Handling Representation Changes by Autistic Reasoning

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Abstract

We discover the patterns of autistic reasoning in the conditions requiring change in representation of domain knowledge. The formalism of non-monotonic logic of defaults is used to simulate the autistic decision-making while learning how to adjust an action to the environment which forces new representation structure. Our main finding is that while autistic reasoning may be able to process single default rules, they have a characteristic difficulty in cases with non-trivial representation changes, where multiple default rules conflict. We evaluate our hypothesis that the skill of representation adjustment can be advanced by learning default reasoning patterns via a set of exercises.

Introduction

The phenomena of autistic reasoning can serve as a powerful tool to investigate human decision making by means of tracking deviations from "normal" reasoning. It is true in particular in the circumstances where some changes in the representation of external and internal worlds are required. Selecting behavior in the real world, it is important that a human agent is capable of changing representation to adjust her choice of action to new environment. This capability is a well-known deficiency of autistic reasoning, referred to as a resistance to any sort of novelty, from eating habits to route selection.

It is well known that typical decision-making of children with autism are much simpler and more repetitive than those of the majority of children of the matched verbal age. Hence exploration of these patterns, which are tractable, might shed a light on the foundation of human reasoning in various domains. In this paper we focus on change of autistic knowledge representation while adjusting actions to new circumstances and environments, and formalize its deviation from what is considered "normal" reasoning.

The syndrome of autism was first identified in the 1940's and exhibits a variety of phenomena: some of an interpersonal and some of a pragmatic character, which is the focus of the current paper. One problem confronting the understanding of the syndrome is that of conceptualization: although the practitioner becomes accustomed to recognizing and responding to the various tendencies exhibited in the syndrome, it can nevertheless be difficult adequately to describe them. Various theories attempt to provide conceptualizations of the syndrome: the best known being the 'theory of mind' account (Baron-Cohen 1995), the 'central coherence' account (Happe 1996), and the 'executive function' account (Russel 1997). These theories all, however, have well-known difficulties, particularly in formal treatment of reasoning patterns including ones required for representation change. There is a need for further *computational* contribution to the conceptualization of the syndrome. In our previous studies we addressed autistic reasoning about action, intention and belief, counterfactual, inductive, and nonmonotonic reasoning (Galitsky 2003, Galitsky 2007).

In this paper default reasoning schema is used to simulate a change in representation while decision making. To express features of new environment, representation of the familiar environment must be changed by introducing new facts and rules, which is essentially non-monotonic. This allows us to characterize some phenomena of autistic reasoning in a fresh and precise way and suggests new line of empirical experimentation. We describe the peculiarities of autistic reasoning in terms of posing the problems a logician needs to solve while applying particular formalisms to implement the decision-making.

Default reasoning is intended as a model of real-world commonsense reasoning in cases which include typical and atypical features (atypical ones require change in representation). 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, and the world model is extended to accommodate new facts and reject some current ones. We will observe that autistic intelligence is capable of operating with stand-alone default rules (consistent representation update) in a correct manner most of times.

When there is a system of conflicting default rules, the formal treatment (operational semantics of default reasoning) 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 planning behavior of people with autism, we will observe that unlike the controls, children with autism lack the capability to choose more appropriate actions instead of less appropriate ones. In this respect we will see that the model of classical default reasoning suits autistic subjects better than controls.

Cases of autistic adjustments of representation

We present the usual cases of autistic adjustment of representation to select actions as a four-tuple <IDCA>:

1) **I**nitial condition,
2) **D**efault action,
3) **C**urrent circumstances (which require change in representation to be handled properly),
4) **A**djusted planning to accommodate for C.

We will consider planning of both physical and mental actions and analyze the common deviation patterns.

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', resisting to change his representation to the one adequate to given situation.

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 in representation 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:

I: the usual routine,
D: enact it all as usual,
C: but today time is short,
A: omit part of it.

The inflexibility found in autism in this regard consists in a tendency to choose the default, generic action (D) rather than the adjusted action (A) in such structures. The routine is enacted in a manner which 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.

Case 2: informing. We now turn to another area of the symptoms of autism in which, despite superficial differences, the same structural features operate. Among the communication planning 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. There follows an illustrative example.

Earlier in the year, Arthur took a trip in which he traveled 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 adjustment in representation in which the part about the hamburger is selected and the rest is concealed, as follows.

I: the story of my journey,
D: tell it exhaustively from beginning to end,
C: but we are talking about hamburgers,
A: tell that part only.

The over-informing found in autism consists in a tendency to choose D rather than A in such structures. One point which this characterization brings out is that this tendency concerns the use of knowledge rather and simply its existence. 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.

Case 3: plan alteration. In conversation, autistics tend either to 'tunnel' on one subject, or suddenly to 'jump' --- change the subject --- destroying narrative coherence.

I: a new subject occurs to me
D: change the subject to this
C: but the conversation's theme is …
A: stick to the theme

Case 5: plans and social scripts with exceptions. 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.

I: ignore strangers in the street, and these are strangers,

D: ignore them,

C: but these are policemen,

A: talk to them.

Case 5': exceptions in plans and social scripts

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.

I: this is my conversation routine

D: do it

C: but this is an old lady and she looks frightened

A: stop

Case 6. executive function in planning and timing.
People with autism show poor performance on clinical tests of 'executive function'. In the experiment on the proper timing of actions, the participant is asked to *grab a marble from a box, after pushing a switch.*

I: grab the marble

D: do it now

C: but push the switch first

A: do it afterwards

Autistics show 'pre-potency' (in relation to C). In the Wisconsin Card Sort Test (WCST, 2003) they show 'perseveration' (in relation to C): they carry on doing something after it has stopped serving its purpose.

Case 7: Plan 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.

I: I am emptying baskets, and these two are bins

D: ignore them

C: but the goal is to remove rubbish, and they contain rubbish

A: empty them too.

In several of the cases given so far, the context serves to narrow our range of actions, causing us to omit or at least particularize certain possibilities. 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 Parameters 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.

I: I am no longer on the north side of the garden, and here are some flowers

D: pull them up

C: but the point of the previous request was to preserve the flower beds in the garden

A: don't pull them up.

Case 9: Planning in the conditions of uncertainty. There are cases in which a cognitive system is provided at one time with a data structure (or database) which 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.

I: this is currently an incomplete structure

D: worry

C: the gaps will be filled tomorrow

A: use it when they are filled

Default reasoning and adjustments of representation

The components of the above four-tuple 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

$$\frac{I}{D}$$

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

$$\frac{I : C}{A}$$

We simulate autistic reasoning as a formal system where the top rule above always holds, and the bottom rules fails either as a stand-alone one or as a combination of such rules with mutual dependence. In accordance to our methodology, a hypothetical autistic reasoning system would then always be capable of producing D but sometimes fails A due to computational problems of deriving A. This computational problem is associated with the necessity to change representation. We have introduced this problem by nine scenarios above, each requiring adjustment of world knowledge representation; and now we proceed to five higher-level phenomena of autistic reasoning. In this study we argue that the inability to adjust representation rules properly leads to certain phenomena of autistic handling of representations identified in the experimental studies (e.g. Happe 1996, Russel 1997, Pilowsky et al 2000):

1. Non-toleration of novelty of any sort;
2. Incapability to change plan online when necessary;
3. Easy deviation from a reasoning context, caused by an insignificant detail;

4. Lack of capability to distinguish more important from less important features for a given situation;
5. Inability to properly perceive the level of generality of a feature appropriate for a given situation,

Note that these peculiarities of reasoning can be distinguished from reasoning about mental attitudes, which are usually corrupted in a higher degree in case of autism (Baron-Cohen 1995).

Our approach considers the mechanisms of how typical reasoning is performed from the computational prospective, and then compares these mechanisms with the limitations of experimentally observed autistic reasoning. We take advantage of significant achievements of logical artificial intelligence in modeling human reasoning and understanding the mechanisms of solving the problems suggested to autistic and controls during the experiments. This computational approach therefore complements the findings of psychological experimentation in the study of autism.

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, 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 the context of artificial intelligence, 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.

Handling a single default rule by autistic reasoning

An abstract default logic distinguishes between two kinds of knowledge: the usual formulas of predicate logic (axioms, facts) and "rules of thumb" (defaults, see 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, Bochman 2001) includes a set of facts which represent certain, but usually incomplete, information about the world; and a set of defaults which 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.

Let us now view this example from the perspectives of five phenomena mentioned above:

Unlike normal subjects, and similar to software systems, autistic subjects can hardly tolerate the *Additional_features_of_envir_do_not_change_routine*

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

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

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

A child knows that birds fly. The child sees observes that penguins do not fly	
Child updates the list of exceptions for not property flies	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

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 phenomenon 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 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 run into the memory/operations overflow whereas a normal human reasoning stops after the first or second rule is applied.

Updating representation by multiple 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 $\Delta=\{\delta_0,\ \delta_1,...\}$ 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:

$In(\{\delta_2\}) = \{ search(X, toy\_lost) \}$,

$Out(\{\delta_2\}) = \{ not\ toy\_lost(X) \}$.

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

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

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

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.

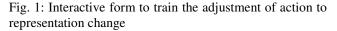An easier training example which was attempted by more than 10 children with autism is depicted at Fig. 1. The focus of this exercise is to develop the capability of changing plans online. The user interface represents a decision-making procedure in changing environment via list boxes.

Learning representation update

Teaching autistic children various reasoning patterns, it is evident that regrettably they experience difficulties transferring these patterns from one domain to another, from home to street environment, from behavior while on holiday or in the class etc. Therefore, although the default reasoning patterns per se are formulated as domain-independent, the same patterns have to be repetitively introduced in each domain. Teaching children with autism proper reasoning patterns while planning and adjusting actions in a context should be conducted in all domains one would expect to make children's behavior more adequate.

The generic interactive form which includes two exercises is shown at Fig. 1. The form specifies the initial conditions and default actions (drop-down boxes on the left) and also current circumstances with adjusted actions (drop-down boxes on the right); actions are chosen by trainees. Selecting the items on the left, trainees imitate respective sequence of (changing) circumstances/ contexts, and the appropriate action adjustment (correct action) should be selected on the right. The link between the selections on the left and those on the right is implemented via default rules.

Fig. 1: Interactive form to train the adjustment of action to representation change

To evaluate our methodology presented in this paper, we observe the results of training of the adjustment of plan sentatbprey autistic children. Adjustment of planning is used to approach a proper application of default rules to handle properly the situations when it is important to adopt an action to an environment.

In Table 1 we compare the trainees' performance completing the tasks they have been trained with, as well as new tasks of a similar complexity. Moreover, we evaluate how the trainees perform applying learned reasoning patterns to real-world situations. The real time performance is evaluated before the training for each category of learners occurs.

Performance completing the exercises which have been introduced earlier verifies how learners can *reproduce* the decisions which have been shown to them earlier. This exercise does not validate whether the learners *understood* the decision making properly because it is expected to be

easy just to memorize how to complete them.

Performance completing the exercises with similar rules in a new domain demonstrates how learners are able to either *memorise* the patterns (rather than details of the offered contexts) of adapting an action to context or to apply them independently, having understood these patterns.

Performance completing the exercises with new rules in a new domain assesses learners' ability to form (invent) new rules on how to adopt an action to an environment.

Finally, observing *correctness of decision-making in similar real-world situations* we can judge on how the learners can apply the skills developed in computer-assisted exercises on default reasoning to 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. In this study we do not evaluate how the learners form new rules in the real world environment as this task is proved to be too hard for the audience of trainees.

Our testing environment includes 20 exercises used for both training and evaluation (second column), 20 exercises using the same logic and structure in a distinct domain, 20 exercises for different domains, and 20 imitations (or reproductions) of real world environments. A drop-down box-based exercise is considered to be completed correctly if more than 80% of choices are correct, when the exercise is run multiple times with different (randomly generated) initial conditions.

Naturally, each evaluation step is more complex than a previous one to complete: we observe the monotonic decrease of the rate of completion for all three categories of learners. For learners from both autistic and other mental disorder groups the performance is declining faster than that of controls.

For the autistic group of learners *similar rules in a new domain* is a hardest step, and for the group of other mental disorders *decision-making in similar real-world situations* is the hardest step; however it may not characterise these groups with respect to their overall skills of the real world abstraction.

On average autistic individuals perform about 5% below individuals with other mental disorders for the first task, 2% for the second task, 9% for the third and fourth tasks but outperform the latter when untrained. This suggests that the case of autism indeed require harder learning efforts.

Hence we observe that the overall increase of performance is more that 3-fold (we do not present statistical evaluation here). Because evaluation takes a short time, it is safe to conclude that this is due to the completion of our exercises only.

		Performance completing the exercises which have been introduced earlier	Performance completing the exercises with similar rules in a new domain	Performance completing the exercises with new rules in a new domain	Correctness of decision-making in a similar real-world situations	Correctness of decision-making in a similar real-world situations without training
Autistic	A_S1	80	75	60	35	*5*
	A_S2	85	60	55	45	*15*
	A_S3	75	60	45	30	*25*
	A_S4	80	65	55	40	*10*
	A_S5	85	70	50	35	*5*
	A_S6	80	65	55	45	*15*
Avg		**80.8**	**65.8**	**53.3**	**38.3**	**12.5**
Other mental problems (matched for IQ) mental age	M_S1	95	60	55	45	*15*
	M_S2	85	55	55	55	*20*
	M_S3	80	65	60	35	*5*
	M_S4	80	70	55	40	*15*
	M_S5	85	75	65	35	*10*
	M_S6	85	70	60	45	*5*
	M_S7	85	75	60	40	*10*
Avg		**85.0**	**67.1**	**58.6**	**42.1**	**11.4**
Controls	C_S1	90	85	75	75	*60*
	C_S2	95	90	80	70	*65*
	C_S3	95	85	85	65	*65*
	C_S4	90	85	90	80	*70*
	C_S5	85	90	85	75	*70*
	C_S6	95	90	80	75	*65*
Avg		**91.7**	**87.5**	**82.5**	**73.3**	**65.8**

Table 1: Evaluation of learners' development. The performance is indicated as percentages of successful completions.

Conclusions

Our thesis is that difficulty arises in autism specifically in those situations where two default rules conflict while performing representation change; and this provides a relatively precise tool for understanding some of the phenomena of autism:

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 while updating representations;
3. Easy deviation from a reasoning context, caused by an insignificant detail, because there is a high number of plausible representations to address at each reasoning step;
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 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 loss of reasoning efficiency due to improper use of default rules leads to a wide range of reasoning problems reflected in behavioral and decision-making characteristics of autistic subjects beyond the domain of planning.

Based on the proposed model of the adjustment of representation for decision-making, we can formulate a methodology for experimental testing of our hypothesis that inability of proper representation change leads to a series of significant deviations of reasoning capabilities in autism. A typical situation where a default rule is naturally applied arises while understanding an ambiguous sentence (command), where one meaning is typical and another is atypical. Conducting a conversation with an autistic individual, an experimenter may ask ambiguous questions or give ambiguous commands, and track the reactions of the patient. Five phenomena of this study can be addressed in such a scenario, and observed in terms of how handling ambiguity via default rules influences these phenomena. We have conducted preliminary experiments along this line, and more detailed experimental observations of this sort are the subject of our further study. The strategies to assist autistic learning on how to efficiently change representations online are proposed in computer science literature (e.g. in Fink 2003).

Exploration of the peculiarities of autistic reasoning is becoming an emerging area involving logic, linguistic, psychology and philosophy (van Lambalgen and Smid, H. 2004). The ideas in this work, in particular, are have just started to contribute to design of rehabilitation software for autistic children, and the current work is one of the first linking these two.

In this study we evaluated how the learners transfer acquired default rules from artificial to real world situations. Rule transfer as a way to change representation 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 substantially increased.

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