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A face recognition system that simulates perception impairments of autistic children

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ABSTRACT

We use a face recognition algorithm to model differences in perception between autistic and non autistic children. With our model it is possible to reproduce several phenomena of autism by assuming that autistic children lack the ability to abstract from horizontal invariants. In particular, we can explain why autistic children are able to better recognize faces from parts of the face while the overall recognition of faces is worse than in non-autistic children. We would like to consider whether ASD may be the result of a version of a sophisticated perceptual system that makes less explicit use of invariants in the real world environment than the typically-developing brain. Some of these invariants may be hard-coded into the system rather than learned. The key point of our system is not the face recognition but the model which can mimic the autistic brain. In the discussion we extend the model by suggesting a general reduced ability to abstract from many different types of invariants and relate these as explanations to typical behavioral issues. In this way we hope to give a complementary insight into autism and ASD.

1. Introduction

Autistic children and children with the broader defined Autism Syndrome Disorder (ASD) are known to have severe communication disorders.

It has been proposed that artificial intelligence and developmental robotics may provide a useful tool for developing a theoretical understanding of ASD and may be useful in proposing possible treatments (e.g. [1]).

Many of the problems of autistic children are social ones. The CDC list of diagnostic criteria [2] describes a total of 8 possible symptoms of ASD with regard to social and communication impairments, such as *lack of speech*, *a lack of spontaneous seeking to share enjoyment, interests, or achievements with other people*, and others.[1]

Psychological symptoms of ASD go beyond problems of social interaction and communication, as autistic individuals also tend to have very unusual interests and interactions with objects and overall structure in the real world, such as (taken from the same list as above): *Restricted repetitive and stereotyped patterns of behavior, interests, and activities, … and restricted patterns of interest that are abnormal either in intensity or focus; apparently inflexible adherence to specific, non-functional routines or rituals; stereotyped and repetitive motor manners* and, *persistent preoccupation with parts of objects.*

Several theories about the causes of ASD exist. In the following, it appears to be useful to distinguish the explanations that concentrate on behavioral issues from the models that focus on perception deficits on the other hand.

One exotic representative of the first type of explanation is the view that autism is a combination of both behavioral and perceptive problems caused by an overdose of testosterone during a critical developmental period [4]. In that sense autism is seen as a result of an extremely *male* brain, which results in pathologically low levels of empathy. Thus, some see ASD as the opposite syndrome to the extreme empathic behavior that exists in the Williams syndrome. Note that Williams syndrome is connected to one particular genetic defect, while concerning autism, a wide range of genetic and other environmental influences are discussed. Remarkably, both syndromes share perception impairments to a certain degree [5].

Different from those explanations, the present work is intended to follow the latter type of explanation.

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[1] It may be an interesting side note that many of the phenomena of autism resemble cognition problems in artificial intelligence [3]. Again here we come back to the théodicée question of AI: Why do non-autistic individuals seem to easily detect objects, recognize faces, and find invariants in temporal sequences of task executions, while the very same tasks are extremely difficult to implement into machine perception.

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The reason for both types of explanation still competing after many years of extensive research of autism and ASD is due to the fact that the disease shows a complex spectrum of phenomena where behavioral issues are in many ways entangled with perception and development.

It is hard to distinguish between unusual behaviors that are a result of perceptive impairments and inherent primary unusual behaviors. However, some experimental evidence is not a result of the latter. For instance, various experiments of gazes show unusual results, such as autistic children focusing on no-feature-regions and the eye scan path seems without strategy [6,7]. Here one would assume that gaze patterns rather to be a result of an ill fated learning process based on badly processed data.

Thus it seems rather promising to consider more recent concepts that put emphasis on perception. Here we also have several theories that partly overlap: from a set of EEG [8] experiments, Ramachandran [9] popularized the notion that one very essential defect lays in the mirror neuron system ('broken mirror theory'). Since the human mirror neuron system and related issues of imitation still bear many unsolved problems in AI and developmental robotics, this type of theory also aroused much interest in those communities (see above).

Even earlier in time, it has been suggested that the behavioral problems may be caused by a "weak central coherence" (WCC) in perception (for a review see [10]), which suggests that all phenomena related to ASD might be understood under a single paradigm of an essential functional impairment that can be modeled.

The basic hypothesis of WCC is that due to enhanced perception of or focus on small details, the autistic individual is not able to perceive the 'big picture', which ultimately lies at the heart of all behavioral problems of autistic children. That is, autistic individuals "cannot see the woods for the trees."

The link between invariants and Ramachandran's mirror theory may be that also for imitation invariants are necessary to detect [11].

If the WCC idea is considered as a general theory of perception in ASD, it could perhaps be extended to understand deficits in social interaction, imitation, and the mirror neuron system. Thus, rather than focusing on initial behavioral impairments, it might make sense to focus first on understanding potential sensory deficits, with pathological behaviors of ASD then viewed as a secondary effect of the underlying sensory problems. Following this idea, we propose in this paper that a major element of ASD may be general impairment in the ability to detect perceptual invariants.

Real-world invariants may often be hard to detect because they are hidden behind several stages of processing. The problem here is quite similar to that of dimensionality reduction in machine learning: knowledge of symmetries and other invariants allows one to reduce the search space and is a basic element of "imagination" and planning. Thus, such knowledge is essential in real-world intelligent agents. Precisely how these invariants come about or where they come from is an open question (and a topic of deep discussion in the literature, see for example [12]). Lack of proper invariants can render even the most powerful machine learning algorithms ineffective, thus designing the right set of features is critical for learning methods applied to real-world tasks.

In some sense mirror neurons and imitation also fit into the context of invariants. The knowledge of which actions of others are equivalent to one's own actions (thus invariance to *self* vs. *other*) may be considered necessary to perform imitation and may be seen as a very complicated perceptual invariant – body parts of the other person have to be identified with one's own body parts, etc. Many of these invariants seem to come on-line even very early in life [13].

In addition, experiments [14] show that while autistic children have an overall reduced capability to recognize persons, they are relatively competent in recognizing persons from parts of their faces. In regard to the latter ability, autistic children have been shown to outperform their non-autistic control group. We use these findings as key elements to verify our idea that the main perceptual problem of autistic children is the inability to abstract from invariants of perceptions.

Last, but not least, the well-known and notorious interest of autistic children in series or repetitions can be considered as a significant hint that autistic children's perception works in a different way. While non-autistic perception filters, i.e. discards, redundancy of identical items, the autistic perception lets an identical feature stick out and thus lets it appear interesting. In this way one may interpret it as another example for the lacking of abstraction from invariants of perception.

To provide a better illustration, this paper presents two different approaches. The first approach (Model I) is a model that uses a very reduced stimulus environment. Here just smiley pictures are used as stimuli. The second model (Model II) is constructed to be able to process real faces of humans. For this purpose several steps of preprocessing are necessary.

Both models follow a similar scheme to simulate the differences between a vision processing that is impaired by effects of autism and another one that is not. Thus, we use these findings as key elements to verify our idea that the main perceptual problem of autistic children is the inability to abstract from invariants of perceptions.

It is important to emphasize here that the system presented below is *not* a technical approach for face recognition, rather it is intended to simulate or rather to illustrate features of human face recognition and consequences of the lack of those features, and to make a connection to symptoms of autism. Thus, in no way the system can compete with technical face recognition. We also do not assume that the impairment of ASD is only caused by the inability to detect positional invariants. Rather we think that in the case of ASD the general impairment can be a place holder for other types of inabilities to generalize from invariants. In the discussion section, we are going to summarize more ideas for invariants which could be considered for children with ASD.

In the following we describe the experimental methods and results. We close with a discussion that includes analog explanations to several phenomena related to autism, ASD and Asperger syndrome.

2. Model I

In this paper we develop a simulation to examine the computational benefits (and costs) when a symmetry constraint is implemented (the "non-autistic" version) and compare this to the case when the same symmetry constraint is not implemented ("autistic" version). The method presented here is a simple feed forward neural network that performs a discrimination task. One way to measure the computational cost is to find the number of neurons that are necessary to perform the discrimination task. The plots that appear below always show the number of neurons versus a later described performance index.

In this section we are going to outline the following properties of the model: first layer, stimulus, receptive field design (for both precedent conditions), and the learning algorithm of the discrimination task.

Stimulus: For the Model I, we use "Smileys". The task is to discriminate a non-smiling "Speechless Smiley"[2] from a standard Smiley. (see Fig. 1, Stim. 1 and Stim. 2). In our model the size of the

[2] This is the notation for this type of pictogram in the Skype chatting system.