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Comparing neurotypical adults differing in their position on the autism spectrum – a qualitative analysis of eye movements

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Abstract: Recent research has brought mixed results about differences in attention allocation measured by eye tracking between autistic and neurotypical individuals. There are several reasons that might be at the core of this confusion, including the given task. We tested 10 neurotypical adults in our experiment: they filled out a questionnaire based on self-evaluation assessing their position on the autistic spectrum. Their eye movements were recorded while viewing several complex visual scenes in two conditions: free viewing and completing a task. We qualitatively compared the visual strategies of two participants scoring on extreme poles of the spectrum in the analysis. Our findings indicate that the task might play a crucial role in research on attention allocation in autism.

Keywords: autism spectrum disorders, eye tracking, attention allocation, task-driven perception

1 Introduction

Autism spectrum disorders (ASD) are characterized by three main symptom areas: qualitative abnormalities in reciprocal social interaction, deficits in communication and a restricted, stereotyped, repetitive repertoire of interests and activities (MKN-10, 1993). Interest in other autistic symptoms has increased of late, specifically sensory alterations in autistic individuals.

The population of autistic individuals is very heterogeneous. Some authors claim that autism can be perceived as an extreme pole of personality traits that are present in non-clinical population as well (Lundström et al., 2012). Relatives of autistic individuals report an increased score in traits linked with ASD (Constantino & Todd, 2005). There is also neurological (Puzzo, Cooper, Vetter, & Russo, 2010) and genetic (Geschwind, 2011) evidence that support the hypothesis about the distribution of a wide variance of autistic traits in the population.

For measuring the specific ways of perceiving visual stimuli, an eye tracking technology is being used increasingly frequently: modern eye trackers obtain data from measuring the position of the corneal reflection in relation to the pupil centre (Duchowski, 2007). There have been several studies carried out to determine whether the visual strategies of autistic individuals differ from those of neurotypical (NT) individuals while viewing social stimuli (typically faces). The results are mixed. A number of studies claim differences between groups exist and individuals with ASD look less at some areas of the pictures (e.g. Klin, Jones, Schultz, Volkmar, & Cohen, 2002), while some did not find a statistically significant difference between groups at all (e.g. Muszkat et al., 2015).

Overall, it seems that autistic individuals look less at the area of the eyes while viewing faces (see metaanalysis Chita-Tegmark, 2016) but the reason for the research inconsistencies remains unexplained. Several factors have been suggested: stimuli used in the procedure, given task and heterogeneity of the experimental group (Benson & Fletcher-Watson, 2011). It is possible that autistic individuals tend to use specific strategies of visual perception, however these strategies might but do not have to be used by them during the experiment setting – this may be influenced by the specific task that is given to the participants (Elsabbagh & Johnson, 2007). A hypothesis has been raised that children with ASD are able to learn and use other visual strategies, although they do not use these strategies automatically. A research paper by Chawarska & Volkmar (2007) supports this hypothesis: it compares autistic children at the age of 2 and 4 and claims that the ability to recognize faces improves with age.

It is not only faces which might be viewed differently by autistic individuals. Visual strategies manifested by autistic individuals during a social scene viewing have been also tested using a combination of people/faces and objects in the visual field of the participant. Some authors have used arrays or faces and objects arranged as competing stimuli (Unruh et al., 2016), while some used complex scenes with a person using some everyday objects in a typical way (Rice, Moriuchi, Jones, & Klin, 2012). The results provide several outcomes which are also contradictory at some points. Unruh et al. (2016) claim, for example, that autistic participants focused more on fixating objects instead of a typical strategy of fixating faces, while in contrast Chevallier et al. (2015)

found that differences between ASD and NT participants were significant only in a specific interactive task. Thus the question of whether ASD individuals use different visual strategies or eventually under what circumstances this is the case, remains unanswered.

The aim of our research is to contribute to the above-mentioned discussion. We assume that individuals who score higher on the autistic traits continuum will manifest atypical visual strategies in scanning the stimuli. These atypical strategies should be similar to those manifested by ASD individuals: shorter fixation time spent on the social objects (information-rich region of interest or ROI) and a longer fixation time spent on an inanimate (information-poor) background. This effect should be present mainly in the free-viewing condition and could be lower or absent in the task condition, since in this case, presumably, participants with different automatic visual strategies could also be able to overcome their strategies in favour of the given task. In this pilot experiment, we analyse two case studies of participants who scored extremely high on a questionnaire assessing autistic traits.

2 Methods

2.1 Participants

Our participants were recruited via social media and their interest was probably based on their curiosity about the eye tracking method. We tested 10 participants (mean age = 26,6, sd = 3,8), where 5 of them were men (mean age = 25,8, sd = 3,5) and five of them women (mean age = 27,4, sd = 4,4). Since most of them were students or fresh graduates, the sample cannot be considered representative. Due, however, to the qualitative and exploratory character of our research and also thanks to our assumption that the group of students will also be heterogeneous in autistic traits, we did not regard this as problematic.

We submitted the research proposal to the ethical committee of the Department of Psychology at the Faculty of Arts, Masaryk University and the research was not considered ethically questionable. Each participant read and signed an informed consent before the start of the experiment and after the experiment an option of a debriefing was offered to every participant.

2.2 Procedure

The experiment took place in the HUMElab laboratory at the Faculty of Arts, Masaryk University.

After the start of the experiment, each participant filled in a self-assessment questionnaire Autism Quotient (which we will address as AQ questionnaire in the text; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001). A participant can gain 50 points in the AQ questionnaire in total, where 32 is considered to be a cut off score for ASD suspicion by the authors of the method. There are five subscales in the AQ questionnaire, each of them measured by ten questions (social skills, attention switching, attention to detail, communication, imagination). We used a Czech version of the questionnaire (Dostál, Plháková, & Záškodná, 2014) which was accessible online (http://docs.autismresearchcentre.com/tests/AQ_Adult_Czech.pdf). We changed the heading on the questionnaire so it would not affect the participants during the administration. The questionnaire was used for similar purposes before (Puzzo et al., 2010).

After administration of the AQ method, each participant took part in the eye tracking part of the experiment (see more below). In the final part of the procedure, a socio-demographic questionnaire was administrated with some questions aiming at added ASD clinical symptoms details.

2.3 Eye tracking apparatus

For the preparation, presentation and analysis of the eye tracking part of the experiment, we used SMI Red250 eye tracker with 250Hz frequency and its corresponding software (Experiment Centre, Be Gaze). All the pictures were adjusted to be equal in size (3000 × 2000 px) and were presented on an LCD monitor at an approximate distance 65 cm.

We used pictures of complex scenes as stimuli. A complex scene is a scene that depicts some people (social stimuli) in their naturalistic environment (background) involved in an activity. We downloaded these images from free online databases (Unsplash, Pexels, Stock Snap, Pixabay); we used pictures with no copyright restrictions. The final set of 14 images was selected from a larger set of original images by the criteria defined in advance. We also used an inter-rater reliability to assess the information rich areas of the images. For more details about the process of stimuli selection, please, see Table 1 (below).

We presented the final set of stimuli in two conditions: free-viewing (with the instruction *Now you will see several pictures*) and task condition (with the instruction *Say out loud what is happening in the picture*). Distribution of the images into the conditions was random and different for each participant. Each picture was presented for 5 seconds. Before the actual data collection, the calibration and validation of the system took place.

Tab. 1: Steps in selection of the stimuli

1.	There are some social and some non-social parts in the image. The social part of the image represents at least 2 people who interact together.
2.	The social part of the image constitutes less than 20% of the overall image area.
3.	Inter-rater assessment provided unequivocal agreement on the information-rich ROI of the images.
4.	The social part of the image represents exactly two people interacting.

3 Results

3.1 Data loss

Before the data analysis, we needed to check the data quality and eventually exclude some participants with high data loss from further analysis. A small percentage of data loss can be caused by blinking or looking away from the monitor display, while a high data loss percentage might indicate problems with calibration that can also affect the rest of the data. Before the data quality check, we defined the exclusive criteria: we would exclude a participant who lost more than 20% of the overall data. We excluded one participant after the data quality check.

3.2 Case studies

First, we placed our participants on the specific points on the autism spectrum based on their score in the AQ questionnaire. You can see the results in Image 1. Participants with extreme scores were easy to detect; we named them participant A (scored low in AQ, represents a "non-autistic" population) and participant B (scored high in AQ, represents a "close-to-ASD population").

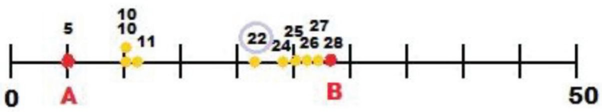

Image 1: AQ score for all participants. The extreme scores of the participant we chose for further qualitative analysis are in red. The participant with score 22 was excluded from the analysis due to high data loss (see above).

We consequently compared participants A and B in several characteristics. It seems that these participants were similar in most of the measured characteristics except for the AQ score: they both were women, aged around 30 (A: 33, B: 31), without a ASD diagnosis present or suspected in their family or themselves, did not wear glasses or contact lens, were not under stress during the data collection (on a scale of 1–10 both chose the answer 1 – not nervous at all), both understood the task very well (on a scale of 1–10 A chose 10 – perfect, B chose 9 – nearly perfect) and considered the images mildly interesting (on a scale of 110 A chose 5 – medium, B chose 7 – more than medium). Participant A worked as a journalist, participant B worked as an assistant and spent most of the day working on a PC. In other words, we did not find any other factor except for their position on the autism spectrum that could influence the eventual differences in their eye tracking measures to a great extent. Their scores on the AQ questionnaire, including subscales scores, are presented in Table 2. The highest differences between the participants were found in the subscales social skills, attention switching and attention to detail.

For further analysis, we decided to use some graphic data visualisations for our qualitative analysis, similar to some other authors (e.g. Bojko, 2006). We specifically used scanpaths (which depict both fixations and saccades) and sequence charts (which show specific points in time when a participant visited an ROI).

Tab. 2: AQ scores of participants A and B

	participant A	participant B
total score	**5**	**28**
percentile*	99	2
social skills	0	6
attention switching	2	9
attention to detail	2	8
communication	1	2
imagination	0	3

* percentile according to Baron-Cohen et al., 2001

First, we compared the visual strategies of participants A and B in the free-viewing condition (see Image 2 for an example of scanpaths for both participants and Image 3 for an example of sequence charts). The analysis showed that participant A stayed focused on the information-rich ROI, while participant B also scanned the background, including the unimportant details. Since the stimuli was presented only for 5 seconds, the information-rich ROI and background could be considered competing stimuli. This is the reason why the decision of participant B to fixate the inanimate background to this extent could be considered at least interesting, or even atypical. In contrast, participant A fixated information-rich ROI (social part of the image) for a long time and her fixations are also quite long. These differences are also clearly visible in the sequence chart: participant A is fixating the information-rich ROI and after leaving it is quickly returning back to it, while participant B fixated the information-rich ROI as well, but left it nearly immediately and in the second part of the stimuli exposure did not fixate it at all.

Image 2: Scanpaths for free-viewing condition in an example stimulus

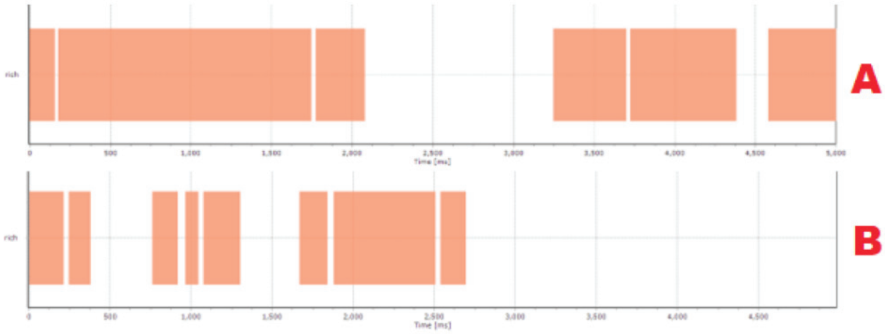

Image 3: Sequence charts for free-viewing condition in an example stimulus

Image 4: Scanpaths for task condition in an example stimulus

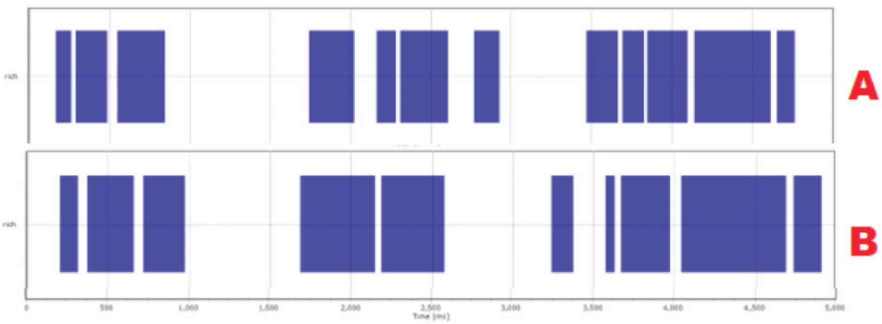

Image 5: Sequence charts for task condition in an example stimulus

The results for the task condition, however, look different: the differences between participants A and B do not seem so significant (see Image 4 for an example of scanpaths for both participants and Image 5 for an example of sequence charts). Both participants start at the information rich ROI, and return to it twice during the stimulus administration. Both of them also spend some time scanning the environment. Participant B seems to be more focused on some unimportant objects (in this case these are the objects on the night stand) than participant A, but the differences are certainly not that strong in this condition. In addition, the sequence charts suggest that the similarities in the visual strategies in the task conditions are not caused entirely by participant B adjusting her visual strategies: we can see that participant A adjusted her scanning patterns as well.

3.3 Free data exploration

The participants' scores in the AQ questionnaire enabled us to divide the sample into two groups easily: four participants scored between 5–11 points ('low' autism score group) and five participants scored between 24–28 points ('high' autism score group, for more details see Image 1). The sample we used was low and the comparison was not planned. In contrast, we planned to explore the data in various ways and the groups differed a great deal – 13 points between the closest score. We consequently decided to use boxplots for comparing group means in the total fixation time on the information-rich ROI for both tasks. The results are shown in Image 6. The graph shows that the difference between groups is larger in the free-viewing task, in the task condition it might be seen as negligible. It seems that the low autism score group spends more time fixating information-rich ROI in the free-viewing condition than the high autism score group; in the task condition their fixation times are similar. Wen we used, however, the Mann-Whitney U test for comparing groups in the free viewing condition, the differences between groups were not significant (U = 31,5, p = 0,4777), in all probability due to the small sample. Our preliminary results have to therefore be tested by confirmatory analysis and on a larger sample.

4 Conclusion

The results of the qualitative and exploratory analysis of eye tracking data visualisations were a little surprising. Although our participants were not clinically autistic, we found some major differences in visual strategies of participants with high and low scores in the AQ questionnaire. Our results are also in line with the assumption that ASD might represent an extreme pole of typical personality traits distributed over the population.

These differences were, however, found only in the free-viewing condition. This demonstrates the importance of the task given to participants during the eye

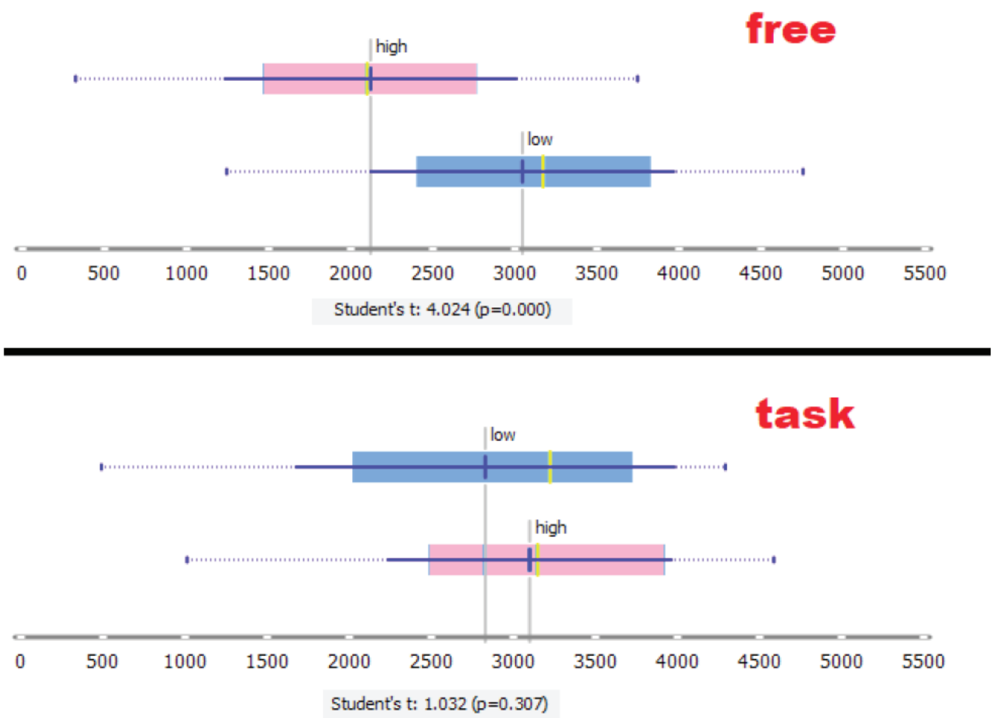

Image 6: Boxplots for the mean time of the fixation time spent on the information-rich ROI, in ms. The pink colour shows the group scoring high on the autism spectrum ("autism group"), while the blue colour shows the group scoring low on the autism spectrum ("typically developed" group)

tracking experiments, especially while autistic individuals are participating. The task could also be the reason for the contradicting results in this research area, since not all the work takes the task role into account. This is also significant because of the character of the used task: it is not all that extraordinary and does not stand out from the automatic task we use to implicitly instruct ourselves during a real life scene viewing – to quickly find out what is happening. This kind of task nevertheless influences the visual strategies of our participants.

The main limit of this research is its exploratory nature. The hypotheses should also be tested in further confirmatory research with a larger sample. There are at least two major possible directions for the further research in the area: testing visual strategies of ASD vs. NT individuals in two task conditions and testing the visual strategies of non-autistic individuals similarly while measuring their autistic traits. In this case, using an AQ subscales scores as separate factors might also be useful. Another interesting research direction is to include individuals from a so-called broader autism phenotype (BAP) in the sample. BAP is a category for individuals with milder autistic traits that do not reach the extent for a clinical diagnosis, for example siblings of ASD individuals (Piven, Palmer, Jacobi, Childress, & Arndt, 1997). In our research, we did not analyse the actual answers on the given task in task condition: a semantic analysis of these could also provide more insight into perception strategies in a broader context.

Dedication

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