

Chapter 2

Computational Models of Autism

2.1 Autistic Deficits

Speaking about the deficits, we describe observable features of CwA irrespectively of how these features can be connected. For example, deficits of a car with a flat tire would be making an unpleasant noise, not following directions, having a rim of the wheel riding on the tire tread, irreparable damage to the tire, loud noise, and flat tire itself. Although all these symptoms are due to the same cause, we enumerate them as car deficits at the same level, as a list.

Our second example will be a set of search engine deficits. Anything in which a given search engine deviates from an ideal one where we can quickly find everything we want is its deficit:

1. There are documents I know exist but the search engine does not give them to me when I search for the corresponding topic. This is called a search recall deficit.
2. It gives me some documents that are misleading, and it should not have given them to me. This is called a search precision deficit.
3. I have to wait for more than a second for search results to show. This is a slowness deficit.
4. When I search with in given topic or context, it gives me documents with the search query keywords but belonging to a different topic. This is called a user intent recognition deficit.

There are multiple reasons for a search engine to display deficits, including its implementation, structure of a search index, relevance model, how keywords are treated and ontologies are employed. A baseline search system such as Lucene/SOLR/Elastic Search without use of learning from users, linguistic processing or domain ontology would possess deficits 1, 2 and 4, but not 3. Any engineering system has some advantages and some deficits (Fig. 2.1).

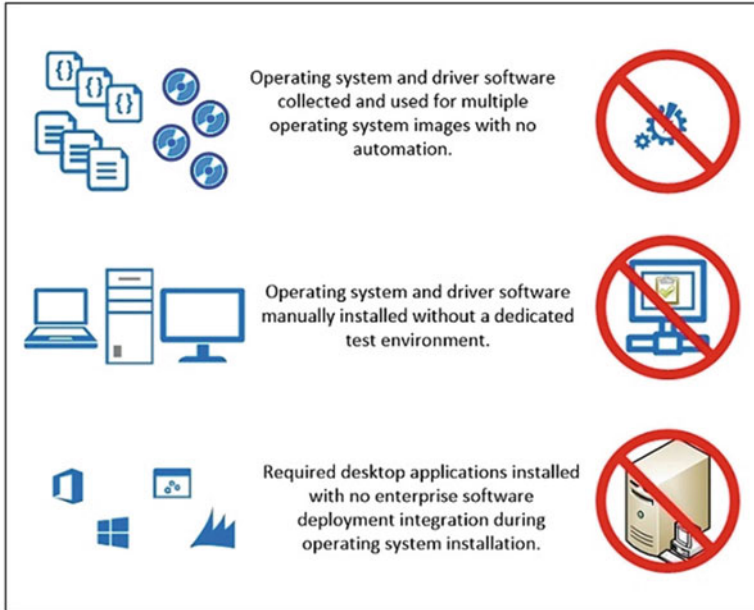


Fig. 2.1 Some symptoms for a problematic operating system (technet.microsoft.com)

Having considered the deficits of an engineering system, we are now ready to enumerate a broad range of deficit of CwA (Fig. 2.2):

1. Higher-level *abstract thinking*, including making inferences (Minsheu 1996; Minsheu and Goldstein 1998). This has long been known to be an area of deficit in autism. The notable finding of this study is the dissociation between intact performance on rule-learning tasks and deficits on concept formation tasks. Rule-learning tasks are ones in which there is a rule to solve the problem and the task is to discover the rule. Although the individuals in this study typically identified the rule correctly, they had difficulty changing rules when the context changed. Changing the rule to fit changing contexts adds to the information processing demands of the task, and is the basis of generalization. Concept formation tasks have no set solutions but require the individual to create one. Concept formation tasks are essentially problem solving in novel situations. This pattern is consistent with the behavior typical of autism, which is typically rule-dependent, lacking in flexibility, failing to consider the implications of context, and inability to cope with novel situations.
2. *Shared attention*, including social referencing and problem-solving (Mundy et al. 1990).
3. *Joint Attention* deficit. By 15 months of age, children are eager to share their interests with others. They show things to others, they try to share their



Fig. 2.2 Some symptoms of autism (chart from the Autism Society of America)

enjoyment, they babble reciprocally and they direct others' attention to objects which interest them. Later, when they have language, they ask about others' interests and ideas, and they share others' enjoyment.

4. *Social cognition* refers to the mental processes involved in perceiving, attending to, remembering, thinking about, and making sense of the people in our social world (Moskowitz 2005). Deficits in social cognition include

- deficits in social and emotional learning including difficulty
 - managing emotions,
 - appreciating the perspectives of others,
 - developing pro-social goals,
 - using interpersonal skills to handle developmentally appropriate tasks (Payton et al. 2000);

- difficulty differentiating one's own feelings from the feelings of others (i.e., Theory of Mind);
 - difficulty integrating diverse information to construct meaning in context (i.e., central coherence) (Frith and Happe 1994; Happe et al. 1996).
5. Deficits in the capacities for *affective reciprocity* (Baranek 1999; Dawson and Galpert 1990). This deficit occurs to the extent to which the person sends various social signals to others, through facial expression, tone of voice and social and emotional gestures. It could be seen as a type of instinctual drive whose function is to cause a child to send social signals to others and to look for social signals. The more the child is driven to interact with others, the more he or she can learn the meaning of such signals. Affective reciprocity is also shown by affectionate and empathic behaviors, greeting others with pleasure and spontaneously offering to share toys or food with others. Deficits in social reciprocity include:
- difficulty initiating and responding to bids for interaction,
 - limitations with maintaining turn-taking in interactions,
 - problems with providing contingent responses to bids for interaction initiated by others.
6. *Motor domain* deficit. The tests responsible were those involving complex motor actions or motor sequences as opposed to isolated motor movements such as finger tapping. This domain was included not only to complete the survey of major cognitive domains but also because dysfunction in higher brain regions often produces problems with complex motor sequences. This is generally called motor apraxia. This motor deficit has been found by many other investigators and motor skills deficits are now being recognized as an integral part of autism and the other disorders in this category. In young children, motor apraxia causes the problems with operating mechanical devices such as door knobs and wind up toys, whereas button pressing is not a problem. Later, motor apraxia is responsible for difficulty holding pencils, cutting with scissors, and tying shoe laces. In school age children, it is responsible for the problems with handwriting, either slowness or sloppiness. In the gross motor area, it is responsible for the lack of coordination in sports and contributes to the inability of many to ride bicycles or rollerblades. It is likely also responsible for the stilted quality to facial expressions.
7. Deficits in language and related cognitive skills include:
- impaired acquisition of words, word combinations, and syntax
 - (i) initial words are often nouns and attributes, while words representing social stimuli, such as people's names (i.e., subjects) and actions (i.e., verbs), are delayed;
 - (ii) the child loses words previously acquired;

- use and understanding of nonverbal and verbal communication
 - (i) facial expressions, body language, and gestures as forms of communication are delayed in the latter part of the first year of life and remain unconventional throughout development;
 - (ii) unconventional gestures (e.g., pulling a caregiver's hand toward an item) emerge prior to more conventional gestures (e.g., giving, pointing, and head nods/headshakes);
 - (iii) understanding of gaze shifting, distal gestures, facial expressions, and rules of proximity and body language is limited;
 - (iv) receptive language appears more delayed than expressive;
 - (v) use of immediate echolalia and/or delayed echolalia (scripted language) is observed;
 - vocal development deficits, including
 - (i) atypical response to caregiver's vocalizations,
 - (ii) atypical vocal productions beyond the first year of life,
 - (iii) abnormal prosody once speech emerges (speech may sound robotic);
 - symbolic play deficits, including
 - (i) delayed acquisition of functional and conventional use of objects,
 - (ii) repetitive, inflexible play,
 - (iii) limited cooperative play in interactive situations;
 - conversation deficits, including
 - (i) limitations in understanding and applying social norms of conversation (e.g., balancing turns, vocal volume, proximity, and conversational timing);
 - (ii) provision of inappropriate and unnecessary information in conversational contexts;
 - (iii) problems taking turns during conversation;
 - (iv) difficulty initiating topics of shared interest;
 - (v) preference for topics of special interest;
 - (vi) difficulties in recognizing the need for clarification;
 - (vii) challenges adequately repairing miscommunications;
 - (viii) problems understanding figurative language, including idioms, multiple meanings, and sarcasm;
 - literacy deficits, including difficulty
8. *Complex language* deficit, i.e., the interpretative aspects of language. These include reading comprehension, story comprehension, comprehension of idioms and metaphors, verbal inference making, and comprehension of complex sentence structure. The latter is particularly important because it is the language of everyday life. It typically involves sentences like: before

you do this, I want you to do that and then do this and so on. These sentences place particularly heavy demands on information processing because they require processing of each segment and then a second stage of processing to determine the meaning of each bit to the next bit. Understanding the meaning of such a sentence requires yet a third level of processing. A similar process occurs with the understanding of a story. The combination of superior formal language abilities and inferior comprehension produces a wide gap between the listener's estimate of the autistic individual's language comprehension and his or her actual comprehension. The failure to understand what the person with autism understands is a major contributor to their dysfunction in many settings.

9. *Memory for complex information* deficit. Complexity can result from increasing amounts of simple information or increasing inherent complexity of the information. In essence, individuals with autism have difficulty with recall of complex material, because they fail to make use of cognitive organizing strategies or to benefit from the meaning of the material. Secondly, this pertained to both visual and auditory information. CwA remember less from the material presented to them than age and IQ matched peers; this has also been shown to reduce the amount of information they remember from recently experienced events. Thus, this memory impairment is likely to contribute to the social, language, and problem solving deficits. Knowledge of this impairment can be used to improve learning. Memory and learning can be improved by reducing the amount of material presented (smaller chunks), preprocessing the information (give the bottom line rather than patterns that require deduction of the bottom line), and increasing the processing time. Visual presentation of information often accomplishes all of these, and likely explains why they benefit from such adaptations. Visual material is constantly present for reference and re-reading, to guide behavior.
10. Deficit in the ability to *selectively manipulate sensory representation*. A different, perhaps more fundamental deficit should be entertained as being present in many persons with autism, particularly if they are low-functioning: a deficit in the ability to selectively manipulate sensory representations, concepts, and thoughts themselves (although these may also be deficient). In basic terms, this is a problem with the ability to imagine. However, it is not a deficit in simple visual imagery; there is self-reported evidence that high-functioning persons with autism not only have visual imaginations but rely upon them (Grandin 2006). Instead, what is referred to here is the ability to select elements of mental states and manipulate them. Normally, humans are able to focus on different aspects of an object or experience, and even seem to break these aspects away from the original experience and manipulate them separately. A person can see a white ball and separate out its whiteness from its shape. PwA are however well known for not being able to do this. They are notorious for context dependence and for apparently focusing on the "wrong" features of everyday objects.
11. Deficit in *social referencing*. Social referencing is known as the seeking and use of information from another individual to help evaluate a situation

(Bruinsma et al. 2004). The reason this may be difficult for individuals with autism is that they may prefer not interact with others and may not find this behavior reinforcing, and would rather engage in self-stimulatory type behaviors instead. Lacking these skills in the classroom can present teaching challenges to the teacher during whole class instruction, choral responding and teaching in the natural environment.

A number of patterns of deficits have been proposed in autism over the years; some of these are still being debated. These include:

- a single primary cognitive-single neural system deficit versus multiple primary co-existing cognitive-multiple neural systems deficit;
- auditory and not visual information processing deficit;
- information acquisition deficit versus information processing deficit,
- and simple versus complex information processing deficit(s).

Instances of essential autistic deficits can be visualized (Fig. 2.3).

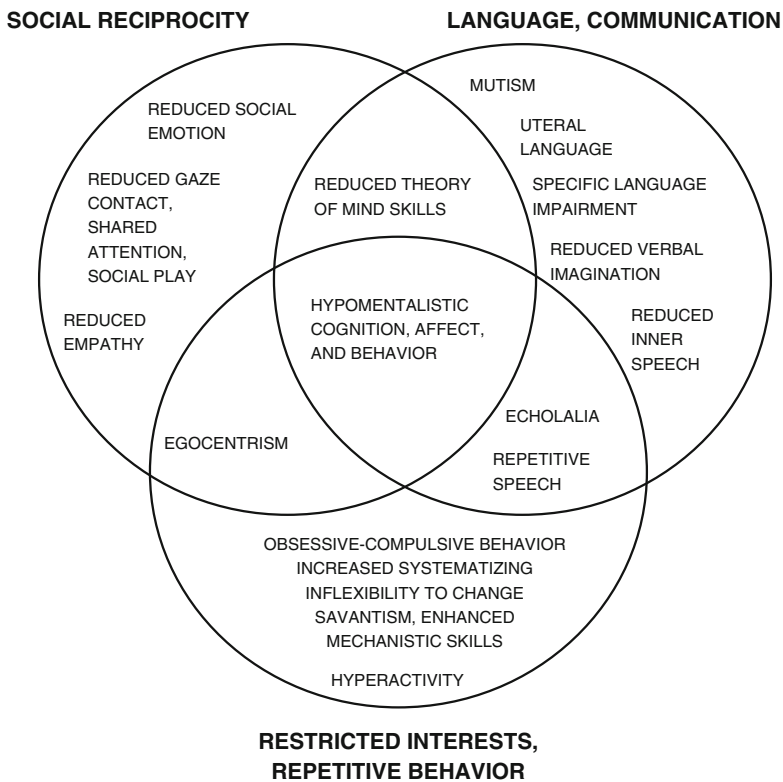


Fig. 2.3 Essential autistic deficits and their inter-relations

2.1.1 Hypotheses for the Origin of Autistic Reasoning

There are a number of other hypotheses concerning autistic reasoning, including (Gopnik et al. 2000) stating that children with autism are impaired in their ability to form theories about the world. Theories provide an understanding of causality to enable children to generate explanations about their environment. Not only mental domain but also reasoning about physical world is corrupted as well (not as strongly as about mental world (Leslie and Keeble 1987; Oakes and Cohen 1990)). Children with autism are less likely to generate “wh-” questions and are impaired on probe questions of causal explanations of emotions and thoughts (Tager-Flusberg 1989). Overall impairment in causal language across two narrative contexts (Losh and Capps 2006) is reported, as well as impairment on causal language relating to mental states and emotions (Capps et al. 2000). Also, a correlation between mental ability or false belief performance and an ability of these children to explain observed scenarios has been established. Relative to controls, CwA have a lower overall ability to provide explanations for voluntary actions and impossible physical and biological events (Sobel and Lillard 2001).

2.2 Tests for Differentiating Normal and Autistic Cognition and Reasoning

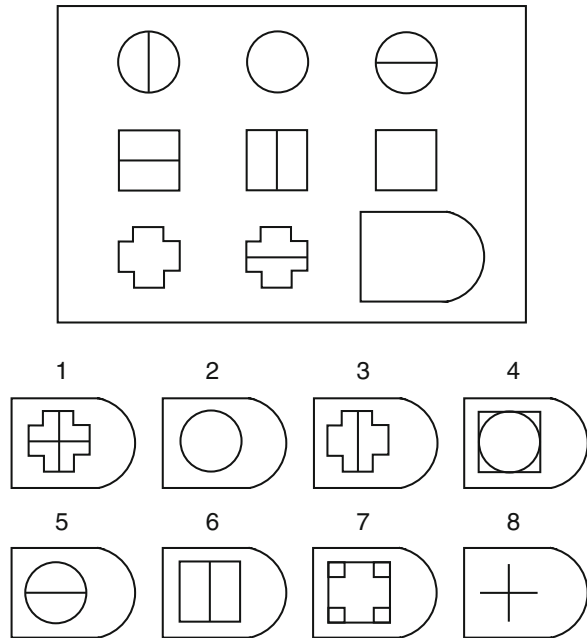
Raven’s Progressive Matrices (RPM) is a standardized intelligence test that consists of problems resembling geometric analogies, in which a matrix of figures is presented with one entry missing and the correct missing entry must be selected from among a set of answer choices (Raven 1936). An example Raven’s problem is shown in Fig. 2.4.

Sally-Anne task (Wimmer and Perner 1983), in which the subject is shown a short play with two dolls, Sally and Anne, shown in (Fig. 2.5). Sally places a marble into a basket and, after Anne leaves the room, moves the marble from the basket into a box. The subject is then asked where Anne will look for the marble when she returns. Responding correctly, that Anne will look in the basket, requires an understanding of Anne’s false belief that the marble is still in the basket; Anne’s belief is false in that it represents something that the subject watching the skit knows is not true.

In a standard version of False Belief task (Wimmer and Perner 1983), the child is introduced to two characters, Maxi and his mother. Maxi places an object of interest into a cupboard, and then leaves the scene. While he is away, his mother removes the object from the cupboard and places it in a drawer. The child is then asked to predict where Maxi will look for the object when he returns to the scene.

A box of Smarties is emptied, refilled with pencils and then shown to a child who is ignorant of the change. The child is asked: “What do you think is in the box?”, and it answers: ‘Smarties!’ It is then shown the contents of the box. The pencils are

Fig. 2.4 An example Raven's problem



put back into the box, and the child is now asked: ‘What do you think your [absent] mother will say is in the box?’

A famous experiment, the ‘false belief’ task investigates how autistic subjects reason about other people’s belief. The standard design of the experiment is as follows. A child and a doll (Maxi) are in a room together with the experimenter. Maxi and child witness a bar of chocolate being placed in a box. Then Maxi is brought out of the room. The child sees the experimenter move the chocolate from the box to a drawer. Maxi is brought back in. The experimenter asks the child: ‘Where does Maxi think the chocolate is?’ The answers to this question reveal an interesting cut-off point, and a difference between CwA and CC.

Before the age of about 4 years, the normally developing child responds where the child knows the chocolate to be (i.e. the drawer); after that age, the child responds where Maxi must falsely believe the chocolate to be (i.e. the box). By contrast, CwA continue to answer ‘in the drawer’ for a long time. This experiment has been repeated many times, in many variations, with fairly robust results. There is for instance the ‘Smarties’ task, which goes as follows. Not shown to the child-subject, a box of Smarties is emptied and refilled with pencils. The child is asked: ‘What do you think is in the box?’, and it happily answers: ‘Smarties!’ It is then shown the contents of the box. The pencils are put back into the box, and the child is now asked: ‘What do you think your [absent] mother will say is in the box?’

We may then observe the same critical age: before age 4 the child answers: ‘Pencils!’, whereas after age 4 the child will say: ‘Smarties!’ Even more strikingly,

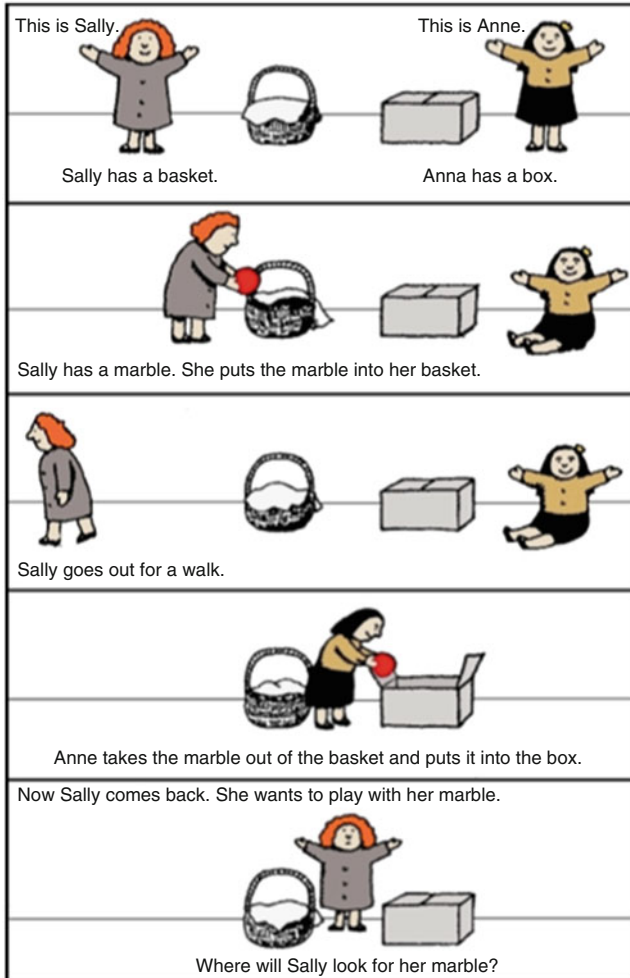


Fig. 2.5 Sally-Anne test (From visualsupportsandbeyond 2016)

when asked what it believed was in the box before seeing the actual contents, the younger child will say ‘Pencils’, even though it has just answered ‘Smarties!’.

Feelings, Attitudes, and Behaviors Scale for Children (FAB-C) (Beitchman et al. 1996). The FAB-C is a self-report instrument designed to assess problems in children 6–13 years of age. It consists of 48 yes/no statements. Children are asked to indicate whether or not the statements describe them by circling yes or no. The questionnaire consists of five scales that measure conduct problems, self-image, worry, negative peer relations and antisocial attitudes.

Conners' Rating Scales-Revised (CRS-R) It provides a parental report of the behavioral, emotional and social functioning of the sibling. This questionnaire is composed of 80 items. Four response choices were available for each question, not true at all (never, seldom), just a little true (occasionally), pretty much true (often, quite a bit), very much true (very often, very frequent), and the score on each item ranged from 0 to 3.

N-back test is a continuous performance task that is commonly used as an assessment in cognitive neuroscience to measure a part of working memory. The n-back was introduced by Kirchner (1958). The subject is presented with a sequence of stimuli, and the task consists of indicating when the current stimulus matches the one from n steps earlier in the sequence. The load factor n can be adjusted to make the task more or less difficult. The visual n-back test is similar to the classic memory game of "Concentration". However, instead of different items that are in a fixed location on the game board, there is only one item, that appears in different positions on the game board during each turn. 1-N means that you have to remember the position of the item, ONE turn back. 2-N means that you have to remember the position of the item TWO turns back, and so on.

For example, an auditory three-back test could consist of the experimenter reading the following list of letters to the test subject:

T L H C H O C Q L C K L H C Q T R R K C H R

The subject is supposed to indicate when the letters marked in bold are read, because those correspond to the letters that were read three steps earlier.

Test for Pretend Play is designed to assess the three types of symbolic play, substituting one object for another object, or person attributing an imagined property to an object or person. Another type of symbolic play is a reference to an absent object, person or substance.

Test for Pretend Play can be used with a wide variety of children to assess a child's level of conceptual development and ability to use. This test also indicates a child's imaginative ability, creativity and emotional status. The test presents two versions of the test using structured conditions: on-verbal version – children up to 3 years and older children with insufficient comprehension to follow the language used in the verbal version, and verbal version – children of 3 years and above.

2.3 Neural Network Models

Advocates of neural network approaches believe that neural simulations act at the middle level, between molecular and behavioral levels. They give a chance for the understanding of the real reasons of causing behavior and linking network dynamics with molecular and genetic properties.

2.3.1 *The Bridge Between Neural Models and Reasoning*

If one considers an abstract reasoning system and looks at its input, output and interaction between black boxes as reasoning units, very little judgment can be obtained about its functioning. The information that can be extracted as a result of such observation is just a communication protocol between the reasoning units, but not the meaning of what each unit is reasoning about. A simulation of such system, based on this data, would be an attempt to reproduce a reasoning protocol and no information about the subjects of reasoning or reasoning domain would be obtained.

Hence neural network models targets the protocol of autistic reasoning, not the reasoning domain itself. Furthermore, numerical simulation of interaction between reasoning and cognitive units only gives a limited, one-sided view of such protocol. To better reproduce autistic reasoning and then all the way towards representing autistic behavior, a logical, not numerical model is required to match the model and its outcomes with experimental observations.

Neural network models are inspired by the fact that brain includes neurons. However, decoding of neuron signals into a semantic representation can be done very superficially, with almost complete loss of information. We believe that unlike reasoning models, neural network models help with neither prediction of health treatment nor some mechanism that can be potentially discovered experimentally.

Reasoning patterns, the subjects of this book, are the most insightful chunks of information that can be obtained, observing autistic phenomenology at different levels, from genetic to neural and to behavioral level. It is rather hard to build a bridge from neural circuitry to reasoning patterns directly. What can be done is establishing some features of existence. Building a neural model of some reasoning patterns, one can show that to implement certain reasoning patterns, there should exist a neural layer with certain patterns of firing. If a neural network can solve a particular AI problem, the conclusion is that *there exists* a way of a biological neural network to implement this functionality in the brain.

Let us imagine a search engine as a part of a brain, implemented as an inverse index searcher. There are certain patterns of activity for how the search engine reads this index from a disk, which can be observable from outside, without knowing semantics of search. Depending of search queries, different areas of index on the disk can be loaded. This pattern of activity becomes much more complicated when a search index is shared between multiple servers and some forms of shards are implemented (Fig. 2.6). Imagine that we have activity patterns data for disk access timing somewhat similar to neuron firing. How much can be said about search algorithms, given the observations of the patterns of activity of a search engine disk reading, having knowledge about Java implementation of memory management? Obviously not much. This example helps to explain our skepticism related to how the neural network models of the brain shed a light on how the brain implements reasoning.

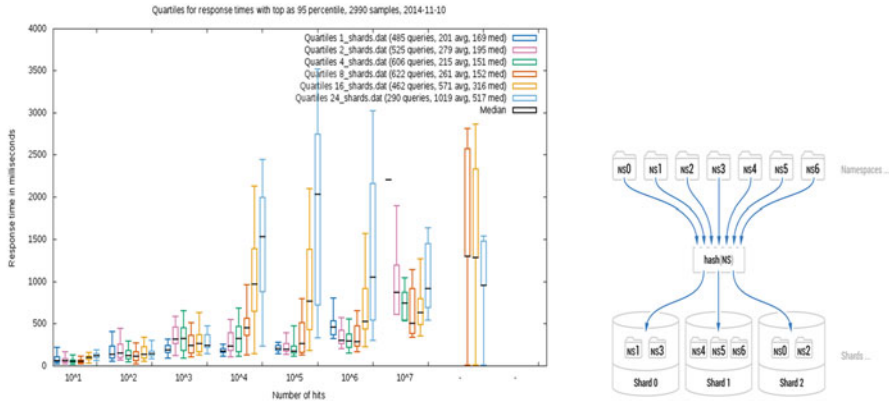


Fig. 2.6 The data on activity of distributed search system (on the *left*) and its architecture (on the *right*)

The idea that cognitive processes arise from the interaction of neurons through synaptic connections has been popular for a few decades. The knowledge in interactive and distributed neural systems is stored in the strengths of the connections and is acquired step-by-step in the course of accumulating experience. How can autistic reasoning and a degradation of semantic knowledge associated with this be explained via neural network models?

McClelland and Rogers (2003) hypothesize that degradation of semantic knowledge occurs through degradation of the patterns of neural activity that attempts to retrieve the knowledge stored in the connections. The authors demonstrate that through simulation models for development and disintegration of cognitive processes, with the focus on domain-specific patterns of generalization in young children and structure change of conceptual knowledge as a function of experience.

Rumelhart and Todd (1993) connectionist network is shown in Fig. 2.7. Inputs, consisting from concept-relation pair, are on the left and activation propagates to the right. Every unit in the pool on the sending side on the left projects to every unit on the receiving side on the right. The network is trained to turn on all these output units that represent the correct completions of the input patterns.

The connectionist neural model suggest there exists a representation unit such as temporal pole that ties together all objects properties with various types of information. Temporal pole is strongly affected by the semantic dementia disease. Temporal lobe can also be a region that stores addresses for conceptual representations. Patterns of activations in the temporal lobe capture semantic similarity between concepts and serve as means of semantic generalization on one hand. Also, damage in these areas disrupts the abilities to activate more specific properties of concepts elsewhere. The parallel distributed processing accounts of cognitive activity have

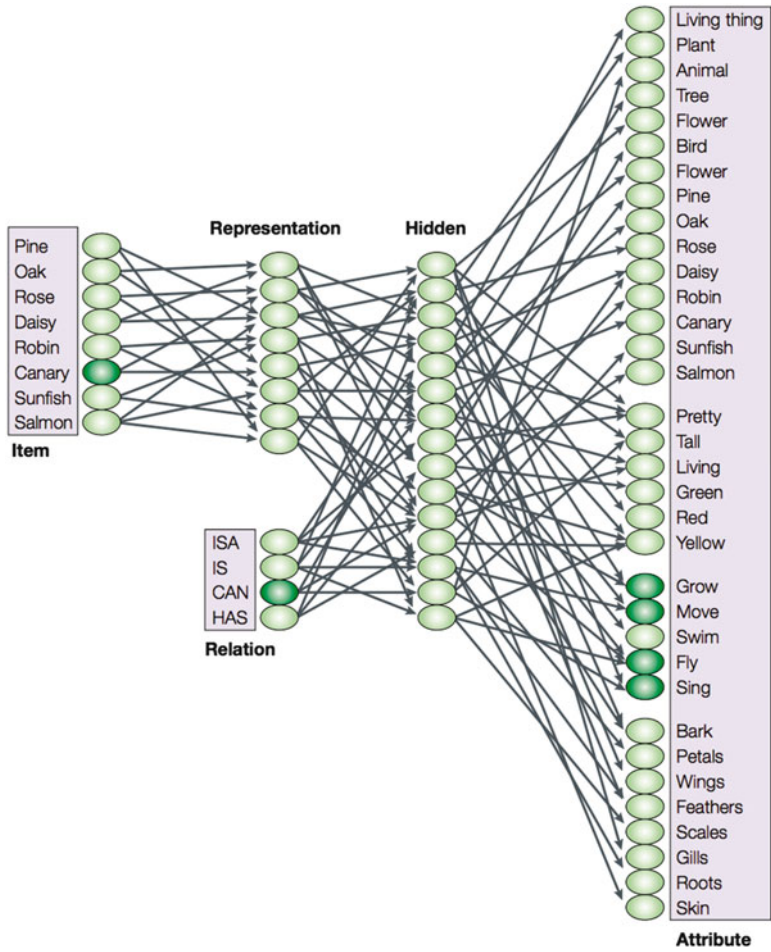


Fig. 2.7 The network used to learn propositions about concepts (From Rumelhart and Todd 1993)

posed a serious and pressing challenge to the view of the mind as a serial symbol manipulator (Clark 1989; Rumelhart and McClelland 1986).

Major brain structures implicated in autism are shown in Fig. 2.8.

2.3.2 Sensory Hyper-sensitivity

The combination of sensory hyperarousal and abnormal attentional selectivity suggests that autism may involve over-connected neural networks, in which signal is insufficiently differentiated from noise or irrelevant information and in which

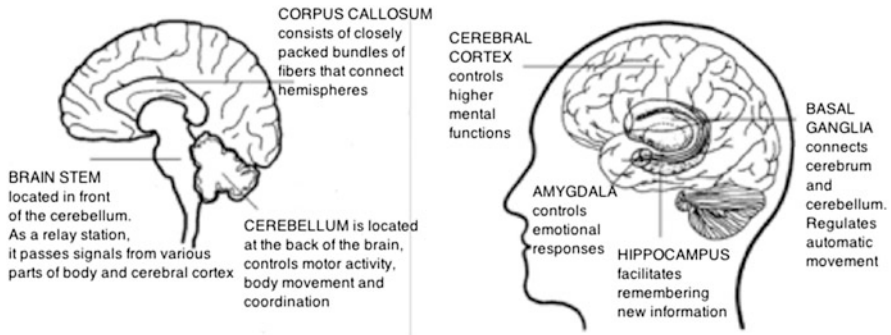


Fig. 2.8 The brain structures implicated in autism

information capacity is therefore reduced (Belmonte et al. 2004). This idea is consistent with genetic and neurochemical results, such as linkage to the 15q11–13 region, which contains a cluster of γ -amino-butyric acid (GABA) receptor genes (Buxbaum et al. 2002), low GABA receptor binding in hippocampus (Blatt et al. 2001), and low GABA levels in blood platelets (Rolf et al. 1993), and with the substantial comorbidity of epilepsy with autism. Also, substantial amount of noise in neural networks is associated with autistic psychophysical anomalies such as high visual motion coherence thresholds (Milne et al. 2002).

Low level visual, tactile and proprioceptive inputs are intact or even improved in CwA. At the same time, visual impairments occur at the level of image interpretation and integration of visual signals; it is still unclear if this is true for other modalities. Hyper-sensitivity and enhanced ability to detect details in input stimulus is augmented with difficulties in integrating sensory information into a coherent pattern. It is hypothesized that these difficulties contribute to motor deficits. The measures of motor coherence are correlated with motor skills of CwA. Gowen and Miall (2005) found out that CwA's performance is worse on motor tasks which require more sensory processing, such as pointing and timing, compared to repetitive tapping and hand turning. A miscalculated sensory input affects determination of the spatial state used to plan and modify movements. Babies who are visually hypersensitive or auditorially hypersensitive will need a more soothing type of enticement to take an interest in that outside world. Babies who are underreactive will require more animated interactions.

Baron-Cohen et al. (2008) argue that the excellent attention to detail in PwA is itself a consequence of sensory hyper-sensitivity. The authors review an experiment from our laboratory demonstrating sensory hyper-sensitivity detection thresholds in vision and conclude that the origins of the association between autism and talent begin at the sensory level, include excellent attention to detail and end with hyper-systemizing.

Mottron and Burack (2001) suggested an approach called 'enhanced perceptual functioning' of CwA associated with a stronger low-level perceptual processing.

Studies using questionnaires such as the sensory profile have revealed sensory abnormalities in over 90 % of CwA (Tomchek and Dunn 2007). In visual processing, PwA are more accurate at detecting the orientation of first-order gratings (simple, luminance-defined) but less accurate at identifying second-order gratings (complex, texture-defined). In the auditory modality, superior pitch processing has been found in PwA. In the tactile modality, Blakemore et al. (2006) showed a hyper-sensitivity to vibro-tactile stimulation to a frequency of 200 Hz but not for 30 Hz. In addition, the CwA group rated supra-threshold tactile stimulation as significantly more intense than CC did.

Hyper-sensitivity could result from a processing difference at various sensory levels including the density or sensitivity of sensory receptors, inhibitory and excitatory neurotransmitter imbalance or speed of neural processing. Belmonte et al. (2004) suggested local range neural over-connectivity in posterior, sensory parts of the cerebral cortex is responsible for the sensory ‘magnification’ in CwA.

2.3.3 *High or Low Connectivity?*

The apparent contradiction between theories of over-connectivity and under-connectivity in autism may arise because of the multiple ways the term *connectivity* can be defined. One should differentiate local connectivity within neural assemblies from long-range connectivity between functional brain regions. On the other hand, one can separate physical connectivity (associated with synapses and tracts) from computational connectivity (associated with information transfer). Physically, in the autistic brain, high local connectivity may develop at the same time as low long-range connectivity develops (Just et al. 2004; Belmonte et al. 2004). It might be caused by frequent changes in synapse reduction and formation that breaks the computationally optimal balance between local and long-range connections. A decrease in network entropy due to indiscriminately high connectivity within local networks could yield abnormally low information capacity and may develop in tandem with abnormally low computational connectivity with other regions.

According to the under-connectivity theory there is an excess of low-level (sensory) processes, with under-functioning of high-level neural connections and synchronization (Gepner and Feron 2009). fMRI and EEG studies suggest local over-connectivity in the cortex and weak functional connections to/from frontal lobes. Under-connectivity is observed mainly within each hemisphere of the cortex. Autism may be in this view a disorder of the association cortex. The theory does not explain how and why this under-connectivity can arise, and how does it explain many specific autistic symptoms.

“Default brain network” (cingulate cortex, mPFC, lateral PC) shows low activity for goal-related actions; it is active in social and emotional processing, mind-wandering, daydreaming. Activity of the default network is negatively correlated with the “action network” (conscious goal-directed thinking), but this is not the

case in autism. Perhaps this is a manifestation of under – connectivity, and shows disturbance of self-referential thought, necessary for development of the theory of mind.

There is an abnormal brain activation in a number of circuits under autism in a mirror neuron system (responsible for imitation) as well as other systems, and at the same time the performance of CwA on various imitation tasks may be normal. Another large neural subsystem related to the representation of the self-structures, the default mode network, has also been affected. The impairment of these two systems may be the result of general under-connectivity between spatially separated brain areas (Gepner and Feron 2009).

2.3.4 Deviation of Neural Network Functioning

The majority of studies in the area of computational autism focuses on autistic perception as most prominent autistic features and attempt to explain how the deviation of perception system architecture might explain what has been observed in experimental studies of autistic cognition. Peculiarities of visual, auditory and tactile autistic perceptions are analyzed.

Neural networks theories of cognitive processes state that many mental operations are carried out through successive sets (layers) of neuronal processing elements (Gordon 1997). With the proper input and training criteria, and the proper learning of rules, such networks have proven to be extremely efficient at extracting rules and patterns that are implicit in the data presented to them. However, the accuracy of this extraction is very dependent on the number of processing elements in the active learning layer (Baum and Hausler 1989). If there are too few elements then the network does not learn with very good accuracy: it, in fact, tends to over-generalize. If there are too many elements, then the network learns each specific situation presented to it and doesn't generalize enough. If some number of working elements leads to adequate performance, a somewhat greater number can result in truly superior performance in learning implicit rules and patterns, as long as it avoids becoming too specific.

This observation might be tied in to normal development, and to the abnormal development(s) that occur in autism, in the following way: the normal development of higher cerebral functions in a child's cortex appears to be driven by at least two major influences:

1. predetermined connections;
2. activity and use.

It has often been noted that the number of genes coding for the brain and neural tissue (about fifty thousand) are insufficient to specify all the connections of the mature brain. Thus, the development of these connections must be guided in part by experience. Edelman (1987) and (Edelman et al. 1997) have suggested that whether

an uncommitted area develops connections with one region or another is based on the outcome of a competition for use. The developing child's brain normally has several primary sensory inputs which are hard-wired, including vision, audition, and touch. Such sensory inputs will attempt to stimulate upstream neuronal processing resources that are not yet employed.

Normally, the multiple influences on a child lead to a balance of forces, with the normal balance of lower and higher processing abilities (and neuroanatomic maps) as a result. The amount of neural tissue that is devoted to each higher function therefore represents a tradeoff between several forces: an attempt to optimize processing, the practical limits on optimization (because of lack of enough experience and training time), and competition with other functions for those same neuronal processing elements.

The hypothesis is that a developing brain of CwA has all those same forces at work, but for some reason some processing systems are impaired or delayed in their development. The systems in question are those involved in speech perception and speech production. Specific genetic deficits in speech generation have been tentatively identified, and it is plausible that there are combinations of deficits with more widespread effects on both speech generation and perception.

We continue to hypothesize that if the systems related to speech perception and speech production were developmentally impaired, then many higher abilities correlated with appropriate auditory input and output would never develop properly. Whatever cerebral tissue would have been devoted to those higher functions would then be free to be incorporated into other processes (assuming the tissue itself was not too badly affected by the same defects). If vision were intact, then visual-related abilities would be expected to rely on extra cerebral tissue. The result would be a child's brain that was not capable of *all* of the normal functions of a child, but that was capable of performing some functions satisfactorily. The brain would not be capable of those abilities that are related to speech and language capability, such as a long-term component of working memory (the part normally dependent upon an articulatory loop), and perhaps even such higher functions as the "inner voice" aspects of consciousness. It would, however, be extraordinarily good at wordless visual perception and analysis. Neuropathologically, such a brain might have only a few, apparently nonspecific, abnormalities. It would not have to have fewer neurons than normal.

In reality, the autistic brain is average or larger-than-average in size (Courchesne et al. 1999). It might be possible to detect additional areas responsible for visual-related functions, but perhaps not with current behavioral tasks and instrumentation. Autism may therefore represent disorders of activity-dependent plasticity during brain development that occur at several different levels: gene, synapse, neuron, network, and neuronal group.

In Fig. 2.9 solid arrows indicate direction of neural transmission, based on current information; large striped arrow depicts uncertain cerebellar effects. Large scissors depict cellular "lesions" in important structures that might contribute to network dysfunction or a "disconnection syndrome." Small scissors show potential sites for disconnection within networks and an example of "functional" (correct: globus

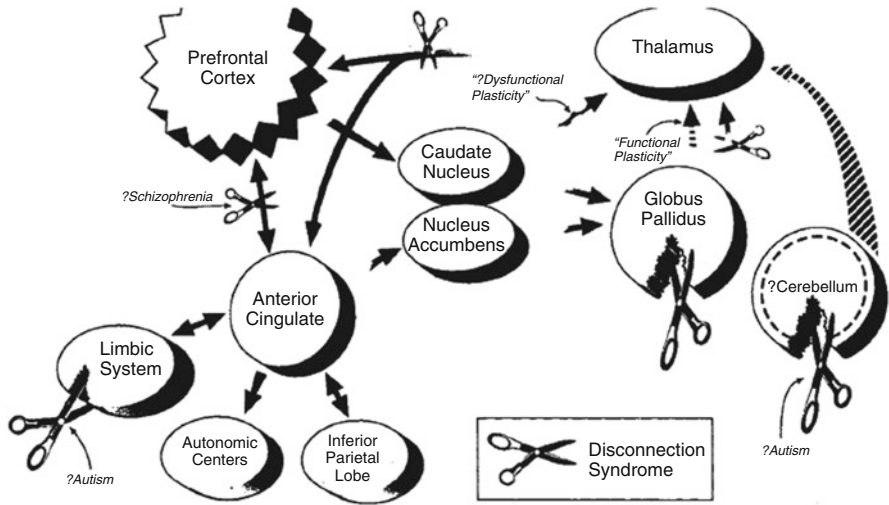


Fig. 2.9 Putative neural networks in autism

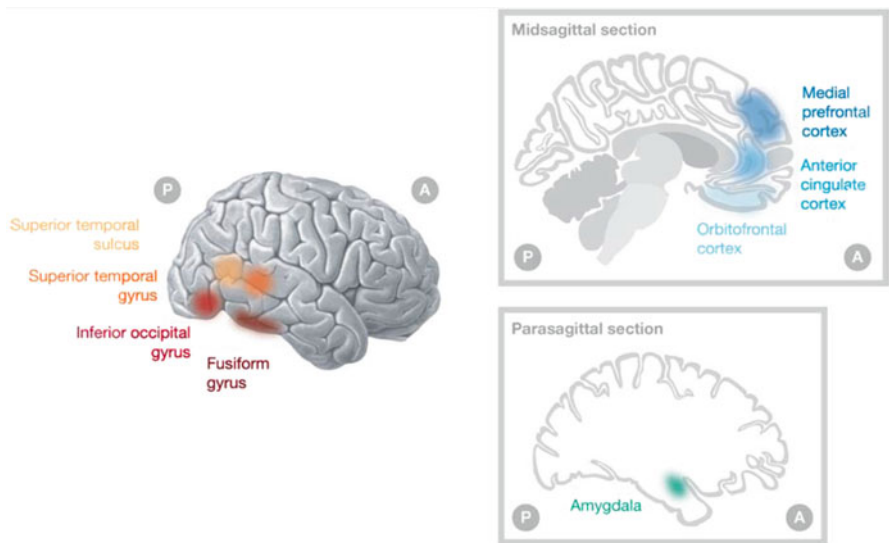


Fig. 2.10 The social brain (Adapted from Talairach and Tournoux 1988)

pallidus to thalamus) or “dysfunctional” (aberrant) repair that might occur from bypassing the globus pallidus. In schizophrenia, a disconnection is thought to occur between the dorsolateral prefrontal area and the anterior cingulate cortex (Benes et al. 1993).

Medial and inferior frontal and superior temporal cortices in Fig. 2.10, along with the amygdala, form a network of brain regions that implement computations

relevant to social processes. Perceptual inputs to these social computations may arise in part from regions in the fusiform gyrus and from the adjacent inferior occipital gyrus that activate in response to faces. This social computational network has been implicated in autism.

2.3.5 *Neural Network Architecture*

iSTART model (Grossberg and Seidman 2006) proposes a neural model which explains how cognitive, emotional, timing and motor processes interact together, involving brain regions like prefrontal and temporal cortex, amygdala, hippocampus, and cerebellum, attempting to reproduce “autistic” symptoms. The iSTART model based on Grossberg’s Adaptive Resonance Theory. According to this model, under-aroused emotional depression in the amygdala, learning of hyper-specific recognition categories in temporal and pre-frontal cortices, and breakdown of attention-based and motor circuits in hippocampus and cerebellum. The model proposes how particular types of imbalanced mechanisms in different parts of the brain can generate “autistic symptoms” through brain-wide interactions.

Autistic people have vigilance (ability to maintain concentrated attention over prolonged periods of time) fixed at such a high setting that their learned representations are very concrete, hyper-sensitive and hyper-specific. While this is an interesting and rather comprehensive attempt to build a theory that explains many symptoms of autism, parameters such as vigilance are hard to connect to the molecular level and physical processes in the brain.

Gustafsson described autism as deficient self-organization of feature map (Gustafsson 1997; Gustafsson and Paplinski 2003). His model is based on Kohonen’s (1995) self-organizing maps where excessive inhibition results in the inadequate formation of cortical feature maps. He hypothesized that excessive lateral inhibition, as a primary deficit, may prevent adequate feature maps from forming. Courchesne and Allen (1997) explained that the parietal lobe and the cerebellum are both involved in the physiology of autism with cerebellar modulation of the use of attentional resources. It has been suggested that autism stems from under-developed and highly specialized and focused cortical maps, without overlap between different concepts. In this model, the initial amount of nerve-growth factor is assumed to influence the map formation.

Björne and Balkenius (2005) proposed a computational model with three interacting components for context sensitive reinforcement learning, context processing and automation to autonomously learn a focus attention and a shift attention task. The performance of the model is similar to that of normal children, and when a single parameter is changed, the performance on the two tasks approaches that of autistic children. To learn associations between stimuli and responses in a context dependent way, the authors use an extension of the Q-learning algorithm (Watkins and Dayan 1992). A ContextQ system learns associations between stimuli and responses based on the reinforcement. The CONTEXT system controls in what

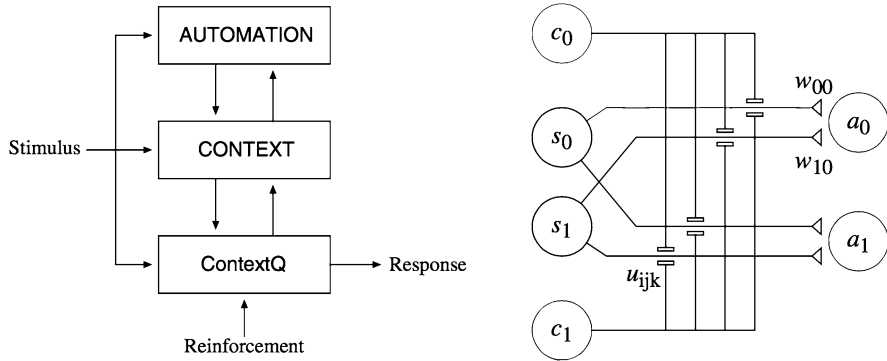


Fig. 2.11 Overview of the reinforcement learning model (on the *left*) and neural network-based implementation of the estimating function (on the *right*)

context each stimulus-response association should be used. The AUTOMATION system learns to produce stimulus-triggered contextual shifts (Fig. 2.11). The function of the context system is to integrate sensory input over time to create a code for the current context (Balkenius 2000). Here, it operates as a working memory for the last potential target that the system reacted to.

The function which assigns a value to each action in each states is approximated via an artificial neural network with shunting inhibition from the context nodes c_k to the association between a state node s_i and an action node a_j (Fig. 2.11 on the right).

Deuel (2002) proposed to represent autism as a common phenotype, characterized and explainable by an early onset of dysfunction in a circuit that involves cerebellar adaptive timing, the limbic and neocortical systems.

Overall, neural network models describe the features of meta-reasoning, and it is hard to correlate them with the feature of object-level reasoning. Majority of information is communicated in object-level, and only its specific parts is in meta-level.

2.3.6 Neural Simulation of Attention Deficit Disorder

To shift attention, neurons need to desynchronize and then synchronize again. In the language of dynamical systems this means that the trajectory of the system, describing neural activity has to leave one attractor basin and jump to another basin. However, neural dysfunctions may make this process difficult. One cause may be due to the damage of leak ion channels that slow down the process of spontaneous depolarization of neurons. Neurons stay in the same activity patterns for extended time, leading to hyper-specific memories, problems with disengagement of attention, and a general lack of flexibility of changing brain states. Lack of frequent changes of brain states in the developmental process will lead to under-connectivity.

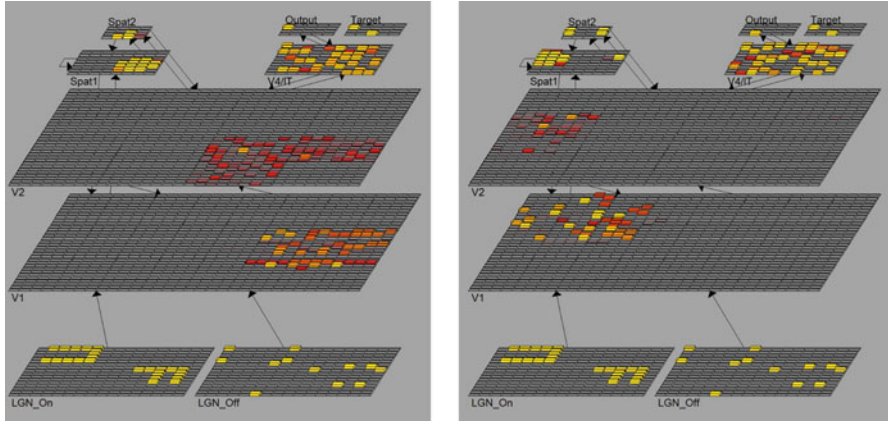


Fig. 2.12 Model of visual recognition (O'Reilly and Munakata 2000) based on Casanova (2007). Two steps of visual recognition simulation: on the *left* the first object was recognized, on the *right* after attention shifted to the second object

This is due to the fact that Hebbian learning mechanisms will not naturally increase the strength of distal connections. Attractor dynamics of two models implemented in the Emergent simulator has been studied to verify the attention hypothesis.

The first example is based on a model of visual recognition (Fig. 2.12), and it involves:

- recognition of two objects presented in the visual field;
- information is first processed by the on-off cells in the retina and passed to the thalamic lateral geniculate nuclei (LGN);
- from the LGN it is passed to the V1 and larger receptive fields of V2;
- the dorsal stream includes the V5/MT layers (Spat 1 and 2 in Fig. 2.12) that help to localize where the object is in the visual field and through the feedback connection helps to maintain the V2 and V1 activity focused on this object;
- the ventral stream includes V4/IT for object recognitions, and has connections with the V5/MT region.

Spat1 has recurrent activations and inhibition, focusing on a single object. In normal situations after a short time neurons desynchronize and synchronize on the second object, and as a result attention is shifted and the second object recognized. Damage to leak channels disables this process and the system cannot disengage attention from the first object for a long time. It is interesting that leak channels may also be damaged in the other direction letting large depolarizing current out, and thus making the system unstable, jumping from one object to the other. This is characteristic of the attention deficit hyperactivity disorder (ADHD).

Thus, relatively simple low-level problem with properties of neurons may lead to autism and ADHD. Considering the influence of such problems on the development, a variety of symptoms may be explained.

2.4 Game-Theoretic Approach

The precise cognitive dysfunctions that determine the heterogeneity at the heart of this spectrum, however, remains unclear. Furthermore, it remains possible that impairment in social interaction is not a fundamental deficit but a reflection of deficits in distinct cognitive processes. To better understand heterogeneity within autistic spectrum, Yoshida et al. (2010) employed a game-theoretic approach to characterize unobservable computational processes implicit in social interactions.

Using a social hunting game with autistic adults, the authors found that a selective difficulty representing the level of strategic sophistication of others, namely inferring others' mindreading strategy, specifically predicts symptom severity.

In contrast, a reduced ability in iterative planning was predicted by overall intellectual level. Our findings provide the first quantitative approach that can reveal the underlying computational dysfunctions that generate the autistic "spectrum."

The game success score was significantly higher for the CwA group than for the control group, while there was no significant difference between the groups for both verbal and strategic intelligence scores. Both the control and the autistic group had a higher game score when they behaved more cooperatively, when the computer agent was more sophisticated. The participants in the autistic group showed a larger variety of behavior than the control participants.

To identify functional abnormalities in the computational processes involved in the task, Yoshida et al. (2010) used the Theory of Mind model and the fixed strategy model. The Theory of Mind model included two model parameters characterizing the cognitive processing: one is the upper bound of sophistication, which defines the capacity of strategic planning, and the other is a forgetting effect, which controls how quickly a player responds to changes in the other's sophistication, thereby representing a measure of cognitive flexibility. For the fixed strategy model, as it is assumed that players do not change their strategy, only the sophistication level is estimated.

Bayesian model selection based on the log likelihoods showed that the Theory of Mind model of CC with belief inference accounted for the behavior significantly better than the fixed strategy model without belief inference. At the same time the fixed strategy model explained individual behavior better for more than two-third of CwA. CwA were guided to a significantly lower degree of belief inference than that of the control participants. CwA also showed deficits in cognitive flexibility as they tend to be tied to their past strategies during the social game rather than a capability to flexibly change rules and strategies by paying attention the other's new actions (Sect. 6.4). Also the level of nested expressions of the mental world (*you think that I think that you think*, etc.) for PwA participants was related to IQ scores. A study using a "Beauty Contest" game has indicated an association between higher-level reasoning in CC and higher intelligence scores (Coricelli and Nagel 2009). Highly intelligent PwA behave cooperatively as if they make predictions over a longer time-horizon. This suggests that the level of sophistication, a key component of higher-level reasoning, can be inferred in more complex dynamic social exchanges.

Bermudez (2005) claims that a mechanism of emotional sensitivity including “social referencing” is a form of low-level mindreading that is required for proper social understanding and social coordination without involving the attribution of propositional attitudes. In game theory there are social interactions that are modeled without assuming that the agents involved are engaged in explaining or predicting each other’s behavior. In social situations that have the structure of the iterated prisoner’s dilemma: “start out cooperating and then mirror your partner’s move for each successive move” (Axelrod 1984). Applying this heuristic rule relies on understanding the players’ moves such as cooperation and defection, based on the information of what has happened in the last round. These are the patterns of social interaction that are conducted on the basis of a heuristic strategy that involves the results of previous interactions rather than their psychological flavor. To play these kinds of games successfully, one does not need to reason about other players’ intents; one only have to coordinate our behavior with theirs.

2.5 Accounts of Autism

A number of psychological theories of autism have been proposed with varied relevance to autistic reasoning and computational interpretation. We will look at these theories from the computational perspective, analyzing which system architecture might be causing the respective algorithmic limitation. Each account is framed as a feature of information processing, which is explained to cause autistic behavior deficits (Sect. 2.1). The competition between the accounts of autism is grounded in how well the link

Reasoning, cognition & information processing → *behavior & skills*

is established, how many features of autistic behavior it can explain (Fig. 2.13), how mutually consistent is the explanation of the causal link, and how compatible is the given account with other popular accounts of autism.

Some of the most popular ones are:

- the Theory-of-Mind (ToM) deficit theory (Leslie 1987). We devote a separate chapter to it since it is mostly computationally feasible among other theories.
- the weak central coherence theory (Happe and Frith 2006)
- the executive function deficit theory (Russell 1997),
- joint attention, and
- the affective foundation theory (Hobson and Lee 1999).

One of the examples of autistic behavior caused by peculiar perception capabilities is stereotypy (Fig. 2.14).

Fig. 2.13 Causes of autistic behavior

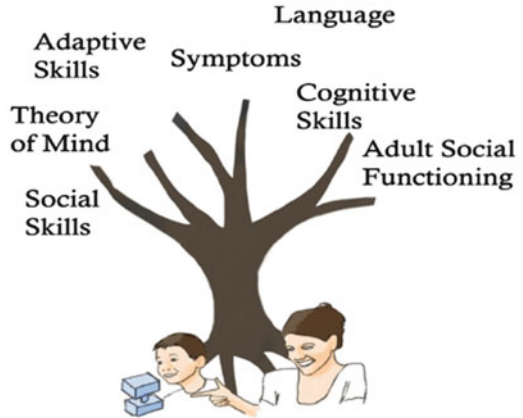


Fig. 2.14 Holding a palm near the mouth is not caused by social habits but stereotypy



2.5.1 Weak Central Coherence Account

(Frith and Happe's 1994) weak central coherence theory of autism refers to an abnormally weak tendency to bind local details into global percepts. This theory is also built on the observation that CwA show certain supernormal abilities, including hyper-sensitivity. PwA are good at things which can be done by attention to detail while ignoring 'the big picture', particularly in some visual tasks. They show a lack of susceptibility to some visual illusions (e.g. Muller-Lyer 1889). Furthermore, they

perform very well on the hidden figures task. The theoretical basis of weak central coherence is (Fodor 1983) theory of the modularity of mind.

Fodor postulated a central processing unit which processes the information supplied by the modules in a modality-free manner. Fodor viewed analogy and metaphor as the essential operations of the central processor. Weak central coherence states that under the distributed architecture in CwA the central processor does not fully perform its integrative function, resulting in the separate modules sharing their own specific information with other modules. As additional support for this account one may refer to the well-known inability of CwA to understand metaphor, and also their failure to exploit analogies in problem solving.

O’Loughlin and Thagard (2000) analyse several tasks on which autistic people are known to fail, such as the false belief task and the box task, and find that these tasks have a common logical structure that is identical to that of the suppression task (Fig. 2.15 This leads to a prediction for autistic people’s behavior on the suppression task, which has been verified. This latter result is analyzed in terms of the neural implementation, which then gives a chance to make a connection to the genetics of autism. However, a structure of excitation and inhibition is fairly trivial and obviously not expressive enough to reproduce logical reasoning in its general form. Hence we believe that although such analysis is useful in understanding

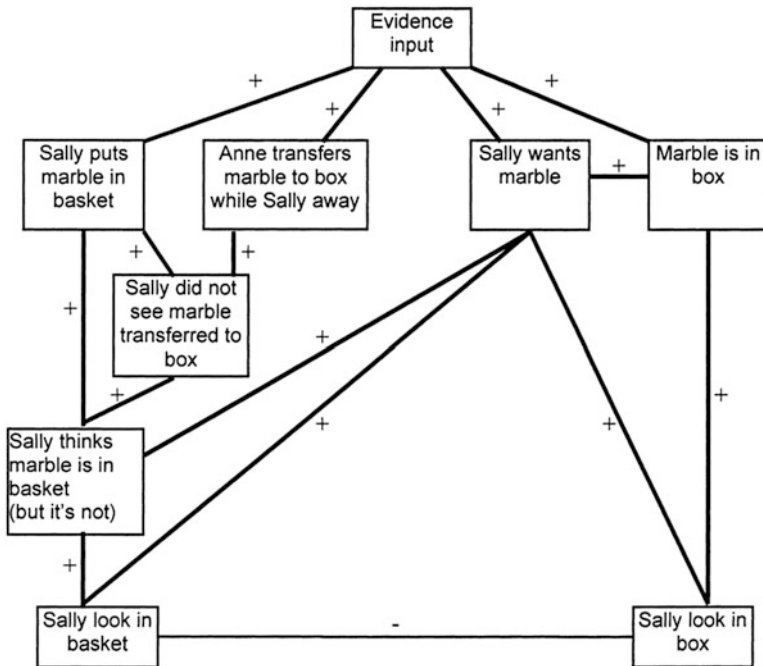


Fig. 2.15 Connectionist model for Sallie-Anne task (O’Loughlin and Thagard 2000)



Fig. 2.16 Getting lost in a number of stimuli of various natures

a probable mechanism of integrative function, it cannot systematically advance our understanding of the reasoning capability of neither CwA nor neural-based intelligent machines.

Weak central coherence in autism has been demonstrated in the context of superior performance on visuo-motor tasks such as the Embedded Figures Test (Jolliffe and Baron-Cohen 1997), the Wechsler Block Design subtest (Shah and Frith 1983), tasks of visual discrimination and visual search (Plaisted et al. 1998), as well as impaired performance on more abstract tasks such as arranging sentences to form a coherent context (Jolliffe and Baron-Cohen 2000). The general pattern is one of superior segmentation of stimuli and attention to detail within these stimuli.

The weak central coherence theory thus predicts that people with autism spectrum conditions will perform best on the tasks and occupations with focus on individual details (Fig. 2.16). At the same time, CwA are also mostly driven by the problems involving tons of details. Also, the Emphasizing-Systemizing theory predicts that people with autism spectrum conditions will be most driven by tasks and occupations that involve analysis of rule-based systems instead of generalization from data.

To a great extent, these predictions overlap: systemizing demands excellent attention to detail to isolate parameters that may then be tested individually for their effects on the system's output. From the ML point, CwA have decent skills to apply individual learning systems but are not capable of integrating them, applying, for example, a family of bagging and boosting algorithms (Zhi-Hua 2012).

However, differences in theoretical predictions arise in complex multimodal systems where a manipulation of inputs produces widespread effects on outputs, or when outputs vary with complex interactions among widely separated inputs.

The central coherence theory, taken by itself, predicts that PwA will be unable to perceive such stimuli because tackling them requires a global view of the interrelations between large sets of inputs and outputs. In other words, this is the engineering ability to combine a meta-detector from individual detectors, meta-recognizer from partial, individual recognition systems.

According to central coherence, CwA are expected to be capable of dealing with simple systems that can be understood in terms of relations between one or a few inputs and outputs. Conversely the Empathizing-Systemizing theory (Sect. 3.2), taken by itself, predicts that (relative to their mental age) people with autism will be able to learn how any sort of regular system works, regardless of its complexity, so long as it can be described by familiar and formalized rules.

2.5.2 *Executive Function Deficit Account*

Russell (1997) executive function deficit account focuses on the data that CwA often exhibit severe perseveration. They go on carrying out some routine when it is no longer appropriate. CwA show great difficulty in adjusting their action to a context (Fig. 2.17).



Fig. 2.17 CwA experience difficulties switching tasks with different movement and perception modes

They experience problems in switching tasks when the context calls for a switch, but it is not governed by any explicit rule. This perseveration gives rise to many of the symptoms of autism: obsessiveness, insensitivity to context, inappropriateness of behavior and literalness of carrying out instructions.

Task-switching is the brief of executive function, a process (or processes) responsible for high-level action control such as planning, initiation, co-ordination, inhibition and control of action sequences. Executive Function deficit also exists in the mental space, maintaining a goal, and pursuing it in the real world under possibly adverse circumstances. In this respect Executive Function deficit is correlated with extreme behavioral rigidity of CwA.

The origin of the concept of “Executive Function” deficit was heavily influenced by the analysis of neuropsychological patients. This has the important consequence that it is often most discussed in terms of its malfunctioning, and it is unclear how the proper executive function performs in humans and machines.

Situation calculus, AI theories of planning are expected to be relevant since they provide analyses of what is involved in planning action. On the contrary, the psychological study of normal planning of CC is mainly explored in the problem solving studies. Note that although CwA lack spontaneity, they may be able to carry out tasks involving fantasy play when instructed, as is indeed necessary if they are to engage with diagnostic tests such as the false belief task at all.

CwA’s problem solving in turn has been most extensively studied in terms of the level of expertise, analyzing the difference between expert and novice problem solving. When discussing cognitive analyses of the malfunctioning of reasoning about mental states, it is natural that much clinical literature is oriented toward giving patients a unique categorization. A popular opinion of the contemporary psychiatry is that the existence of clusters of such categories is not always transparent. PwA are substantially more depressed, as measured by the relevant clinical diagnosis instruments, than the controls are.

It is unclear if executive dysfunction observed in autism is the same as the executive dysfunction observed in depression. The latter can be referred to as meta-executive dysfunction since depression affects reasoning about reasoning, not the object-level reasoning patterns like autism does. It is unclear if one could fractionate autistic problems, could the executive function subset be due to the accompanying depression. Studies (Ozonoff and Strayer 2001) challenge the view that PwA perform the Tower problems, WCST and similar complex problem solving tasks poorly because of a deficiency in working memory itself. Alternative theories have proposed that individuals with autism perform poorly on executive function tasks because of primary or inherent deficiencies in conceptual reasoning and planning abilities (Frith 1989; Frith and Happé 1994; Just et al. 2004). These models, the central coherence, complex information processing and underconnectivity models (Sect. 2.3) were proposed on the basis of the observation of a spectrum of deficits in higher order cognitive abilities and intact basic abilities in the same domains. In more detailed studies of individual cognitive domains, a relationship between increasing information processing demands and the emergence of deficits has been shown.

Following along these lines, we observe that successfully applying simple axioms for reasoning about mental states, CwA fail to apply more complex ones. At the same time one cannot say that ALL axioms in a given domain are absent. A reasoning system can possess an executive processing unit in the form of meta-reasoning, or reasoning about reasoning process that helps to control it. However, it is hard to imagine how a deep learning neural network system has a central coherence or executive function capability. Given a training set, it can be trained to solve a given problem, and it needs to be re-trained to solve another problem. An ensemble of deep learning systems would need an executive processor, but it has to have the same layered architecture so it is hard to imagine how it can implement the executive, meta-reasoning functionality that is totally different from multidimensional optimization functionality implemented by layered deep learning network.

Over last few decades, the popularity of neural networks was going up and down. After being a popular trend in the 1980s, they were dismissed as bunk by the AI establishment and the idea of “deep learning” was seen as scientific lunacy. At the time of writing of this book the neural network approach became popular again in the form of deep learning. Deep learning has become seen as technology’s next big thing, sparking bidding wars among companies like Google to acquire companies researching ways to use deep learning. Deep learning applications are already working in major search engines including the image search. These algorithms allow users to image search terms like “handshake”, get Smart Replies to their Gmail accounts and rely on machine translation. Deep learning is expected to be applied to other major problems like climate science, energy conservation, and in genomics.

Human brain has 1000-trillion synapses (10 to the power of 15). The largest computers have about a billion synapses, a million times less than brain. Deep learning scientist believe that expanding computer power and the size of training sets they can achieve the performance of the human brain. However, the observation of autistic brain does not support this belief: a huge sufficiently uniform neural network such as autistic brain is unable to learn from experience even simplest rules, such as that other people might have intent. It means that a uniform layered topology of a neural network, which includes fully functional neurons, cannot learn even very simple facts such as a basic binary relation between a subject and a mental object. Therefore, the claims about a connection between the deep neural network and the brain are premature.

Due to peculiar deviation in active learning process, as we will show in Sect. 7.3, people with autism spectrum conditions show unusually strong repetitive behaviors, a desire for routines, and a need for sameness.

The executive dysfunction theory also states that autism involves a form of frontal lobe pathology leading to perseveration or inability to shift focus. Although evidence for such executive deficits does exist (Pennington and Ozonoff 1996; Russell 1997), the high variance in measures of executive function in autism spectrum conditions, along with the lack of correlation between measures of executive function and measures of reciprocal social interaction and repetitive

behaviors (Joseph and Tager-Flusberg 2004), suggests that executive dysfunction is unlikely to be a core feature of autism spectrum conditions.

The executive account has also traditionally ignored the content of repetitive behaviors. There are different ways repetitive behavior is explained. We demonstrate it by the deficiency in autistic active learning system, as a result of autistic cognitive development. On the contrary, Empathizing-Systemizing theory draws attention to the fact that much repetitive behavior involves the child's obsessional or strong interests, the foci of which cluster in the domain of strongly regular systems (Baron-Cohen and Wheelwright 1999). Rather than primary executive dysfunction, these behaviors may reflect an unusually strong interest in systems. Our explanation of this is that CwA have such strong interest in behavior patterns because they are unable to recognize less repetitive ones, not because of superior analytical skills.

Whilst some forms of repetitive behavior in autism, such as "stereotypies" (e.g., twiddling the fingers rapidly in peripheral vision) may be due to executive deficits, the executive account has traditionally ignored the content of "repetitive behavior".

The current account draws attention to the fact that much repetitive behavior involves the child's "obsessional" or strong interests with mechanical systems (such as light switches or water faucets) or other systems that can be understood in physical-causal terms. Rather than these behaviors being a sign of executive dysfunction, these may reflect the child's intact or even superior development of their folk physics. The child's obsession with machines and systems, and what is often described as their "need for sameness" in attempting to hold the environment constant, might be signs of the child as a superior folk-physicist: conducting mini-experiments in his or her surroundings, in an attempt to identify physical-causal principles underlying events.

A recent study of obsessions suggests that these are not random with respect to content (which would be predicted by the content-free executive dysfunction theory), but that these tests are clustered in the domain of folk physics (Baron-Cohen and Wheelwright 1999).

2.5.3 *Autistic Memory*

In the case of verbal linguistic tasks, increasing grammatical complexity of sentences leads to the emergence of deficits in high functioning autistic individuals, as did the transition from syntax to discourse (words to sentences to stories). In a study of memory using an extensive battery of tests, memory for simple information was demonstrated to be intact, documenting the preservation of basic associative memory processes (Minshew and Goldstein 2001). However, as the complexity of the task is getting higher, autistic deficits became more and more visible, as the use of contextual structure and organizational strategies to support memory diminishes (Fig. 2.18).

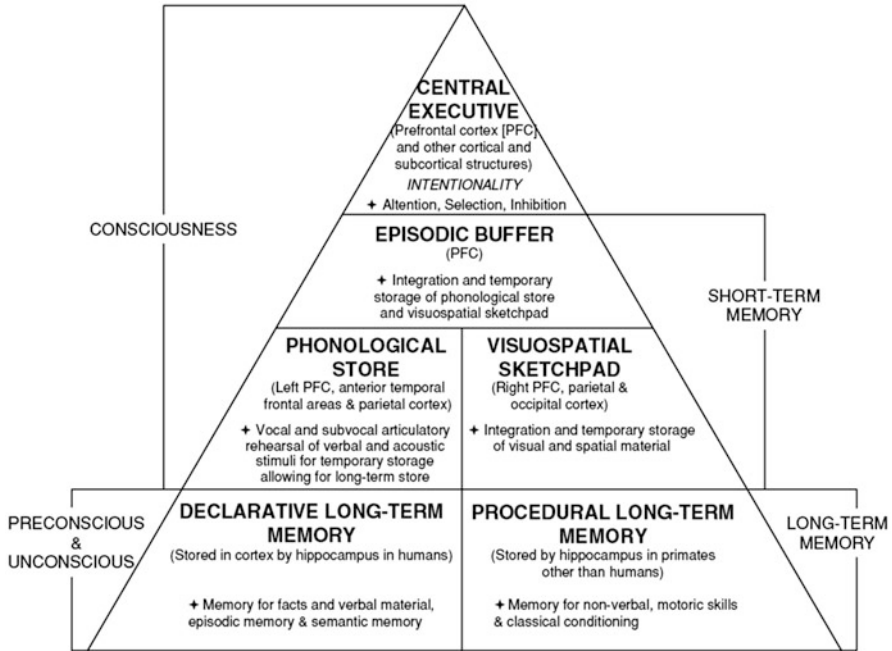


Fig. 2.18 The architecture of consciousness and working memory

An interesting discovery in autism research is that having verbal working memory intact, CwA’s spatial working memory may possibly be corrupted. Ozonoff and Strayer (2001) used a spatial memory-span task (recall of the location of three to five geometric shapes on a computer screen) and a box search task (participants had to search for objects hidden behind colored boxes using a method that required holding the color of the boxes in working memory during the search). Significant differences between CwA and CC were not found for either of these two tasks. Other measures of spatial working memory such as eye movement studies have also provided different results. The delayed oculomotor response task (memory-guided saccade) has been used as a measure of spatial working memory since the development of the technique with non-human primates by (Kojima and Goldman-Rakic 1982). In this procedure, the participant fixates on a central point, a peripheral target is presented and then extinguished, and the task is to make an eye movement to the remembered location of the target following a delay. Minshew et al. (1999) showed that CwA did significantly less well on this task than did CC with increased rates of response suppression errors and impaired precision in reaching the target. The saccades of CwA were very close to the target location but did not achieve the precise location.

Williams et al. (2005) attempted to address the inconsistent literature regarding verbal working memory and spatial working memory in CwA by using tasks that

assess the status of working memory components without involvement of planning or reasoning tasks. The authors also verified the hypothesized intactness of verbal working memory and impairment of spatial working memory by assessing these different abilities in the same individuals with high-functioning autism.

If the autism groups do more poorly than controls on the spatial tasks but not on the verbal tasks, it may be because the spatial tasks are more difficult and, therefore, more sensitive to cognitive deficits associated with autism. A traditional method of evaluating task difficulty is to evaluate the degree of association between task performance and general intelligence (Full Scale IQ).

The children, adolescents and adults with autism performed at similar levels relative to the cognitive and age-matched controls on the working memory tasks that involved the articulatory loop and performed poorer than the controls on the tasks that involved the visuospatial sketchpad. These findings demonstrate a dissociation between verbal and spatial working memory in the same individuals with autism. Intact verbal working memory and impaired spatial working memory have been demonstrated in multiple studies.

Williams et al. (2005) found no deficit in verbal working memory or the articulatory loop in high-functioning PwA. They exhibited difficulties in spatial working memory or the visuo-spatial sketchpad. These data do not support spatial or verbal working memory impairments as the core deficits underlying problem solving and planning impairments in PwA but confirm the existence of inherent dysfunctions in problem solving itself as the source of difficulty on tasks such as the Tower of London/Hanoi.

2.5.4 Account of Complex Information Processing Failure

It is now generally understood that the behavioral syndrome of autism is the result of multiple primary deficits and that these deficits involve the processing of information and are the result of the underdevelopment of the neural systems of the forebrain and not regional dysfunction (Minshew and Goldstein 1998). Although five to ten percent of CwA are the result of other diseases, the majority of cases are thought to be the result of about five abnormal genes coding for or regulating brain development (Rutter et al. 1994).

For humans and machines, complex information processing is a conceptual construct, not a specific ability. It is a term for a class of abilities that place high computational demands on the brain or a processing unit. Deficits in specific abilities such as theory of mind and executive function that are commonly discussed in connection with autism all fall under this general construct (Sutton et al. 1999).

The value of this conceptual construct is that it emphasizes the need to evaluate tasks autistic individuals cannot do in terms of the computational demands on the brain. This approach provides guidelines for modifying the demands of tasks that individuals are unable to do. However, the scientific value is that this term is also used in the neurophysiology to characterize delayed cognitive potentials. This

account also encourages thinking about brain algorithms in terms of developmental processes in the brain involved in the emergence of the intricate circuitry of the forebrain. The complex information processing account makes it easy to relate findings across several levels of the pathophysiology of autism. Such links are critical if the cause of autism is to be understood.

According to the current account, autism is a selective disorder of complex information processing abilities with intact simple information processing abilities. The common denominator of deficits in autism is the high demands placed on information processing or computation by the brain. The complex information processing model explains why these particular symptoms together form a syndrome and the failure of IQ scores. This model also predicts the common co-occurrence of mental retardation in autism, and the difference between autism and general mental retardation. The validity of this characterization of cognitive functioning in autism is supported by its reciprocal relationship with the neuropsychologic profile for the simple information processing disease. The presence of this same dissociation between deficient complex and intact simple abilities in the motor domain further confirms the validity of this construct. The relationship of deficits in autism to their computational demands on the brain is helpful in comprehension and analysis of behavioral and academic difficulties of CwA.

The human mind's activity of taking in, storing, and using information is shown in Fig. 2.19. In early models, input flows into the sensory registers (eyes, ears) and then information proceeds to short-term memory. Short-term memory holds information for only a moment, and then it combines it with information from the long-term memory. With effort, information moves into long-term storage. The short-term memory generates responses (output).

Information is encoded in sensory memory; perception determines what will be held in working memory. Working memory manages the flow of information and integrates new information with knowledge from long-term memory. Connected information that is thoroughly processed can become part of long-term memory. When that information is activated it moves to working memory. Each part of

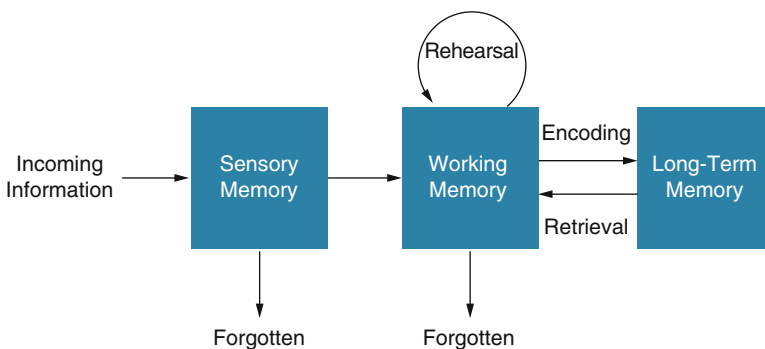


Fig. 2.19 From sensory to long-term memory

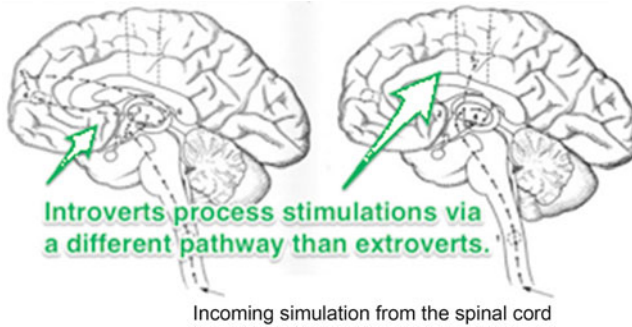


Fig. 2.20 A difference between the information processing pathways of extraverts and introverts

the system interacts with the others to guide perception; represent, organize and interpret information; apply and modify propositions, concepts, images, schemas, and strategies; construct knowledge; and solve problems (Fig. 2.19). Extrovert individuals process information via a different pathway to introvert individuals, including CwA (Fig. 2.20). Acetylcholine pathway of introverts is longer than the one of extraverts.

2.5.5 *Affective Foundation Account*

Greenspan (1997) attempts to derive ToM from a fundamental ontogenetic processes – in particular from the affective foundations of interpersonal communication. Humans uniquely control shared attention, especially by gaze (Fig. 2.21). We diagnose where others' attention is focused from information about where they are looking. 'Intersubjectivity' is established through mutual control of attention. Just as Piaget saw the child's sensorimotor activity as achieving the child's mastery of where itself left off and the world began, so Hobson sees the child's understanding of itself as a social being separated from others being achieved through joint attentional activity. The child must learn that the other can have different representations, and different wants and values. Hobson proposes that it is autists' valuation of these experiences of intersubjectivity which is abnormal. If the child does not experience the achievement of intersubjectivity as rewarding (or even experiences it as aversive), then any cognitive developments founded on it will not develop normally. Cognitive symptoms of autism are, on this theory, consequences of this valuation.

Hobson et al. (2013) followed pretend play among young children with autism. Age- and language-matched children with autism, autism spectrum disorder, and developmental disorders without autism were administered for the Test of Pretend Play (Lewis and Boucher 1997), with an additional rating of 'playful pretense'. As predicted, children with autism showed less playful pretend than participants



Fig. 2.21 CC's attention to a foot being grabbed by someone by a CC

with developmental disorders who did not have autism. Across the groups, playful pretense was correlated with individual differences in communication and social interaction, even when scores on the pretend play test were taken into account. Limitations in creative, playful pretend among children with autism relate to their restricted interpersonal communication and engagement.

In *The Growth of the Mind* (1997), Greenspan showed how emotions create, organize, and orchestrate many of the mind's most important functions, including intelligence and emotional health. He further showed that intellect, academic abilities, sense of self, consciousness, and morality have common origins in our earliest and ongoing emotional experiences and that emotions are the architects of a vast array of cognitive operations throughout the life span.

During the formative years there is a sensitive interaction between genetically – set abilities and environmental experience, which we formalize via active learning framework in Sect. 7.3. Experience appears to adapt the infant's biology to his or her environment (Hofer 1995). In this process, however, not all experiences are the same. Children seem to require certain types of experiences involving a series of specific types of emotional interactions geared to their particular developmental needs.

The difficulty in connecting affect to motor planning and symbols discussed in the last section is only one part of a larger set of transformations of affect that depend on specific types of emotional interactions. To more fully understand the importance of affect in autism, and the development of intellectual and social skills, it may prove useful to explore a number of affective transformations during the first 3 years of life.

In the first year, affects become more complex. There is a transition from simple affective states like hunger and arousal to, by 8 months, complex affect states like surprise, fear and caution, joy and happiness, and enthusiasm and curiosity. As the child progresses, affects become more differentiated. Eventually, affects organize reciprocal interactions and problem-solving. Then they become symbolized. Eventually, it becomes possible to reflect on them. The transformation procedure can be described in terms of six core early organizations that give the organism its desire to act and underlie intelligence and emotional health (Greenspan 1997).

First, to attend to the outside world, and eventually to have joint attention or shared attention, requires affective interest in the world outside one's own body—in sights, sounds, and movements. Obviously, parents who provide pleasurable sights and sounds to a new baby will entice the baby into focusing on the world.

The affect diathesis account focuses on the inability to connect affect or intent to motor planning capacities and emerging symbols capacities for empathy, psychological mindedness, abstract thinking, social problem-solving, functional language, and affective reciprocity all stem from the infant's ability to connect affect or intent to motor planning capacities and emerging symbols (Greenspan 1992).

Relative deficits in this core capacity leads to problems in higher-level emotional and intellectual processes. The core psychological deficit in autism may, therefore, involve an inability to connect affect (i.e., intent) to motor planning and sequencing capacities and symbol formation.

Consider a 14-month-old child who takes his father by the hand and pulls him to the toy area, points to the shelf, and motions for a toy. As the father picks him up, and he reaches for and gets the toy, he nods, smiles, and bubbles with pleasure. For this complex, problem-solving social interaction to occur, the infant needs to have an emotional desire or wish (i.e., intent or affective interest) that indicates what he wants. The infant then needs to connect his desire or affective interest to an action plan (i.e., a plan to get his toy). The direction-giving affects and the action plan together enable the child to create a pattern of meaningful, social, problem-solving interactions. Without this connection between affect and action plans, complex interactive problem-solving patterns are not possible. Action plans without affective direction or meaning tend to become repetitive (perseverative), aimless, or self-stimulatory, which is what is observed when there is a deficit in this core capacity.

2.5.6 Thinking in Pictures Account of Autism

Kunda et al. (2010) analyze the hypothesis that some individuals on the autism spectrum may use visual mental representations and processes to perform certain tasks that typically developing individuals perform verbally. They present a framework for interpreting empirical evidence related to this "Thinking in Pictures" hypothesis and then provide comprehensive reviews of data from several different cognitive tasks, including the n-back task, serial recall, dual task studies, Raven's Progressive

Matrices, semantic processing, false belief tasks, visual search and attention, spatial recall, and visual recall.

In her well-known autobiographical book “Thinking in Pictures”, Temple Grandin (2006) describes how her visual thinking style benefits her work in engineering design but also creates difficulties in understanding abstract concepts. Assuming that CC are able to use both visual and verbal mental representations, Kunda et al. (2010) build upon the observation that CwA prefer the former over that latter.

For an abstract hardware image understanding system, how can one determine whether it operates with visual patterns directly (being a pictorial-level representation system) or use a logic forms layer where information extracted from an image is represented “verbally”? Usually, the latter system is much more flexible and robust to image deviations. For a simpler object identification task, there are two classes of approaches:

1. Given a database of images of candidate objects, compare its records with the given image within the sliding window till we get a high value of pixel similarity. In case of high similarity of a database image of a given object with a certain area of the image being recognize, we conclude about the respective recognize object. This kind of system is close to Google Image Search, when given an image, the system attempts to find a similar one, without deep interpretation.
2. Given an ontology of features of objects to be identified, we first ascend from the level of pixels to the level of presentation of these features as logic forms, and then try to satisfy the “verbal” definitions of these objects. This approach is much less sensitive to noise in the image, to how an object can be viewed, illumination conditions etc. Also, this approach is much more efficient since a rule system and an ontology is much more compact than a database of sample images. Such systems are employed in abroad range of applications from medical to driver-less cars.

Hence from the engineering standpoint, a verbal system is much for advantageous than a pictorial, non-verbal, operating with images directly without an upper abstraction layer.

Evidence from neuropsychology has suggested that visual and verbal semantic memory are somewhat dissociated, in that brain lesions can selectively impair the use of one or the other (Hart and Gordon 1992).

In the n-back task (Sect. 2.2, Kirchner 1958), a subject is presented with a sequence of stimuli and asked whether the current stimulus matches the one shown n steps ago. The variable n can take the value of one (respond “yes” to any succession of two identical stimuli), two (respond “yes” to any stimulus matching the one presented two steps back), and so on. Stimuli can vary as to their content and presentation, such as letters presented visually or auditorily, pictures, etc.

For CC the n-back task is thought to recruit verbal rehearsal processes in working memory (i.e. phonological verbal representations), among other executive resources (Smith and Jonides 1999). Recent fMRI studies have shown that, while behavioral measures on the n-back task may be similar, there can be significant differences

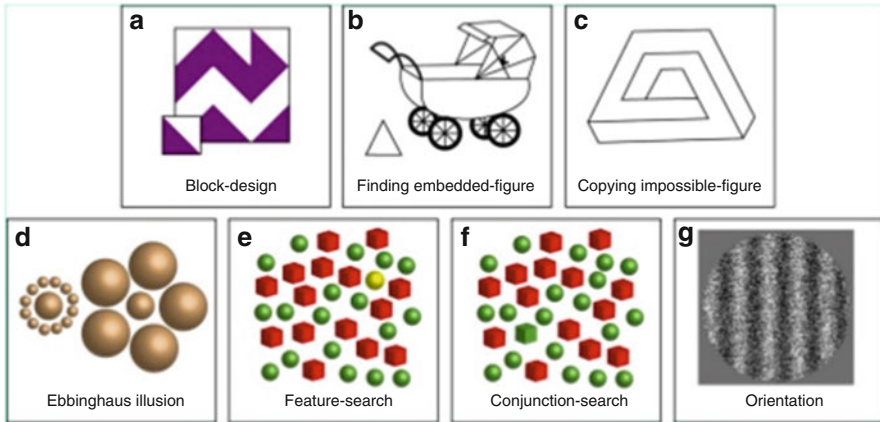


Fig. 2.22 Cognitive strengths in autism

in patterns of brain activation between CwA and CC. In one study using stimuli of visually presented letters, the autism group showed less brain activation than controls in left prefrontal and parietal regions associated with verbal processing and greater activation in right hemisphere and posterior regions associated with visual processing (Koshino et al. 2005). In another study using stimuli of photographs of faces, a similar decrease in left prefrontal activation was found in the autism group (Koshino et al. 2008). These studies suggest that individuals with autism may be using a visual strategy for the n-back task, whereas controls use at least a partially verbal strategy.

Visual strength in autism is depicted in Fig. 2.22. On the top, left to right: Block Design part of the Wechsler test of intelligence, Locating embedded figures, copying impossible figures. On the bottom: Identifying target size in Ebbinghaus illusion, Finding the odd-man-out in cluttered displays whether the target is defined by a single feature or a conjunction of features, tolerating higher levels of noise in determining an object orientation.

Weak Central Coherence account hypothesizes that individuals with autism have a limited ability to integrate detail-level information into higher-level meanings, or are at least biased towards local instead of global processing (Happe and Frith 2006). This trait is presumed to account for some of the stereotyped patterns of behaviors and interests in individuals with autism. These observations can also be explained under the Thinking in Pictures hypothesis by enhanced visual attentional strategies that could arise from a bias towards pictorial representations. Other evidence for Weak Central Coherence often includes verbal tests, such as deficits in homograph pronunciation in sentence contexts (as cited in Happe and Frith 2006). These tests, while measuring local, word-level versus higher-order, sentence-level processing, can also be interpreted as tests of verbal reasoning skills, which would be impaired under the Thinking in Pictures account.

2.5.7 *Joint Attention Family of Accounts*

Joint attention, or coordinated attention between social partners to share interest in entities, objects or events, is an essential PwA deficit. Reduced joint attention in infancy is correlated with an autism diagnosis. At the same time a range in joint attention deficits among PwA predict development across a range of cognitive domains. Joint attention includes two types of behaviors, initiation of joint attention and response to it, which may exhibit independent but related development steps and associations with other domains. Communities of default software agents do not have joint attention and have to be coded explicitly to be capable of perceive stimuli in a coordinated manner. Agents require an interaction protocol or a meta-agent to control the cognition efforts and obtain the most reliable results; it is hard to imagine if the agents can derive such protocol as learning results.

According to social-cognitive theory of joint attention, it is yielded by understanding of others' intentions. At the same time, according to the parallel and distributed processing model of joint attention, it develops with increasing representational skills. The evidence that joint attention deficits are caused by face-to-face difficulties is rather weak. This evidence is supported by associations between joint attention and developmental levels, which backs up the parallel and distributed processing rather than the social-cognitive model.

There is a popular opinion that initiation of joint attention is more of a core difficulty in autism than response to joint attention, since it may be more consistently impaired in the course of life of a PwA. However, when thoroughly measured, a response to joint attention may also be impaired across development. The evidence that starting of joint attention is more of a core deficit than responding to it is rather weak.

Joint attention is a pivotal skill that novices can use to acquire information from others – it is related to subsequent development across a range of domains for CC and CwA. Individual differences in joint attention among people on the spectrum are predictive of adaptive skills, symptoms, social functioning, linguistic skills and cognitive development.

An associations between early joint attention and subsequent development are often considered as evidence for the social-cognitive theory of joint attention where the development of joint attention from simpler social behaviors (such as face-to-face engagement) reflects an emerging understanding of others as intentional agents that in turn initiates a subsequent symbolic development (Fig. 2.23).

Alternatively, rather than arising from and being defined by an understanding of others' mental states, joint attention may not initially reflect social understanding but may lead to social knowledge (Fig. 2.24, Gillespie-Lynch 2013). According to the parallel and distributed processing model of joint attention, it arises from an increasing ability to integrate information about oneself, another and the conjunction of the self and other in relation to an external object (triadic relations). The key distinction between the two models is the relative importance of understanding another person's mind versus the importance of practice representing triadic relationships.

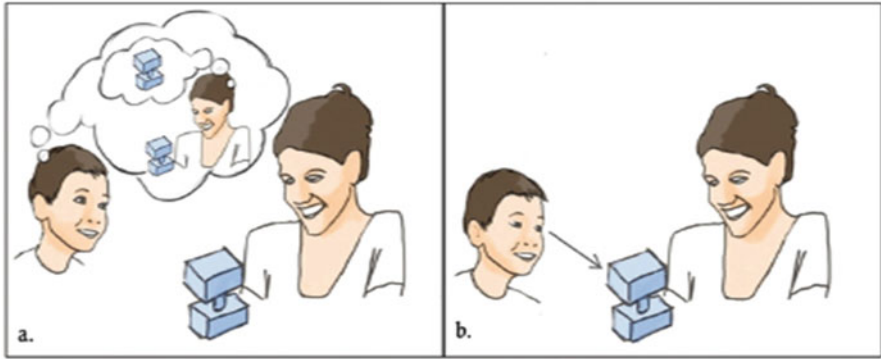


Fig. 2.23 The child turns to attend to the object because he realizes that the adult has communicative intent

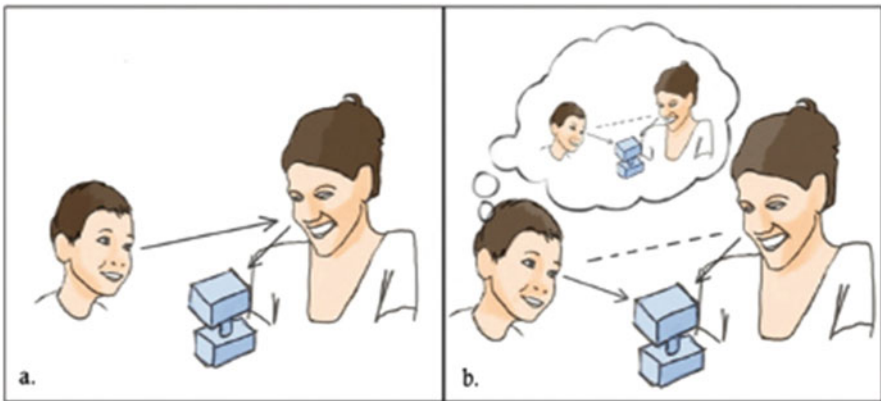


Fig. 2.24 Under parallel and distributed processing model of joint attention, the child practices representing triadic relations by engaging in joint attention

Passing a ball, a human involves a triadic relation between herself and her intent to have a peer grab the ball, the intent of the ball receiver and the ball itself (Fig. 2.25). Learning triadic relation can be a substitute for learning the actual mental world if there is a difficulty understanding the latter.

2.5.8 From Intent to Symbolic Representation

The brain can operate as an analogue or symbolic solver. Literature on brain research does not explicitly differentiate between these two classes of solvers that makes the discussion not as concise as desired. We will now define these classes of

Fig. 2.25 Triadic relation between two persons and the ball



solvers to better explain what are the symbolic operations in the brain. To control the movement, an analogue system needs to solve a certain equation, and it is implemented as a neural subsystem which is described by this equation, plus a measurement component which links the internal analogue solver with external sensors and control components.

Conversely, a symbolic solver has symbols for external objects which it comprehends and controls, and also symbols for relations between these objects. To make a control decision, the internal solver manipulates these symbols to arrange them in a position that can be interpreted as a control scenario.

As the ability to form symbols emerges, a child needs to connect her inner affects (intent) to symbols to create meaningful ideas, such as those involved in functional language, imagination, and creative and logical thought. The meaningful use of symbols usually emerges from earlier and continuing meaningful (affect-mediated) problem-solving interactions that enable a toddler to understand the patterns in her world and eventually use symbols to convey these patterns in thought and dialog.

Without affective connections, symbols like action plans are used in a repetitive (perseverative) manner (e.g., scripting, echolalia). The capacity to connect affect to action plans and symbols is likely part of a larger transformation of affect. The infant goes from global and/or catastrophic affective patterns (in the early months of life) to reciprocal ones. The capacity for engaging in a continuous flow of reciprocal affective interactions enables the child to modulate mood and behavior, functional preverbal and verbal communication, and thinking.

It also enables more flexible scanning of the environment because the child gets feedback from what he sees and, based on that feedback, explores further. There is, therefore, more integrated visual-spatial and motor functioning because intense global affects push for discharge and vigilant or overly focused or highly distractible

Fig. 2.26 Trying to attract attention



visual-motor patterns, whereas long chains of reciprocal interaction support back-and-forth exploration of the environment and, therefore, flexible, broad, integrated perceptual patterns.

In facilitating back-and-forth interaction with the environment, the capacity for reciprocal interaction also facilitates associative learning. Associative learning (building up a reservoir of related experiences, thoughts, feelings, and behaviors which give range and depth to one's personality, inner life, and adaptive responses) is necessary for healthy mental growth. Its absence leads to rigid, mechanical feelings, thinking, and behavior patterns, as are often seen in CwA (Fig. 2.26).

Processing deficit occurs early in life, it can undermine CwA capability to engage in expectable learning interactions essential for many critical emotional and cognitive skills. For example, CwA may have more difficulty causing usual expected interactions from his parents. CwA may perplex, confuse, frustrate, and undermine purposeful, interactive communication with even very competent parents. Without appropriate explicit introduction of the rules of interaction, he will be unable to either comprehend these rules of complex social interactions himself or to develop a sense of himself. These may include implicit social functions and social "rules," and developing friendships and a sense of bond with his peers, which are learned mostly between the age of 12 and 24 months (Emde et al. 1991). By the time CwA with processing difficulties officially diagnosed, his challenging interaction patterns with his peers have already excluded him from important learning sessions and may have amplified his difficulties. The loss of engagement and intentional, interactive relatedness to key caregivers may cause CwA to withdraw more idiosyncratically into his own world. CwA then becomes even more aimless and/or repetitive. What later looks like a primary biological deficit may, therefore, be part of a dynamic process through which the child's lack of affective reciprocal interactions has

intensified specific, early, biologically-based processing problems and derailed the learning of critical social and intellectual skills.

2.5.9 *Steps in the Normal Development*

An early and continuing component of shared attention involves attention to the world outside of one's own body with rhythmic, affectively-mediated motor patterns of perception. For example, in the early months of life, babies can be observed to move their arms and legs in rhythm to their mother's voices (Condon and Sander 1974; Condon 1975). Soon children begin integrating what they hear and see (Sect. 7.3). By 4–5 months, one can readily observe synchronous movement in rhythm with mother's affective communication via her voice, facial expressions, or body movements. As development proceeds, reciprocal gestural, vocal, and verbal communication generally occurs in an interactive rhythm. A consequence of this may be the observation that it's harder to remember or understand verbal phrases presented in a monotone than in an affective rhythm.

The second functional developmental capacity is *engagement*. For an infant to engage with a caregiver requires joy and pleasure in that relationship. When that's not present, children can withdraw and become self-absorbed. For children who have processing problems, it may be much harder to pull them into that joyful relationship.

(Greenspan 2001) observed that most children can be pulled into various degrees of relating through therapeutic work that works with processing differences and relationships of CwA at the same time. Engagement and relating appears to be a very flexible capacity. While language and certain cognitive functions may improve slowly for some children, the capacity for warmth and relatedness seems to progress more readily.

The third functional developmental capacity is *two-way purposeful communication*. Two-way communication and affective reciprocity obviously requires affect to provide the "intent." When an infant reaches for his daddy to take the rattle off his head or hand it back to him, or gets into a back-and-forth smiling game, one clearly sees affect (intent) guiding the interaction (i.e., the infant wants that rattle). According to (Greenspan 2001), Piaget thought that means-ends relationships occurred at 9 months with motor behavior (i.e., an infant reaching and pulling a string to ring a bell).

The baby's affective probe occurs much earlier than the motor probe. Causal affective behavior occurs earlier than causal large muscle motor behavior. First we see a smile causing a smile, a frown getting a frown. Later on, we see the baby reach for and give back objects. At this stage as well, the affect diathesis is occurring, now transforming relating into two-way, affective communication (rather than just joyful interest in the caregiver).

The fourth level of transformation occurs between 10 months and 18 months. It involves the development of a range of new capacities, all related to the toddler's ability to *engage in longer sequences of affective reciprocal interactions* with clear intent or problem-solving goals and the ability to perceive and interact in these larger patterns. This transformation enables the toddler to form a more integrated sense of self, integrate affective polarities, social problem-solve, and broaden visual-spatial and auditory processing abilities.

In this fourth stage, the child is also beginning to integrate affective polarities. Early on, infants tend to have extreme affect states—all happy or gleeful or all sad—but by 18–19 months we see children begin to shift affect states more readily and actually integrate affect states such as happiness and sadness, anger and closeness.

They can be angry and then seem to want forgiveness and make up. When playing with a 13-month-old child, it feels like if he were angry and had a gun, he very well might pull the trigger. With the 18-month-old, it feels like he integrates his caring and anger. He might look mad and feel connected and warm at the same time. One can often feel the quality of these affect states when playing with infants and toddlers at different ages.

At the fifth level, transformations involve the affect system investing ideas. For example, in pretend play, affects or desires drive the theme (dolls hugging or kissing) as well as functional language (“I’m hungry,” “I’m angry,” “Give me that.” “Look! I want to show you something.”). Functional language, whether it’s on a need basis (“Give me juice.”), or at a collaborative “show you this or that,” or sharing opinions “I didn’t like that” basis, is very different from simply labeling objects or pictures.

Here is also where IQ tests fall down. IQ tests do not differentiate well enough between the different uses of ideas and language, such as between pragmatic language or creative and abstract thinking versus a simple using language to label objects or for rote, memory-based problems.

At the sixth level of transformation, a child builds bridges between affectively meaningful ideas. Establishing reality-testing, a symbolic sense of self, and moving back and forth between a fantasy to reality depends on reaching this next level. For example, critical to establishing reality-testing (which is the basis for later abstract thinking) is an affective “me” intending to do something with an affective “other.”

There has to be an interaction involving affect between the “me” and the “other” to establish a psychological boundary (i.e., an affective sense of what’s “me” and an affective sense of what’s “outside me”). That boundary doesn’t come out of reading books or out of doing puzzles. It comes from interactions involving the exchange of affective gestures and symbols. It comes out of interactions such as “I want this.” “No, you can’t have it,” or “Yes, you can.” In addition, these interactions must be part of a continuous flow of back-and-forth affective gestures. Islands of affective interactions followed by self-absorption leads to an “in and out” affective probe or rhythm with the external world (reality). A stable sense of reality requires a continuous interactive relationship to the significant “others” in our lives. Abstract and inferential thinking grows from a solid reality boundary.

2.5.10 Accounts of Autism and Corporate Environment

Having compared CwA with controls, we observed a number of ways the deficiency of the former can be described and represented as a series of models. A control child have an ability to execute well each of these models. Is it true for a community of agents (a multiagent system, an organization, a company) each of which possesses ToM, proper executive function, proper central coherence, and other reasoning capabilities? The answer is “no”. With a certain motivational structure of agents, which can be referred to as “bureaucratic”, a multiagent system of capable agents evolves into an entity whose behavior is rather abnormal. In this section we consider various accounts of autism in the context of multiagent systems and demonstrate that multiagent systems are frequently closer to CwA than to CC in terms of the accounts of this chapter.

Once capable in individual capacity agents (human and possible automated) are functioning in the framework of an organization (a company), their motivational and knowledge structure is such that as an overall system they frequently become totally unintelligent (from the standpoint of an external observer, a user of this company). This is because the agents (of a company customer support) have conflicting goals: to impress the user that they want to satisfy his requests on one hand, and to save company’s resources on the other hand. At the same time, the customer support agents have their personal goals to save their own resources (Sect. 4.1.2). Having these conflicting goals, the multiagent system impresses their users and peers as the one with corrupt reasoning patterns. We will share the examples from the personal experience of the author.

A financial company providing online Tax services, H&R Block assists its customers with filing tax returns online. Driven by a broad range of government regulations, H&R block is concerned with a lot of issues of compliance with the regulations, including privacy, security, disclosure to tax officials, and others. Nevertheless, they loose online customer tax return data and get away with this. Maintaining their focus on less important issues (from the customer viewpoint), they are unable to retain the customer data worth of hours of work to re-input. Nothing can be worse from the customer viewpoint. Their customer support is unable to address this problem either, citing the split between H&R Block Online Services that do not have their own customer support and H&R Block customer support that is detached from the Online Services. Hence the way some multiagent systems are frequently formed show the lack of central coherence.

Another example is a Citibank scenario:

- A customer applied for a credit card
- Citibank responded that the application was denied
- In a month Citibank sent a bill with an annual fee for this credit card (this card was never received and never activated).
- In 2 months Citibank sent a bill for the unpaid annual fee plus the late payment charge for this fee because this annual fee was never paid (because the card was never issued, according the customer).

- The customer becomes aware of this incident and tries to cancel the non-existing cards and dispute the fees. This process takes months and months.

There is an unlimited amount of documents on the web reporting an unreasonable behavior of multiagent systems in the form of corporations, interacting and communicating with single agents (individuals). Taking into account that each agent of this multiagent system is a rational agent (a control human with full-functioning systems described in autistic accounts, Sect. 6.2), we express this phenomenon as *distributed incompetence*. Although the reasoning about knowledge community analyses how knowledge is multiplied if agents are combined into multiagent systems, in this book we observed the opposite phenomenon when multiagent system is formed in a way which reproduces autistic accounts.

Hence having drawn the classes of autistic reasoning → behavior and control reasoning → behavior, multiagent systems in the form of corporations mostly belong to the former class. Most of times they do not follow common sense and demonstrate deviations described by a number of autistic accounts presented in this chapter.

A broad range of features of autistic cognition can be observed in multiagent system with non-trivial motivational patterns. Corporate environment is a good example of such system: frequently, agents are not uniformly motivated to perform their functions, or not motivated at all. Some bureaucratic structures clearly display certain features of autistic cognition. This is an example for how an external observer describes behavior of such system in terms of how its representative describes his mission:

The only thing I am authorized to do is to tell you that I am not authorized to do anything.

2.6 Autistic Linguistics

2.6.1 *Cognitive Skills and Processes Involved in Making Sense of Text*

Reading for understanding is especially challenging for CwA, although CwA usually demonstrate well-developed word recognition skills, but their reading comprehension is severely impaired (Nation et al. 2006). An extreme profile of word recognition skills developing in advance of reading comprehension, termed *hyperlexia*, is associated with autism (Grigorenko et al. 2003). The ability to decode words has a neural basis: hyperlexic reading is caused by involving both the left hemisphere's phonological and the right hemisphere's visual systems (Turkeltaub et al. 2004). Computers can also be referred to as hyperlexic readers: it is so easy to program them to recognize words and so difficult to make them recognize meanings of individual words and especially phrases. Text comprehension is extremely complex problem for a computer which some state-of-art NLP systems have only tackled in a very limited manner.

CwA tend to demonstrate well-developed word recognition skills in absence of corresponding skills in constructing meanings. In CC, such ability as text integration, metacognitive monitoring (Sect. 4.1.3), reasoning and working memory all contribute to variability in the reading comprehension skills.

Inference making is an especially difficult skill for both CwA and computational linguistic program to acquire. It has been suggested for CC by Perfetti et al. (2005) that limited processing resources or working memory, not knowing when to draw inferences, and failure to monitor comprehension for text coherence (i.e., focusing on words rather than global meaning) all lead to the problems in text comprehension. Comprehension monitoring is prompted by a high standard for text coherence: readers who strive to make sense of what they read will be more likely to monitor and repair their understanding than readers with a low standard of coherence, the latter will fail to detect inconsistencies at the sentence level.

Propositional, non-linguistic verbal representations are necessary to form false belief concepts. Propositions can be thought of as the building blocks of a low-level representational system, where a single proposition takes the form of a related set of symbols that carries semantic meaning. Linguistic representations occur at a much higher level of abstraction than propositions and are explicitly tied to a particular language.

There are hypotheses that false belief impairments in autism has a low-level representational origin; the development of false belief concepts has been described as requiring, for instance, the representation of “complements” (Hale and Tager-Flusberg 2003) or “meta-representation” (Leslie 1987 and Sect. 4.1.3).

Hale and Tager-Flusberg (2003) demonstrated that training on sentential complements leads to improved ToM performance, and that this linguistic influence is highly specific and did not extend to children trained on another type of embedded construction, namely relative clauses. Traditionally, a complement is a constituent of a clause, such as a noun phrase or adjective phrase, that is used to predicate a description of the subject or object of the clause. As to examples of sentential complements, let us consider the following:

1. Mike read *the newspaper*. (direct object complement of the verb)
2. Make gave it *to me*. (indirect object complement of the verb)
3. Peter put it *in the suitcase*. (must-present locative complement of the verb: it is not enough to just say, *Peter put it*.)
4. This question seems *quite ambiguous*. (adjective phrase complement of the verb).

In order to represent a false belief, one must have some mechanism for representing a belief as being held to be true in one context (e.g. by a character in a story), as well as the property of a belief being false in a different context (e.g. in the story itself). Recent modeling work in cognitive architectures has found that this type of information can be represented within a propositional logical system (Bello and Cassimatis 2006). It is hard for CwA to understand the narrative text structure because they are unable to determine character’s motives or identify with characters’ emotions or perspectives due to their ToM limitations.

Especially when reading longer texts, memory dysfunction may contribute to reading comprehension deficits. Connecting sentences together to construct a global understanding requires substantial memory capacity. At the time of writing, rhetoric parsers require more than 100 times more memory and processing time compared to sentence-level syntactic parsers. Although high-functioning CwA have strengths in formal memory, memory unattached to interpretation of symbols, they have memory impairment due to poor use of organizational strategies, especially when the information is complex and requires the creation of an organizational structure to facilitate memory (Williams et al. 2005). Reading for understanding requires individuals and machines to construct an organizational structure and schema to aid memory. In addition to memory deficits and poor organization strategies, a tendency to focus on details makes it challenging for CwA to perform discourse-level analysis. For computer rhetoric parsers, a high-dimensional training setting requiring extensive morphological and syntactic information is required.

In terms of semantic processing, CwA can be characterized as “speaking like foreigners”. When CwA selects words they do not understand the logic of words and instead speaks by separate thoughts. At the discourse level, CwA do not understand the rhetoric structure of a sentence, how a sentence starts, develops and stops. When a person speaks a foreign language, she expresses her thoughts as a combination of words in his native language, translated into this foreign language on a one-by-one basis. This is similar to how CwA forms their sentences. CwA speaks by separate units each of which expresses a separate feeling.

ASD is characterized by both lower-order behaviors such as motor movements and higher-order cognitive behaviors such as circumscribed interests and insistence on sameness. Both of these are manifest in language as well. Van Santen et al. (2013) reported an automated method for identifying and quantifying two types of repetitive speech in ASD: repetitions of what child him or herself said (intra-speaker repetitions) and of what the conversation partner said (inter-speaker repetitions, or echolalia).

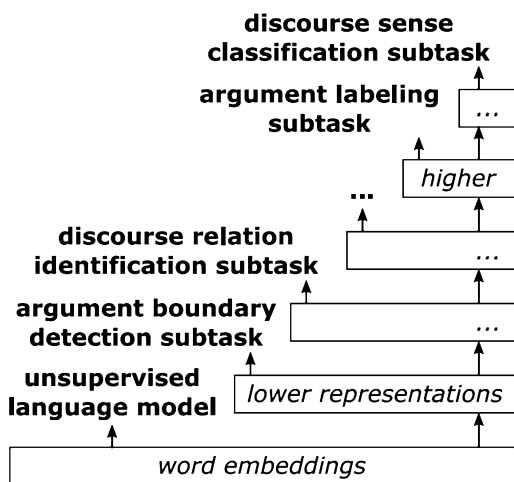
Rouhizadeh et al. (2015) automatically assess the presence of repetitions in language, specifically at the semantic level, in children’s conversation with an adult examiner during a semi-structured dialogue. CwA are expected to talk about fewer topics more repeatedly during their conversations. The authors hypothesize that a significantly higher semantic overlap ratio between dialogue turns in CwA compared to those with typical development. In order to calculate the semantic overlap at different turn intervals for each child, we apply multiple semantic similarity metrics (weighted by child specificity scores) on every turn pair in four distance windows. The result of this analysis is that the CwA group had a significantly higher semantic overlap than the CC group in most of the distance windows. The patterns of semantic similarity between child’s turns could provide an automated and robust CwA-specific behavioral marker.

Since individuals with autism are hypothesized to have weak central coherence then one would predict that the clinical groups would have difficulty integrating information globally so as to derive full meaning. Two experiments were designed by Jolliffe and Baron-Cohen (2000) to test global coherence. The first experiment

investigated whether CwA could arrange sentences coherently. The second experiment explored if CwA are less able to use context to make a global, discourse-related inference. CwA groups have lesser skills to arrange sentences coherently and to use context with the aim at a global inference. The results confirm the impaired global coherence of CwA. Arranging sentences and making global inferences are highly inter-dependent, so central coherence is required to complete these different tasks in a coordinated manner. Of the two clinical groups, the autism group had the greater deficit.

It is well known in computational linguistics that to automatically derive rhetoric structure, or to validate text coherence, all lower level linguistic information, including morphology, syntax and semantics, needs to be taken into account. Instead of depending on mostly hand-engineered sparse features and independent separately developed components for each rhetoric parsing subtask, (Weiss 2015) proposed an integrated approach for text level discourse parsing relying on deep learning. Firstly, each of the discourse parsing subtasks, such as argument boundary detection, labeling, discourse relation identification and sense classification, need to be formulated in terms of recurrent neural networks (Elman 1990) and similar derivable learning architectures. To benefit from their ability to learn intermediate representations, the layers of this neural network will be partially stacked on top of each other, such that the last but one layer (i.e. output layer) for each subtask is shared with other subtasks. By placing increasingly more difficult subtasks at different layers in one deep architecture, they can benefit from each others intermediate representations, improve robustness and training speed. Figure 2.27 combines unsupervised training of word embeddings with the layer-wise multi-task learning of higher representations and illustrates our goal of a unified end-to-end approach for text-level discourse parsing utilizing different layers of representations.

Fig. 2.27 Illustration for how a multi-compartment approach for text-level discourse parsing with multi-layer multi-task learning of higher representations can work



2.6.2 *Grammar and Affect*

Even grammar, which Chomsky and other linguists have assumed to be innate, depends on affect and affective interactions to become functional. CwA frequently verbalize nouns in a repetitious way (“Dog, dog, dog.”). If the intervention can get them affectively interactive, however, they can often learn to use proper grammar. For example, a child is opening and closing a gate. We get stuck behind this gate. If they push us away, they are becoming purposeful.

Purposeful behavior that is stimulated by an affect creates a foundation for the purposeful and meaningful use of words. The child who pushed us away and said nothing at some point will say “go” while doing this. We may then say, “Where go? Where go?” We might further say, “Should we go away or stay? Away or stay?” The child may say, “Go away, go away.” Following this dialog, CwA is using the correct grammar. From the viewpoint of the corpus of research on autism and affect, one might disagree with (Chomsky 1966) when he writes that grammar is largely innate and that only life experience in a broad sense led to turning on the language switch in humans. As we discussed in the previous section, grammar requires certain types of affective experience, and specific grammar features are correlated with special forms of affect and the features of the Theory of Mind. Affective reciprocity is needed to create purposeful action and then related purposeful symbols or words. The affect, by providing intent, enables the components of language to align (e.g., “open door” versus “door, door, door.”). Many investigators may have missed the importance of affective reciprocity because it occurs routinely with most infants and toddlers and their caregivers.

Reciprocal affective interactions also influence the basic grammar and semantic aspects of language. We have found, for example, that children not capable of reciprocal affective interactions (e.g., children with autistic spectrum disorders), tend to use words ungrammatically, repeating nouns or verbs in a perseverative manner.

Interestingly, if we try to simply correct their grammar, it doesn’t work very well. They make progress, however, when we first help them engage in reciprocal affective gesturing and use their affect and gesturing purposefully (e.g., we get stuck behind the door they are opening and closing and they eventually learn to push us away). At that point, they begin to align their verbs and nouns in a grammatically correct manner—“Daddy, go!” or “Leave me alone.” We observe the same patterns in children from deprived backgrounds, such as orphanages. Whether the intrusions are environmental or biological, it appears that a prerequisite for correct use of grammar is the purposeful use of affects in interactive relationships. This fact may have been missed by linguists who suggested grammar was largely innate and simply turned on or off by global features of the environment because it’s easy to take reciprocal affect cueing and other preverbal aspects of communication for granted. They occur so regularly.

It's only when we find circumstances where they don't occur that we can see their true impact. Similar to grammar, the meaning of words, both the semantic and pragmatic aspects are also imbedded in the earlier reality of gestural interactions, which are used to explore and know the world. The literal meaning of a word or concept, for example, the concept of a door or a table or a mommy or a daddy is first known through gestural interactions with it. The capacity to form the word is then linked to what is already partially known. The known entity takes on additional meaning through context and further emotional experience with it. Therefore, both the literal and the relative meaning of words and concepts emerge from reciprocal affective interactions which provide the foundations and context for meanings.

The capacity for long chains of reciprocity and the basic capacity to plan and sequence actions may also support the ability to sequence words or ideas and eventually concepts in a speech, essay, or debate, or simply a long conversation. Sequencing ideas relates both to this basic ability to abstract meaning from earlier preverbal experiences and then sequence them meaningfully.

2.6.3 *Understanding Metaphors*

Highly abstract or figurative metaphors are problematic for certain groups of language users amongst CwA. As a result of impairment in communication, social interaction and behavior, CwA are characterized by atypical information processing in diverse areas of cognition (Skoyles 2011). CwA experience difficulties when a figurative language is encountered. Happé (1995) describes:

A request to “Stick your coat down over there” is met by a serious request for glue. Ask if she will “give you a hand”, and she will answer that she needs to keep both hands and cannot cut one off to give to you. Tell him that his sister is “crying her eyes out” and he will look anxiously on the floor for her eye-balls . . .

The reduced skills of CwA to understand metaphors in language communication as well as figurative language is obviously an obstacle in communication, since most people “think in metaphors” and a language system is inherently figurative (Lakoff and Johson 1980). The growing demand to overcome this barrier has led to the investigation of possible ways in which NLP can detect and simplify non-literal expressions in a text.

The *simile* is a figure of speech that builds on a comparison in order to leverage certain attributes of an entity in a striking manner. A simile compares one entity with another entity of a different kind. Simile is used to make a description more emphatic or vivid (e.g. *as fast as a cougar*).

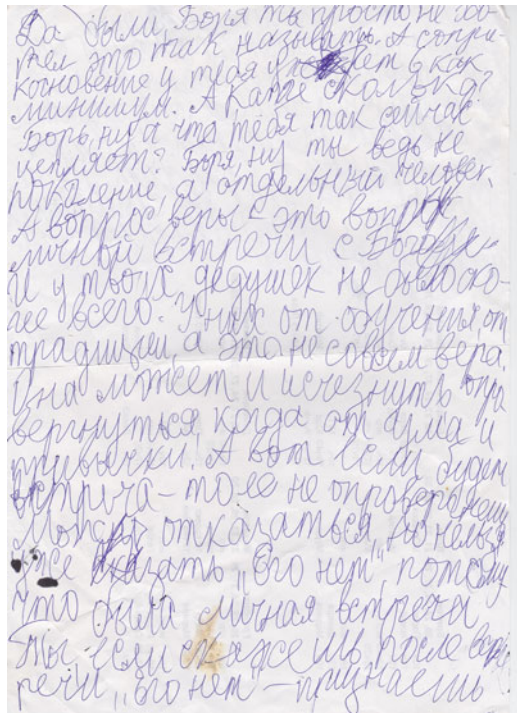
CwA and message understanding systems show almost no impairment in comprehending the similes which have literal meaning (Happé 1995). This relative ease in processing is probably due to the fact that metaphors in the form of comparison contain explicit markers (e.g. like and as), which evoke comparison

between two things in a certain aspect. With regard to understanding figurative similes, Hobson et al. (2013) describes in the case of fifteen-year-old:

He could neither grasp nor formulate similarities, differences or absurdities, nor could he understand metaphor.

One of the most obvious markers of similes, the word *like*, could be a source of a lot of misinterpretations (Niculae and Yaneva 2013). For example, ‘like’ could be a verb, a noun, a preposition, or Facebook attribute, depending on the context. Given that autistic people have problems understanding contexts (Skoyles 2011, Sect. 6.4), how would an autistic reader perceive the role of ‘like’ in a more elaborate and ambiguous comparison? Another possible linguistic reason for the corrupt understanding of similes might be that *like* is used ambiguously in many expressions which are neither similes nor comparisons, such as *I feel like a soup* or *I feel like something goes wrong a wrong way*. Even if the expression does not include such an ambiguous use of like, there are other cases in which a CwA might be confused. For example, if the simile is highly figurative or abstract, it may be completely incomprehensible, such as in the example of *A love is like a flame* (Fig. 2.28).

Fig. 2.28 An example of autistic writing on philosophical topics. Hand support is necessary to help in writing. Text includes answers to certain questions and some associated thoughts



2.7 Our Account of Autism: Reasoning Engine → Behavior

Having outlined most popular accounts of autism, we intend to formulate the one most valid in terms of an artificial computational system which controls a behavior of a human or robot in the real world. This account will not include neural or genetic considerations: it will be brain component – neutral. Whereas most accounts, including computational ones, try to combine psychological, behavioral, cognitive, neural, genetic and even philosophical considerations, we prefer to have a model fully formalized and self-contained (Fig. 2.29, Minshew and Goldstein 1998). Such model should be viewed as an engineering design model, providing sufficient details so that a software engineer can build it from our specification. This specification should be formally consistent and do not contradict to the experimental observation of autistic cognition and behavior.

The desired features of such system are as follows:

- It should only take into account the details of what we know about human brain and its specifics under autism related to reasoning processes.
- It should treat the features of behavior as thoroughly as possible, and explicitly link behavior to reasoning. Only forms of behavior which can be expressed concisely are used.
- The intelligence, problem solving and communication skills are formally defined and are formalized in as much degrees as possible. Behavioral capabilities are taken from the studies within the above accounts and beyond them.
- No hypotheses about meta-functioning, interaction between hypothetical components, hypothetical control scenarios of these components are relied upon.

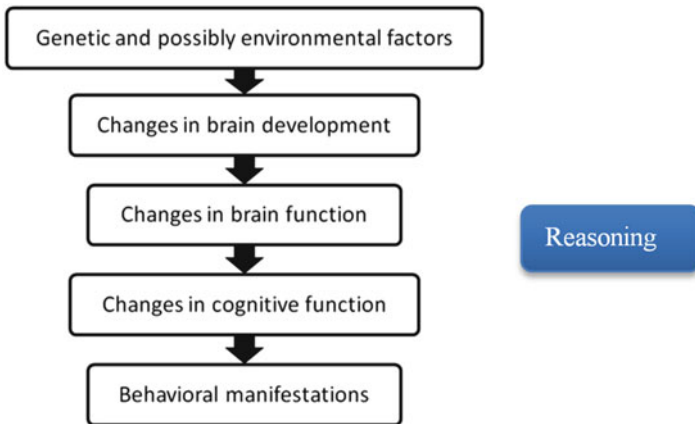


Fig. 2.29 Etiology of autism

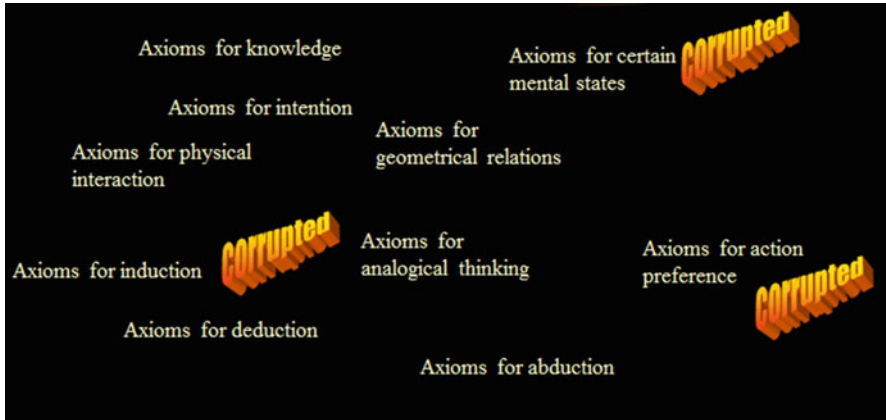


Fig. 2.30 Corruption happens at the level of individual axioms, responsible for a particular reasoning domain

Once these features are approved, the nucleus of our account becomes fairly compact and self-contained:

1. Specific behavior is caused by a deviation in a reasoning system;
2. Deviation in a reasoning system is caused by lack of certain axioms.

Then the treatment methodology is to teach these missing axioms as rules once they are identified.

In our account of autistic reasoning, corruption happens at the level of axioms (Fig. 2.30). From the theoretical reasoning standpoint, we assume that the reasoning machinery itself is functional and the only cause of a lack of reasoning skills in a given domain is a lack of a respective axiom.

As a first example, we consider the missing axiom “Other people have intentions”. Without this axiom, children ignore questions “what he wants”. Once the child is explained that other people have such “things” as desires, wants and intentions, which can come and go, this child starts answering the above question. This means that the axiom is *acquired*, when this question is answered about an arbitrary intent.

Proceeding to another example, we state that to be able to generalize from samples and to formulate rules, an individual or a reasoning machine needs an axiom of induction. If an individual or reasoning machine cannot perform generalization from samples, he is missing an axiom of induction. In this case, the range of skills generally referred to as ‘machine learning’ is missing.

An intelligence machine needs to acquire axioms to answer questions, in particular, the axioms for intend and for generalizing from samples. Before such axioms are fed into this machine, it is unable to answer questions in these domains. After the acquisition of the axioms, the machine becomes capable of answering these questions.

How to figure out which axiom is missing in a give child? If, having certain axioms disabled, an artificial reasoning system displays the same behavior (in particular, answers questions and fails to answer questions in a similar manner) as a given individual, then we conclude that this individual is missing this axiom.

Each CwA can then be represented as a profile of missing vs intact vs acquired axioms. What can be observed is that more complex derived axiom can be missing when the basis, simpler axiom is present, but not the other way around. We will evaluate this observation in Sect. 9.10.

2.8 Discussion and Conclusions

We enumerated the generally accepted accounts of autism and showed their strong and weak points. On the positive side, they cover a broad range of features of autistic behavior and cognition and link them with neural layers and mechanisms, as well as genetics and cognitive components. On the negative side, these accounts are incomplete as information systems, a lot of their schemas are informal and not necessarily plausible. It is unclear, if one can build a computational system which corresponds to a given account, so that its output can imitate the described behavior.

Each account of autism focuses on a specific features of reasoning and cognition, and explains how it affects the autistic behavior and skills. Each account splits reasoning and cognition into different components and then hypothesizes which components are intact and which are broken. Each account then attempts to explain the peculiarities of autistic behavior given the functionality of the broken components. Since these components and the addressed features of behavior overlap, each account positions itself among other accounts with similar components and features of behavior.

For example, a text understanding system includes morphological, syntactic, semantic, pragmatic and discourse components. The behavior of text understanding system can be the way its answers questions, and following accounts explaining its malfunctioning can be plausible:

- System intent to understand questions is broken
- Particular processing level is not tuned well, so some words in the input questions are missed
- Communication between processing levels is broken, so answering of Boolean/conjunctive queries is incorrect
- Control of how different classifiers are combined in a hybrid system is not adjusted well, so it cannot answer compound queries

Similar structure can be applied to image, video, sound, abstract pattern recognition system and recognition in other modalities.

Multiple accounts of autism illustrate that there are multiple psychological characterizations of autism. These accounts share some commonalities and they are not mutually exclusive at all. Hobson's theory can be viewed as explaining where

ToM abilities are coming from, genetically determined module or being develop out of learning to communicate. ToM's theory-theory does not provide any evidence for the genetic basis of ToM corruption. Also, executive function and central coherence are presumably computational capacities of systems and as such they might be components of whatever system provides an implementation of ToM abilities.

One of our points of criticism of the current computational accounts of autism is that they attempt to describe a meta-language for implementation of reasoning instead of focusing on the object-language level. Since one can only hypothesize about the signals in the natural neural network, a formal computational model of a neural network is essentially a meta-language level model. When the activity of an artificial neural network is similar to that of a natural one, it means that the meta-language model might potentially be plausible, and nothing can be said about an object – level. For a reasoning system implemented as a neural network, its reasoning domain belongs to its object-language, and neural signals, communication protocols, which can be experimentally assessed – to the meta-language level.

There are examples in science and humanities where a phenomena is expressed using meta-language only, without employing a power of language-object. One of the purest example of it is Kafka's novel "The Trial". In this novel the author presents only a meta-level account of what is happening with a character being prosecuted; language-object level description is absent. From the scientific standpoint, his description of an observation of society functioning is far from being perfect and efficient. Similarly, neural network models of the functioning of autistic brain involves only a single layer of information processing.

Having analyzed the accounts of autism, we decided to pursue a pure computational and less intuitive, holistic account and to observe how far we can go in terms of completeness of our account, its prediction capabilities and values for rehabilitation. This account should provide a conceptual basis for improving autistic reasoning as well as a foundation for software for autistic rehabilitation.

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