier	Dialectic barrier
	Low	Synthetic barrier	Dialectic and synthetic barrier

criteria, we can assume that the subjectively satisfying solution to this problem can be found in a dialectic process. Accordingly, a first sketch will be evaluated with regard to both external consistency (e.g., concerning the requirements of the environment) and internal consistency. This sketch must probably be modified or revised and will then be evaluated again, and so on. Another example for a dialectic process of problem solving is the production of a master's thesis.

The type of barrier evidently depends on the prior knowledge and the applicable skills of the problem solver. If, for example, an individual does not know anything about chemistry then the production of ammonia will be a problem with a synthetic barrier, whereas it will only be a problem with an interpolation barrier for a chemist. Moreover, a complex problem may contain not only one barrier but possibly all kinds of barriers. The experience of a barrier motivates problem solvers to varying degrees to grapple with a problem and leads them to test different solutions.

Problems also vary in terms of how structured they are. Jonassen (1997) classifies problems on a continuum from *well structured* to *ill structured* (see also the entry on ► Problem Typology). This differentiation corresponds to the distinction between *well-defined* and *ill-defined problems*, which has its origins in the specification of components of a problem space. Well-structured problems have a well-defined initial state, a known goal state or solution, and a constrained set of known procedures for solving a class of problems. In other words, they require the application of a limited and known number of concepts, rules, and principles (e.g., means-ends analysis) studied within a restricted domain. In contrast, the solutions to ill-structured problems are neither predictable nor convergent because they often possess aspects that are unknown. Additionally, they possess multiple solutions or solution methods or often no solutions at all.

Problems vary in complexity. The complexity of a problem is determined by the number of issues, functions, or variables it involves; the degree of connectivity among these variables; the type of functional relationships between these properties; and the stability of the properties of the problem over time (cf. Funke 1992). Simple problems, like textbook problems, are composed of few variables, while ill-structured problems may include many factors or variables that may interact in unpredictable ways. For example, international political problems are complex and unpredictable. Finally, problems vary in their stability or dynamicity. More complex problems tend to be dynamic; that is, the task environment and its factors change over time. When the conditions of a problem change, people must continuously adapt their understanding of the problem while searching for new solutions, because the old solutions may no longer be viable. For example, investing in the stock market is often difficult because market conditions (such as demand, interest rates, or confidence) tend to change, often dramatically, over short periods of time. Static problems are those in which the factors are stable over time. Clearly, ill-structured problems tend to be more dynamic, whereas well-structured problems tend to be fairly stable.

Important Scientific Research and Open Questions

Although cognitive psychologists on both sides of the Atlantic generally agree on the point that problem solving should be considered as information processing, different lines of research have emerged in North America and in Europe. Initiated by the work of Herbert Simon, researchers in *North America* began to investigate problem solving separately in different natural knowledge domains – such as physics, writing, or chess playing – thus relinquishing their attempts to extract a unique and comprehensive theory of problem solving. The North American line focused on the investigation of problem solving within specific domains such as reading, calculating, political decision making, and personal problem solving (cf. Funke and Frensch 1995). Newell, Shaw, and Simon (1959) introduced the General Problem Solver (GPS), which simulates human problem-solving behavior. This computer program was proposed to provide an essential set of processes to solve a variety of different problems. Accordingly, the GPS solves distinctive formally described problems or tasks by itself and with a specific analogy to human problem-solving performance, which presupposes the sequential transformation of knowledge structures. During a problem-solving process, mental operators generate the shift from an initial knowledge state to the desired final state. An example of such serial information processing is the aforementioned *Tower of Hanoi* problem. Although the GPS was expected to be a general problem solver, it clearly was limited to "well-defined" problems, such as word puzzles, chess, or the proving of theorems in logic. Nevertheless, the GPS provided a basis for a wide range of common problems in different domains. Whereas the GPS was concerned with solving any given problem in any domain, expert systems (ES) were domain specific to a high degree. ES were developed to aid in decision making and to present results in a well-founded manner to the expert who makes the final decision. But human decision making is not based on individual constituents, even if they are well founded. Due to a lack of systematic empirical research, the effectiveness of ES could not be clarified.

While the North American line of research focused successfully on the implementation of problem solving in computer systems, the European line focused on the simulation of complex environments to empower human problem solving and decision making within complex domains. Two approaches surfaced, one initiated by Donald Broadbent (1977) in the United Kingdom and the other by Dietrich Dörner in Germany (Dörner 1976). The two approaches have a common emphasis on relatively complex, semantically rich, computerized laboratory tasks constructed to resemble real-life problems. The approaches differ somewhat, however, in their theoretical goals and methodology. The tradition initiated by Broadbent emphasizes the distinction between cognitive problem-solving processes that operate under awareness versus outside of awareness and typically employs mathematically well-defined computerized systems. The tradition initiated by Dörner, on the other hand, is interested in the interplay of the cognitive, motivational, and social components of problem solving and utilizes very complex computerized scenarios (e.g., the Lohhausen project by Dörner et al. 1983).

Both approaches focused on laboratory problems with complex structures that were computerized and analogous to real-life situations. Broadbent's experimental research emphasized the distinction between cognitive problem-solving processes in explicit and implicit modes (Berry and Broadbent 1995). These experimental approaches helped to categorize expert problem solving further, thus strengthening the understanding that there is nothing like *one single problem-solving skill* or deterministic algorithm which accurately describes human problem solving and that each of the categories comes with different sets of knowledge and skills. On the other hand, Dörner developed complex computer environments with more than 2,000 variables (Dörner et al. 1983). Several experimental studies with the Lohhausen scenario revealed typical errors which occur when one works with complex systems (Dörner 1989). However, the computational models were no longer used to *simulate* (or imitate) the problem-solving process but to *stimulate* them. Instead of trying to compute the problem-solving process (as in GPS) or support the decisions, Dörner developed research instruments for a better understanding of problem solving and at the same time provided environments to train problem solving skills. On the computational level, the environments of course still have to be deterministic in order to be implemented. But due to the many variables it was not possible for subjects to understand all of their effects. Having models which are fully available to the researcher (or to the instructor) and yet unable to be disclosed to the learners led to a better understanding of the problem-solving process. These insights still provide us with opportunities to train systematically human complex problem solving today.

Cross-References

► Complex Problem Solving
► Problem Typology
► Problem-Based Learning

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Problem-Solving

► Collaborative Learning and Critical Thinking

Problem-Solving Efficiency

► Cognitive Efficiency

Problem-Solving Tasks

► Cognitive Tasks and Learning

Procedural Knowledge

Knowledge about how to perform a specific task. It is not episodic knowledge (in that it cannot be easily verbalized), but rather it is implicit or tacit knowledge. An example of procedural knowledge would be the ability to ride a bicycle. Generally, procedural knowledge is knowledge of how to perform tasks and solve problems. It is commonly conceptualized as a condition-action pair (i.e., a production) that links an initiating cue with appropriate cognitive or psychomotor responses. With deliberately acquired skills, the development and refinement of effective productions begins with heavy involvement of declarative knowledge to support proportionately large quantities of consciously determined steps. As procedural knowledge is refined through practice, the relevant conditional cues become more refined, and skilled performance becomes less dependent on declarative knowledge. Extensive practice leads to the development of skill automaticity, in which procedural knowledge is executed without any need for conscious monitoring.

Procedural Learning

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Synonyms

Habit learning; Implicit learning; Perceptual skill learning; Sequence learning; Serial-order learning; Skill learning

Definition

Procedural learning refers to the acquisition of motor skills and habits, and certain types of cognitive skills. Unlike declarative learning and memory, procedural memory is typically inaccessible to conscious recollection. While factual information is consciously recalled in declarative or explicit memory, in procedural learning, acquisition and memory are demonstrated through task performance. In declarative learning, fact acquisition can occur very quickly, even upon single exposure to an event, but procedural learning usually requires repetition of an activity, and associated learning is demonstrated through improved task performance. Declarative learning and memory lends itself to explicit, conscious recollection. Procedural learning and memory are implicit; the actual learning is inferred from an individual's improvement in performing the task. Classic but simple examples of procedural learning include learning how to ride a bicycle, learning how to knit or crochet, learning how to use a computer keyboard, or even learning the skills necessary to play a musical instrument such as a piano.

Because the most common examples of implicit learning concern acquisition of motor skills, there is a tendency to erroneously equate procedural learning with motor learning. However, procedural learning also includes acquisition of certain cognitive skills. For instance, it has been demonstrated that performing a number of neuropsychological problem-solving tasks, such as the Tower of London test or the Tower of Hanoi test, depends upon procedural learning mechanisms. Similarly, acquiring certain skills such as borrowing and carrying when performing numerical operations can be considered forms of procedural learning. Although conscious cognitive input may be necessary in the initial phases of task acquisition, task performance becomes automatic and independent of conscious cognitive input and control as the task is acquired. Task sequencing comprises a central feature for all of these activities; the activity in question needs to be performed the same way, every time, until the "procedure" is learned or established. Once the relevant procedures are acquired, they are very robust and are not easily forgotten. Due to procedural memory's robust nature, it has been considered a division of "long term" memory.

Theoretical Background

Any organism's primary purpose is survival. We survive through interacting with the environment, in other words, through *adaptation*. Successful human adaptation requires meeting several sensory and motor conditions. Sensory conditions comprise an ability to correctly identify and locate objects in the environment. Moreover, an ability to remember what these objects are and where they are located would provide a decisive advantage in adaptation. Therefore, there must have been considerable evolutionary pressure to develop the declarative memory system, which essentially allows sensory-perceptual experience to persist over time. This type of memory is mediated by the medial temporal lobe system, which lies in sensory-perceptual brain regions posterior to the central sulcus. Successful adaptation would also require an ability to benefit from the *experience* of interacting with the environment, which involves motor function. In other words, adaptation would require benefitting from *activity* in addition to benefiting from *perception*. This condition involves the procedural memory system, which is governed by cortico-striatal and cerebro-cerebellar interactions. The procedural memory system involves the frontal lobes, and projects vertically to the basal ganglia and cerebellum. The declarative and procedural memory systems comprise interactive but dissociable mechanisms.

For example, H.M. became amnestic after bilateral medial temporal lobe resection, a surgery that was performed to manage his uncontrollable seizure activity. After his surgery, he was unable to learn or remember any new sensory-perceptual or factual information. However, he was able to learn a variety of new motor and cognitive skills, including mirror tracing and solving the Tower of Hanoi. Nevertheless, he had no conscious memory of ever performing those tasks. Conversely, patients with Parkinson's disease, in which the cortico-striatal system is primarily affected while the medial temporal lobe system remains intact, have great difficulty in learning mirror tracing and tower-type tests, while learning and memory dependent upon the medial temporal lobe system is preserved (dependent upon the stage of the deteriorating disease process).

Important Scientific Research and Open Questions

The neuroanatomy of the medial temporal lobe memory system is reasonably well understood at this point. However, a number of questions remain about the procedural learning system. Despite this, certain inferences can and have been drawn, and are receiving increasing support. Neuroanatomical imaging studies, clinical studies, and computational models of functional neuroanatomy all imply that procedural learning is dependent upon a network of cortical, striatal, and cerebellar brain regions. The networks involved are described as *dynamic*, because as learning for a task in question occurs, the neural representation of that behavior changes within the brain.

In the medial temporal lobe memory system, the hippocampal region is believed to bind various aspects of sensory-perceptual experience stored within distributed cortical regions into an integrated, whole percept. In the procedural memory system, imaging studies have demonstrated that regions of the frontal lobes, the head of the caudate nucleus (the sensory aspect of the striatum) and anterior regions of the putamen (the motor aspect of the striatum) are initially highly activated during the course of procedural learning. Activity within the prefrontal lobes appears to reflect the "executive control" necessary to guide performance of a new serial-order processing task. Notably, activity in this region slowly but markedly decreases as learning occurs. This decrease in brain activity accompanying acquisition of the motor skill or sequence reveals that representation within the brain becomes more efficient as automaticity (which is measured through improved performance) occurs. Different brain regions are involved in first acquiring the task, and then in performing the task automatically, reflecting a dynamically changing neuroanatomy. The basal ganglia's main function in this process appears to be "chunking" units of behavior or thought together. This "chunking" promotes automated development of behavioral and cognitive units that need particular temporal or sequential order. In this regard, the basal ganglia function in an analogous way to the hippocampal medial temporal lobe system in "binding" the information necessary for automatic task performance.

The role of the cerebro-cerebellar system in procedural learning can be understood as regulating the rate, rhythm, and force of any given behavior. In other words, the cerebellum performs a *refinement* function. The sequence processing demands of frontal-striatal interactions depends in part on appropriate intensities and durations of neuronal discharges in cortical regions. The cerebellum regulates the intensity and duration of impulses through its inhibitory refinement functions. When these "timing" functions related to motor circuits are disrupted by cerebellar disease processes, the resulting behavior commonly observed is dysmetria, in which movements become erratic in size and direction. The motor program and the motor intention are retained, but the quality of the movement is affected.

The cerebellum is also believed to play a role in the automation of new motor and cognitive procedures. For example, learning a new motor skill requires planning and sequencing a program of activity through repeated cortical-striatal interactions. An efficient procedural learning process would require some sort of sensory "feedback" in order to benefit from error by correcting the behavior. However, cortical sensory feedback operates slowly. Therefore, the cerebellum is believed to develop a short-cut, anticipatory control model. This internal cerebellar model comprises the most efficient neural pathways through which movements and activities (procedures) can be executed quickly and efficiently, independent of higher-order thinking. The cerebellar model is based upon its storage of multiple episodes during which it has already done so, allowing behaviors to be executed on the basis of sensory-perceptual anticipation, instead of direct, and slow, sensory feedback. The cerebellar model is corrected and refined through engaging in multiple successful episodes of the procedure. This allows the procedure to become automatic, independent of cortical control, so that the brain always stores and retains the most efficient representation of the behavior or procedure. Through this anticipatory control model, the cerebellum serves to "speed up" the process of the sensory-perceptual processing necessary for the acquisition and elegant execution of previously novel procedures. These anticipatory functions are increasingly thought to contribute to "intuition," and "ah ha" cognitive experiences, and dysfunction in these as well as cortico-striatal circuitries contributes to a variety of neurodevelopmental and neurodegenerative disorders.

Cross-References

- ▶ Adaptation and Learning
- ▶ Automaticity in Memory
- ▶ Developmental Cognitive Neuroscience and Learning
- ▶ Implicit Sequence Learning
- ▶ Memory Codes
- ▶ Neuroeducational Approaches on Learning
- ▶ Routinization of Learning
- ▶ Routinized Learning of Behavior

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Procedural Memory

Memory for knowledge about how actions are executed. Procedural memory contains memory for actions such as tying a shoe or hitting a baseball.

Cross-References

- ▶ New Learning in Dementia

Procedural Memory Consolidation

- ▶ Sequence Skill Consolidation in Normal Aging

Procedural Rationality

The notion that rationality should be studied by focusing on the decision processes and on the decision maker. Sometimes used as a synonym for bounded rationality.

Cross-References

- ▶ Bounded Rationality and Learning

Procedural Rhetoric

The relationship between a video game's content and the governing rules and action that guide game play.

Proceduralization

- ▶ Routinization of Learning
- ▶ Task Sequencing and Learning

Process

- ▶ Trajectories of Participation - Temporality and Learning

Process Algebra

A process algebra is a mathematical language used for formal modeling and analyses. Early process algebra concentrated on modeling concurrent systems. Distributed computer systems, multiprocessor chips, and cell phone networks are examples of systems that exhibit concurrent characteristics. Many specialized process algebra have been proposed over the years. One such contemporary process algebra is the stochastic pi-calculus, which is suitable for modeling stochastic phenomena that have changing structures over time. It has found its niche within systems biology as a means for modeling and simulating biochemical reactions.

Procrastination and Learning

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Synonyms

Dilatory behavior; Self-handicapping

Definition

Procrastination can be defined behaviorally as the act of postponing initiating or doing work that is necessary to complete a task that one intends to complete within a specific timeframe. The manifestation of procrastination with regard to school tasks, assignments, or obligations is known as ► academic procrastination. Academic procrastination has been examined in relation to academic performance along with numerous other outcomes. For the most part, academic procrastination has been linked to several negative indicators of learning outcomes (e.g., Schouwenburg et al. 2004). Beyond its behavioral understanding, there are variations in the definition of procrastination provided by researchers in the sciences of learning and cognition. One alternative understanding is that procrastination must include individuals' experience of stress, anxiety, or other negative emotional responses as a result of putting off work for a task. This more restrictive view highlights the idea that merely reducing the priority or putting off when certain tasks get addressed should not be considered procrastination. Another conceptual divide exists between those who define procrastination primarily through specific behaviors versus those who view it more as a personality trait that must be displayed habitually across multiple contexts. Finally, contrary to the normative view that it is maladaptive, some have argued that procrastination can at times be purposely planned and adaptive.

Theoretical Background

Research on procrastination has been conducted within fields such as education, psychology, political science, economics, and sociology. Much of the research, however, has focused on examining this phenomenon within academic settings where there continues to be debate about the nature, causes, and outcomes of procrastination. More firmly established both empirically and anecdotally is that procrastination is a widespread occurrence within academic settings, especially among college students. Estimates suggest that between 50% and 95% of college students procrastinate on a regular basis (e.g., Ferrari and Pychyl 2000; Schraw et al. 2007; Steel 2007). Another reason that procrastination studies have focused on academic settings is because of the negative learning implications that may result from this behavior. Studies suggest that procrastinators not only tend to perform more poorly than non-procrastinators but also experience poorer health, higher levels of stress and fatigue, mild depression, anxiety, and lower self-esteem (Schraw et al. 2007; Steel 2007); all affective attributes that may impact the learning experience. Based on these negative outcomes, procrastination is often considered a form of ► self-handicapping or actions taken by students that serve to undercut their own ability to perform at optimal levels.

Antecedents of Academic Procrastination

A plethora of psychological variables and task characteristics have been examined in an effort to understand why students procrastinate on academic tasks. In terms of task characteristics, studies have consistently shown ► task aversiveness to be a positive predictor of procrastination. Not surprisingly, when students' perceive tasks to be unpleasant, boring, or difficult they are more likely to put off getting started on them.

Prior knowledge may also influence procrastination behavior in that courses that require less prior knowledge may foster higher levels of procrastination. Another task characteristic examined is the amount of time allotted to complete a task, sometimes labeled timing of rewards and punishment. The logic here is that individuals are less likely to procrastinate as a deadline nears because the positive or negative repercussions of completing the task become more immediate and significant (Schraw et al. 2007; Steel 2007).

Researchers also have explored situational or instructional conditions impacting procrastination such as teacher organization, teacher expectations of work quality, and punctuality of assignment submission. Teachers who provide unclear directions for their class and who are perceived as having low expectations for their students' work may promote procrastination (Schraw et al. 2007). Further research needs to be conducted in this area to get a better understanding of what other classroom practices and teacher characteristics may inadvertently encourage dilatory behavior.

Two demographic variables have most often been examined as moderators of procrastination: gender and age. From this work, it appears that males are slightly more likely to procrastinate than females, and procrastination seems to decrease with age (Steel 2007). Researchers have conceptualized the more psychological variables that impact procrastination using the ► Big Five Personality Traits. Weak to no significant direct relationship has been found between procrastination and Openness to Experience or Agreeableness. Extraversion has been found to have a weak relationship with procrastination except for the impulsiveness component of extraversion which has been found to play a significant role in predicting procrastination. Facets of neuroticism such as fear of failure, perfectionism, self-handicapping, depression, evaluation anxiety, self-consciousness, ► self-efficacy, and self-esteem have been more commonly studied in relation to procrastination. Despite popular beliefs that these various aspects of neuroticism are strongly related to procrastination, only self-efficacy and self-esteem have been consistently found to be strongly and negatively associated with procrastination. Finally, empirical findings support the notion that conscientiousness is the strongest negative predictor of procrastination among the Big Five Personality Traits, particularly the facets of self-control, distractibility, organization, and need for achievement. This consistent finding has led some researchers to characterize procrastination as self-regulatory failure (Steel 2007). Hence, this pattern may be why research related to procrastination has moved toward examining this behavior with ► self-regulated learning constructs (e.g., Wolters 2003).

Outcomes of Academic Procrastination

Two outcomes of procrastination have been commonly studied in empirical quantitative research: mood and academic performance. Researchers suggest that mood initially may be improved by procrastinating since the student is putting off any stress or anxiety that may be experienced otherwise. Findings have been mixed, however, in terms of whether procrastination influences mood more generally. In terms of academic performance, studies have consistently found negative relations between procrastination and long-term indicators of learning such as cumulative GPA and task-specific indicators of learning such as final exam scores and assignment grades (Steel 2007). However, these relations have been absent in some studies and somewhat weak in others.

Important Scientific Research and Open Questions

Understanding Procrastination Within a Theory

One unresolved scientific question is how best to integrate procrastination into a larger theory of learning. There is no widely accepted formal model of the procrastination process, particularly not one that is formulated within a larger theoretical framework of learning. More recently, some researchers have proposed conceptualizing procrastination within existing models of learning and motivation (Steel 2007; Wolters 2003), while others researchers have set forth in developing an inductively based paradigm model of procrastination (Schraw et al. 2007).

To investigate procrastination within a central model of learning and motivation, Wolters (2003) examined this behavior within a self-regulated learning framework to examine how procrastination is associated with several motivational and cognitive constructs. Overall, his findings supported the notion that students with certain characteristics of a self-regulated learner, particularly those who report higher levels of self-efficacy, are less likely to engage in procrastination. Further research needs to be conducted with a broad array of self-regulation learning variables to better understand how procrastination fits within models of self-regulated learning.

Steel (2007) proposed examining procrastination within a multidisciplinary integrated theory of motivation known as Temporal Motivation Theory. This model states that individuals are more likely to engage in tasks that they feel self-efficacious about, value, and perceive as more immediately rewarding. These relationships are also contingent upon a person's degree of distractibility, impulsivity, and self-control. In other words, an individual is more likely to procrastinate if they do not feel confident in successfully completing the task, if they find the task boring or irrelevant, if the repercussions for completing the task are far in the future, and if they lack self-control. Findings from Steel's (2007) meta-analytic study provided support for his model. However, further studies are needed to evaluate how well each of the component variables functions simultaneously to predict procrastination behavior.

Schraw and his colleagues (2007) took a different approach and formulated a ► grounded theory of academic procrastination. In their theory development they identified emergent principles that guide students' procrastination. These principles highlight the idea that college students purposely plan to procrastinate because they perceive it as an efficient use of their time and as a method that enhances their motivation. In addition, they prefer to procrastinate because they are rewarded for their last minute efforts by receiving quick feedback and satisfactory grades. These findings raise the question of whether a positive form of procrastination exists.

Proposed Academic Procrastination Interventions

Another on-going issue in the study of procrastination concerns the development of effective interventions. Various counseling programs for students who procrastinate have been developed. Schouwenburg et al. (2004) highlighted some of the overarching themes of these interventions such as self-regulation training, use of cognitive-behavioral techniques to reframe irrational thinking and increase self-efficacy, and support groups. Studies have shown that interventions can be effective in reducing procrastination, at least in the short term, although the effects are not very large. Schouwenburg et al. (2004) calls for interventions that are more in line with research findings by emphasizing the improvement of self-regulation, enhancing self-efficacy, and reducing the likelihood of distractibility. The emphasis of these areas is consistent with Steel's (2007) meta-analysis findings.

Classroom-level interventions designed to reduce the amount of procrastination by students are very scarce. However, researchers have proposed ideas informed by their research findings about how teachers can reduce procrastination in their classroom. Recommendations include making courses more interesting and relevant. Also, setting incremental deadlines for stages of a larger project or administering multiple quizzes before a major exam is given so that students get more immediate rewards/feedback throughout the semester. Based on Schraw et al.'s (2007) findings it appears that teachers could also reduce procrastination by holding high expectations for students' work and setting firm deadlines. As alluded to previously, however, research supporting these ideas is lacking.

Is There an Adaptive Form of Procrastination?

Another open question regarding procrastination is whether it can, in some cases, be viewed as an adaptive, beneficial, or strategic behavior. In line with some prior work, Schraw et al.'s (2007) study suggests that some students perceive procrastination as a positive strategy that can improve ► cognitive efficiency, challenge, interest, and flow. Despite prevalent indications that procrastination is maladaptive and typically involuntary, researchers have attempted to capture an adaptive form of procrastination labeled ► active procrastination. Active procrastination is defined as a more positive, purposeful, and less debilitating form of dilatory behavior, wherein students deliberately delay academic activity yet still meet deadlines and achieve satisfactory outcomes. Some investigations have found that active procrastinators are more similar to non-procrastinators in comparison to traditional procrastinators when it comes to their levels of self-efficacy, purposive use of time, and academic performance. Based on this work, Choi and Moran (2009) recently developed and validated a new instrument that measures four dimensions of active procrastination (preference for pressure, intentional decision to procrastinate, ability to meet deadlines, and outcome satisfaction) that they claim distinguishes this type of behavior from the more maladaptive form of procrastination. However, many questions remain as to whether differences exist between active procrastinators and traditional procrastinators especially in terms of important self-regulated learning and achievement outcomes.

Cross-References

- ▶ Academic Motivation
- ▶ Achievement Motivation and Learning
- ▶ Anxiety, Stress, and Learning
- ▶ Cognitive Efficiency
- ▶ Fear of Failure in Learning
- ▶ Learned Helplessness
- ▶ Personality and Learning
- ▶ Personality Effects on Learning
- ▶ Self-efficacy and Learning
- ▶ Self-regulated Learning

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Production Rule System

▶ Production Systems and Operator Schemas for Representing Procedural Learning

Production Rules

A production rule is constructed from propositions joined into a "condition-action" pair. One proposition is the goal, while the other defines the subgoal(s) that must be satisfied. These types of rules are important in "expert systems," as used in artificial intelligence and computer models of human learning and behavior.

Production Systems and Operator Schemas for Representing Procedural Learning

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Synonyms

Production rule system; Rule system

Definition

Productions and production systems emerged as a central concept of Artificial Intelligence in the 1970s and were adopted subsequently from cognitive scientists/psychologists to cast complex theories of procedural learning.

Basically, a production system (or *production rule system*) is a computer program, which consists of a set of rules about behavior. Rules in general have the following structure:

If A	Then B
[condition]	[answer]
	(execution of an operation)

This type of structure is also called "production." If a production's condition matches the current state of the world, then the production is said to be *triggered* and produces an answer. If a production's operation is executed, it is said to have *fired*. Basically, a production system contains a database, which maintains data about current states of knowledge, and a rule interpreter. In addition, a rule interpreter provides a mechanism for prioritizing productions when more than one is triggered.

From a psychological point of view, production systems can be understood as *operator schemas*. An operator schema is a general program of operations or actions that execute an operator (Lewis and Anderson 1985). The basic idea is that internal operations are organized as schemas which contain a finite number of examples defined as instantiations of the schema. Thus, operator schemas describe the range of applicable operations.

Theoretical Background

Following the distinction made by Ryle (1969) between "knowing that" and "knowing how" cognitive scientists began in the 1980s to differentiate between declarative and procedural knowledge (see, for example, Anderson 1983). Declarative knowledge comprises potentially conscious notions, which may be represented in the form of semantic network structures, while procedural knowledge includes potentially nonconscious cognitive operations, which can be represented in the form of "productions." Although the term production systems originated in computer science, where they model information processing, cognitive psychologists have found production systems to be one of the most direct ways to cast complex theories of procedural learning. There have been many scattered studies on production systems since they were first proposed as computational models of human problem-solving behavior in the 1980s (Klahr et al. 1987). According to these theoretical approaches, learning in a new domain always begins as acquisition of declarative knowledge; procedural knowledge is acquired as making inferences from declarative knowledge. Consequently, a production system consists of:

1. A *knowledge base*, which includes
   (a) The declarative knowledge relevant for a task or problem
   (b) A certain quantity of productions

   that operate on conditions of declarative knowledge and cause inferences from them.
2. An *interpreter* which executes the rules defined in a production; e.g., "*If* a thing has four legs and fur, *then* it is a dog" leads to the identification of a dog.

To illustrate the representational functions of productions we can refer to an example given by Shuell (1986): the way a child learns to solve addition problems. This task can be represented as productions (P):

P1:	IF	the goal is to solve an addition problem
	THEN	add the numbers in the rightmost column
P2:	IF	the goal is to solve an addition problem and the rightmost column has already been added
	THEN	add the numbers in the second column

With sufficient practice, these productions will be compiled into higher-order productions (see Anderson 1982, p. 371):

P3:	IF	the goal is to solve an addition problem
	THEN	the subgoal is to iterate through the columns of the problem
P4:	IF	the goal is to iterate through the columns of the addition problem and the rightmost column has not been processed
	THEN	the subgoal is to iterate through the rows of rightmost column and set the running total to zero

From a psychological perspective a production system can be understood as an *operator schema* defined here in terms of a general program of operations (or actions) which execute an operator (Lewis and Anderson 1985). As in its original sense in logic and mathematics, the starting point for an operation is the effective use of an operator to produce the necessary transformations of states in a problem space. Accordingly, a *procedure* is a chain of operations executed according to a plan which is designed to lead to a certain end state (e.g., the solution to a problem). However, this requires that (1) operations of a higher order must be formed that (2) must receive adequate conditions for execution in order to realize the operator schema relevant for the solution. That's the point where operator schemas and production systems coincide: Production systems provide systems of conditional operations containing precise instructions to apply an operator or a production if certain conditions for the application of an operator have been fulfilled.

The development of operator schemas – discussed here as central components of production systems – grounds on various principles: (a) the *principle of equivalent operators*, which states that operators are equivalent (i.e. of the same value) if they cause the same transformations to occur, and (b) the *principle of reduction*, which states that one may combine several steps of a sequence of transformations of them without changing the end state. VanLehn (1989) has described the principle of the reduction as *compounding* of operations as a fundamental basis for creating macro-operations which lead to a reduction of necessary transformation steps. Additionally, VanLehn named three further elementary learning mechanisms as preconditions for the development of macro-operators: Proceduralization, strengthening of operations, and rule induction. *Proceduralization* can be conceived as the functional incorporation of declarative knowledge of actions in chains of operator applications (i.e., procedures). The "trick" of proceduralization consists in the fact that declarative knowledge about actions (knowledge of what should be done in a particular situation) becomes an integral part of a procedure through repetition and practice. *Strengthening* was originally introduced by Anderson (1982) and states that an operator has more or less strength depending on how many times it has been applied successfully. The strength of an operator plays a role in the selection of operators since people always tend to select the "stronger" operators to solve a problem. The function of this learning mechanism is simply that it increases the strength of an operator each time it is applied successfully. Finally, *rule induction* was first developed by Sweller (1988) and attributes a central significance to the "routinization" of operators. Rule induction corresponds with a schematization of operators and enables one to solve problems of the same class more quickly since it allows one to concentrate on making a suitable plan for a solution during information processing rather than on executing the solution procedure.

Cognitive psychologists assume that the application of operators requires constant conscious control only when one begins to learn a skill, the procedure becoming increasingly automated and unconscious through repeated practice. Although we can assume that there are many reality domains in which the possible actions or operations are based on only a small amount of elementary operators, at the same time, there are many other domains where the application of elementary operators fails and macro-operators are necessary.

Important Scientific Research and Open Questions

Productions and production systems can be found as a basic representation form in automated planning, expert systems, and action selection. A good example to illustrate this application is the GOMS model as introduced by Card et al. (1983). GOMS (Goals, Operators, Methods, and Selection rules) is a specialized human information processing model for human computer interaction. GOMS reduces a user's interaction with a computer to elementary actions which can be physical, cognitive, or perceptual. Based on production systems for representing human procedural knowledge GOMS models are typically used by software designers in order to analyze a user's behavior in terms of the components *goals* (i.e., what the person wants to do), *operators* (defined in terms of perceptual, cognitive or motor actions) applied to achieve the goals, *methods* (discussed in terms of procedures and sequences of subgoals and operators), and *selection rules* (i.e., subjective rules of deciding what method can be used in a particular situation). As mentioned above, GOMS models have been applied mostly in the area of human computer interaction with its well-defined tasks. Accordingly, there are some limitations of GOMS models: (a) The tasks to be accomplished must be specified in terms of procedural knowledge (how to do). (b) GOMS models represent only skilled behavior and are not useful for ill-defined and complex problems.

Another theoretical approach which operates with production and production systems is the ACT* theory ("Adaptive Control of Thought"), developed by Anderson (1983) and widely accepted in cognitive psychology. ACT* is without doubt one of the most popular theories on how cognitive operations function (cf. Shuell 1986). It has formed the basis of numerous assumptions on the capacity of memory and the processing, organization, and representation of knowledge. ACT will be described in another entry of the encyclopedia.

Both ACT and GOMS models work with production systems that can be seen as standard procedures applicable on well-defined problems and routine tasks. However, they are not applicable in the area of ill-defined problems where heuristics for applying operators are more appropriate. For instance, a person who understands all of the rules of chess and knows which moves are permitted is not necessarily a good chess player. In addition, good chess players must also be capable of linking the individual moves (= operations) together correctly. As Dörner (1983) emphasizes, there is no standard procedure in chess for this ability. Rather, this ability requires the use of procedures to construct chains of operations which can be adapted to the situation at hand. Such procedures are known as *heuristics* and are described by Dörner (1976) as "searching procedures" for deciding which operator to select in a particular situation. They are, "so to speak, programs for mental procedures which enable one to solve problems of a certain form under certain circumstances" (Dörner 1976, p. 38). Furthermore, this author argues that "development in most of the reality domains people have to deal with intensively . . . is characterized by the formation of macro-operations" (p. 23). The formation of macro-operators is generally a difficult process dependent on many successful applications of interrelated elementary operators. However, it makes possible, for example, for an experienced chess player, to think in an entire sequence of operations and to act accordingly.

In sum, we can see a dichotomy of representational forms in the area of procedural learning related to problem solving: Productions and production system are applied for representing procedural knowledge as it is involved in solving well-defined problems, whereas ill-defined problems presuppose the application of heuristics which hardly can be conceptualized as production systems.

Cross-References

- ► ACT (Aadaptive Control of Thought)
- ► Complex Declarative Learning
- ► Complex Skill Acquisition
- ► Heuristics and Problem Solving
- ► Knowledge Representation
- ► Procedural Learning
- ► Proceduralization
- ► Rule Formation

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Professional Development

- ► Lifelong and Worklife Learning
- ► Teaching Experiments and Professional Learning

Professional Learning

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

Professional Learning and Development

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Synonyms

Continuing professional development; Learning organizations; Lifelong learning; Professionalism

P

Definition

Professional learning and development are complementary rather than competing concepts. Both are widely acknowledged as being essential to the continuing growth, effectiveness, efficiency, and efficacy of professionals. Professional learning may be distinguished from the planned interventions which professional development experiences and activities represent because: (1) it does not always occur as a consequence of, nor is necessarily in association with planned interventions, though it may occur during such interventions; (2) it does not require external organizational support; (3) it is usually motivated by the disposition of the professional who is a lifelong learner or by the need to solve a pressing problem; (4) it is unconnected to a time frame. Professional learning and development, therefore, consist of all natural learning experiences and those conscious and planned activities which are intended to be of direct or indirect benefit to the individual, group, or organization. They are means by which, alone and with others, they acquire, review, and renew the knowledge, skills, and understandings essential to good professional thinking, planning, and practice through each phase of their working lives.

Theoretical Background

Professionals are distinguished from other groups of workers because they have: (1) a specialist knowledge base; (2) a strong service ethic; (3) professional commitment; and (4) professional autonomy. Learning and development are seen to be necessary because it is assumed that the needs of the organization in which they work will vary as the result of external social and economic and internal, personal changes. While some research has argued that professionals learn by experience through a series of linear growth stages, novice – advanced beginner – competent – proficient – expert, others argue for a more dynamic model in which potential growth phases overlap and collide in response to such circumstances. The ability of professionals to become and remain effective is thus subject to their capacity to manage combinations of positive and negative personal, workplace, and policy influences. There are thus persuasive arguments for targeting learning and development opportunities at professionals in particular phases of intellectual, experiential, career or role development.

Challenges to Professional Learning and Development

Whereas commentators agree on the necessity for professional learning and development, they also identify a number of key personal, organization, and policy influences which may have positive or negative effects. Wenger (1998, p. 9) argues that "in a world that is changing and becoming more complexly interconnected at an accelerating pace, concerns about learning are certainly justified." He proposes that participation in understanding and supporting learning in different contexts should be at three levels:

- *For individuals*, it means that learning is an issue of engaging in and contributing to the practices of their communities.
- *For communities*, it means that learning is an issue of refining their practice and ensuring new generations of members.
- *For organizations*, it means that learning is an issue of sustaining the interconnected communities of practice through which an organization knows what it knows and thus becomes effective and valuable as an organization (Wenger 1998, p. 7–8).

Learning at these three different levels is interconnected and interdependent in terms of supporting individual and collective needs and creating and strengthening learning conditions which support rather than hinder teacher learning and development. Yet, this provides only a first-level analysis of the locations for learning without also examining the nature and efficacy of these.

The most recent longitudinal research into teachers' work and lives (Day et al. 2007) demonstrates clearly that, to be of benefit to organizational improvement, professional learning and development must focus upon both inner learning (intrapersonal) and outer learning (interpersonal).

Workplace Learning and Organizational Performance

The workplace itself holds the greatest potential for professional learning and development. Building upon his extensive research on workplace learning among different professions in the UK, Eraut (2007) found a "triangular relationship between challenge, support and confidence" (Eraut 2007, p. 417) provided within the organization. The relative strength of effect of any one or a combination of these varied according to its significance "for individuals at particular points in their careers" (Eraut 2007, p. 417). Significant associations were found between the ways in which opportunities for challenge, support, and feedback and the growth of confidence enhanced learning for individuals and groups, the growth of individual, relational, and collective motivation and commitment, the development of the organization as a "learning community" and the enhancement of "retention, quality improvement and organizational performance" (Eraut 2007, p. 421). These findings were similar to those of Day et al. (2007)in a 4-year mixed methods project with 300 teachers in 100 schools in England which focused upon variations in teachers' work, lives, and effectiveness, and in which statistical and qualitatively robust associations were found between the level teachers' commitment and students' measurable achievements.

Important Scientific Research and Open Questions

The purposes of continuing professional learning and development are to maintain and extend teachers' professional knowledge, defined as "the knowledge possessed by professionals which enables them to perform professional tasks, roles and duties with quality" (Eraut 1996, p. 1). Both, therefore, draw upon learners" store of prior knowledge of practice in any given setting much of which is implicit and unstated. Raising this tacit dimension of professional knowledge to an explicit level is a key consideration on the design of professional development activities and programs. However, it is more difficult to access through modes of informal learning since, by definition, while they imply engagement in reflection, these processes may not necessarily result in the examination of consistencies and inconsistencies within and between what Argyris and Schön (1974) term "espoused theories" which describe or justify behavior (what we say about what we do) and "theories-in-use" (what we do and the ways we do it).

Professional learning and development will also be influenced by predisposition and experience of the learner and these will shape their attitudes to a range of factors, such as perceptions of the work environment and the benefits of participation; support of the senior leadership team; sense of positive professional identity; self-efficacy; aspirations for career advancement; and events in their lives outside the workplace. Such factors are important because they affect, positively or negatively, motivation and commitment to their professional learning and growth and the benefits which they and the organization might derive from this commitment. Variations in professionals' experiences and competence to manage the realities of work-life tensions, together with a difference in the levels of support available within the workplace, create particular conditions for their learning and development and lead to variations in their concerns and needs at different critical moments or phases of their professional and personal lives.

Effective professional learning thus requires conditions which enable the development of a dialectal relationship between professional learning and development and organizational improvement. Much research internationally into effective and successful organizations has identified leadership as a key influence on quality in workplace cultures. Central to such cultures is the attention which leaders give to the creation and ongoing support for professional learning and development of all kinds which is differentiated according to informed judgments about individual, group, and organizational needs. Robinson (2007) in a meta-analysis of empirical research identified five key dimensions of effective leadership. Among these, support for and participation in professional development had by far the largest effect.

Cross-References

► Adult Learning/Climate of Learning
► Conditions of Learning
► Informal Learning
► School Climate and learning
► Tacit Knowledge
► Workplace Learning

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Professional Learning Community

► Teaching Experiments and Professional Learning

Professional Performance

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

Professionalism

► Professional Learning and Development

Programmed Learning

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Programmed learning is an individualized and systematic instructional strategy for classroom learning and self-learning. Since the 1960s, it has emerged as one of the most important innovations in the field of education. Programmed learning received its major impetus from B. F. Skinner and is based on his theory of operant conditioning, according to which learning is best accomplished in small, incremental steps with immediate reinforcement, or reward, for the learner. Therefore, the learning material is broken down into small chunks of information and is followed by a comprehension question to be answered by the learner, who receives immediate feedback with regard to the correctness of the answer. If the answer is correct, the learner may proceed to the next chunk; otherwise he or she must go back to the previous chunk and try it again. Thus, programmed learning is based on the principles of small steps, self-pacing, and immediate feedback.

Two types of programmed learning have become standard: linear and branching programming. *Linear programming* involves a simple step-by-step procedure and immediately reinforces student responses that approach the learning goal. In contrast, *branching programming* provides the student a bigger chunk of information combined with a multiple-choice question or recognition response. After responding, the student can proceed to another information chunk in order to learn whether the choice was correct, and if not, why not.

Skinner believed programmed learning to be superior to traditional teacher-based instruction due to the immediate feedback it provides. Programmed learning became very popular in the 1960s and spawned much educational research and commercial enterprise in the area of programmed instructional materials.

Numerous studies revealed programmed learning to be superior to conventional teaching methods, but other studies found it to produce similar or inferior learning in comparison to traditional approaches (Kulik et al. 1982; Köbberling 1971).

In the late 1970s, the use of programmed learning was in decline. However, it did not disappear but rather changed its characteristics over time. More recent programmed learning is typically based on larger step sizes and multiple-choice questions (e.g., Kromrey and Purdom 1995; Kurbanoglu et al. 2006).

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Programming by Demonstration

► Robot Learning from Demonstration

Project-Based Learning

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Synonyms

Constructivist learning; Inquiry learning

Definition

Project-based learning is a comprehensive instructional approach to engage students in investigation. The learning activities are organized around an authentic and meaningful question. The question has real-life significance and may be multidisciplinary in nature (e.g., how to prevent cyber bullying). Students pursue solutions to the problem by asking and refining questions, debating ideas, making predictions, planning investigation, collecting and analyzing data, drawing conclusions, communicating their findings to others, and creating artifacts such as reports, models, computer programs, and video productions (Blumenfeld et al. 1991). Project-based learning requires active engagement of students' effort over extended period of time. The projects may span several weeks or months. Compared to other inquiry-based activities, project-based learning has an emphasis on cooperation among students in group work. There are three essential components of project-based learning: (1) a driving question that is anchored in a real-world problem and the content of this question is meaningful to students; (2) opportunities for students to carry out investigation so that they can learn concepts, apply information, and create artifacts that represent their knowledge about the driving question; and (3) collaboration among students so that knowledge can be shared in the learning community. Project-based learning and problem-based learning share much in common. Both of them engage students in inquiry and have similar theoretical background. However, in project-based learning, students have more control of the project they will work on and what they will do in the project. In problem-based learning, a specific problem is usually specified by the course instructor.

Theoretical Background

Project-based learning arises from the constructivist revolution in learning. This revolution is an antithesis to the tradition of direct or didactic teaching. According to constructivist theories of learning, concepts cannot be *transferred* from teachers to students. Instead, concepts have to be *conceived* by students. Learning requires self-regulation and the building of conceptual structures through reflection and abstraction (von Glasersfeld 1995). To memorize and regurgitate the information given by teachers or textbooks is not learning. To foster conceptual change, instruction needs to make students dissatisfied with their old concepts and urge them to come up with new concepts that are more viable and useful. Direct instruction, with the purpose to transmit information from teachers to students, does not foster conceptual development. To rectify the limitations of direct instruction, constructivist approaches emphasize the active role of students. The job of teachers is to encourage reflection among their students by providing the physical and social experiences. Because of the emphasis on students as active learners, constructivist teaching strategies are often called student-centered approaches so that they can be differentiated from the traditional approaches in which teachers are the center. In student-centered approaches, teachers are the "guide on the side" instead of the "sage on the stage."

Constructivism in education has deep roots in the work of Piaget (1970) and Vygotsky (1978). Piaget pointed out that individuals achieve conceptual change in the process of functional adaptation (assimilative vs. accommodation). Cognitive change takes place when previous concepts go through a process of disequilibrium in light of new information. To acquire knowledge, students need to transform complex information, to check new information against old concepts, to revise old concepts, and to construct new concepts. While Piaget focused on the individual's personal construction of meaning through interaction with the physical environment, Vygotsky emphasized social construction of meaning in a social context in which learners interact with and internalize modes of knowing and thinking represented and practiced in a community. Project-based learning, as a teaching strategy in the constructivist approaches, epitomizes the work of Piaget and Vygotsky. Students are active learners in collaborative inquiry. Proponents of project-based learning claim that by placing students in realistic, contextualized problem-solving environment, project-based learning enhances student motivation. It also helps students acquire deeper understanding of the key principles and concepts when they investigate and seek resolutions to authentic and meaningful problems (Blumenfeld et al. 1991). Most importantly, it does not only promote knowledge of subject area but also generic skills, such as collaboration, communication, and problem solving. These generic skills are essential to students' survival in a knowledge-based and rapidly changing society.

Important Scientific Research and Open Questions

Despite the many advantages claimed by the proponents of project-based learning, not all teachers are ready to use this new approach in their classrooms. In fact, many teachers are skeptical and resistant to it. Their reluctance is understandable because this new approach bears little resemblance to either their current practices or to the methods they had learned and experienced as students themselves. In addition, the implementation of project-based learning requires adequate planning and support. Without careful design and implementation, it can turn into doing for the sake of doing without real learning. Barron et al. (1998) poignantly pointed out that slapdash curriculum reform may invite political backlash that favors back-to-basics and rote learning over authentic inquiry. They suggested that project-based learning should be implemented and supported by four principles: (1) crafting the driving question carefully to make connections between activities and the underlying conceptual knowledge that one might hope to foster; (2) providing scaffolds to students before completion of projects; (3) including multiple opportunities for formative self-assessment, and (4) developing social structures that promote participation and a sense of agency. The last principle is particularly important to the group work in project-based learning. Cheng et al. (2008) found that the quality of group processes played a pivotal role in students' learning efficacy. Their results indicated that project-based learning enhanced students' learning efficacy only when the group processes had the following four elements: (1) positive interdependence; (2) individual accountability; (3) equal participation; and (4) social skills.

In recent years, technology has been playing an increasingly important role in project-based learning. As Blumenfeld et al. (1991) pointed out, technology can enhance student motivation in learning because it can contribute to interaction with others and production of artifacts. It can also make information more physically and intellectually accessible to students. Traditionally, teachers and books have been the key sources of information. With the help of Internet and electronic data bases, students can easily access to massive amounts of information through personal computer. The advances in technology facilitate the active role of students in collaborative inquiry. Nevertheless, many questions about the use of technology need to be addressed. Educators need to know how to design and use technology effectively to support project-based learning. This is a new area for the research and development in project-based learning.

Cross-References

- ▶ Collaborative Learning Strategies
- ▶ Cooperative Learning
- ▶ Discovery Learning
- ▶ Learning by Doing
- ▶ Problem-Based Learning
- ▶ Student-Centered Learning

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Prompted Recall

► Cued Recall

Prompting

► Cueing
► Situated Prompts in Authentic Learning Environments

Propaganda

► Persuasion and Learning

Propositional Knowledge

Knowledge of facts (knowledge “that”), e.g., knowledge of colors as opposed to knowledge of how to achieve goals.

Proprioception

Proprioception refers to senses of body position, based on signals from muscle, joint, tendon, and skin receptors.

Prosocial Development

This is the process through which young people develop an awareness of moral, ethical, and civic values and act in accordance with these values.

Prosocial Learning in Adolescence: The Mediating Role of Prosocial Values

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Synonyms

Moral internalization

Definition

Prosocial values are beliefs esteemed by an individual or group that promote concern and care for the welfare of others. Examples include kindness and caring.

Theoretical Background

Adolescence is a period of change and growth, not just physically, but psychologically and socially. It is also a time of adjustment and adaptation as adolescents take on greater responsibility and independence compared to childhood. One of the hallmarks of adolescence is the rapid development of identity, including one’s concept of a moral being (Hardy and Carlo 2005). Adolescents are still acquiring their value sets and developing consciences, but it does seem that both emotions and cognitions are integrated in their moral reasoning. There is also evidence that adolescents consider abstract principles and the context of the situation more than children. As adolescents’ autonomy and social connections grow, behavioral motivation seems to shift from primarily parent-orientation to peer-orientation to, ultimately, personal (i.e., internalized) motivation (Padilla-Walker and Carlo 2007). Adolescents’ mobility and personal decision making also increase, along with amount of time spent with peers. Peer relationships become a more central concern during adolescence, providing a means of social comparison, norm-learning, and rewards or sanctions for behavior. All of these changes provide impetus for internalization of prosocial and moral values during this age period.

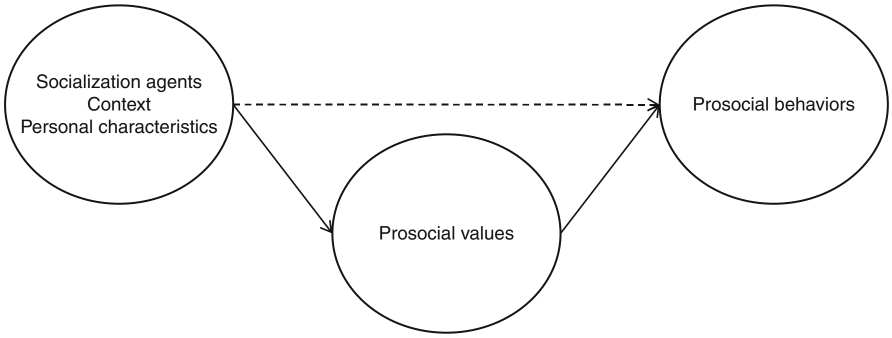
Moral internalization is defined here as the process of understanding and accepting moral values as one’s own and integrating them into one’s identity, decision making, and source of choices for one's actions. One main line of research on moral internalization focuses on social learning experiences as a source of information influencing conscience development. Scholars such as Hoffman, Grusec, and Kochanska have examined the social influences of moral internalization, especially parenting. While this approach allows for the inclusion (or assumptions) of cognitive development to help explain how moral internalization occurs, it also emphasizes socialization experiences as an important contribution to moral formation. Parents and other caregivers have the most opportunity to assist in children's moral internalization; they have the most contact with children and are their strongest role models for interpersonal behavior and sources of information (such as values) and guidance. Scholars like Carlo et al. (2007) have noted parents may influence their children not just through disciplinary practices, but by modeling and reinforcing positive behavior (i.e., using prosocial parenting practices). When caregivers are sensitive to children's characteristics and abilities (as opposed to being cold, unresponsive, and inappropriately demanding or punitive), can read good opportunities to teach children moral values (as opposed to situations in which the main goal should be saving or calming the child), and react appropriately, it is in these experiences the children may learn from the caregiver on many levels. Additionally, adolescents have greater exposure to peers together with less parent monitoring. Thus, peers may be a source of social learning experiences and social values. Other extrafamilial examples of socialization agents include the media/media exposure and religion/religious instruction (see Hardy and Carlo 2005).

Prosocial behavior is an umbrella term to represent any kind of behavior intended to benefit another. Researchers have operationalized prosocial behavior in a variety of ways, from observing whether study participants help a stranger, obtaining self-reports of how much one volunteers, quantifying the amount of sharing by preschoolers during playtime, and so on. The apparent motivation of seemingly helpful behavior is key, as opposed to whether the behavior met the intended goal. Some prosocial behaviors, while benefiting others, may also occur to gain social approval, but others done anonymously (e.g., donating money) obviously would not garner public attention. As such, prosocial values may be differentially related to a large variety of prosocial actions as a function of the nature of the behavior and the situation. In the context of adolescent development, it may be seen as a type of social competence. There are mixed findings on adolescents' prosocial behavior in terms of frequency, type, and motivations, which may reflect the multiple transitions occurring in this stage of development.

Important Scientific Research and Open Questions

Hart and Fegley (1995) found that adolescents nominated by their communities as being care exemplars were more likely than their matched control counterparts, who did not differ from the care exemplars in level of moral reasoning, to describe themselves in terms of moral traits, beliefs, and ideals, and to subscribe to the beliefs of their parents. Hardy and Carlo (2005) found that the prosocial value of kindness mediated the relation between religiosity and both altruistic and compliant prosocial behaviors. They concluded that perhaps certain types of prosocial behavior are more related to internal processes (e.g., altruism), while others are more situation-based (e.g., helping in emergencies). The researchers also theorized that religion may help promote prosocial values and provide opportunities for prosocial action, which all help youth internalize the values. Padilla-Walker and Carlo (2007) found that prosocial values mediated the relation between maternal and peer expectations and prosocial behaviors, but not maternal and peer expectations and antisocial behaviors. This indicates that prosocial values may be more salient and relevant with regard to prosocial behavior than antisocial behavior, and that the two types of behavior have different antecedents. These three studies used participant samples of adolescent students in the USA, but there is reason to believe further research on the mediating role of prosocial values across cultures is needed (Fig. 1).

Scholars believe culture (both an ecological context and a source of meaning-making) interacts with the roles and behaviors of various socialization agents (including parents and others), values, and behavioral norms. Thus, different cultures may have different patterns of behavior (including socialization processes), different values, and different views of acceptable behaviors (Whiting et al. 1988). Context, such as what is deemed appropriate behavior from parents and adolescents, and meaning, such as what behaviors



Prosocial Learning in Adolescence: The Mediating Role of Prosocial Values. Fig. 1 The mediating role of prosocial values on adolescents' prosocial learning

and values are considered prosocial and/or moral, may affect adolescents' internalization of values. Further research is needed on the role of culture in this process.

Further research is also needed on the specific mechanisms of change involved in the internalization of prosocial values, and how this relates to prosocial behavior. Both causally interpretable experiments and longitudinal studies of the process over time seem necessary to fully understand what predicts adolescents' prosocial behavior. Socialization agents outside the family, such as peers and the media, also need to be studied in more depth.

Cross-References

- ► Altruistic Learning
- ► Moral Learning
- ► Religiosity and Personality
- ► Social Cognitive Learning
- ► Social Learning
- ► Social Learning Theory
- ► Value Learning

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Prospective Adaptation

► Anticipation and Learning

Prospective and Retrospective Learning in Mild Alzheimer's Disease

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Synonyms

Declarative; Episodic memory; Explicit; Memory of the future

Definition

As defined by *Webster's Comprehensive Dictionary* (1996), *learning* is "the act of acquiring knowledge of or skill in by observation, study, instruction, etc.," while *memory* is "the mental process of representing and recollecting in mind an act, experience, or impression, with recognition that it belongs to time past." Memory is a complex mental function, and different subtypes have been proposed (Tulving 1987). *Episodic retrospective memory* is the memory of the past and represents events in our personal biographic history. It involves conscious recollection of these episodes (e.g., when one was getting married), and it is typically evaluated by means of learning a list of words or a series of figures. *Semantic memory* constitutes our conceptual knowledge, for example, knowing that one is married without taking into account the time and place (episode) of the marriage. *Working memory* refers to the temporary, short-term storage of verbal-phonological, spatial, and sensory information that is being processed in any of a range of cognitive tasks (e.g., when interpreting, learning, or reasoning). *Prospective memory* is the memory of the future, and consists in remembering to carry out intended actions at an appropriate point in the future, such as to give your roommate the message that a friend called, keep appointments, pay bills, take medicine, and carry out domestic chores, so it is crucial for an older person to function independently in an everyday life context.

Theoretical Background

Philosophical speculations about learning and memory started in ancient times (e.g., with Aristotle) and were prominent among seventeenth and nineteenth century empiricist philosophers such as John Locke, John Stuart Mill, and Thomas Brown. They conceived learning and memory as a combination or association of sensory impressions, mental content, ideas, and feelings, so that the appearance of one of them facilitates becoming aware of the others. The scientific investigation of association formation began with the German scientist Ebbinghaus, whose pioneering research was published in his treatise *On Memory* in 1885. The discovery of simple experimental means for studying learning and memory, first by Ebbinghaus, and then by Pavlov (1904) and Thorndike (1911), led to a rigorous empirical school of psychology called *behaviorism*. Behaviorists, such as Watson (1930) and Skinner (1938), considered all mental processes occurring between the stimulus and the response as irrelevant to scientific study, and they argued that behavior (even complex human actions) could be studied with precision only if students abandoned speculation about what goes on in the mind and focused instead on observable aspects of behavior. Thus, behaviorists excluded from their study the most fascinating features of mental life, which were tackled by the founders of experimental *cognitive psychology*, starting in the 1930s with Piaget, Vygotsky, and Bartlett, and then Tolman, Miller, Chomsky, Neisser, Simon, and others. The cognitive psychologists took as theoretical background evidence from Gestalt psychology, psychoanalysis, and European neurology, based on which they analyzed the *constructive* processes by which sensory information is transformed into perception, memory, and action, and discovered how external events are *internalized* or *mentally represented* in the brain. Cognitive psychology paved the way for the development of contemporary *neuropsychology* and *cognitive neuroscience*, which conceive memory (and any other higher mental function) as a *complex functional system* or *neurofunctional network* comprising various subtypes or basic mental operations organized in a dynamic assembly of interconnected brain regions, each region making its specific contribution to the functioning of the system as a whole. This insight on mental functions was first articulated by the English neurologist Jackson (1958), who conceived psychological functions as organized in different levels of complexity and abstraction (the voluntary, conscious; and the involuntary, automatic, unconscious). As regards memory and learning, there are the conscious retrospective, prospective, and working memories, the unconscious conditioned learning and emotional memory, and the partially unconscious semantic and *procedural* memories. The concept of *functional system* implies that the memory subtypes interact with each other as well as with other psychological functions. This interplay is taken into account in the neuropsychological evaluation, which comprises tests specifically for memory as well as tests for other functions that can influence performance on memory tasks, such as perception, attention, language, and mood state (so-called "counter-proofs").

One of the most used tests for retrospective memory (RM) is the Rey Auditory Verbal Learning Test (RAVLT), which consists of 15 words read aloud for five consecutive trials (list A), followed by a free recall test. After the fifth trial, a new interference list of 15 words is presented (list B), followed by a free recall of that list. Soon afterward, a free recall of the first list is tested without new presentation. After a 20-min delay, subjects are again required to recall words from list A. Finally, the patient must identify list A words from a list of 50 words which includes lists A and B, and 20 other words phonemically or semantically related to lists A and B. Prospective Memory (PM) tasks can be either time-based (to make an intended action at a particular time of day or after a certain period of time has elapsed), event-based (to execute the intended action upon the occurrence of a particular environmental event), or activity-based (to do something when a particular activity has been completed).

As typical examples of prospective memory (PM) tests, one can mention the appointment and the belonging subtests of the Rivermead Behavioral Memory Test (RBMT): (1) Remembering an appointment: The subjects are required to ask for their next appointment when they hear the ringing of an alarm clock, which is set to go off 15 min after the instruction is given. (2) Remembering a belonging: At the beginning of the session, the examiner borrows from the subject a personal belonging (pen, comb), which the examiner hides from the sight of the subject (e.g., in a drawer or cupboard) with an instruction that the subject ask for it to be returned at the end of the test session. Then, at the end of the session, the examiner says "That is the end of the testing session." If the subject does not request the belonging of his own accord, the examiner gives a prompt: "Was there something you were going to ask me for?"

McDaniel and Einstein (2007) have proposed guidelines for creating typically prospective and informative tasks: (1) not to be executed immediately after the intention, but delayed or postponed to some point in the future; (2) to be embedded in another ongoing activity; (3) to have a constrained window of opportunity for initiating the intended action; (4) to have limited a time frame for accomplishing the action; (5) to be based on a consciously formed intention or plan; and (6) the formed intention should not be maintained in working memory, in the focus of consciousness, but temporarily forgotten during performance of other activities; otherwise it would constitute a vigilance task, not a PM task.

Important Scientific Research and Open Questions

Memory complaints are usually the first and most important symptoms among Alzheimer's disease (AD) patients. Impaired ability to learn new information or to recall previously learned information (i.e., retrospective episodic memory) is required for the diagnosis of the disease. In AD, RM deficit, particularly the free and delayed recall of series of words, sentences, or objects occurs earlier than the medial temporal atrophy shown by magnetic resonance imaging, and it is considered the most reliable predictor of the disease in its earliest stage.

Memory is, however, a complex functional system, and other types of memory (e.g., semantic, prospective) may be impaired early in AD. PM is the memory type that declines most with aging, particularly when the prospective action is cued only by the time at which it has to be performed, and these PM difficulties are more remarkable when the elderly person has to rely on internal, self-initiated reminding, and less when there are more environmental, external cues. Age differences are thus large in prospective tasks ("remembering to remember") and in free recall, and less in cued recall, and less again in recognition memory.

To perform a PM task, one must remember that there was an intention (the prospective component) and also the content of the intention, "what to do" (the retrospective component). This retrospective component is highly dependent on the medial temporal lobe structures, and it is what makes PM (to memorize a list of things to do in the future) similar to RM (to remember a list of events from the past). It is also one of the reasons why PM and RM are usually impaired in the early stages of AD, but in this stage PM does not need to correlate with RM (Jones et al. 2006; Martins and Damasceno 2008). This similarity has led some authors to claim that there is not enough conceptual necessity to distinguish these two types of memory. The prospective component is, however, what characterizes PM as unique, in that it is the memory of an intention, essential for goal-directed behaviors. As highlighted by Karantzoulis et al. (2009), even this prospective component is a complex process that involves at least four stages: (1) intention formation – to plan the future activity, i.e., what to do and when to do it; (2) intention retention – to hold the intention in memory while other activities are occurring, i.e., during the ongoing task; (3) intention initiation – the point at which the appropriate cue (e.g., an event) triggers an effortful and controlled search of memory for the intention;

and (4) intention execution – when the retrieval context actually occurs and the action of the intended action is executed.

There are indications that PM and RM depend on different cognitive processes and different brain regions. PM performance is more reliant on intention formation, strategic planning, self-initiated retrieval, and interruption or inhibition of ongoing actions, which are cognitive processes highly dependent on the frontal lobes but not on the hippocampal system. In fact, positron emission tomography (PET) studies of young adults performing PM tasks have found several localized brain activations, particularly in the right dorsolateral and ventrolateral prefrontal cortices, anterior cingulate gyrus, left parahippocampal gyrus, and midline medial frontal lobe (Burgess et al. 2001). These authors related the localized activations to specific cognitive operations involved in PM, such as holding an intention toward future behavior, checking target items within presented stimuli, and dividing attention between the planned PM action and the routine activity in which it was embedded.

Cross-References

► Capacity Limitations of Memory and Learning
► Delinquency and Learning Disabilities
► Developmental Cognitive Neuroscience and Learning
► Diagnosis of Asperger Syndrome
► Neuropsychology of Learning
► New Learning in Dementia

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Prospective Cognition

► Planning in Birds

Prospective Judgment

► Calibration

Prospectivity

► Anticipation and Learning

Protocol

► Self-Reflecting Methods of Learning Research

Protosemantic

Associations between words, or between words and objects, that are initially arbitrary (such as a new item of vocabulary and the object it refers to) that will come to be incorporated into a semantic network as a function of repeated exposure.

Prototype

A prototype is the most typical or representative member of a category. For stimuli with quantitative stimulus dimensions, the prototype is often defined as the average category exemplar. Many categories, however, have more than one prototype.

The term prototype refers to a collection of characteristic features of a category, a central tendency of a category, or an ideal exemplar of a category, serving as an abstract representation of the category. Many natural categories are represented by their prototypes, where prototypes consist of a number of typical category features, none of them necessary or sufficient for category membership.

Prototype Effects

► Typicality Effect on Learning

Prototype Extraction

► Prototype Learning Systems

Prototype Learning Systems

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Synonyms

Concept learning; Neural basis of prototype learning; Prototype extraction; Prototype learning systems

Definition

A ► *prototype* is an average or best exemplar of a category, or ► *concept* (e.g., prototypical cat, prototypical graduate student). Prototypes provide a concise representation for an entire group (category) of entities, providing means to anticipate hidden properties and interact with novel stimuli based on their similarity to prototypical members of their group. A *prototype learning system* is a system of cognitive processes together with their underlying neural structures that enables one to learn (extract) a category prototype from a set of exemplars.

Theoretical Background

Prototypes provide the abstract representation for many natural categories and concepts, such as the concept of a bird or a game. In prototype-based categories, category members are clustered around prototypes based on the *family resemblance* principle, where most members share a number of characteristic features (like members of a family), but none of the features are necessary or sufficient for category membership. For some categories, explicit rules may exist dictating what is a member and what is not (e.g., triangle = polygon with three sides). However, category membership in many categories is graded based on the comparison of an instance to the category prototype. Some members of a category are better examples of the category than others (e.g., a sparrow is a better example of a bird than a penguin). The more *similar* an item is to the category prototype, the faster and more reliably it can be verified as a category member. Prototypes are also extracted during novel *concept learning*, even without an explicit instruction, and are less susceptible to forgetting than individual trained exemplars (e.g., Posner and Keele 1970). The majority of categorization in children is based on prototype learning, and also adults tend to represent categories in terms of prototypes when learning is incidental, even though they prefer explicit category membership rules when learning to categorize intentionally (Kemler-Nelson 1984).

Given that prototype abstraction is a key cognitive process involved in novel concept learning as well as natural concept representation, a body of research has focused on understanding the cognitive and neural processes that support prototype learning. Initial neuropsychological and neuroimaging findings were largely inconsistent with one another, with a major debate focusing on the role of *declarative memory* and the supporting medial temporal lobe in prototype learning. A seminal paper by Knowlton and Squire (1993) demonstrated that amnesiac patients are able to learn prototype tasks, suggesting that prototype learning is based on non-declarative forms of memory. However, others argued against this finding. Papers were published on both sides of the debate, with neuropsychological research showing a mixture of intact and impaired prototype learning in patients with a compromised medial temporal lobe and neuroimaging research showing discrepant findings regarding loci of activation in functional MRI. Eventually, review articles began to emerge pointing to existing differences in prototype learning tasks and experimental methods used in the prototype literature that could account for the discrepancies.

Important Scientific Research and Open Questions

Recent research has begun to consolidate some of the discrepant findings, critically demonstrating the existence of multiple dissociable prototype learning systems. The relative recruitment of each system for a given learning task depends on the category structure, method of learning, and the nature of encounter with category exemplars.

The first key differentiation among prototype learning tasks is between a multiple category/multiple prototype learning task, also referred to as an "*A/B task*," and a one category/one prototype learning task, also referred to as an "*A/not A task*." In the A/B task, participants learn to classify exemplars into two or more contrasting categories. This version is representative of concept learning in children when a parent walks around with a child, pointing out different exemplars from different concepts. "Look, this is a cow, this is a horse, this is a goat." In the A/not A task, only one category exists and participants learn to differentiate items belonging to the category from those not belonging to the category. This version is representative of concept learning in children based on an exposure to a large number of exemplars of one concept. "Look, a flock of chickens. These all are chickens." The cognitive and neural processes recruited by these two types of tasks differ. In the A/not A task, a representation of a single prototype is formed. If a new stimulus is sufficiently similar to this prototype, it will be assigned to the category; otherwise, it will be categorized as a nonmember. Novelty or familiarity signals from early sensory processing areas may be used as a basis for successful categorization. In the A/B task, a symmetric representation of two distinct categories centered on two prototypes is formed. New stimuli are compared to both of these prototypes and assigned to the category of the prototype that is closer to the current stimulus. Familiarity or novelty signals are not sufficient for successful performance. Rather, specific contextual information, such as the correct category label, must be retrieved from memory. Prototype learning in amnesia is impaired when the A/B task is used but preserved when A/not A task is used (for a review, see e.g., Ashby and Maddox 2005). A recent neuroimaging study directly compared the neural underpinnings of the two prototype learning tasks while keeping the actual underlying category structures identical (Zeithamova et al. 2008). The study found widespread activation within the episodic memory system, including medial temporal lobe, frontal and parietal cortices supporting performance in the A/B task. The A/not A task was associated with increased activation within basal ganglia and posterior visual areas – regions implicated in non-declarative *perceptual memory* and *procedural learning* – but also recruited anterior portion of the hippocampus, a region associated with novelty and familiarity processing. These differences suggest that the A/B task is dependent on the declarative memory system supported by the medial temporal lobe, while the A/not A task is primarily based on non-declarative memory, but can recruit structures in the medial temporal lobe in healthy adults to provide familiarity judgment that further aids categorization (e.g., Aizenstein et al. 2000; Zeithamova et al. 2008).

A number of studies demonstrated that prototype learning, primarily in the A/not A task, can occur automatically and incidentally, without an explicit instruction or intention. The ability to automatically extract the gist or statistical regularities across a number of exemplars is instrumental in the world where no two experiences are exactly alike. However, the learning mode – *incidental* or *intentional* – also significantly alters both what category representations are acquired (e.g., Kemler-Nelson, 1984) and which neural structures are recruited. Aizenstein and colleagues (2000) directly compared functional MRI activation in incidental and intentional versions of the A/not A task. They found that the incidental condition lead to *decreased* activation in extrastriate visual areas for categorical items, indicating that the ► *perceptual representation system*, also involved in ► *priming*, supports incidental prototype learning. The intentional condition showed *increased* responses for categorical items in the extrastriate visual cortex and medial temporal lobe, suggesting that the explicit memory system based on familiarity supports intentional A/not A prototype learning.

While a lot of confusion regarding the cognitive and neural basis of prototype learning has been cleared when specific task type is taken into account, variability in the results of many studies indicate that further advancements in the mapping between the specific task versions and the learning systems are needed. For instance, multiple learning systems have been implicated for the intentional A/not A task, including the procedural learning system, the perceptual representation system, and familiarity-based declarative system. While these systems are all likely to operate in parallel and contribute to successful learning in a healthy brain, a number of factors may determine which system is going to be dominant, such as the nature of the stimuli and their within- and between- category similarity, order of encountered stimuli, the specific instruction and training method, etc. All of these factors have been shown to influence learning in various tasks, but their effects on the recruitment of the different prototype learning systems has not yet been rigorously tested. Some discrepancies in the findings also persist regarding the A/B task, where both declarative and non-declarative learning systems have been indicated. One of the key contributing factors may be that two distinct training methods – feedback-based training and observational learning – are used interchangeably for the A/B task. However, the effects of feedback and observational training on the neural basis of prototype learning are yet to be directly compared.

Despite these challenges, the current stage of research indicates that at least three prototype learning systems exist, with their relative recruitment being dictated by specifics of the task. Each prototype learning system relies on a distinct memory system and the underlying neural substrate. The ► *perceptual representation system*, subserved by repetition-related changes within sensory cortices, is critical in abstracting prototypes during the incidental A/not A task and likely contributes to some extent to all forms of prototype learning. However, it requires relatively high perceptual similarity among categorical items in order to support learning. The *procedural learning system*, subserved by structures within the basal ganglia, tends to be recruited during the intentional A/not A task as well as feedback-based A/B task. The *declarative memory system*, subserved by structures within the medial temporal lobe, is critical for the observational A/B task, and may contribute to the intentional A/not A task and feedback-based A/B task as well. Two subsystems of declarative memory exist: *recollection*-based and *familiarity*-based. Recollection-based memory, such as *episodic memory*, supports recollection of specific details of an experience. Such recollection is critical in the A/B task, where members of both categories are equally familiar and category labels need to be retrieved for successful performance. Familiarity-based memory provides feeling-of-knowing without the retrieval of further information, such as the context of a previous encounter. Familiarity signals in the A/not A task will be strongest for items close to the category prototype and weakest for items far from the prototype, thus serving as a basis for categorization. Recollection and familiarity depend on partially dissociable substructures of the medial temporal lobe, with familiarity often being preserved to some extent in amnesiac patients. Therefore, the recollection/familiarity distinction can explain why some neuroimaging studies report medial temporal lobe recruitment in the A/not A task despite observed dissociations between the A/B task and A/not A task in amnesia.

Understanding dissociations among multiple prototype learning systems has several important implications. By accepting that different prototype task versions may be supported by different learning systems, we can interpret previously contradictory findings in a new light. Once the relationship between different prototype learning tasks and the memory systems that underlie them is well understood, the prototype tasks can become important tools for studying the memory systems themselves. The correspondence between prototype tasks and learning systems can be utilized for neuropsychological diagnosis, such as Alzheimer's disease or dementia. Also, as concept learning constitutes a major portion of formal education, teaching methods and instruction can be improved by utilizing the best match between a teaching method and a given task, or by utilizing multiple learning systems simultaneously rather than relying exclusively on explicit memorization. Future research detailing various task factors, such as the training method and category structure, and their relationship to the recruited prototype learning system will further increase the applicability of prototype learning research in practice.

Cross-References

► Categorical Learning
► Categorical Representation
► Concept Formation
► Episodic Learning
► Memory Structure
► Priming, Response Learning and Repetition Suppression
► Procedural Learning

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Prototyping

► Innovation and Learning Facilitated by Play

Provocation

► Incentives and Student Learning

Proximal Guidance

► Guided Learning

PSFMA System

System of planned, stage-by-stage formation of mental actions or the PSFMA system.

Psychoanalysis

► A Tripartite Learning Conceptualization of Psychotherapy

Psychoanalytic Perspective on Burnout

► Burnout in Teaching and Learning

Psychoanalytical Theory of Learning

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Synonyms

Freud's theory of learning

Definition

Sigmund Freud's psychoanalytic theory attempts to explain why some people are healthy while others suffer from mental disorders; it also provides a framework for explaining personality development (Strachey 1953).

Theoretical Background

The following aspects of psychoanalytic theory are often taught in psychology classes, and it is important that students understand them.

The Basics of Psychoanalytic Theory

According to Colby Srsic, a counseling psychologist in Worthington, Ohio (http://www.healthgrades.com/health-professionals-directory/colby-srsic-phd-d0edb8cc), psychoanalytic theory holds that everyone has conflicting thoughts and emotions, which are repressed because they are painful. Although these thoughts may not be consciously experienced, they remain active and leak out into behaviors.

Freud believed that by being aware of these thoughts, people could consciously experience their emotions and relieve negative psychological symptoms. The goal of therapy, then, was to help people gain insight into repressed thoughts and emotions and begin to deal with them.

Personality Development in Psychoanalytic Theory

According to Freud, personality includes the following three components:

- Id- This primitive, puerile part of the personality seeks pleasure and instant gratification, ignoring possible consequences.
- Ego- The rational part of personality, the ego guides a person through life and enables him or her to make good choices.
- Super-ego- This is the opposite of the id; it is the moral aspect of personality, and it allows a person to experience guilt.

These three parts of the personality work together, but they can malfunction, according to Freud. Someone with an underdeveloped super-ego, for example, may engage in criminal activity.

Psychosexual Stages, According to Freud

Freud divided development into the following five psychosexual stages:

- Oral- During this stage, which occurs from birth to 18 months, babies derive pleasure from chewing, drinking, and putting things in their mouths.
- Anal- From 18 months to 3 years, children find pleasure in being able to go to the bathroom at the appropriate times.
- Phallic- Occurring from 3 to 6, gender roles develop during this stage. Girls must navigate through the Electra complex, which involves dealing with sexual feelings for their fathers. Boys must repress sexual desires for their mothers, and overcome the Oedipus complex. Girls also suffer from penis envy, as they realize that unlike boys, they do not have penises.
- Latency- Freud said that nothing sexual happens during this stage that occurs from ages 6–12; developing children focus on learning and establishing friendships.
- Genital- This stage persists through adulthood, when people are able to engage in successful romantic relationships and give back to their communities.

Freud regarded these stages as being prominent in childhood development; if a child does not successfully navigate through one of these stages, he will be “stuck” and have trouble completing the other stages.

Defense Mechanisms

Freud also believed that people use defense mechanisms to ward off anxiety. Freud described the following eight defense mechanisms as being relevant:

- Sublimation- Channeling repressed desires into socially acceptable outlets. Aggression, for example, may be channeled into being a competitive athlete.
- Denial- Refuse to recognize the real nature of one’s behavior.
- Rationalization- Giving a plausible alternative explanation for one’s behavior, in hopes of hiding one’s real motives.
- Projection- Attributing one’s own desires and motives to others.
- Displacement- Deflecting feelings on less threatening targets; a parent may be angry at a boss, but take the anger out on his/her children, for example.
- Reaction Formation- Acting in a way that is opposite of what one actually wants.
- Intellectualization- Continuing to repress certain impulses, even when one is aware of them.
- Compensation- Dealing with shortcomings in one area by devoting oneself to another area.

If defense mechanisms failed, Freud believed neurotic symptoms, such as depression and anxiety, would result.

Important Scientific Research and Open Questions

Dealing with Neurotic Symptoms

Once defense mechanisms failed and a person needed counseling, Freud upheld a technique known as psychoanalysis. In this form of lengthy therapy, the counselor or analyst remains neutral and out of the view of the client. The client then engages in free association, saying whatever comes to mind.

During therapy, the analyst may also engage in dream analysis, and interpret any resistance displayed by the client. According to Srsic, this form of therapy is still used from time to time, especially in the North East, but it has been replaced by more modern techniques, such as relational therapy.

Dealing with Unconsciousness

According to Westen (1998), the most important implication that distinguishes psychoanalysis from other theoretical systems is the postulation of unconscious mental processes. Freud (1926/1953) considered unconsciousness as the cornerstone of psychoanalytic theory. Until the 1980s, psychoanalysis was actually the only psychological theory that postulated unconscious mental processes. Today, the basic understanding that many cognitive processes occur unconsciously is widely excepted in cognitive and experimental psychology (see, for example, Kihlstrom 1987). Westen (1998) has described the various approaches of cognitive psychology that refer to Freud's theory of unconsciousness in order to explain implicit and explicit thought and learning processes.

Cross-References

- ► Adler, Alfred
- ► Freud, Anna
- ► Freud, Sigmund
- ► Jung, Carl G.

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Psychodynamics of Team Learning

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Synonyms

Group dynamics; Interrelatedness

Definition

As workplaces grow increasingly complex, teams are often tasked to respond creatively to unprecedented challenges in unpredictable environments, learning in the moment to develop a viable solution. To accomplish this effectively, teams must understand the psychodynamics of team learning: The conscious and unconscious mental and emotional processes that impact a team's operational performance in scenarios where a procedural response is either inappropriate or has not been delineated.

Theoretical Background

The complexity of our increasingly globalized, highly technical, interconnected world has made working in teams more common – and leadership and teambuilding skills more important – than ever in a wide variety of industries. No one person can manage the plethora of information created by our sophisticated systems. It takes a team. Yet, all teams have subtle, and not so subtle, dynamics that impact operational performance. These conscious and unconscious mental and emotional processes underlie all aspects of teamwork by influencing the attitudes, motivations, and behaviors of individuals within the team environment (Fraher 2005, 2011).

Teams operating in high-risk fields – such as aviation, military, law enforcement, fire fighting, emergency planning, medicine, nuclear power, or off-shore drilling – have unique, often covert, characteristics influenced by the nature of their tasks, their hazardous and unforgiving operating environments, and the ambiguous ways clues to a crisis often emerge. Factors such as time urgency, peer pressure, exposure to personal risk, professional competitiveness, fear of malpractice suits or other forms of retribution, inter- and intra-team conflicts, reputation management, shifting tasks, conflicting goals, uncertainty, dealing with casualties, handling media pressures, and otherwise living with the weighty repercussions of one's decisions often combine to make decision-making in high-risk teams an exceptionally stressful activity. In addition to high-risk professionals managing these stressors, recent disasters have illuminated a surprising range of leaders required to act as key decision-makers during a crisis, especially during the initial onset of a problem when it may not yet be clear what the issue is. For instance, actions taken by principals, teachers, and university administrators during school shootings, hospital employees during hurricane evacuation, hotel managers during natural disasters, plant supervisors during industrial accidents, and chief executives during product recalls play central roles in determining when, and if, a situation escalates to full blown crisis. As a result, it is evident that a wide range of professionals require the ability to think through crisis and manage anxiety, sifting through ambiguous and often conflicting data in order to determine a course of action. This requires the team to analyze the unfolding situation, make proper sense of information as it emerges, and learn how to cope in the moment. Therefore, it is important to understand the psychodynamics of team learning (Fraher 2005, 2011).

New frameworks based on the psychoanalytic study of disasters have emerged with a particular focus on sense-making, analyzing factors leading to team performance breakdown, and organizational failure. Examples include studies of Enron, Long Term Capital Management, Parmalat, nuclear power plants, Mount Everest climbing expeditions, medical operating rooms, NASA explorations, wildfire fighting, oil platforms, and post-9/11 airlines, to name a few. Previously, most research explained disasters as resulting from a single flawed decision and analysis focused almost exclusively on operator errors while training aimed to mitigate the recurrence of these individual failures through technical repetition, for instance, more time in the flight simulator or on the firing range. Few leaders considered the influence of group dynamics or systemic factors like regulatory oversight, licensing criteria, financial concerns, or organizational culture on team performance prior to or during the disaster period. Yet as our increasingly complex systems produce more and more unpredictable challenges, it becomes clear that a new understanding of teamwork is required; one that considers the impact of the system as well as the team in which individuals are operating. This is where a psychodynamically informed perspective can be helpful.

Participating in teams often causes anxiety in individuals who feel conflicted about "joining" the group. Most people want to belong and enjoy the camaraderie and safety of being part of something. At the same time, they may feel reluctant to commit and threatened about their loss of individual identity. This often results in two distinct, yet competing feelings: fear of being swallowed up, or fused, by the power of the team, and fear of rejection and abandonment. While the nature of this "fusion-abandonment tension may not be self-evident to the individual in the group setting, the anxiety that emanates from it usually is" (Smith and Berg 1987, p. 66).

Feelings such as excitement about the task, meeting new colleagues, and completing the assignment may conflict with memories of bad team experiences and anxiety about fitting in and being seen as competent. Adding to this a secondary fear can emerge that these anxieties may not go away and may in fact escalate out of control. To manage these conflicting feelings, teams often attempt to ignore this anxiety, pretending it does not exist, by engaging in rituals and behaviors that seem acceptable to other team members. As a result two strategies often emerge: One approach is to remain connected and undifferentiated as a group, operating under the assumption that everyone agrees on everything that is being said and done; the second approach involves holding back, employing a wait-and-see attitude as things evolve. Unfortunately, each of these approaches stirs up more anxiety. As it becomes clear that the measures employed to alleviate the tensions are not working, and anxiety is actually escalating, the team environment begins to feel unsafe, stifling members input as sense-making and learning grind to a halt. The team is now confronted with a paradox: It may be personally dangerous to invest energy in this process, but if one does not jump in and gain some influence, things may spiral out of control. In either case, working within this team now feels quite risky. This switch – from managing self-processes to making judgments about the team as a whole – especially as individual anxiety is increasing, is a difficult yet significant human process often represented in both psychological and anthropological literature as *splitting*.

Psychoanalyst Melanie Klein (1955) observed that when anxiety becomes high, people manage their discomfort by dividing, or *splitting*, their feelings and *projecting* or attaching these feelings on all-good and all-bad *objects*. In this manner, someone or something else is made to take on the all-bad characteristics that the individual unconsciously wants to disown, allowing the individual to retain the all-good feeling for themselves, alleviating their anxiety. Wilfred Bion (1961) applied Klein's theories to groups, observing that one of the key consequences of *splitting* in organizations is that certain subgroups are expected to carry unpleasant emotions for the entire system.

Here is an example: Have you ever been part of an organization that had *one* troubled department? It was common knowledge throughout the organization that if only that *one* department could get themselves organized, things would finally run smoothly. Yet, no matter who worked in that department, it remained the *scapegoat* for the entire system. Instead of being dealt with directly, unwanted or difficult feelings – such as competition, envy, and fear of failure – were *split off* and *projected* onto the one problem department, when in fact, the problem existed throughout the organization. In this environment, it is not uncommon for *group think* to emerge where group members suppress their personal ideas, putting social acceptance and group harmony above proper sense-making and reaching a good decision (Fraher 2005).

An infamous example of the danger groupthink to team learning can be found in the events leading up to the explosion of the Space Shuttle *Challenger* in 1986. After decades of success in space exploration, NASA found itself in the 1980s under pressure to keep up its ambitious project schedule, yet remain within tight budgetary constraints. Pushed to do more with fewer resources, a new organizational climate emerged. Deluded by its history of success, NASA acted as if it was infallible, launching the shuttle despite several urgent warnings by mid- and lower-level employees about the deterioration of O-ring seals. Yet, rather than delay the launch to investigate these warnings, NASA charged ahead succumbing to *groupthink*. Employees attempting to voice concern were either ignored or forced out, as rational decision making and safety were sacrificed in favor of social acceptance and group harmony. The *Challenger* exploded on launch, killing all seven of its crew members (Schwartz 1987, 1989).

Like these previous examples, recent research suggested that organizational errors often result from a breakdown in team learning in response to anxieties created by changes in the environment. In other words, disasters often resulted from a team's failure to sense the severity of an impending problem, ask questions, surface conflicts, and discuss errors in a timely fashion. In contrast, team learning is fostered when team members: effectively identify and integrate resources; authorize themselves to speak up, ask questions, investigate points of conflict and identify errors; resist jumping to conclusions by tolerating ambiguity and a state of not knowing as information unfolds over time; and actively analyze the situation in order continue to evolve their mental model. A study of surgical teams in action found that rather than educational background, medical experience, physician seniority, or institutional prestige, one of the key determinants of team performance was its ability to adapt to new ways of working. Team leaders needed to create an environment conducive to learning in which teammates could speak up, ask questions, and take action without fear of reprisal. Therefore, the way teams were assembled and how members drew on their experiences was central in operating room team success puzzling through challenging new situations (Edmondson et al. 2004, p. 104).

Yet there are often significant cultural obstacles to achieving this level of teamwork. Numerous studies found that healthcare professionals routinely deny the impact of outside stressors and anxiety on their job performance. For instance, 70% of surgeons deny the effect of fatigue on their job performance compared with only 26% of airline pilots; 82% of doctors believed a true professional can leave personal problems behind when working, and 76% believe their decision-making during emergencies was as accurate as during routine operations (Sexton et al. 2000, p. 748). Another recent study found that about one third of the anesthesiologists and about a quarter of the operating room teams studied "failed to ask for help, did not accept help when it was offered, or did not work together effectively in a crisis." In particular communication issues emerged such as "speaking into thin air, not clearly addressing a co-worker, or being imprecise about what they wanted done" (Groopman 2005, p. 52).

Other studies found that perceptions of teamwork differ significantly by operating room role. Although surgeons rated their operating room teamwork highly 85% of the time, nurses only rated surgeons highly 48% of the time (Makary et al. 2006, pp. 746–752). Perhaps most disturbing is that one third of intensive care responders did not acknowledge that they made errors while more than half reported it was difficult to discuss mistakes in their organization or ask for help. Reasons given to account for this poor teamwork were personal reputation (76%), threat of malpractice (71%), high societal expectations (68%), fear of disciplinary action by licensing boards (64%), job security (63%), and the egos of team-mates (60%) (Sexton et al. 2000, p. 748). Some of the issues underlying teamwork breakdown are the nature of communication and training within these professional groups. For instance, nurses are trained to communicate holistically, often describing good collaboration as having their input respected. While physicians are trained to communicate succinctly, describing good collaboration as working with teams who anticipate their needs and follow instructions (Makary et al. 2006, pp. 746–752).

These differences have deep roots in educational and professional cultures and will not be easily changed. Yet understanding the psychodynamics of team learning can help to create a team culture conducive to proper sense-making improving team performance in all fields, particularly when encountering unpredictable challenges.

Important Scientific Research and Open Questions

Although teams have become increasingly popular in the workplace, we still know very little about the dynamics that make them effective or ways to improve their operational performance. The research that has been accomplished is typically quantitative in nature, ignoring the fact that teams operate differently when challenged by unique situations, particularly crises which have no procedural responses and no training protocol. To address these unpredictable problems, teams must learn how to manage anxieties and make sense of the unfolding scenario in order to develop their own solution. Training teams to understand the psychodynamics of team learning will prove helpful in these situations. Yet, further research needs to be conducted in this area.

Cross-References

► 21st Century Skills
► Action Learning
► Emotional Intelligence and Learning
► High-Performance Learning Spaces
► Stress and Learning

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Psycholinguistics and Learning

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Synonyms

Psychology of language

Definition

Psycholinguistics is the interdisciplinary endeavor of psychologists and linguists trying to shed light on the representation of linguistic knowledge, from sound to meaning, the processing of this knowledge in speech production and comprehension, as well as its acquisition. Whereas, before the beginning of the twentieth century, the major contribution of language to human competence has been considered to be the association of words and concepts, the major topics since then have been the often complicated rules and constraints of how sounds can be put together to form syllables, how syllables form words, and how syntactically and semantically coherent sentences can be generated from those words.

Theoretical Background

Modern linguistics has shown that human language is highly complex. The syntactic and semantic rules governing the relation of sequences of words and meanings are complicated and hard to disentangle by linguists. Still, human children learn all those rules easily, simply by being exposed to language and mostly without being aware of their linguistic knowledge which remains implicit most of the time. One of the central questions in psycholinguistics is how it is possible that nearly every human being eventually manages to speak and understand at least one language (and in a majority of cases more than one). Obviously, our brains are equipped with the capacity to learn whichever language ever spoken or to be spoken anywhere on earth by humans. Put healthy infants of whichever origin in a linguistic environment and they will learn the language spoken around them, and this even fairly independently of how their parents are trying to teach them.

A first theory of language acquisition was proposed by B.F. Skinner (1957). He considered the production and comprehension of utterances as "Verbal Behavior," a special case of operant conditioning. For Skinner, knowing a language meant learning a set of behavioral dispositions to produce certain utterances in reaction to the environment and to react appropriately to utterances from other speakers. The conditioned response to an utterance such as "Please, pass the salt." would be to pass the salt. The reaction to being passed the salt would be to utter "Thank you." – given that this behavior has been reinforced (recompensed) in the history of the individual. Children's knowledge of a target language gradually converges with that of a greater community by a history of punishments (e.g., misunderstandings) and rewards (e.g., communicative success or parental approval).

In his famous critique of Skinner, Noam Chomsky (1959) convincingly showed that a child learning a language cannot be compared to a rat learning its way inside a maze. Parents do not systematically reward grammatically well-formed utterances and punish incorrect ones while they generally punish children for not telling the truth. Still, children grow up producing more and more complex and grammatically well-formed sentences, and they continue telling lies. Moreover, children understand and produce sentences they have not ever heard before. Children of almost every language go through a phase where they overgeneralize linguistic rules, they say "Daddy goed to work." – a sentence they most probably have not encountered before. They apparently extract complex rules of sentence formation that cannot possibly have been gathered from their caregivers input alone, following Chomsky. How, for example, can question formation be learnt from the simple sentences of the input to young children? A plausible hypothesis would be to move the first verb to the beginning of the sentence (1a,b).

1. (a) Doggy is eating.
   (b) Is Doggy eating?

However if children ever pursued this hypothesis, they should produce ill-formed questions like (2) where the finite verb of the embedded relative clause is erroneously fronted. This kind of errors is, however, very rare if not inexistent in children's productions, although children's linguistic input does not exclude it (the so-called Poverty of Stimulus argument).

2. Is doggy who eating is sick?

Why do children never come up with certain hypotheses although they would be compatible with their linguistic input?

A possible solution to the fact that children succeed in acquiring highly abstract and seemingly even unobservable rules of language is the assumption of an innate mental organ, a language faculty, which comprises the basic regularities common to all languages possibly spoken by human beings. For the past 50 years, the search for the Universal Grammar underlying all languages has been one of the central issues in formal linguistics. Psycholinguists, on the other hand, were concerned with the question of how such knowledge can be put to use, of what are the mechanisms of human language processing.

How can different languages be learnt with a universal grammar? Recent proposals assume a kind of switchbox circuitry where all switches are set to some default position, they may, however, be flicked to other positions based on linguistic experience. Consider for example the fact that Spanish speakers can leave out a pronominal subject: They can say "Hablo Español," leaving out the "Yo," meaning "I," whereas an English, German, or French speaker has to say "I speak Spanish," "Ich spreche Spanisch," or "Je parle espagnol." By default, the switch for pronominal subjects may be set to "obligatory," but encountering subjectless sentences may have it switched to "optional." This process is termed "Parameter setting" in Chomsky (1990).

The nativist approach to language learning proposed by Chomsky has recently been challenged, based on new evidence on probabilistic learning algorithms. Arguments put forward in favor of an inborn capacity to learn languages are the so-called Critical Period Hypothesis (CPH; Lenneberg 1967), the consistent localization of language-related processes in the brain, as well as language-specific deficits that seem to have a genetic component (Gopnik 1997).

The Critical Period Hypothesis

It is a well-known fact that languages can be learnt more easily at a very young age (best before the age of 3) and that after the onset of puberty (about the age of 10) learning is more effortful and native-like performance in the target language is rarely attained in particular for segmental phonology, inflectional morphology, and syntax. Young children suffering from a brain trauma usually (re)learn language much more easily than adolescents or adults. Children confronted with a second language before the age of 3 generally develop native-like competence whereas this is rarely the case for late bilinguals who started learning their second language after the age of 10. A prominent argument for a critical period is the case of so-called wild children who suffered from a significant lack of linguistic input before the onset of puberty (such as the girl Genie who grew up in suburban Los Angeles locked up alone in her room). These children are apparently unable to acquire even rudimentary grammatical knowledge when starting to live in a richer linguistic environment. The data available to date are, however, more compatible with the notion of a "sensitive period" where learning a language is easier than with that of a "critical period" where learning beyond that period is virtually impossible. In many cases, language recovery after brain traumas is possible at least to a certain extent even for adults. Second language proficiency of late bilinguals (age >10) seems to depend on the input: The similarity of the new language to the native language as well the time spent in the new country and specifically the time spent listening to and speaking the second language play a major role in how close to native-like performance even late bilinguals can get. The cases of "wild children" are difficult to judge given the amount of confounding factors due to the consistent deprivation. Deaf children growing up with speaking parents without any early confrontation with sign languages may provide further insight on that issue.

Localization of Language Processing in the Brain

The area most systematically related to syntactic processing in the brain is Broca's area (or Brodmann's areas 44/45) located in parts of the left inferior frontal gyrus (IFG). Other brain areas are systematically involved in prosodic and semantic processing (see Friederici 2002 for an overview). Broca's area is systematically more active when complex sentences have to be processed. Damage in Broca's area can lead to agrammatic speech and to severe deficits in the comprehension of sentences where semantics does not guide interpretation such as in (3).

3. (a) The girl was seen by the boy.
   (b) The horse that the cow kicked ran away.

Even though being one of the most reliably activated areas in sentence comprehension and production, Broca's area is not the locus for the language faculty, given that it is involved in nonlinguistic processes as well, such as music perception, or the perception of the rhythm of motion. Broca's area may thus rather support rule-based processes for different cognitive functions. Recovering from severe traumas in Broca's area moreover often involves cerebral plasticity, in this case the displacement of language-related processes to other brain areas well equipped to perform the necessary computations (e.g., the right inferior frontal gyrus).

The Language Gene

Gopnik (1997) strongly defends the existence of specialized brain circuitry for language that has developed during the evolution of the human brain and even proposes a specialized gene (or a set of genes) underlying the human capacity for language. Two major arguments have been put forward to substantiate her claim: The largely intact verbal capacities of children with William's Syndrome with otherwise substantial deficits in general intelligence contrast strongly with the performance of children suffering from Specific Language Impairment (SLI) whose general intelligence is mostly unaffected whereas they show severe deficits in phonological, morphological, and syntactic processing. Specific cases of SLI seem, moreover, to run in families: In the much studied KE family, the distribution of specific morphosyntactic deficits suggests the implication of a dominant gene. In fact, the gene FOXP2 has been identified as a highly likely candidate for the deficits shown in the KE family. FOXP2, however, though certainly important for linguistic abilities, seems to be not only relevant to language-specific processes but also to more general motor circuitry.

More generally, we can say that although certain prerequisites of language acquisition and processing are certainly part of our genetic endowment, they are not necessarily specific to language processing. It may thus not be the brain that has evolved to be adequate for language processing but languages may have evolved in order to oblige to the computational power of the brain.

Important Scientific Research and Open Questions

More recent work on usage-based or probabilistic models and neural networks sheds a new light on the ways language may be acquired and processed. Tomasello (2003) criticizes the generative grammar approach where children learn words on the one hand and complex and abstract morphosyntactic rules to put those words together on the other hand. He proposes an alternative acquisition model, where children learn "constructions," communicative entities on various levels of abstraction, which start off as concrete entities, closely linked to situations experienced by the child, and converge progressively toward adult-like, more abstract representations. Constructions may be objects like "doggie" or apparently complex but unstructured expressions like "lemme-do-it." Paradigmatic categories such as "noun" and "verb" are learnt by distributional analyses of their functions across constructions. Abstract functional roles across constructions (such as "Pass me the salt" and "Pass me the sugar") are derived by schematization and analogy. Frequency of successful usage of a construction is central to generalization. The decoding of communicative intentions plays a role in the process of developing more abstract constructions, since different constructions may convey different communicative intentions in the same situation. Tomasello's approach is thus anti-nativist in the sense that he considers the children's innate endowment necessary for language acquisition not to be language specific. It involves the ability to segment the speech stream into constructions on different levels of abstraction on the one hand and general cognitive abilities, such as decoding other's intentions and general reasoning skills on the other hand.

Probabilistic models still have to show that they are capable of learning all and only those rules and generalizations learnt by human speakers, including the constraints to be derived from sensitive periods of acquisition and specific impairments of language processing. This will be one of the big challenges for the near future.

Cross-References

► Analogy/Analogies: Structure and Process
► Grammar Learning
► Linguistic Factors in Learning
► Language Acquisition and Development
► Verbal Behavior and Learning

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Psychological Trauma

► Learned Helplessness

Psychological Treatment

► A Tripartite Learning Conceptualization of Psychotherapy

Psychology of Language

► Psycholinguistics and Learning

Psychology of Learning (Overview Article)

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Synonyms

Acquisition of knowledge; Conditioning; Storage

Definition

In general, psychologists view *learning* as a long-term change in behavior or mental associations as a result of experience. Very temporary changes (e.g., remembering a telephone number only long enough to dial it) do *not* constitute learning, nor do changes that result solely from physiological maturation, brain injury, mental illness, dementia, or use of mind-altering substances (e.g., alcohol, amphetamines). Learning does not necessarily involve a permanent change, however; learned information and skills can be lost (forgotten) if they are used infrequently or not at all.

Theoretical Background

When psychology emerged as a distinct discipline in the late 1800s, theoretical perspectives of learning (e.g., Wilhelm Wundt's *structuralism,* John Dewey's *functionalism*) lacked a solid research base. The primary research methodology at the time was introspection: Researchers simply asked their subjects to reflect on and describe their internal, mental experiences. But beginning in the early 1900s, some psychologists criticized this approach as being highly subjective and lacking in scientific rigor. For example, American psychologist John Watson called for focusing psychological research on observable, objectively measurable phenomena – in particular, on environmental stimuli (Ss) and on organisms' overt responses (Rs) – and argued that mental processes (i.e., thinking) were nothing more than tiny, potentially measurable movements in the tongue and larynx.

Especially in North America, some of Watson's professional colleagues took up the call, giving birth to ► behaviorism as one dominant perspective of learning in the first half of the twentieth century (e.g., see Bower & Hilgard 1981). Common to early behaviorist research was a focus on stimulus–response (S–R) associations, and learning was operationally defined as a change in *behavior,* without consideration of possible underlying mental phenomena. Most behaviorist research involved laboratory experiments with nonhuman animals (e.g., rats, pigeons), allowing for tight control of environmental conditions and simple, easily measurable behaviors. For example, B. F. Skinner described a phenomenon he called *operant conditioning,* in which such responses as pushing a metal bar and pecking a plastic disk increased in frequency when followed by certain *reinforcing* stimuli (e.g., small nuggets of food). Russian physiologist Ivan Pavlov's research with salivation responses in dogs – leading to his theory of *classical conditioning* – provided an additional foundation for the behaviorist movement.

While the behaviorist movement flourished in North America, much of Europe was taking a more cognitively oriented approach to the study of learning. For example, a perspective known as *Gestalt psychology* flourished in Germany. Initially spurred by Max Wertheimer's study of a common optical illusion, Gestaltists focused largely on mental phenomena (e.g., perception) and complex behaviors (e.g., problem solving). Meanwhile, in a research program with children that spanned several decades, Swiss developmentalist Jean Piaget and his colleagues focused on logical reasoning processes. And in Russia, psychologist Lev Vygotsky speculated about the social and cultural origins of such complex cognitive processes as reasoning and problem solving.

In the latter decades of the twentieth century, cognitively oriented approaches increasingly came to dominate theories of learning (Ormrod 2008). This trend was partly the result of more frequent communications among psychologists of different countries and languages, but also partly due to apparent limitations of the behaviorist approach. For example, in a refutation of Skinner's proposal that reinforcement is often a necessary condition for learning, American psychologist Edward Tolman found that laboratory rats can learn many things about their environment simply from having opportunities to freely explore it. Furthermore, when researchers studied human language learning using traditional behaviorist methodologies, they sometimes discovered that people work hard to impose meaning on what they are learning – that is, they actively work to make mental sense of new information. In addition, researchers became increasingly willing to move beyond the observable facts to draw inferences about the cognitive phenomena that must logically underlie those facts.

In the 1960s and 1970s, American psychologist Albert Bandura reconceptualized behaviorist principles to include cognitive variables (e.g., expectations, self-efficacy). Bandura also noted that people acquire many new behaviors simply through observation and modeling of others' actions; hence, he called his approach ► social learning theory. Social learning theory has more recently been expanded in significant ways to include the importance of human agency and self-regulation (e.g., intentionality, planning, self-evaluation) in learning and behavior. To reflect its current focus on cognition as much as on behavior, social learning theory is now more commonly called *social cognitive theory.*

Rather than gradually drift toward more cognitively based explanations (as social learning theorists did), other psychologists abandoned behaviorism altogether and instead sought largely cognitive explanations of how human beings learn. With the advent of widespread access to computer technology came ► information processing theory, a perspective that initially hypothesized that people think about and learn new information in much the same way that computers process information. For example, many information processing theorists proposed that people's memories include both short-term, active processing mechanisms (similar to a computer's random access memory, or RAM) and long-term storage mechanisms, and they often used computer lingo (e.g., *encode, store, retrieve*) in their explanations. And in the area of artificial intelligence, psychologists have created a wide variety of software programs designed to mimic human thinking and problem solving.

The computer analogy has not always held up under close scrutiny, however. Human beings often deal with new information in ways that are difficult to explain in algorithmic, computerlike ways. For instance, people's inclination to find meaning in events – and, in fact, to fill in gaps in information so that meaning-making is possible – has led some psychologists to abandon traditional information processing models in favor of approaches collectively known as ► constructivism, in which learning is depicted as a process of actively and idiosyncratically building one's own interpretations of environmental stimuli and events. Other psychologists have successfully integrated information processing and constructivism in their efforts to explain perception, memory, problem solving, and other complex cognitive processes.

In the 1980s, thanks in part to the Soviet Union's *glasnost,* and in particular to its increasing willingness to share ideas and research findings with scholars worldwide, Lev Vygotsky's writings were translated from Russian into other languages and thus became accessible to a much larger audience. His emphasis on the importance of social interactions for children's learning and development – and on the importance of culture and society more generally – has led to ► sociocultural theory, which places much of the impetus for a person's learning back on the environment. In contrast to behaviorism, however, sociocultural theory focuses more on general cultural practices than on specific environmental stimuli and events.

Recent advances in neuropsychology have some learning theorists proceeding in a very different direction. For example, functional magnetic resonance imaging (fMRI) technology has revealed that many parts of the brain become activated even in very simple learning and memory tasks. This common finding has led to a perspective known as *parallel distributed processing (PDP)*, which acknowledges that normal human cognitive processes and internal representations of objects and events are widely distributed across the brain and almost certainly involve a great many basic neurological processes working together. PDP is sometimes known as *connectionism*, but it should not be confused with an early behaviorist theory (that of Edward Thorndike), which was given the same label in reference to the many S–R connections that learning purportedly involves.

A complete understanding of the complex phenomenon we call *learning* undoubtedly requires multiple vantage points. Hence, in recent years many psychologists have been willing to consider – and, to the extent possible, they have integrated – two or more theories into their explanations of how human beings and other species learn about and adapt to their environments.

Important Scientific Research and Open Questions

Learning clearly involves a wide variety of processes, some external and observable (especially when behavioral changes are involved) and others internal and beyond easy scientific scrutiny and measurement. Research on learning processes, then, is proceeding in numerous directions. Following are examples of topics that many researchers are currently studying:

- *The nature of basic cognitive processes.* Researchers working within an information-processing perspective seek a better understanding of such processes as attention, sensation, and perception. Others are trying to pin down the nature of short-term and long-term storage and retrieval processes. For example, some research indicates that attention is a multifaceted phenomenon that involves both involuntary, automatic processes and more voluntary, controlled ones. Other research reveals a *working memory* component to cognition – a limited-capacity mechanism that can hold and actively manipulate only a small amount of information at a time.
- *The distinction between explicit and implicit knowledge.* Historically, most cognitively oriented researchers have focused on *explicit* knowledge – that is, on learning and remembering things that the learner can consciously describe. But in recent years researchers have found that a good deal of knowledge is *implicit* – that is, it is largely inaccessible to conscious recall and mental inspection but nevertheless can have significant effects on behavior. For example, early language acquisition appears to be largely an implicit process: Although linguists have struggled to identify all of the syntactic rules that guide sentence construction in a particular language, most young children learn these rules within a few short years. In addition, many socially or culturally transmitted attitudes and beliefs seem to take an implicit rather than explicit form. Quite possibly, explicit and implicit knowledge are learned in qualitatively different ways.
- *The nature and potential applications of behaviorist paradigms.* A great deal of basic behaviorist research, much of it conducted with laboratory animals, has helped to refine our understandings of classical conditioning, operant and instrumental conditioning (whereas operant conditioning involves only reinforcing stimuli, the term *instrumental conditioning* encompasses both reinforcing and punishing stimuli), and related S–R phenomena. For example, some research has revealed the possible role of classical conditioning in the formation of human attitudes, stereotypes, and phobias, and also in human drug addiction and withdrawal symptoms. And instrumental conditioning has proved to be a useful tool in therapeutic and educational settings, especially in situations where significant behavior changes are sought. Behavior modification, applied behavior analysis, functional analysis, and positive behavior support all involve intervention techniques that are based on behaviorist principles.
- *The importance of human agency in learning.* In research with human subjects, numerous researchers are focusing on how learners actively control both what and how they learn. For example, some researchers have proposed that human cognition includes a *central executive* that oversees and directs explicit learning processes (sustained attention, interpretation of incoming information, etc.). Other researchers have found that a variety of consciously controlled self-regulation processes can enhance the amount and quality of learning. For example, in classrooms, students typically learn and remember academic subject matter more effectively when they try to clear their heads of distracting thoughts, work hard to make sense of confusing statements, and regularly check themselves to make sure they can still remember what they have recently studied.
- *The cognitive bases of motivation for learning.* Early behaviorists portrayed motivation largely in terms of drive reduction – that is, organisms behave in order to address internal, physical needs (e.g., hunger, thirst) and restore physiological homeostasis. In the early behaviorist view, external, reinforcing consequences often have their power either by virtue of the fact that they address these internal needs or (in the case of secondary reinforcers) through

frequent association with drive-reducing consequences. But within the past few decades researchers have found that on many occasions, reinforcement and a need for homeostasis cannot adequately explain learners' motives. In fact, external reinforcement can sometimes *undermine* motivation, especially when it is perceived as being overly controlling and manipulative. Researchers have proposed and investigated a variety of cognitive factors involved in motivated learning, including interests, values, goals, self-efficacy, and attributions regarding one's prior successes and failures.

- *The close, interactive relationship between learning and affective variables.* Early in the twentieth century, Sigmund Freud suggested that people may be unable to recall events that were highly traumatic for them – a phenomenon he called *repression.* Although true repression of traumatic memories has been difficult to replicate in laboratory settings, researchers are increasingly finding that learning and memory are closely intertwined with affective variables (e.g., moods, emotions). Generally speaking, information is more easily learned and remembered when it evokes strong emotions, such as excitement, anger, or disgust. Furthermore, information and its affective dimensions (e.g., liking or disliking) appear to be closely associated in memory.
- *The fallibility of learning and memory.* In studies with human subjects, it has become increasingly apparent that "knowledge" and "memories" are not always accurate. For example, several eyewitnesses may report differing descriptions of the same crime. Even recollections of highly traumatic events (e.g., what a person was doing when he or she first heard about the terrorist attacks on New York's World Trade Center in 2001) can be full of inaccuracies, despite their seemingly vivid, "snapshot" quality. Constructive, interpretive processes in both storage and retrieval – which depend to a considerable degree on one's prior knowledge and beliefs about the subject matter at hand – appear to be at least partly responsible for such inaccuracies.
- *The resilience of existing knowledge and beliefs.* Not all learning involves acquiring new knowledge and skills; some learning instead involves revising one's existing knowledge and beliefs to be more consistent with objective reality or scientifically supported understandings (e.g., the heliocentric nature of our solar system, evolution as an explanation for species development and diversity). Researchers have found that this latter form of learning (known as *conceptual change)* can be remarkably difficult to bring about. For a variety of reasons, both cognitive and affective, learners often hold stubbornly to existing erroneous perspectives (often self-constructed), even in the face of considerable information to the contrary.
- *The effects of individual-difference variables on learning.* Although the basic processes through which human beings learn may be universally shared across the species (and perhaps shared with other species as well), individual and group difference factors clearly have their influence. For example, differences in rate of learning have observed in a variety of species (e.g., people, laboratory rats), with some individuals consistently acquiring new behaviors and skills more rapidly than others do. In human beings, such differences are sometimes attributed to intelligence, a complex construct that is probably the result of both hereditary and environment factors. Temperament and personality often come into play as well. For instance, temperamentally hyperactive individuals may have more difficulty focusing their attention on information that needs to be learned, and a disposition known as *need for cognition* predisposes some individuals to be especially eager to seek out new ideas and challenging tasks.
- *Effective instructional techniques.* Researchers collectively known as educational psychologists devote much of their time to examining applications of various learning theories in instructional settings (e.g., see Ormrod 2006). For example, they have found lectures to be more effective when they are logically organized and accompanied by visual illustrations (thereby promoting effective memory storage processes), and one-on-one tutoring is more effective when tutors give individually tailored hints that help to guide students toward mastery. But small-group and whole-class discussions appear to have benefits that more teacher-controlled instruction does not provide. For example, in the process of exchanging diverse ideas about

a complex and possibly controversial topic, students must clarify their beliefs sufficiently to explain and justify them to others, and they may be exposed to more sophisticated and productive perspectives.

Theorists' understanding of the nature of learning continues to be a work-in-progress. Following are examples of questions whose answers remain partly or largely unanswered:

- To what extent are learning processes universal across species? To what extent are certain learning processes species-specific?
- Within the human species, to what extent and in what ways do cultural differences impact learning?
- Which learning processes may be specific to particular age-groups? For example, why do young children appear to have greater ability than adults to acquire subtle grammatical structures of a new language? Can research findings for college students be reasonably generalized to 5-year-olds or to 60-year-olds?
- To what degree and in what ways is learning constrained by species-specific neurological mechanisms and/or incomplete brain maturation?
- What is consciousness? Is it an integral part of learning, or is it merely a phenomenological by-product of other, more central learning processes?
- How and why do some knowledge and skills appear to be lost or forgotten over time?
- What neurological structures and changes underlie learning? What specific role does physiological consolidation of new memories play in learning?
- Perhaps most importantly, how can the many, diverse theories of learning be integrated into a single mega-theory of how human beings and other animals learn? *Can* these diverse theories ever be integrated?

Cross-References

▶ Behaviorism and Behaviorist Learning Theories
▶ Connectionist Theories of Learning
▶ Constructivist Learning
▶ Operant Behavior
▶ Piaget's Learning Theory
▶ Self-Regulated Learning
▶ Social Learning
▶ Sociocultural Research on Learning

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Psychology of Musical Thinking and Acting

▶ Cognitive Psychology of Music Learning

Psychopathology

▶ Abnormal Avoidance Learning

Psychopathology of Repeated (Animal) Aggression

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Synonyms

Abnormal aggression; Behavioral pathology; Maladaptive behavior; Violence

Definition

Psychopathology of aggressive behavior in animals is behavioral pathology formed as a result of long repeated aggression accompanied by social victories in daily agonistic interactions with male conspecifics. Positive fighting experience leads to development of abnormal aggression, high impulsivity, stereotypic reactions, hyperactivity, hostility, disturbances in social recognition and motivated behaviors, pronounced anxiety, addictive state, etc. The effects of repeated aggression, its expression, and the kind of the pathological symptoms developing in animals may depend on the duration of aggressive experience, hereditary predisposition (strain), species, and context.

Theoretical Background

For a long time studies of aggressive behavior in animals were centered on stimulating or inhibiting mechanisms of natural aggressiveness in provoking conditions. It is well known that demonstration of violent aggression by animals is uncommon in nature and in experiments. As a rule, aggression stops when provoking factors disappear (Lorentz 1966). Moreover, there are numerous social, physiological, and hereditary-defined mechanisms inhibiting aggression between animals. However, in humans, recurrent aggression can be the result of various psychiatric disorders such as manic-depressive disorder, compulsive-obsessive disorder, schizophrenia, drug abuse, etc. Putting aside criminal aggression, human society at times demands that aggression should legitimately be exhibited over a long period of time, for instance, in military actions, warfare, professional sports and regular army, security services, and so on. This kind of human aggression is considered by psychologists as ► learned aggression, which, although in part based on the instincts, might also originate from social activity, including learning process. War veterans are known to suffer by chronic, combat-induced posttraumatic stress disorder, violence, social problems, anxiety, alcohol abuse, mental illness, etc. This means that violent and recurrent aggression in people can be a consequence of a pathological state of the brain.

According to many authors, aggression is rewarding and, like other basic behaviors, aggressive behavior in animals and humans is strongly influenced by previous experience of aggression and any positive ► reinforcer can create a tendency to behave aggressively (Scott 1971; Hsu et al. 2005). Rats and mice who have previously won fights in agonistic encounters attack more frequently in subsequent encounters (Brain and Kamal 1989). The same refers to humans: the individuals who once displayed aggressive behavior tend to do so again when in a frustrating environment (Baron and Richardson 1994). Accumulation of the positive fighting effects from day to day was suggested to be accompanied by significant dynamic changes of brain neurotransmitter activity in animals (Kudryavtseva 2006). These changes arise due to a rearrangement of brain regulation involving (consecutively or simultaneously) the processes of neurotransmitters' synthesis, catabolism, receptors and genes, providing these processes. As a consequence, the normal innate mechanisms regulating aggressive behavior are transformed into pathological ones, which are based on neurochemical shifts in the brain appearing as a result of repeated aggression and victories. These changes form pathological states, which themselves stimulate aggression.

Important Scientific Research and Open Questions

As the criteria of behavioral psychopathology developing in animals under positive fighting experience were used:

- Change (increase or decrease) in the *duration* and/or *expression* of demonstration of behavioral forms
- Emergence of *novel behavioral forms*, which have not been demonstrated by animals before
- *Inadequacy* of behavioral response to social or environmental stimuli, uncontrollable behavior
- *Maladaptive* behavior in some environmental conditions or experimental situations
- *Generalization* of dominating motivation, and disturbances in motivated behaviors
- Prolonged *persistence* of changes in behavior and emotional states
- Expressed multiple *neurochemical alterations* in the brain

Positive fighting experience in daily intermale confrontations changes many forms of individual and social behaviors in the winners. Unlike the controls (male mice without consecutive aggression experience), the experienced winners demonstrate: *motor hyperactivity* and *hypersensitivity* to sensory stimuli in many experimental situations; s*tereotypic and repetitive behaviors* and *hyperkinetic reactions* – repeated spontaneous jumps, back circles, turning movements, rigid tail, etc; *pronounced anxiety*; *disturbances in social recognition* – inability to recognize partners with different social status, age, and sex; *maladaptive* behavior – reduced capability to demonstrate defensive behavior (freezing or immobility) in unavoidable frightening conditions; *high impulsivity* and l*owered threshold for aggression* even in low provoking conditions. In the experienced winners, aggressive motivation dominates in all situations of social interactions with other conspecifics. Some males show vigorous attacks and demonstrate *violent aggression* which is not corrected by situational factors. Winners with long positive fighting experience develop enhanced level of aggression after a no-fight period, compared to their aggressiveness before the fighting deprivation. The effects of repeated aggression and the kind of the pathological symptoms developing in animals may depend on the duration of aggressive experience, hereditary predisposition (strain), species, and context.

It has been shown that balance between the activities of the brain's neurotransmitter systems is disturbed in male mice that have had a long positive fighting history. This disbalance is due to a reduced activity of the serotonergic system and an enhanced activity of the dopaminergic systems. As a result, the inhibitory processes become overwhelmed by excitation processes. In these circumstances, a low threshold for aggressive behavior is established in male mice. Pharmacological studies have demonstrated involvement of the opioidergic systems in the effects of repeated aggression: opioid receptors may be desensitized or sensitized depending on the amount of aggression experience. Changes in the brain opioidergic systems in male mice with repeated aggression experience were noticed to be comparable to those in drug addicts. It might well be that long positive fighting experience makes the brain reward systems hypersensitive to aggression-associated stimuli and the neurochemical mechanisms that normally regulate aggressive behavior misregulate it, hence a pathology. Under certain circumstances, the effects of endogenous opioids may be abrogated, and emotional and physical discomfort may ensue. This state eventually leads to forming internal drive for aggression, which can result in seeking out an occasion for behaving aggressively or an outbreak of aggression. In this context, a detailed study of social and neurophysiological mechanisms forming psychopathology of aggressive behaviors under positive fighting experience in animals may be useful for understanding the ways of preventing aggression and violence in human society.

Cross-References

► Learned Aggression in Humans
► Reinforcement Learning

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Psychophysiological Experience of Emotion

► Neuropsychology of Emotion

Psychophysiology of Learning

► Neuropsychology of Learning

Psychosemiotic Perspective of Learning

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Synonyms

Study of psychological symbols in socialization; Study of symbol-mediated thinking and learning; Study of symbols as thinking instruments

Definition

Intersecting between psychology and semiotics, psychosemiotics seeks to understand the development of psychological symbols, symbolic functions in communication, and symbol-mediated learning and development. Central to psychosemiotics is the view that symbols are abstractions and generalizations of systems of relations between ideas and understanding. They arise, as reflected in their Greek etymology, συν– (syn–), meaning "together," and βολή (bolē), meaning to throw, when differentiated and contrastive psychological elements are brought together. Within the relationship formed between the elements a creative tension arises due to the proximity of contrasting aspects. This tension is resolved with the adoption of a new structure marked by greater abstraction and generality. The results are more compact and broadly applicable thoughts with increased farsightedness in their reasoning and problem-solving capacity (Krutetskii 1976). Symbols are distinct from *signs* or *codes*, being connotations of what consciousness is yet to comprehend, rather than denotations of what is already known. The intellectual growth of our minds is mirrored by the evolution of symbols as living forms.

Symbolic functions are characteristic of authentic, reflective communications, whether monologic or dialogic, spoken or written. In formal education the development of symbols and symbol-mediated learning begins with socialization, with the dialogic and leads to internalization, the monologic. Intra-personal reflexivity originates from inter-personal, reflective dynamics. In learning, the individual is not a passive recipient of knowledge but is encouraged to communicate reflectively *about* as well as *with* the concepts at hand. In reflective exchanges, concepts gain psychological relevance and vitality. In teaching, discussions of concepts cannot be conducted as post-mortems of hard-and-fast facts. To evoke vitality for learning, the teacher's speech needs to mediate the concepts to be learnt as symbolic formations, pregnant with meaning yet to be realized. When a teacher relates to a student through symbolic operations, they are sharing their deeper inner thoughts and connections. Through such a personal and involved act, it is not only the learner but also the teacher who may experience change and development in classroom interaction.

Theoretical Background

As a bourgeoning, interdisciplinary area of research, psychosemiotics has its early roots in classical language, psychological and philosophical theories. Many of its ideas may be traced back to: language theorists such as Condillac, Herder, von Humboldt, and Cassirer, who argued for the essential role of language in the origin of knowledge and thinking; psychologists such as Lewin and Mead, who postulated the constitutive role of the social environment in individual change; and philosophers including Spinoza and Leibnitz, who held a unified (monist) vision of subject and object in the development of the mind. Of the twentieth century theorists, Vygotsky stands out as the figure of prominence, fundamentally influencing many of the current psychosemiotic theories. Forming the contemporary landscape are Grzybek, Mininni, Watt, Bouissac, Smith (2007), and Vygotsky's followers such as Wertsch and Zinchenko.

Primarily rooted within the disciplines of psychology and semiotics, the contemporary field of psychosemiotics draws from specific research domains such as developmental, educational and psychodynamic psychologies, communication and discourse studies, as well as philosophy and epistemology.

The main questions addressed in psychosemiotics include: what are symbols; how do symbols mediate thinking and learning in the individual; how do psychological symbols develop in socialization; and also, how are symbolic functions manifested in speech or semiotic structures. The basic tenets that psychosemiotics subscribes to include: (a) Symbols enable abstract and reflective thinking, free from the immediate constraints of the sensory, perceptual world; (b) Symbols mediate authentic, reflective socialization; (c) Individuals develop through socialization. Intra- and inter-personal dynamics are inseparable in understanding learning and change; and (d) To understand meaning-making in socialization, one must look beyond external, conventional definitions of signs and examine the internal relationship and coherence in the semiosis that the individual constructs.

Specifically, psychosemiotics defines its core subject of study, symbols, as generalized structures in which differentiated ideas and notions relate. Symbolic structures develop as the relations between ideas and concepts grow in quantity and later in structural organization. Associated with qualitative, structural (re)formations, symbols allow thinking that is generalized and suspended from concrete realities. In mathematics, for instance, algebraic thinking is symbol-mediated reasoning resulting from generalized concepts. For example, let us look at one of the earliest recorded algebraic problems, that of Ahmes, an Egyptian of about 1650 B.C.E, who asked, if “Heap and one-seventh of a heap is 19; what is heap?.” “Heap” is the unknown variable representing the piling of any material to be reconciled. The unknown nature of the material does not prevent the extrapolation of the relations (addition, equivalence, etc.) between factors. In order to achieve solution, it is the mathematical relations rather than concrete objects, numbers and measurements that are the required structures to hold and manipulate in mind. This is the work of symbols as thinking tools. They enable one to carry out the necessary mathematical operations, inverting and reversing relationships independently from the immediate physical situation. To the frustration of many a mathematics teacher, students lacking the relevant mathematical symbolic attainment are reduced to rote-learning a concrete script.

To reach this symbolic “height” of abstract problem solving requires initial symbolization not in the absence of immediate experience but in the wealth and fullness of it. As mental faculties expand, accompanying symbols scale a trajectory from the concrete to the abstract, becoming ever more reflective, dynamic, and creative. In the end, the original sensory and perceptual content is consumed and transcended.

In formal learning the psychosemiotic perspective emphasizes the role of the social environment. It maintains that the learning of psychological symbols is initiated through the social, i.e., through interpsychological dynamics. The notion of *interpsychology* or *intersubjectivity* refers to the encounter and integration of minds. Through their reflective dialogue, teacher and learner form a unified conceptual field. Within this field, the thinking dynamics in one individual strive to *resonate with*, rather than prescribe, those in the other. It is the view of psychosemiotics that the teacher does not cause the learning effects experienced by the student, but rather learning is a phenomenon of this shared integration. Importantly, the learning may flow in both directions. Thus mutual change in both the teacher and the learner is the consequence of authentic socialization in the classroom.

In psychosemiotics, *abbreviation* is considered a central phenomenon in the manifesting of symbolic functions in speech and semiotic structures (Vygotsky 1987; van Oers 2000). Abbreviation in speech is the act in which an individual, when verbalizing their ongoing thinking, necessarily omits content that is known, established, and shared by the interlocutors. To introduce a new concept, we actively unfold its nature through relation with other concepts. Reference to the known concepts is abbreviated and the new, yet to be known, relationships are the focus. This focus gives rise to a cognitive tension in the social space, enticing engagement of thinking in the dialogic partner. Abbreviated discourse reflects language as symbolic and not as a code.

Epistemologically, psychosemiotics presents a promising attempt at uniting the subjective and the objective, the conscious and the unconscious, the individual and the social, and the cultural-historical past and the micro-genetic present of learning and thinking. Recent development in psychosemiotics has seen its applications in both educational research (e.g., van Oers 2000, on a psychosemiotic view of mathematics teaching and learning) and psychotherapy (e.g., Keinänen 2005).

Important Scientific Research and Open Questions

As a newly emerging, multidisciplinary area, psychosemiotics is yet to find its unique identity independent from established fields such as psycholinguistics and social semiotics. To do so, it needs to demonstrate its theoretical and practical progress from psycholinguistics in its inclusion of social, affective, and nonconscious resources in accounting for learning. Advances continue to be made to demarcate from social semiotics by psychosemiotics’ portrayal of psychological symbols, rather than social coding conventions, as the mediators of structural change in thought.

Important for the ongoing maturing of the field are the definitions of its central subjects of research, namely, symbols, symbolic functions, and symbolic interactions. They need greater articulation to more fully distinguish psychosemiotics from its adjacent fields. It would then be legitimate to extend these definitions to establish a systematic analytical framework that combines epistemological visions and empirical purposes. The absence of such an applied framework for analyzing speech and thinking as a unity is the main reason for the domain’s current ambiguous and indecisive identity. In the psychosemiotic framework of analysis, a clarified stance needs to be taken, in particular, on the nature of the unit of analysis. (Despite Vygotsky’s identification of the unit of analysis in “word meaning,” which was observed to synthesize speech and thinking, and generalization and socialization, no attempt was made in forming a systematic, applied speech analysis framework.) The identification of the unit of analysis should be congruent with the monistic viewpoint of speech and thinking, learning and communication, and the individual and the social.

Cross-References

- ▶ Internalization
- ▶ Mediators of Learning
- ▶ Psycholinguistics and Learning
- ▶ Reflective Dialogues: Integrating Social and Cognitive Dimensions
- ▶ Semiotics and Learning
- ▶ Vygotsky's Philosophy of Learning

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Psychostimulants

▶ Amphetamine, Arousal, and Learning

Psychoticism

Eysenck's third major dimension of personality. Individuals scoring high on this dimension are emotionally cold, cruel, manipulative, and impulsive. Psychoticism has been found to be negatively correlated with conscientiousness and agreeableness.

Public Education

▶ Compulsory Education and Learning

Punishment and Reward

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Synonyms

Negative punishment; Negative reinforcement; Positive punishment; Positive reinforcement

Definition

The terms "punishment" and "reward" refer to operant learning processes, or learning that occurs due to the consequences of behavior. Punishment refers to a change in the environment after behavior occurs that causes the behavior to decrease in the future. ▶ Positive punishment involves the addition of an event that was not previously present following behavior, whereas ▶ negative punishment involves the removal of an event following behavior. Conversely, reward (also known as ▶ reinforcement) refers to a change in the environment after behavior occurs that causes the behavior to increase in the future. Two types of environmental changes can function as reward: the addition of an event that was not previously available (termed ▶ positive reinforcement) and the removal of an ongoing event (termed ▶ negative reinforcement). Both punishment and reward are consequences of behavior, and the defining characteristic of each process is the effect it has on behavior (i.e., its *function*).

Theoretical Background

The work on conditioned reflexes (also known as ▶ respondent conditioning) of early Russian physiologists, such as Ivan M. Sechenov (1829–1905) and Ivan P. Pavlov (1849–1936), provided the foundation for an objective account of environmental influences on behavior. Later, Edward L. Thorndike (1874–1949) conducted pioneering research on problem solving by mammals that illustrated the importance of consequent events in learning. However, it was B. F. Skinner's (1904–1990) comprehensive analysis of the role of environmental influences on behavior that served as the basis for contemporary understanding of behavior and how it is modified (Skinner 1938). According to Skinner, behavior caused by the consequences it produces is formally termed ► operant behavior and has been shown to play an important role in a variety of human activities, such as language, education, business practices, gambling, drug addiction, and social behavior.

Two fundamental behavioral processes involved in operant learning are punishment and reward (also known as *reinforcement*), and these processes are defined by their effect on the future occurrence of behavior. Both punishment and reinforcement are natural processes that have been demonstrated to operate on the behavior of all living organisms in hundreds of studies. There is nothing inherently "good" or "bad" about the processes or the behaviors changed by them. Furthermore, the processes do not require conscious awareness on the part of the individual for behavior to change. Punishment and reinforcement are simply consequences that operate directly on behavior, causing it to decrease and increase, respectively.

Over the past 80 years, the basic process of punishment and reinforcement has been studied extensively with nonhuman animals and, to some extent, with human animals in the laboratory. The application of these basic learning processes to human behavior of social importance has led to effective treatments for a variety of disorders, including autism, drug addiction, and mental illness, and for problems in the community (e.g., theft, littering, speeding).

A variety of environmental events can serve as punishers or reinforcers, some of which do not require any learning history to be effective and some of which are learned through experience. For example, an unlearned (or *unconditioned*) event that appears to be a universally effective punisher is electrical stimulation, or shock. Food is an example of an unlearned, or unconditioned, positive reinforcer. Other events (termed *conditioned* punishers or reinforcers), such as a stern look from a parent or a smile from a friend, only function to decrease (punish) or increase (reinforce) behavior after pairing with already effective punishers or reinforcers. In addition, punishers and reinforcers can be delivered by an agent (e.g., a reprimand or praise) or can occur automatically (e.g., stubbing one's toe on furniture or obtaining some ice cream from the freezer).

Punishment procedures are further classified as *positive punishment* and *negative punishment*. Positive punishment causes behavior to decrease via the presentation of an event following behavior. Examples of positive punishers include reprimands, forced exercise, and shock. Negative punishment causes behavior to decrease via the removal of an event following behavior. Examples include response cost, such as monetary fines, and timeout, or loss of access to reinforcers for a specific period of time. Reward, or reinforcement, is also further classified as *positive reinforcement* and *negative reinforcement*. Positive reinforcement involves the addition of a stimulus or event following behavior that causes the behavior to increase, such as requesting and receiving food, receiving praise for diligent work, or drinking coffee and feeling more alert. Negative reinforcement involves the removal of a stimulus or event following behavior that causes it to increase, such as turning off an alarm clock (terminates noise), putting on sunglasses (reduces overly bright light), or taking pain medication (attenuates a physical ailment).

Individuals engage in two types of behavior related to negative reinforcement – escape and avoidance behavior. Escape involves behavior that terminates an ongoing stimulus (e.g., quickly removing a hand from a hot pan), and avoidance involves responding prior to the onset of a stimulus that prevents it from occurring (e.g., putting on an oven mitt before moving a hot pan). Although escape responses are acquired more rapidly than avoidance responses, research has shown that human and nonhuman animals can learn to avoid the occurrence of events with or without warning signals that the event is imminent.

Important Scientific Research and Open Questions

Research findings have shown that punishment and reinforcement produce symmetrical but opposite effects on responding. Both directly decrease or increase the behavior that leads to the consequence, and the effects persist as long as the relation between the response and the consequence remains. Studies with human and nonhuman animals have identified a variety of factors that influence the effectiveness of punishment and reinforcement. For example, punishment is most effective in decreasing behavior if it is implemented with at least moderate intensity immediately following each occurrence of the behavior, if the behavior does not also produce reinforcement, and if an alternative behavior is reinforced (Azrin and Holz 1966). Punishment also may be associated with problematic side effects (e.g., emotional or aggressive behavior), and individuals who experience severe or repeated punishment might stop responding entirely (known as *generalized response suppression*). Like punishment, reinforcement is most effective if it is delivered immediately following the behavior. The reinforcer should follow each occurrence of the behavior during initial learning. Once a behavior is acquired, performance will maintain as long as the reinforcer follows at least some proportion of responses, an arrangement called *intermittent reinforcement.* Skinner conducted much of the definitive research on intermittent schedules of reinforcement, showing that different schedules reliably produce different patterns of responding (Ferster and Skinner 1957).

Research findings on punishment and reinforcement have been quite consistent across nonhuman and human animals, revealing the generality of these learning processes. However, researchers have observed some discrepancies between the behavior of nonhuman and human animals, possibly due to the role of language. For example, response characteristics under certain intermittent reinforcement schedules are very different in nonhuman and human animals (e.g., Hyten and Madden 1993). Although language might play a critical role in these discrepancies, inconsistent research findings across nonhuman and human animals could be due to differences in the way learning has been studied with these two populations. For example, nonhuman animals typically receive unconditioned reinforcers (e.g., food) as rewards, whereas human animals typically receive conditioned reinforcers (e.g., points on a computer screen). Even when responding in nonhuman and human animals is similar, however, the behavior of human animals may be influenced by variables related to language, such as the construction of rules, instructions, and hypotheses. Research in this area is ongoing and more information is needed on the variables that control these self-constructed rules and hypotheses, along with the link between language and other behaviors under study. Although the influence of language on other behaviors is not fully understood at this time, numerous studies have demonstrated the role of consequences in the development and maintenance of language (e.g., Guess et al. 1968). Finally, the amount of basic and applied research on reinforcement greatly eclipses that on punishment, and our knowledge of variables that influence the process of punishment is far from complete. For example, factors that (1) promote the long-term effects of punishment, (2) increase the effectiveness of delayed punishment, and (3) reduce the undesirable side effects of punishment remain to be explored (Lerman and Vorndran 2002).

Cross-References

- ▶ Avoidance Learning
- ▶ Behavior Modification as Learning
- ▶ Behaviorism and Behaviorist Learning Theories
- ▶ Fear Conditioning in Animals and Humans
- ▶ Feedback and Learning
- ▶ Instrumental Learning
- ▶ Operant Behavior
- ▶ Reinforcement Learning

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Purifying of the Emotions

▶ Catharsis Theory

Purpose

► Motivation and Learning: Modern Theories

Purposelessness

► Boredom in Learning

Purposive Striving for Learning

► Volition for Learning

Pursuit of Learning

► Interests and Learning

Pursuit Regression

► Learning via Linear Operators

Puzzle

► Intuition Pumps and Augmentation of Learning