Chapter 6
Reasoning Beyond the Mental World

Whereas for CwA reasoning about mental world is the key for they successful adaptation to the real world and development, other limitations of reasoning are needed to be addressed as well. We focus on various forms of reasoning and rationality and conclude which reasoning features need to be learned and in which form.

6.1 Mental vs Physical World

Mental-physical distinction is considered a fundamental cornerstone of ToM, and one that is not explicitly taught by parents or teachers. The test for this distinction involves the child listening to stories in which one character is having a mental experience (e.g., believing that the rain will start) whilst a second character is having a physical experience (e.g., getting wet from this rain). The experimenter then asks the subject to judge which operations the two characters can perform (e.g., which character can stroke the dog?). Whilst 3–4 year old normal children can easily make these judgments, thereby showing their good understanding of the differences between mental and physical entities and events, CwA have been found to be significantly impaired.

In the literature on autism, mental and physical worlds are usually considered from distinct standpoints in terms of children capability to reason about them. Baron-Cohen et al. (2001) define *folk psychology* as comprising both low-level social perception, and higher-level social intelligence.

Low-level here broadly refers to skills present in human infancy (Johnson 2000). These include being able to judge:

1. if something is a human agent, animal or neither (Premack 1990);
2. if another person is looking at you or not;

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3. if another individual is expressing a basic emotion (Ekman 1992), and if so, what type.
4. if engaging in shared attention, for example by following gaze or pointing gestures (Mundy and Crowson 1997; Tomasello 1988);
5. showing concern or basic empathy at another's distress, or responding appropriately to another's basic emotional;
6. being able to judge an agent's goal or basic intention (Premack 1990).

Higher-level here refers to skills present from early childhood and which continue to develop throughout the lifespan. These include the following:

1. Attribution of the bread spectrum of mental states to herself and others, including pretense, deception, belief (Leslie 1987);
2. being able to recognize and respond appropriately to complex emotions, not just basic ones (Harris et al. 1989);
3. being able to link such mind-reading to action, including language, and therefore to understand and produce pragmatically appropriate language (Tager-Flusberg 1989);
4. using mind-reading not only to make sense of others' behavior, but also to predict it, and even manipulate it;
5. having a sense of what is appropriate in different social contexts, based on what others will think of our own behavioral conduct;
6. having empathic understanding of another mind. This understanding includes the skills involved in normal reciprocal social relationships and in communication.

According to (Baron-Cohen et al. 2001), folk psychology domain is quite focused and narrowly defined with the focus of understanding the mental world and social causality between its inhabitants. At the same time, folk physics comprises both low-level perception of physical causality, and higher-level understanding of physical causality. Low-level here refers broadly to skills present in early human learning of th e physical world, such as the perception of physical causality (Leslie and Keeble 1987) and expectations concerning the positions, speeds and other properties of physical objects. Higher-level here refers to skills present from early childhood and which continue to develop throughout the lifespan, the entities related to mechanics (Karmiloff-Smith 1992). Similarly to folk psychology, folk physics is not expected to rely on a single cognitive process.

Both mental and physical domains:

1. are aspects of our causal cognition and are associated with causal links;
2. are acquired and/or developed in a universal way,
3. show little if any cultural variability,
4. have a specific but universal ontogenesis,
5. are adaptive,
6. may be open to neurological dissociation.

Baron-Cohen et al. (2001) employed the model that the human brain has evolved in at least two independent directions of cognition: folk psychology and folk physics. In the extreme case, severe autism may be characterized by a total lack of folk psychology (and thus “mindblindness”). Autism spectrum conditions come by degrees, so different points on the autistic spectrum may involve degrees of deficit in folk psychology (Baron-Cohen 1995). In CwA who have no accompanying mental disability (having intelligence in the normal range), the child’s folk physics would develop not only normally, but even at a superior level. AS children were functioning significantly above their mental age in terms of folk physics, but significantly below their mental age in terms of folk psychology.

Impaired folk psychology, together with superior folk physics in AS might be partly the result of a genetic liability. This is because autism appears to be heritable (Gillberg 1991), and because there is every reason to expect that individuals with such a cognitive profile could have been selected for in hominid evolution. Good folk physics would have possess important advantages in using tools and hunting skills.

Different computer systems operate in physical and mental worlds, including multiagent systems. Control systems, device drivers and auto-pilots are examples of the former world, whereas search, recommendation, decision-support and customer care systems need to simulate and take into account user intent and mental worlds of their users (Galitsky et al. 2009).

6.1.1 Autistic Generalization

Although children with ASD can be guided to make a generalization from parts to whole, they have difficulty with inference making at the abstract level. Preschool CwA can categorize animate and inanimate objects based on surface features (Johnson and Rakison 2006). CwA tend to rely on explicit rules only to support inductive inferences such as an entity that have legs versus things that have wheels. These explicit rules lead them to make some inappropriate categorizations such as classifying a table as an animal. CwA are unable to perform a metareasoning task (Sect. 4.1.3) to decide when it requires the information on a prototype or some kind of abstract representation. For example, it is hard to CwA to formulate features of animate and inanimate objects that would distinguish these objects beyond surface appearances. CwA are delayed in the process of concept formation, performing more like infants than typically developing children of the same preschool age. However CwA sometimes rely on inductive reasoning to form categories, although they did not always attend to all the defining attributes. This suggests that CwA may rely on their ability to focus on details that are salient to them, ignoring other attributes that matter. Hence CwA may benefit from guided concept formation that calls attention to those attributes that distinguish one concept from another.

Abstract reasoning skills are particularly critical for reading comprehension, especially when reading narrative text. Reading expository text, such as a set of rules or directions, or descriptions of processes, requires less abstraction than reading narrative, where readers engage cognitive processes to infer character's traits, draw conclusions, and identify causal attributes. CwA typically prefer expository text, such as science texts. This may be because they find narrative text especially challenging because it required abstract and social reasoning patterns (Randi et al. 2010).

6.2 Reasoning, Cognitive Science and Rationality

Autistic individuals, along with machine intelligence systems, are considered less rational reasoners compared to control. In this section we treat in depth the issue of rationality and explore the directions rationality of CwA can be intervened.

Traditionally, rationality is taken to be a defining characteristic of human nature: "man is a rational animal," apparently capable of deliberate thought, planning, problem-solving, scientific theorizing and prediction, moral reasoning, and so forth. "Rational" means here a rational discourse where an agent wants to arrive at justified true belief. This definition of rationality is from an era oriented toward theory. A pragmatically oriented definition extends this concept of rationality to actions. "Rational agency" can be defined (MIT Encyclopedia of Cognitive Science) as a coherence requirement:

> agent must have a means-end competence to fit its actions or decisions, according to its beliefs or knowledge representations, to its desires or goal-structure.

Without such coherence there is no agent. The main condition here is *fit* that has a logical load. If an action is performed which is not part of a plan derived to achieve a given goal, there is no fit. In this sense checking the weather before getting online and logging on to the network is irrational, as well as first plugging out the power unit of a modem.

CwA are capable of making decisions, applying knowledge available to them and based on available beliefs, achieve their desires. For example, by bursting into tantrum and crying to make his mother give him some chips. His action of crying fits to the desire of getting chips, which would be hard to achieve otherwise.

At the same time, CwA are simplest such rational agents in terms of amount of knowledge and structure and depth of beliefs, due to their special cognitive skills.

Judged by these standards, reasoning of CCs, not just CwA in the laboratory is very poor and irrational (as shown by the seminal experiments of (Wason 1968) for logic and (Kahneman and Tversky 1972) for probability), and it has therefore been said that humans, both PwA and controls are actually not rational in the sense defined above. The objective is to make the reasoning of CwA as rational as possible.

Wason describes the students in his experiments showing irrationality of human thinking.

> The old ways of seeing things now look like absurd prejudices, but our highly intelligent student volunteers display analogous miniature prejudices when their premature conclu-

> sions are challenged by the facts. As Kuhn has shown, old paradigms do not die in the face of a few counterexamples. In the same way, our volunteers do not often accommodate their thought to new observations, even those governed by logical necessity, in a deceptive problem situation. They will frequently deny the facts, or contradict themselves, rather than shift their frame of reference.

Stanovich (1999) discussion of rules governing reasoning introduces a distinction between normative, descriptive, and prescriptive rules. We give brief characterizations of the three kinds, followed by representative examples.

- *Normative rules*: reasoning as it should be, ideally. These rules should be taught to CwA in its original form
  - *Modus tollens*: $\neg q, p \rightarrow q / \neg p$
  - Bayes' theorem: $P(D \mid S) = P(S|D)P(D)/\mathrm{P(S)}$.
- *Descriptive rules*: reasoning as it is actually practiced. These should be explained to CwA as being used by other people, so that CwA can better understand them. CwA are also encouraged to apply these rules if normative rules are not applicable.
  - Many people do not endorse *modus tollens* and believe that from $\neg q, p \rightarrow q$ nothing can be derived.
  - In doing probabilistic calculations people do not do normalization and assume $P(D \mid S) = P(S \mid D)$. For example, estimating a probability of a disease given a set of symptoms, specialists neglect the base rate, the one occurring among healthy people.
- *Prescriptive rules* result from taking into account our bounded rationality, i.e., computational limitations (due to the computational complexity of classical logic, and the even higher complexity of probability theory) and storage limitations (the impossibility of simultaneously representing all factors relevant to a computation, say, of a plan to achieve a given goal). Prescriptive rules should be taught to CwA for approximation of what can be derived in the real world.
  - The classically invalid principle $\neg q, p \wedge r \rightarrow q / \neg \mathrm{p} \wedge \neg \mathrm{r}$ is correct according to closed–world reasoning, which is computationally much less complex than classical propositional logic, and helps with memory issues when implemented in a computer.

In terms of these three kinds of rules, Stanovich distinguishes the following positions on the relationship between reasoning and rationality:

> Human reasoning competence and performance is actually normatively correct. What appears to be incorrect reasoning can be explained by such maneuvers as different task construal, a different interpretation of logical terms, etc.

Actual human performance follows prescriptive rules, but the latter are in general (and necessarily) subnormal, because of the heavy computational demands of normatively correct reasoning. The performance of actual human reasoning still does not reach prescriptive standards, which are themselves subnormal; and this is a significant potential improvement area for rehabilitation of autistic reasoning.

In the life of CC, reasoning happens infrequently in everyday life, and mainly in schools. And for CC the true rationality is adaptiveness in taking quick decisions that are optimal given constraints of time and energy. On the contrary, we expect CwA who acquired reasoning skills and axioms as a result of training to reason intensively behaving in everyday life. Even though adaptation capabilities of CwA are rather limited, learned rules are supposed to compensate for it and still maintain acceptable behavior. Hence the role of learning and applying rules is higher for CwA compared with CC.

Interpretation of formal symbols is of high importance in reasoning. But even if interpretation is important, and interpretations may differ from person to person, people may reason in ways that are inconsistent with their chosen interpretation. From a methodological point of view this means that if one uses a particular interpretation to explain something, one must have evidence for the interpretation that is independent of this “something”. Stanovich’s scheme is predicated on the assumption that reasoning is about following rules from a fixed, given set, say classical logic, rules that should apply always and everywhere. For if there is no given set of rules which constitutes the norm, and the norm is instead relative to a “domain,” then the domain may well include the cognitive constraints that gave rise to the notion of prescriptive rules, thus promoting the latter to the rank of norm.

Piaget’s *logicism* (Piaget 1953) tells that the acquisition of formal-deductive operations is due to cognitive development. Piaget was the first to show that preschool children are not capable of applying classical predicate logic; they need to grow older to do that. This is in contradiction with Wason’s selection task, a striking deviation from classical logical reasoning. Piaget’s work can be considered as undermining the role of logic as an inference mechanism. A further criticism concerned the alleged slowness of logical inference mechanisms, especially when search is involved, for example when backtracking from a given goal. The production system of Newell and Simon only includes *modus ponens* rule, allowing fast forward inference process, but the other forms if inference are substantially slower.

A few decades back the production systems were used and explore the manipulation of mental representation. *Logicism* is one central characterizing of production system models which is followed in this book’s rehabilitation strategy. As production systems involve, perception and action are added to production systems to approach active learning (Sect. 7.3). Modern production systems preserve Logicism and follow the *sense-think-act* cycle. At the same time, Piaget theory of cognitive development accepts the idea that Logicism is founded upon actions in the world. From both computational and experimental observations one can see that human cognition is based on *sense-think-act* and *sense-act* chains. The external world starts to play more important role in the cognition; some researchers argue that cognition is mediated by a set of cognitive agents (Minsky 2006). Then the process of thinking is not just application of logical rules but instead a combination of *sense-think-act* and *sense-act* chains which interact with the real world to solve problems (Wilson and Dupuis 2010).

If logical laws were like physical, empirical laws about psychological events, they would have to be approximate, preliminary and subject to refinement, like all laws in natural science. But logical laws are exact and unassailable, hence they cannot be empirical. Psychologism about logical laws also leads to skeptical relativism: as we observe in CwA, different people reason according to different logical laws, so that what is true for one person may not be true for another – truth, however, is absolute, not indexed to a person.

Stenning and van Lambalgen (2008) analyzed 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 which is identical to that of the suppression task (McKenzie et al. 2011). This leads to a prediction for autistic people's behavior on the suppression task. Both adolescents with ASD and typically developing controls were presented with conditional reasoning problems using familiar content. The task relies on both valid and fallacious conditional inferences that would otherwise be suppressed if counterexample cases are brought to mind. Such suppression occurs when additional premises are presented, whose effect is to suggest such counterexample cases. In this study (Stenning and van Lambalgen 2008) predicted and observed that this suppression effect was substantially and significantly weaker for autistic participants than for CC. The authors conclude that CwA are less contextualized in their reasoning, a finding that can be linked to research on autism on a variety of other cognitive tasks.

6.3 Autistic Probabilistic and Counterfactual Reasoning

Probabilistic inference and conditioning calculates the conditional probabilities of dependence between states. If event A only correlated with event B dependent on event C, then C defeats A as a cause of B (Gopnik et al. 2001). Counterfactual and subtractive reasoning is focused on predicting mental states which are dependent on facts known to be false. Studies of typically developing children have shown strong associations between false belief and subtractive reasoning tasks (Harris et al. 1996; Peterson and Galitsky 2004).

Counterfactual version of the false belief task has been proposed by Riggs et al. (2000). This task was intended to show that difficulties in counterfactual reasoning cause unsuccessful performance in the false belief task. In each condition, a false belief state task and a corresponding physical state task in the same domain were constructed. For example, the following image of the Maxi task was constructed: a child, a mother-doll and an experimenter are in a kitchen. The child sees that there is a chocolate in the fridge. The mother-doll now bakes a chocolate cake, in the process of which the chocolate moves from fridge to cupboard. The experimenter now asks the child: *Where would the chocolate be if mother hadn't baked a cake?*

The structure of answers is highly correlated with that on the false belief task. Before the cut-off age of four, the child answers: ‘in the cupboard’; afterwards, she answers ‘in the fridge’. There is no ToM involved in answering correctly; instead one needs insight into the commonsense reasoning inertia of the world: states only change when they are affected by actions, explicit causes. It is unclear what causes the younger child to answer ‘in the cupboard’: a simple failure to apply inertial reasoning can bring the response ‘it could be anywhere’, due to the events that could have happened in this alternative world.

Answers such as this would be yielded by applying causal reasoning without closed world reasoning for occurrences of events. The answer ‘in the cupboard’ more likely reflects a failure to apply causal reasoning altogether, turning instead to a “default” response. In one out of three of (Riggs and Peterson 2000) experiments the false belief task was considerably more difficult for the children than the counterfactual task, since ToM reasoning is the hardest for CwA.

Peterson and Bowler (2000) demonstrated this issue by comparing CwA, CC and children with severe learning problems’ performance on false belief tasks and counterfactual tasks. CC showed high correlation on these tasks, but a dissociation turned out to be obvious in both CwA and children with severe learning problems. For all children, the majority of those who failed the counterfactual task also failed the false belief task, due to the fact that the counterfactual reasoning domain is necessary for the false belief domain. Three-quarters of the typically developing children who completed the counterfactual task also pass the false belief task, but these ratios go down in the other groups: sixty % in children with learning difficulties, 44 % CwA. The authors suggest that one factor is the necessity to ‘generate’ Maxi’s false belief, whereas in the counterfactual task the false statement is given. The authors also show the correlation of this feature with other supposed failures of the ability to generalize in autism (Sect. 6.4), such as the difficulty of spontaneous recall compared to cued recall. In the false belief task the CwA and CC have to see the relevance of Maxi’s not observing the crucial event to perform the computation. In the counterfactual task all the ingredients are given, and only an inertial computation is necessary.

In terms of CwA education, our conclusion is that the axioms of inertia need to be taught for both mental and physical worlds.

The understanding of emotions based on counterfactual reasoning was studied (Begeer et al. 2014). Children were presented with eight stories about two characters who experienced the same positive or negative outcome, either due to their own action or by default. Relative to the comparison group, children with high-functioning autism spectrum disorder were poor at explaining emotions based on downward counterfactual reasoning (i.e. *contentment* and *relief*). There were no group differences in upward counterfactual reasoning (i.e. *disappointment* and *regret*). In the comparison group, second-order false-belief reasoning was related to children’s understanding of second-order counterfactual emotions (i.e. regret and relief), while children in the high-functioning autism spectrum disorder group relied more on their general intellectual skills.

All scenarios involved two characters who experienced the same outcome (i.e. both either achieve or do not achieve what they desire). For the target character, a counterfactual alternative was available that would have resulted in a better (upward) or worse (downward) outcome. In the simple stories, emotions were yielded by demonstrating that the target character nearly achieved a positive or negative outcome. The near attainment of the outcome was intended to yield disappointment (when a positive outcome was avoided) or contentment (when a negative outcome was avoided). In the second-order emotion stories, a target character always made an active decision that led to the avoidance of a positive or negative result. This was intended to yield regret or relief. At the end of each story, children were reminded of the outcome and of the critical element of the story that differentiated the characters involved. Following this, children were asked whether one character would feel "better," "worse," or "the same" about the results compared to the other character and explain why.

6.3.1 Example Relief Story and Questions

Bill and Pete are going on a school trip. They are allowed to choose between going on a sports day in the playing fields or to a kids' museum. Bill wants to go to the museum. Pete chooses the sports day. When the teacher asks them what they chose, Bill says he wants to go to the museum. Pete changes his mind and also says he wants to go to the museum. On the day of the trip, it is pouring with rain. Children who chose to go to the sports day in the playing fields have to stay at school.

Questions Who is happier about choosing the museum, Bill, who chose the museum right away, or Pete, who changed his mind, or do you think they are both equally happy? Why?

6.3.2 Example Regret Story and Questions

Miriam and Susan go to the same school. Miriam usually takes the bus. Susan usually goes on her bike. Today, Susan decides to take the bus. Both Susan and Miriam are waiting at the bus stop but the bus does not come, and they have to wait a long time for the next bus. They both arrive at school very late.

Questions Who is more annoyed with being late for school, Miriam, who usually takes the bus, or Susan, who usually goes by bike, or do you think they are both equally annoyed? Why?

6.4 Autistic Planning and Adjustment of Action to a New Environment

Current studies of autistic reasoning overlooked such aspect of reasoning as operating beyond strict rule-following. Everyday reasoning requires more than applying literal rules since most all rules are associated with exceptions. Most rules in the real life are *defeasible* and can be modified as new information comes. For example, we put on our own shoes to go out and assume it will fit. However, we will withdraw this assumption if it turns out that someone put a small ball in the shoe. Since one has to adjust a conclusion when the context changes, some flexibility in reasoning is required to handle cases with exceptions.

Although reasoning about the physical world of autistic patients is corrupted in a lesser degree than reasoning about mental world (Galitsky 2002), it still has serious limitations and needs to be substantially improved. Various reasoning domains that are the subjects of explorations in traditional logical Artificial Intelligence, such as space, time, and probabilities are explored in the context of autism. It turns out that each of these domains is affected of autistic development in one way or another. In this section we focus on autistic way to adjust actions to a new environment, employing a formalism of default logic (Brewka et al. 1995; Bochman 2001). The finding here is that while people with autism may be able to process single default rules, they have a characteristic difficulty in cases where multiple default rules conflict. Even though default reasoning is intended to simulate the reasoning of typical human subjects, it turns out that following the operational semantics of default reasoning in a literal way leads to the peculiarities of autistic behavior observed in the literature (Peterson and Galitsky 2004).

6.4.1 Triangulation Structure

We first introduce the concept of triangulation by way of an illustrative scenario:

> *Arthur habitually follows a route to school which involves walking straight down a particular pavement. One day this pavement is blocked by a puddle. Should Arthur walk straight through the puddle, or walk round it?*

What Arthur needs to do in this example is to depart temporarily from his standard route to school, in response to a passing circumstance. He does not need to jettison or revise this standard route: tomorrow, when there is no puddle, he can follow it without interference. But today his actions need to reflect a compromise between the standard route and the additional circumstance. This structure can be represented as follows. The basic unit of knowledge (in this case, the standard route to school) we call the *source* (S). The default, usual, normal action (such as walking straight ahead) that can be performed when the source is as usual, or considered in isolation, is called the *generic action* (G). The additional factor (the presence of a puddle) that indicates a modification, adjustment of this norm, we call the *context*

(C). And when the context causes us to select an adjustment of the generic action G (to walking round the puddle), we call this a *triangulated action* (T). Thus we have the following structure:

S: the standard route to school
G: walk straight
C: today there is a puddle in the way
T: walk round it.

In such situations two separate perspectives, the source and the context, bear on the same issue of action. The agent is thus faced with the cognitive task of coordinating these demands, in a process of practical reasoning which we call *triangulation*:

S, so do G, but C, so do T

This kind of task can be encountered by any cognitive system, whether natural or artificial, but our present concern is with people with autism. We therefore turn to a series of tendencies found in autism, in each case using the triangulation structure identified above to analyze an illustrative example. This serves two purposes:

1. It reveals a pattern common to some of the tendencies found in autism, thus advancing our conceptualization of the syndrome.
2. It provides a systematic basis for computer support which allows users to navigate and experiment with these structures.

It is worth emphasizing from the outset that we are dealing here with tendencies: people with autism do not follow these patterns all of the time (and people without autism do not always avoid them). Rather the point is that where these tendencies do occur, their structure can be identified.

6.4.2 Triangulation Cases

Case 1: Performance of Routines People with autism show an inflexible relationship with routines. On an occasion when it seems that the best thing is to alter, abbreviate or terminate the performance of a routine, the person with autism may step through a standard procedure in a manner which is 'rigid', 'formal', 'obsessive', or 'ritualistic' (Kanner 1943, DSM C). A typical example follows.

Arthur's routine for getting up in the morning takes 30 minutes and involves a shower, washing, drying and brushing his hair, eating a breakfast of muesli, toast and tea, and brushing his teeth for 2 minutes. He begins this at 8.00 am, so as to be ready for the school bus at 8.32 am. One day, when Arthur is in mid-routine, his mother receives a phone call saying that the school bus will arrive 10 minutes early, so she tells this to Arthur through the bathroom door. Should Arthur continue to enact his routine as usual, or should he omit or accelerate parts of it so as to catch the bus on time?

We have here a routine which is perfectly reasonable, but an occasion on which an adjustment is needed. One solution, for example, would be to omit breakfast, and eat a sandwich on the bus instead. (Another solution would be to do everything more quickly than usual.) This gives the following pattern of reasoning:

S: the usual routine
G: enact it all as usual
C: but today time is short
T: omit part of it

The inflexibility found in autism in this regard consists in a tendency to choose the generic action (G) rather than the triangulated action (T) in such structures. The routine is enacted in a manner that is unresponsive to special circumstances: faithful to one perspective rather than two. Furthermore, the person may become upset and agitated when asked to adjust, indicating that this is not easy to do. This is not to say that routines are bad, or that this one is in need of revision. Routines serve as labor-saving devices, and this one promotes hygiene, nourishment and dental care. Rather, the problem in the example scenario is that the routine and its goals constitute one of two frames of reference, and a compromise is needed. Again, this is not to say that accommodation of a second perspective is necessarily a good thing: Arthur might have decided that he is tired of being messed about by an unreliable bus service and so he will let things go wrong. However, in the cases typically seen in autism the second perspective is not rationally rejected, but is simply unengaged.

Case 2: Informing We now turn to another area of the symptomatology of autism in which, despite superficial differences, the same structural features operate. Among the communication difficulties found in autism are tendencies to *over-inform*. That is, where only part of a story is relevant to a particular audience or topic of conversation, the person with autism may nevertheless recite the story from beginning to end and in all its detail. (Equally, where expansion and extra explanation are needed, there is a tendency in autism to *under-inform*). There can be many reasons for editing the telling of a story: perhaps only part of a story is relevant to the current conversation, perhaps the audience was present during most of events described, perhaps one of the audience becomes visibly upset as we start to tell the story. There follows an illustrative example:

Earlier in the year, Arthur took a trip in which he travelled by bicycle from York to London, visiting museums along the way, and on arriving in London he happened to eat a hamburger. One day, Arthur meets some people who ask him about the quality of hamburgers in London. Should he tell the whole story of his trip, or just the part about the hamburger?

The story of Arthur's trip is a data structure whose default execution is step-by-step recitation starting at the beginning. This might be just what is needed, for example when recording it in a diary. However in the present context what is needed is a compromise in which the part about the hamburger is selected and the rest only briefly mentioned, as follows.

S: the story of my journey
G: tell it exhaustively from beginning to end
C: but we are talking about hamburgers
T: tell that part only

The over-informing found in autism consists in a tendency to choose G rather than T in such structures. One point which this characterization brings out is that this tendency concerns the use of knowledge rather and simply its existence (Peterson and Bowler 2000). In our example, Arthur knows the story of his trip, and he knows that he has been asked about hamburgers: what is missing is a coordinated response to the two. This tendency may cause trouble, since the capacity to adjust the presentation of information is central to communication, rhetoric and tact, all of which show deficit in autism. No general value judgment is forthcoming here: whether we prefer the charm of smooth talking to a grave and comprehensive recitation of facts will vary from case to case. However, as above, in the cases typically seen in autism the grave recitation is due to insulation rather than judgment.

Case 3: Tunnel or Jump In conversation, CwA tend either to 'tunnel' on one subject, or suddenly to 'jump'—change the subject—destroying narrative coherence.

S: a new subject occurs to me
G: change the subject to this
C: but the conversation's theme is ...
T: stick to the theme

Case 4: Interpretation of Ambiguity Homonyms are the words in written form that have two (or more) meanings with different associated pronunciations. Autistics are unreliable in choosing the one that is indicated by sentence context.

S: 'tear' can mean X or Y
G: take either
C: but the sentence context indicates Y
T: use Y

There is a class of social interactions that involve our predicting and/or explaining the actions of other participants, but in which the relevant predictions and explanations seem to develop without us having to attribute propositional attitudes. These social interactions rest on what social psychologists call "scripts" ("frames" in artificial intelligence), that is, complex information structures that allow predictions to be made on the basis of the specification of the purpose of some social practice (for example, eating a meal at a restaurant), the various individual roles, and the appropriate sequence of moves.

Case 5: Social Scripts Brittleness & amalgamation of exceptions

Arthur is told not to speak to strangers in the street. Some policemen address him, and he ignores them and gets into trouble.

S: ignore strangers in the street, and these are strangers
G: ignore them
C: but these are policemen
T: talk to them.

Case 5′: Social Scripts 2

Arthur was taught a conversation routine involving sitting near a person and nodding. He got on the underground late at night, entered a carriage with just one old lady in it, and began his routine. She panicked.

S: this is my conversation routine
G: do it
C: but this is an old lady and she looks frightened
T: stop

Case 6. Executive Function People with autism show poor performance on clinical tests of executive function (Sect. 2.5.2). In the experiment on the proper timing of actions, the participant is asked to grab a marble from a box, after pushing a switch.

S: grab the marble
G: do it now
C: the switch needs to be pushed first
T: do it (grab the marble) afterwards

Autistics show 'pre-potency' (in relation to C). In the Wisconsin Card Sort Test they show 'perseveration' (in relation to C): they carry on doing something after it has stopped serving its purpose.

Case 7: Generalization There exist situations in which the main point or purpose is not stated explicitly, and so constitutes an implicit context.

Arthur is asked by his father to empty all the waste paper baskets in the house. When he has finished, his father asks why he has not emptied two receptacles. Arthur replies that these are bins, not baskets.

Once the context has been detected it can be applied as follows.

S: I am emptying baskets, and these two are bins
G: ignore them
C: but the goal is to remove rubbish, and they contain rubbish
T: empty them too.

In several of the cases given so far, the context serves to narrow our range of actions, causing us to omit certain possibilities or at least select a partial case of them. In the above case the opposite is true: apprehension of the context broadens our understanding of the situation and extends our range of actions.

Case 8′: Controlling the Scope of Actions

Arthur is found pulling up flowers on the north side garden. His mother says 'please don't do that'. So Arthur then goes to the south side of the garden and carries on pulling up flowers there.

The main point or objective here was not stated explicitly by Arthur's mother. Unless Arthur detects it or makes a guess at it, it will seem reasonable to do as he does.

S: I am no longer on the north side of the garden, and here are some flowers
G: pull them up
C: but the point of the previous request was to preserve the flower beds in the garden
T: don't pull them up.

Case 8: Alternative Contexts Another case in which we need to project possible contexts is when we try to think of alternative uses for an object. In which new contexts could the object serve a useful function?

Arthur is asked 'think of lots of uses for a brick'. He refers to standard examples, as indicated by the definition of a brick, rather than connecting with alternative contexts so as to give alternative uses.

S: bricks are for building
G: give examples of building
C: but I need an ashtray (imagined), and bricks have appropriate indentations
T: give example of ashtray

Case 9: Suppression of Irrelevant Details A common occurrence in autism is that a person focuses on insignificant or non-functional details in a situation. These can be parts or aspects of objects or situations that would normally be regarded as inconsequential (American Psychiatric Association 2000). This inconsequentiality is not an inherent feature of the detail in question, but rather a relation with a context; it is determined by seeing that the detail is not relevant to the purpose or function expressed in the context. The detail may be inherently interesting, but from the perspective of the context it is not. The context says *ignore such details, we have a job to do*. Therefore, what we need to do (in the current situation) is to subtract or ignore the detail in question. The question is the usual one: S may be correct or interesting, but given C what do we *do* about it now?

Arthur usually has a blue cup for water. When presented with a green one, he refuses to drink at all.

S: my usual cup is blue, and this one is green
G: refuse it
C: but the point is to drink water, and it's OK for drinking
T: accept it (i.e. the colour is unimportant to C)

Arthur gets upset when a minor change is made to the arrangement of furniture in his room.

S: the arrangement of my room has been slightly changed
G: worry about this
C: but the functions of my room are ...
T: don't worry (i.e. the change is unimportant to C)

During a car trip to LA, Arthur gets upset because his underwear is not exactly as usual, and wants to return to where his usual ones are bought. [from Rain Man]

S: my underwear is different from usual
G: worry about this
C: but our purpose is to drive to LA
T: forget it for the moment

Case 10: Subtraction One aspect of learning is that we refine our knowledge by removing non-functional elements from our knowledge-structures. In the situation in which we initially encounter something there may be details which are inessential, and so we need subsequently to remove these.

Arthur first hears the word 'impolite' pronounced as 'im-pol-ite'. Thereafter he always pronounces it this way. What is odd about this?

Here the data structure is a correct record of the initial experience (as usual the problem in autism is not simply one of truth or accuracy). However, subsequent context indicates that an element in the data structure is nevertheless in appropriate.

S: pronunciation as 'im-pol-ite'
G: use this
C: frequent experience of hearing alternative pronunciation as 'impolite'
T: subtract the non-functional element

It is likewise notable that autistic routines may have non-functional 'extras' that are maintained despite being non-functional.

Case 11: Dealing with Open Structures There are cases in which a cognitive system is provided at one time with a data structure (or database) that is incomplete, and at a later time with the details required to fill its open *slots*. The usual approach is to treat this as an issue of time: we have some of what we need now, and we look out to get the rest later, completing our decision 'on the fly'. This is problematic in autism, where such open structures can evoke anxiety due to their indefinite nature.

S: this is currently an incomplete structure
G: worry
C: the gaps will be filled tomorrow
T: use it when they are filled

6.4.3 Discovering Commonalities Between the Triangulation Cases

We proceed with the discussions of how the cases are inter-related. There are many differences between the cases examined above. Some involve understanding of other people while others do not. Some involve language while others do not. Some make greater call on imagination (cases 7 and 8) than others. Our point however is that they are variations on a theme in the following sense:

1. each case presents a task which is of a type well known to present difficulty in autism;
2. each task can be analyzed as a triangulation task;
3. in these terms, the tendency found in autism is a tendency to produce the 'generic' rather than the 'triangulated' response.

This analysis serves as a tool for understanding: the moment when we identify a triangulation structure and its elements can be the moment when we understand another person's actions, the moment when we say *oh, that's where he is coming from*. The analysis serves as a basis for a computer-based therapeutic facility, since it identifies a common structure which people with autism need practice in navigating. Below, we will provide a more formal analysis of the triangulation structure.

The source in the structure gives us a generic or standard action; the context indicates how, when, where or with whom to perform the action, what to change, repeat or omit, when to stop, or whether to do it at all; and the cognitive system needs to work out in each case what the nature of this adjustment should be. These adjustments fall into two broad categories, narrowing and widening of the actions performed, and in each case above there is an established tendency in autism not to make the relevant adjustment.

We attempt to cover these eleven scenarios by five well-known deficiencies of autistic reasoning described in the literature:

1. Non-toleration of novelty of any sort (cases 1, 9, 11).
2. Incapability to change plan online when necessary (cases 1, 2, 5, 6, 11).
3. Easy deviation from a reasoning context, caused by an insignificant detail (cases 2, 3, 4, 5, 5′, 8).
4. Lack of capability to distinguish more important from less important features for a given situation (cases 2, 7, 9, 10).
5. Inability to properly perceive the level of generality of a feature appropriate for a given situation (cases 2, 4, 7, 8, 10).

Note that each deficiency covers multiple cases, and each case is covered by two or more deficiencies. Also, these deficiencies of reasoning can be distinguished from reasoning about mental attitudes, which are usually corrupted in a higher degree in case of autism (Baron-Cohen 2000).

6.4.4 Building a Bridge Between Triangulation and Default Reasoning

Default reasoning is intended as a model of real-world commonsense reasoning in cases which include typical and non-typical features and situations. A default rule states that a situation should be considered as typical and an action should be chosen accordingly unless the typicality assumption is inconsistent. We observe that autistic intelligence is capable of operating with stand-alone default rules in a correct manner most of times.

When there is a system of conflicting default rules, the formal treatment (operational semantics) has been developed so that multiple valid actions can be chosen in a given situation, depending on the order in which the default rules are applied. All such actions are formally accepted in such a situation, and the default logic approach does not provide means for preference of some of these actions over the other ones. Analyzing the behavior of people with autism, we will observe that unlike the controls, CwA lack the capability to choose the more appropriate action instead of a less appropriate. In this respect we will illustrate that the model of default reasoning suits autistic subjects better than controls.

Default reasoning is a particular machinery intended to simulate how human reasoning handles typical and atypical features and situations. Apart from reasoning about mental attitudes which is essential in presenting autism, we apply default reasoning to conceptualize a wide range of phenomena of autistic reasoning presented in Chap. 2, taking advantage of the experience of computer implementation of default reasoning. Peculiarities of autistic reasoning can then be matched against the known possibilities of malfunctioning of artificial default reasoning systems.

In this Chapter we argue that the inability to use default rules properly leads to certain phenomena of autistic reasoning identified in existing experimental studies. Conducting research of human reasoning in AI, the phenomena of autistic reasoning are of particular interest, since they help us to locate the actual significance of formal models of default reasoning. At the same time, we expect this study to shed light on how autistic reasoning may be improved by default reasoning-based rehabilitation techniques.

Abstract default logic distinguishes between two kinds of knowledge: the usual formulas of predicate logic (axioms, facts) and "rules of thumb" (defaults, Antoniou 1997). Corrupted reasoning may handle improperly either kind of knowledge, and we pose the question which kind may function improperly in autistic reasoning. Moreover, we consider the possibility that an improper interaction between the facts and rules of thumb may be a cause for corrupted reasoning.

Default theory (Brewka et al. 1995) includes a set of facts that represent certain, but usually incomplete, information about the world; and a set of defaults that cause plausible but not necessarily true conclusions (for example, because of the lack of a world knowledge or a particular situation-specific knowledge). In the course of routine thinking of human and automatic agents some of these conclusions have to be revised when additional context information becomes available.

Let us consider the traditional example quoted in the literature on nonmonotonic reasoning:

$$\frac{bird(X): fly(X)}{fly(X)}$$

One reads it as *If X is a bird and it is consistent to assume that X flies, then conclude that X flies*. In the real life, if one sees a bird, she assumes that it flies as long as no exceptions can be observed.

fly(X):- not penguin(X). fly(X):- not sick(X). fly(X):- not just_born(X). ...

Exceptions are the potentially extensive list of clauses implying that X does *not fly*. It would be inefficient to start reasoning based on exceptions; it should be first assumed that there are no exceptions, then verified that this is true and then proceed to the consequent of a default rule.

A penguin (the bird which does not fly) is a *novelty* (it is atypical). Conventional reasoning first assumes that there are no novelties (there is no exception) and then performs the reasoning step, concluding that X flies. If this assumption is wrong (e.g. X-novelty is taking place) then the rule is inapplicable for penguins and it cannot be deduced that X flies. It is quite hard for autistic reasoning to update this kind of belief because it handles typical and atypical situations in the same manner, unlike the default rule machinery suggests. It is quite computationally expensive to handle typical and atypical situations similarly, because a typical situation is compact and most likely to occur, and an atypical situation comprises an extensive set of cases (clauses) each of which is unlikely to occur.

Having outlined the triangulation reasoning pattern, we proceed to a formal treatment of such structure using default logic. The components of triangulation structure can be represented as a pair <*classical rule, default rule*>. If the state S occurs, action G is to be performed. Hence we have a rule

$$\frac{S}{G}$$

However, if C occurs in addition to S (serves as a context of S)

$$\frac{S:C}{T}$$

We simulate autistic reasoning as a formal system where the top rule above always works, and the bottom rule fails either as a stand-alone one or as a combination of some rules with mutual dependence. In accordance to our methodology, a hypothetical autistic reasoning system would then always be capable of producing G but sometimes fails T due to a computational problem of deriving T. We have initially described this problem as enumeration of 11 cases, and then as five higher-level phenomena of autistic reasoning.

6.4.5 Handling a Single Default Rule by Autistic Reasoning

Let us now consider the above examples from the perspectives of five deficiencies. Unlike normal subjects, and similar to software systems, autistic subjects can hardly tolerate the

Additional_features_of_en_do_not_change_routine
when they have a *Usual_intention* to *Follow_usual_routine*:

$$\frac{Usual\_intention : Additional\_features\_of\_env\_do\_not\_change\_routine}{Follow\_usual\_routine}$$

Table 6.1 Capabilities in revising beliefs and adjusting to new environments

A child knows that birds fly. The child sees observes that penguins do not fly	
Child updates the list of exceptions for not property flying	Child adds new rule that penguins do not fly
The *flying* default rules stays intact	It is necessary to update the existing rule of *flying* and all the rest of affected rules
The process of accepting new exceptions is not computationally expensive	This process takes substantial computational efforts and, therefore, is quite undesirable and overloading
Observing a novelty and remembering exceptions is a routine activity	Observing a novelty is stressful

This default rule schema is read as follows: when there is a *Usual_intention*, and the assumption that

Additional_features_of_env_do_not_change_routine is consistent, then it is OK to *Follow_usual_routine.* There should be clauses specifying the situations where this assumption fails:

Additional_features_of_env_do_not_change_routine:- not (alarm(fire) ∨ *desire(DoSometrhingElse)* ∨…).

This clause (assumption) fails because of either external reasons or internal ones, and the list of potential reasons is rather long.

In the following Table 6.1 we compare the features of default reasoning for a CC (on the right) and a CwA, once new observation becomes available and beliefs change.

A good example here is that the autistic child runs into tremendous problems under deviation in an external environment which typical cognition would consider to be insignificant.

We proceed to the deficiency of *Incapability to change a plan online when necessary*. A characteristic example is that of an autistic child who does not walk around a puddle which is blocking her customary route to school, but rather walks through it and gets wet as a result. This happens not because the autistic child does not know that she would get wet stepping through a puddle, but because the underlying reasoning for puddle avoidance is not integrated into the process of reasoning. Let us consider the reasoning steps a default system needs to come through.

Initial plan to follow a certain path is subject to application (verification) by the following default rule:

$$\frac{need(Child,\ cross(Child,\ Area)) :\ normal(Area)}{cross(Child,\ Area)}$$

abnormal(Area) :- wet(Area) v muddy(Area) v dangerous(Area).

Here we consider a general case of an arbitrary area to pass by, *Area* = *puddle* in our example above. The rule sounds as follows: *If it is necessary to go across an area, and it is consistent to assume that it is normal (there is nothing abnormal there, including water, mud, danger etc.) then go ahead and do it*. A control individual would apply the default rule and associated clause above to choose her action, if the *Area* is normal. Otherwise, the companion default rule below is to be applied and alternative *AreaNearBy* is chosen.

$$\frac{need(Child,\ cross(Child,\ Area)),\ abnormal(Area) : normal(AreaNearBy)}{cross(Child,\ AreaNearBy)}$$

Note that formally one needs a similar default rule for the case when something is wrong with *AreaNearBy: abnormal(AreaNearBy).* A control individual ignores it to make a decision with reasonable time and efforts. On the contrary, autistic child keeps applying the default rules, finds herself in a loop, gives up and goes across the puddle.

In other words, autistic reasoning literally propagates through the totality of relevant default rules and runs into the memory/operations overflow whereas a normal human reasoning stops after the first or second rule is applied. Therefore it is hard for CwA to make a choice appropriate for a given context (Fig. 6.1).

Fig. 6.1 A child is selecting a direction of movement towards one of two helpers

What are the peculiarities of how autistic children apply a newly acquired rule? First of all, they do their best in applying it; however, they follow it literally. Let us consider the following example:

An autistic girl was advised by her parents not to speak with strangers in the street. On one occasion a policeman approached the girl and started asking questions, but was ignored by her. In spite of his multiple attempts to encourage the girl to communicate, they failed and he became upset.

After the parents were told about the incident they suggested that the girl should not have treated policemen as a stranger. They also confirmed that the girl new who policemen were. The girl required that she needed the new explicit rule overwriting the initial one that a policeman was not a typical stranger and should have been treated differently.

On the basis of the analysis presented here, this anecdote could be given the following interpretation.

1. The subject is doing her best to follow the rule, and readily accepts new rules
2. The girl did know that the approaching man was a policeman, but she did not know him as a person, therefore she categorized him as a stranger in the context of the behavioral rule.
3. In this situation the girl was familiar with who policemen are, as she knew that policemen should not be ignored.
4. However, she was not able to handle a policeman as an exception in the rule for stranger.
5. If she had had the explicit rule for how to respond to strangers who are policemen then she would have followed it.

We conjecture that the girl had sufficient knowledge of the subject and was capable of applying the rules, taken separately. What she was not able of doing was to resolve a conflict between considering the same individual as *a stranger* and as a *policemen* in the context of decision whether to communicate or to ignore.

$$\frac{\textit{in\_street(me) :- stranger(Person)}}{\textit{not talk(me, Person)}}$$

Usually, strangers do not fall into a special category; however, exceptions are possible:

$$\textit{stranger(Person) :- not (policeman(Person)} \vee \textit{rescue(Person)} \vee \textit{military(Person} \vee \ldots).$$

Indeed, the girl is likely capable of identifying the categories of persons above, but not in the context of a *stranger* rule. The latter is an opposing rule to the one for handling exceptions:

talk(me, Person):- not (Person).

If the parent would incorporate the rule above into the default rule explicitly, then it is likely that the girl would treat the policemen properly.

6.4.6 Handling Conflicting Default Rules

In this section we proceed to the situation where there are multiple (conflicting) default rules, and the results of their execution depend on the order these rules are applied. Here we propose an informal description for such situations, introducing *operational semantics* for default reasoning.

The main goal of applying default rules is to make all the possible conclusions from the given set of facts. This is the bottleneck for autistic reasoning: a child may come to a single conclusion without being aware than other solutions may be as valid. A control subject is usually capable of identifying the totality of conclusions and of applying some kind of preference criteria to select a more appropriate one. Presenting the operational semantics, we bear in mind that in contrast to controls, autistic reasoning follows it literally. Following the operational semantics of default reasoning in case of conflicting rules provides conclusions similar to what autistic subjects produce, because both lack the machinery to apply preference and select a more adequate solutions, taking into account circumstances which are neither expressed by facts nor rules in the default system.

What is the nature of conflict under operational semantics? If one applies only one default, we can simply add its consequent to our knowledge base. The situation becomes more complicated if we have a set of defaults because, for example, the rules can have consequents contradicting each other or, a consequent of one rule can contradict the justification of another one. In order to provide an accurate solution we have to introduce the notion of *extensions* : current knowledge bases, satisfying some specific conditions.

Suppose D is a set of defaults and W is a set of facts (our initial knowledge base). Let Δ be an ordered subset of D without multiple occurrences (it is useless to apply the default twice because it would add no information). We denote a deductive closure (in terms of classical logic) of Δ by $In(\Delta)$: $W \cup \{cons(\delta)|\delta\in\Delta\}$. We also denote by $Out(\Delta)$ the set $\{\neg\psi\,|\,\psi \in just(\delta),\ \delta\in\Delta\}$. We call $\Delta = \{\delta_0, \delta_1, \ldots\}$a process iff for every k δ_k is applicable to $In(\Delta_k)$, where Δ_k is the initial part of Δ of the length k.

Given a process Δ, we can determine whether it is successful and closed. A process Δ is called successful iff $In(\Delta)\cap Out(\Delta) = \varnothing$. A process Δ is called closed if Δ already contains all the defaults from D, applicable to $In(\Delta)$.

Now we can define extensions. A set of formulae $E \supset W$ is an extension of the default theory $<D, W>$ iff there is some process Δ so that it is successful, closed, and $E = In(\Delta)$.

Let us consider an example of a *lost toy*; a child needs to decide on which action to choose. Let us suppose that W is empty and D is the set of

$$\delta_1 \quad \frac{true : not\ toy\_lost(X)}{not\ toy\_lost(X)}$$

$$\delta_2 \quad \frac{true :\ toy\_lost(X)}{search(X,\ toy\_lost)}$$

These rules describe a situation when children toys are normally not assumed to be lost if not immediately seen, but, if it's consistent to assume that the toy has been taken by someone, then it is worth searching for.

After we have applied the first rule, we extend our knowledge base by *not toy_lost(X)*:

$$In(\{\delta_1\}) = \{\ not\ toy\_lost(X)\ \},$$
$$Out(\{\delta_1\}) = \{\ toy\_lost(X)\ \}.$$

The second rule is not applicable to $In(\{\delta_1\})$. Therefore the process $\Delta = \{\delta_1\}$ is closed. It is also successful, so $In(\{\delta_1\})$ is an extension. Suppose now we now apply δ_1 first:

$$In(\{\delta_2\}) = \{\ search(X,\ toy\_lost)\ \},$$
$$Out(\{\delta_2\}) = \{\ \text{not}\ toy\_lost(X)\ \}.$$

The rule δ_1 is still applicable now, so $\{\delta_2\}$ process is not closed. Let us apply δ_1 to $In(\{\delta_2\})$:

$$In(\{\delta_2,\delta_1\}) = \{\ search(X,\ toy\_lost),\ not\ toy\_lost(X)\ \},$$
$$Out(\{\delta_2,\delta_1\}) = \{\ \text{not}\ toy\_lost(X),\ toy\_lost(X)\ \}.$$

Now $In(\{\delta_2,\delta_1\}) \cap Out(\{\delta_2,\delta_1\}) \neq \varnothing$ so $\{\delta_2, \delta_1\}$ is not successful and {*search(X, toy_lost)*, *not toy_lost*(*X*)} is not an extension. This comes in accordance with our intuitive expectations, because if we accept the later statement to be a possible knowledge base, then we conjecture that the toy will be searched always, not only when we suspect that it has been taken by someone.

However, if there are two extensions (possibilities for actions), then more than one action are deemed formally legitimate. In a real-life situation, normal individuals, unlike autistic ones, possess additional machinery to select appropriate actions. On the contrary, autistic children, if capable of using default rule, follow the above methodology literally. They therefore may choose an action inadequate from the perspective of control subjects, but nevertheless correct from the perspective of formal default reasoning.

Due to literal following of the operational semantics, autistic children have significant difficulties understanding natural language sentences and reacting to commands including multiple ambiguous words. Analyzing combinations of meaning, autistic reasoning may produce formally valid but inadequate (from the viewpoint of control subjects) representations.

We conclude this section by the training example we have been using in the autistic rehabilitation Center "Our Sunny World" (Moscow, Russia). The exercise teaches autistic children to operate with multiple possible interpretations of natural language expressions. Indeed, autistic children have problems understanding situations where there are multiple ambiguous words in a query and the totality of overall meaning for a sentence is a combination of meanings of these words. Let us consider the following expression (in Russian):

"Эта *картина* заставила его забыть о своем *состоянии*"

The first ambiguous word, *картина,* has two following meanings:

1. A work of art, a painting;
2. A set of events observable at a certain time.

The meanings of the second word, *состояни*e (normalized), are:

2.1. Monetary assets of an individual;
2.2. Mental and physical state of an individual.

The respective default theory has four extensions with the following meanings:

1.1–2.1. This painting made him forgot about his poverty/wealth;
1.2–2.1. This accident made him forgot about how poor/rich he was;
1.1–2.2. This painting made him ignore his feeling unwell;
1.2–2.2. This accident distracted him from his thoughts.

The children are demonstrated that all above meaning are valid; however, some of them are more appropriate than others in a certain context. This is also the case under disambiguation for question answering (Galitsky 2003).

An easier training example which was attempted by eleven children with autism is depicted at Fig. 6.2. The focus of this exercise is to develop the capability of changing plans online. The user interface represents a decision-making procedure in changing environment via list boxes.

Another form of nonmonotonic reasoning is a closed world assumption. It is based on the statement that is true is also known to be true (Antoniou 1997). At the same time, what is not currently known to be true, is false. Stenning and van Lambalgen (2008, 2012) identified a number of areas to which closed world reasoning is applicable, each time in slightly different form:

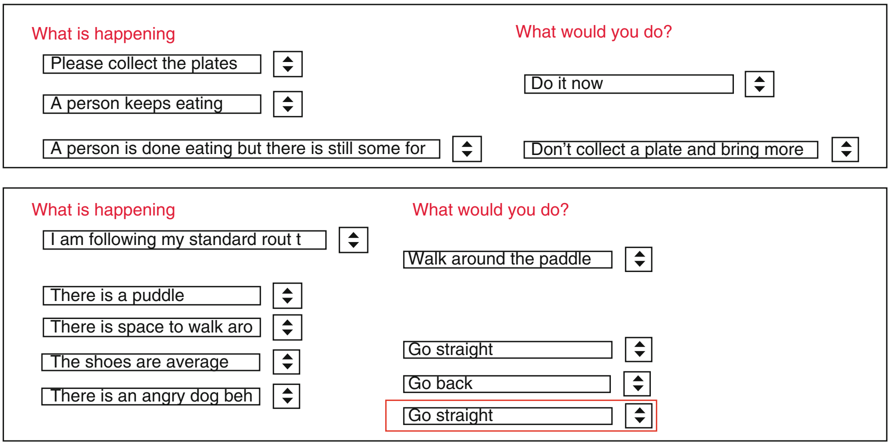

Fig. 6.2 A form to train adjustment of actions

1. lists, sequences, in space and time, train schedules, airline databases, ...;
2. diagnostic reasoning and abduction;
3. analogical reasoning;
4. arbitrary deduction;
5. unknown preconditions and post-conditions;
6. causal and counterfactual reasoning;
7. attribution of beliefs and intentions.

PwA have difficulties with at least items (2), (3), (5)–(7). CwA are pre-occupied with lists, in the sense that they feel lost without lists, such as timetables to organize daily activities; they have great difficulty accommodating unexpected changes to the timetable, and try to avoid situations such as holidays in which rigid schedules are not applicable. One may view this as an extreme version of closed world reasoning, sometimes even applied in inappropriate circumstances. But before one concludes from this that PwA are good at closed world reasoning to the point of over-applying it, one must carefully distinguish several components of closed world reasoning.

On the one hand, there is the inference from given premises which reduces to a computation of the minimal model of the premises and checking whether a given formula holds. Non-monotonic reasoning also involves 'pre-processing' the given situation or discourse, that is, encoding the law-like features of a situation in a particular type of premises.

Laws and regularities always allow exceptions, and a skill to handle exception is required based on identifying and encoding the relevant exceptions, and knowing when "enough is enough". CwA appear to perform significantly worse than CC doing that, although they behave normally with respect to the non-monotonic inferences themselves.

6.5 Discussion and Conclusions

In this Chapter we focused on the reasoning domains of the secondary importance for CwA after the mental world. As we explore the deviation between the conventional (rational, adult) reasoner from the one of the young children, irrational, autistic, we are getting closer to the nature of reasoning about the physical world, choice of action, non-monotonic, probabilistic and counterfactual domains. Whereas in the domain of reasoning about mental world one can localize the exact axioms that are missing, the general observation in other reasoning domains is that CwA cannot *achieve the required level of complexity* to behave and act in the real world. In these domains just learning particular axioms is necessary but not sufficient and more general operations including certain metareasoning patterns, like operations on defaults, are required.

It is well known that it takes significantly less amount of data for a human to learn than for a computer to learn. In machine learning, approaches like deep learning, relying on a high volume datasets and high speed computing, are becoming more available and popular. For CwAs with hyper-sensitivity a capability to maintain high volume of data and perform high efficiency computations may potentially approach deep learning-like architectures for learning from vast data. At the same time, inductive learning from a limited set of examples is a most typical way control humans acquire knowledge.

In this chapter we used default logic to provide a framework for understanding of the elusive phenomena of autistic reasoning. Our thesis is that difficulty arises in autism specifically in those situations where an appropriate default rule should be applied, or conflicts between two default rules are to be resolved. This model of autistic reasoning provides a relatively precise tool for understanding some of the phenomena of autism and autistic behavior. Our model provides an explanation on how the five major problems in autistic reasoning outlined in Chap. 2 and Sect. 6.4.3 arise:

1. Non-toleration of novelty of any sort, because it requires update of the whole commonsense knowledge, since it is not adequately divided into typical and atypical cases, norms and exceptions;
2. Incapability to change plan online when necessary, because it requires substantial computational efforts to exhaustively search the space of all possibilities;
3. Easy deviation from a reasoning context, caused by an insignificant detail, because there is an extremely high number of issues to address at each reasoning step; each such issue is seemed to be plausible and there is no proper feature selection mechanism present;
4. Lack of capability to distinguish more important from less important features for given situation, because feature importance is mainly measured in the context of being a justification of a default rule.
5. Inability to properly perceive the level of generality of features appropriate for a given situation is due to the problem of estimating which generality of a given feature is most typical, and which is less typical to be applied as a justification of a default rule.

We observed that a loss of reasoning efficiency due to improper use of default rules leads to a wide range of decision-making problems reflected in behavioral characteristics of CwA. To teach children how to overcome their decision-making problems, we developed a set or exercises encouraging default reasoning in a number of environments (Chap. 8). We will evaluate how the learners transfer acquired default rules from artificial to real world situations, which is more feasible task for the target category of children with autism than forming new rules to match the real world environment. This step requires the learners to be capable of *transferring* acquired reasoning patterns from simulation to real world environment and their *application* to real-life objects. The evaluation of the developed set of exercises has shown that performance of children with autism in real-world situations can be dramatically increased (Sect. 8.9.3).

Therefore, having an artificial environments for teaching children with autism and other mental illnesses how to adjust their actions in specific domains is beneficial. An alternative to this of postponing such training to the mental age when learners can be expected to form new rules in the real world independently would delay the overall development of learners and therefore seems unacceptable.

Exploration of the peculiarities of autistic reasoning is an emerging area involving logic, linguistic, psychology and philosophy has been conducted by van Lambalgen and Smid (2004). The ideas in this area have just started to contribute to design of rehabilitation software for autistic children, and the current book is one of the first linking these areas. Pijnacker et al. (2008) investigated inference patterns which can be revised as new informaticon is coming. The authors used a behavioral task to investigate conditional reasoning and its suppression. In the suppression task (Sect. 2.5.1, McKenzie et al. 2011) a possible exception was made salient, which could prevent yielding a conclusion. This study confirmed our finding (Galitsky and Peterson 2005) that CwA experience difficulties with yielding conclusions in the environment of exception. This is due to the fact that CwA require a flexibility in thinking to adjust to the context, which is frequently not present. Similar to our earlier studies, Pijnacker et al. (2008) hypothesized that CwA experience difficulties handling exceptions in reasoning sessions, and also discussed the neural underpinnings of reasoning in autism. Conditional reasoning is a high-order cognitive process involving such components as linguistic processing, information access in long-term memory, maintaining and manipulating verbal information in working memory, attention and inhibition of responses. Some of these components belong to executive function (Sect. 2.5.2). Executive functions are possibly regulated by frontal lobes. Studies including (Goel and Dolan 2004) investigated the neural basis of reasoning and found that frontal-temporal and frontal-parietal networks are involved in deductive reasoning.

The model presented here applies techniques of logic to an issue of psychology, and so raises the issue of the relation between the two. Logic is the study of reasoning, and psychology is the study of the mind and behavior, and so one might expect a consonant relationship between the two, since minds (the subject of psychology) use reasoning (the subject of logic) to arrive at decisions, beliefs, and actions. Since the end of the nineteenth century, however, there has been a tendency for work in logic to focus on a particular type of reasoning: one that constitutes a small fraction of the range used in real life. This is 'monotonic' reasoning, in which a conclusion, once inferred from a premise, will not be altered or retracted in light of further evidence.

Our interest to non-monotonic reasoning is motivated by the fact that it is in this area that people with autism show difficulty. Monotonic reasoning patterns, as found for example in arithmetic, seem to be much less problematic in autism (excluding reasoning about mental worlds). This monotonicity is reflected in what has become a standard definition of valid deduction in logic: X follows from Y if it is impossible that Y be true and X false. It would be inadmissible that Y is accepted and X rejected, even given further evidence.

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