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Adaptation to the Speed of Biological Motion in Autism

Questa è la Versione finale referata (Post print/Accepted manuscript) della seguente pubblicazione:

Original Citation:

Adaptation to the Speed of Biological Motion in Autism / Themis Karaminis; Roberto Arrighi; Georgia Forth; David Burr; Elizabeth Pellicano. - In: JOURNAL OF AUTISM AND DEVELOPMENTAL DISORDERS. - ISSN 1573-3432. - ELETTRONICO. - (2020), pp. 0-0. [10.1007/s10803-019-04241-4]

Availability:

This version is available at: 2158/1175350 since: 2020-05-19T12:16:15Z

Published version:

DOI: 10.1007/s10803-019-04241-4

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Publisher copyright claim:

(Article begins on next page)

09 April 2024

Journal of Autism and Developmental Disorders
Adaptation to the Speed of Biological Motion in Autism
--Manuscript Draft--

Manuscript Number:	JADD-D-19-00023R1
Full Title:	Adaptation to the Speed of Biological Motion in Autism
Article Type:	Article
Keywords:	Autism; perception; adaptation; biological motion; running speed
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Funding Information:	Medical Research Council (MR/J013145/1) — Professor Elizabeth Pellicano European Research Council (STANIB) — Professor David Burr European Research Council (ECSPLAIN) — Professor David Burr H2020 European Research Council (832813) — Professor David Burr
Abstract:	Autistic individuals often present atypicalities in adaptation – the continuous recalibration of perceptual systems driven by recent sensory experiences. Here, we examined such atypicalities in human biological motion. We used a dual-task paradigm, including a running-speed discrimination task (‘comparing the speed of two running silhouettes’) and a change-detection task (‘detecting fixation-point shrinkages’) assessing attention. We tested 19 school-age autistic and 19 age- and ability-matched typical participants, also recording eye-movements. The two groups presented comparable speed-discrimination abilities and, unexpectedly, comparable adaptation. Accuracy in the change-detection task and the scatter of eye-fixations around the fixation point were also similar across groups. Yet, the scatter of fixations reliably predicted the magnitude of adaptation, demonstrating the importance of controlling for attention in adaptation studies.
Response to Reviewers:	3rd September 2019 Dr Carla Mazefsky, Associate Editor, Journal of Autism and Developmental Disorders

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Dear Dr Mazefsky,

Please find enclosed a revision of the manuscript titled, “Adaptation to the Speed of Biological Motion in Autism”, which we would like to be considered for publication in Journal of Autism and Developmental Disorders.

We were very pleased to receive such positive comments on the original manuscript from Reviewers #1 and #3, and we are grateful for the opportunity to submit a revision of the paper for further consideration. We very much appreciate the insightful and constructive points raised by the reviewers. In light of these comments, we have made appropriate adjustments throughout the manuscript and we outline our point-by-point response to the reviewers’ comments below.

We thank you and the two reviewers very much, once again, for all of the incredibly helpful suggestions. We believe that the current version is now a much stronger paper. We hope that you will find this version suitable for publication in the Journal of Autism and Developmental Disorders.

Yours sincerely,

Authors

Reviewer’s #1 comments:
The authors examined the extent of adaptation to point light walker running speed in 19 autistic children and 19 matched controls. Contrary to expectations, they found equivalent adaptation in the two groups and equivalent fixations on the fixation point. However, they also found that those who fixated less well exhibited less adaptation, and therefore in principle differential fixations between groups may explain some previous findings of lower adaptation in autism.

The study appears to have been well designed and executed and the manuscript was clear and balanced. I suggest that after some revisions it is likely to make an interesting contribution to the literature.

I only have one important suggestion: Given that the main claim made in this paper relates to the lack of a group difference in adaptation, I think the non-significant p should be accompanied by a Bayesian test demonstrating support for the null rather than inconclusive evidence.

RESPONSE:
We thank the reviewer for their positive comments about our study and for their suggestion. We have complemented our analysis by a Bayesian test, which suggested that our data provide substantial evidence in favour of the null hypothesis. We added the following paragraph in the revised manuscript (p. 13).

We also performed a Bayesian independent samples t-test using JASP software (Version 0.8.0.0; JASP Team 2016) and estimated a Bayes factor using Bayesian information criteria (Wagenmakers 2007), which allowed for a comparison of the fit of our data under the null hypothesis that there are no differences between autistic and typical children in the magnitude of the adaptation to the speed of biological motion, and the alternative hypothesis that adaptation differs in the two groups of participants. The Bayes factor (null/alternative- estimated using a Cauchy distribution prior with a scaling factor of 1) was 3.38, suggesting that our results were 3.38 times more likely to occur under the null hypothesis than under the alternative hypothesis. Our data, therefore, provided substantial evidence (Wetzels et al. 2011) that autistic and typical participants adapted to the speed of biological motion to a comparable degree.

Minor points:
1. Last page of the introduction, first line. Edey et al. (2019) Autism Research could be added here.
RESPONSE:
Thanks for this suggestion. We have included this reference in the revised manuscript (p. 4).

2. The authors claim it is likely attenuated adaptation would be found, given it's been found for faces and there is overlap in the supporting cortical systems (STS). I did not find this reasoning clear given there are additional distinct supporting systems and it is not apparent that STS is specifically responsible for face effects. Could the authors either elucidate this reasoning further or remove? Relatedly, perhaps they could additionally motivate the study by considering what it adds to the existing van Boxtel experiment?
RESPONSE:
We thank the reviewer for this comment. There are two main reasons for which we are interested in examining adaptation to biological motion in autism. First, adaptation is a ubiquitous property of perception and, second, there is extensive evidence for attenuated adaptation in autism in a range of domains, including social and non-social stimuli. Thus, it is likely that attenuated adaptation is domain-general and manifests in most perceptual domains.
Biological motion is a good candidate domain to examine adaptation because of its affinity to face processing. Both biological motion and face stimuli involve processing socially-relevant information, which is important given autistic people’s characteristics in social interaction. Yet, while earlier studies have examined adaptation in autism in relation to a wide range of facial attributes (identity, facial configuration, gaze direction, emotional expression), there is, to our knowledge, only one study that examines adaptation to biological motion in autism (van Boxtel et al., 2016; focusing on action discrimination).
Regarding the evidence from neuroimaging studies, we appreciate that there are additional distinct neural networks supporting the processing of facial or biological motion stimuli and that STS is not specifically responsible for face effects. Apart from the STS, additional neural networks are involved in both the processing of faces and biological motion, for example, the fusiform and the lingua guri (ventral regions) (Gobbini et al, 2007; Vaina et al., 2001). The presence of neural networks involved in the processing of faces and biological motion implies that biological motion is a good candidate domain to look for attenuated adaptation (compared to the hypothetical case of a double dissociation).
We have made amendments to make our reasoning in the introduction clearer. The amendments also clarify what this study adds to the study by van Boxtel et al. (2016). First, that our study extends the study of the adaptive coding of biological motion in autism considering a new attribute, namely the running speed. Second, our study examines attention rigorously as it employs an empirical control task and eye-tracking methods.

3. From description the psychometric functions were analysed by eye and poor fits excluded. This method is unlikely to have generated bias due to the observers being blind to group membership. However, were they using specific criteria? E.g., PSEs outside of presented range, precisions above certain values? If so, it would be helpful to add these.
RESPONSE:
Many thanks to the reviewer for this comment. The individual data were eyeballed by two expert psychophysicists using a double-blind design. We did not apply quantitative criteria to identify poor fits, but to assure the reviewer that our procedures were robust, we provide two examples of good and two examples of bad fits in a figure we have submitted as a Supplementary file.

4. It may make the methods an easier read if some of the 'stimuli' section was moved to the 'procedure'. E.g., description of fast and slow adaptors, and stimuli appearing first on one side and then the other, were hard for me to parse when I had not read yet about the basic trial set up.
RESPONSE:
We have made amendments in the methods to make this section an easier read. We have also included a new Figure (Figure 1 in revised manuscript) presenting details on the trial and task structure and the stimuli.

5. Any reason why RTs are presented only for the change-detection task?
RESPONSE:
We thank the reviewer for raising this interesting point. RTs were not measured for the

speed-discrimination task because responses for this task were registered offline, after the 4 sec period in which the test stimuli were presented had elapsed. We have alluded to this detail in the revised manuscript (p. 12).

6. It would be helpful if the scatterplot of greatest relevance (the final one) could be highlighted for the reader.
RESPONSE:
Done. We added a frame to highlight the scatterplot.

7. When the authors consider the distinction between the present findings and those of van Boxtel they discuss that one cause may be the different perceptual feature being judged (running speed vs type of movement). When considering this possible difference it may be interesting for the authors to speculate on the likely correspondence between the kinematics of the PLD and the participants' own running speed. One study suggests faster velocity arm movements in autistic participants (e.g., Cook, Blakemore, Press, 2013, Brain), which may arguably translate also to faster velocity running. Is it possible that individuals with autism display lower adaptation in principle, but that the kinematics of the particular stimuli shown were closer to autistic typical running kinematics? This perceptual similarity could render the movements easier to encode / predict by the autistic group relative to other types of movement, and this effect could mask the generalised difficulty.
RESPONSE:
Thanks for this interesting suggestion. We now speak to this account in the revised manuscript (p. 17).

8. The double-blinding has not worked, with the ethical compliance section at the end and the ethics section in the methods.
RESPONSE:
We apologise for this. During the initial submission process, we were asked by the editorial office to include the section on ‘compliance with ethical standards’ in the manuscript. We have since blinded the information contained within this section.

Reviewer’s #3 comments:
This article examines perceptual adaptation in autism using point-light-display biological motion stimuli. The hypothesis that basic disruptions of perceptual abilities may interfere with processing of social information is of interest, and the autism (ASD) and healthy control groups are well characterized and matched. Still, there are several notable concerns with the manuscript in its present form, most of which I believe can be addressed by clarifying the way information is presented. Several more minor issues also are noted below.

Major points
1. While the topic of this study is of interest, it was unclear whether the authors were proposing that difficulties in perceptual adaptation relate to and are specific to biological motion processing issues, sensory issues, or both. Also, justification for these linkages were not entirely clear. For example, there is an extensive biological motion literature in ASD using point-light displays, though most of this literature is only superficially discussed and not described in relation to basic perceptual or adaptation processes. Why would perceptual adaptation impact biological motion processes - would the effect be predicted to be more or less profound than more basic face or social processes?

RESPONSE:
We are delighted to hear that the Reviewer found that the topic of this study is of interest and we thank them for this interesting comment.
In the first instance, our study is motivated by empirical and theoretical work proposing that atypicalities in perceptual adaptation could be one fundamental difference between the perceptual systems of autistic and typical people. As adaptation is ubiquitous in perception, it is likely that attenuated adaptation is found in biological motion in autism, similar to other perceptual domains. In that sense, difficulties in perceptual adaptation examined in this study relate to general sensory issues in autism, in particular, fundamental characteristics of perception and sensation in autistic people. Furthermore, the presence of domain-general limitations in adaptation in autism could account for sensory issues in the condition (e.g., why autistic people

might find certain sounds particularly disturbing), as well as core social difficulties, on the basis of a common neural mechanism (Lawson, Aylward, Roiser, & Rees, 2017). We have made amendments in the introduction to present our ideas more clearly (p.3). We thank the Reviewer for highlighting the need to link the literature on biological motion in autism literature to adaptation processes. We have made amendments to present the study by van Boxtel et al. (2016), who examined both discrimination and adaptation to biological motion in autism (type of movement) in further detail, also alluding to the lack (to our knowledge) of other studies on this topic (p. 4).

2. Examples in the background of key concepts would be helpful (e.g., first paragraph of intro, ex of how limitations in speed of adaptation would relate to sensory function/issues in ASD). Related to this point, the authors contend that their data speak to sensory issues in ASD in both background and discussion sections, but this relationship is not clearly described, nor do their data speak to this relationship as they test processing of social percepts.

RESPONSE:
We thank the reviewer for this comment. We have provided examples of key concepts in the introduction (pp. 1 and 3).

We appreciate that the data collected in this study refer to the processing of social percepts. Nevertheless, as adaptation is a ubiquitous property of perception, our findings are also relevant to accounts positing that autistic people present fundamental atypicalities in adaptive coding. Together with evidence from earlier studies on adaptation in autism, our data suggest that these atypicalities are not pervasive in the condition and that more nuanced accounts are warranted.

3. I found the descriptions of the experiment and analysis approach difficult to follow. More specifically, the experimental stimuli, including the timing and various conditions, were quite complex and not readily accessible based on the text alone. My suggestion would be to present the task stimuli and various conditions as a figure(s) so that this information is more easily processed.

RESPONSE:
We thank the reviewer for this comment. We have included a figure to present more clearly the experimental design and the stimuli (Figure 1).

4. Related to this point, some of the descriptors critical to understanding task outcomes warrant more detailed explanations. For example, the following statements are not clearly explained "adaptation may relate to the atypical encoding of precision in the perceptual hierarchy in autism" AND "The two conditions elicited adaptation aftereffects in the opposite direction thereby implementing a 'push-pull' adaptation protocol".

RESPONSE:
We thank the reviewer for this comment. We have added additional details so that these statements are clearer (p. 2 and pp. 8-9 and 11).

5. The thresholding procedure for determining psychophysical functions should be more clearly described - specifically, these functions often are difficult to reliably define/estimate, particularly in pediatric or patient populations. Criterion for convergence should be explained.

RESPONSE:
We thank the reviewer for highlighting this issue.

We agree that it is challenging to estimate psychophysical functions in pediatric or clinical populations. Our team, however, is well versed in the use of both developmentally appropriate and child-friendly methods to ensure that get the best responses from children, including children on the autism spectrum. In the speed discrimination task, we used the adaptive algorithm QUEST to choose the speed of the test stimuli. Please note that we did not derive precision thresholds of individual participants from QUEST per se (we did not use the values to which QUEST converged), to avoid problems related to local minima or attentional lapses (see also Manning et al., 2018). Rather, we employed QUEST to ensure that testing trials focused around the precision thresholds of individual participants. To obtain a good distribution of data around the precision thresholds, a random jitter of 0.1 log units was added to the estimates of the QUEST. After testing has been completed, we employed offline best-fitting procedure to determine precision thresholds with a customised MatLab function. Threshold estimates were taken as the standard deviation of the best-fitting cumulative Gaussian function.

Manning, C., Jones, P. R., Dekker, T. M., & Pellicano, E. (2018). Psychophysics with children: Investigating the effects of attentional lapses on threshold estimates. Attention, perception & psychophysics, 80, 1311–1324. doi:10.3758/s13414-018-1510-2

We have made amendments to the manuscript (pp. 9, 10, and 11) to provide more details on our thresholding procedures.

6. The above point is particularly salient in the context of such a large number of participants being excluded due to their data not fitting a discernible function. Describing participant characteristics for these individuals would be helpful in the context of the null findings from many of the group comparisons here - were these strong/weak performers across the board, were they younger/older, lower/higher IQ, more/less ASD symptoms?

RESPONSE:

We thank the reviewer for this comment, which prompted us to identify a confusing typo in the original manuscript, for which we apologise. The correct number of participants excluded due to poor psychometric curves is seven (not fourteen, as mentioned in the first manuscript- the total number of exclusions was fourteen). This corresponds to three autistic and four typical participants. Thus, the rate of exclusions due to poor psychometric curves was 18% of the final sample, which is comparable to the number of exclusions in other developmental psychophysical studies. The typo has been corrected on p. 6.

For the Reviewer’s information, we provide data in the table below on the profile of the excluded participants.

ID ----- Autistic/Typical --------- Age ----- IQ (Full Scale) ----- ADOS Algorithm score ------- SCQ
BD743 --- Typical ---------------- 10 --------- 114 ------------------ n/a --------------------------- 2
BD712 --- Typical ---------------- 17 --------- 93 ------------------- n/a --------------------------- n/a
BD739 --- Autistic --------------- 8 ---------- 87 ------------------- 9 ---------------------------- 13
BD636 --- Typical --------------- 11---------- 78 ------------------- n/a ----------------------------18 (above cutoff)
BD826 --- Autistic --------------- 16 --------- 64 -------------------- 17 ---------------------------- 29
BD845 --- Autistic ---------------- 8 ---------- 93 ------------------- 9 ----------------------------- 28
BD110 --- Typical ----------------- 7 --------- 106 -------------------n/a --------------------------- n/a

7. It would be helpful for the author to clarify how using different stimulus sizes allows them to ensure that percepts were made based on higher-level processes, or how that was verified?

RESPONSE: We thank the reviewer for raising this important issue. We have made amendments to clarify the usefulness of this manipulation. More specifically, we have added the following paragraph in the revised manuscript (pp. 9-10).

The Test stimulus appeared in three possible sizes, small (8° x 4°), medium (10° x 5°), and large (12°x 6°). This manipulation ensured that our participants could not solve the discrimination task (and give good psychometric curves) by relying on the local speed of the dots constituting the PLDs. For example, let’s assume that the two test stimuli (Reference and Test) moved at the same speed (say, a gait cycle per second) and that the Test stimulus was small. Because of this size difference, the distance covered by the individual dots of the Test stimulus (e.g., the feet) during a cycle gait would be shorter than the distance covered by the corresponding dots of the Reference stimulus. Based on this difference, if participants relied on a local-speed response strategy, they should present a bias to respond that the Reference stimulus would be faster. By contrast, if participants relied on a global response strategy, they should not present this bias.

Minor points:
8. On several occasions the authors refer to "recent" research that is 3-5 years old. I would remove use of adjective "recent" from these statements.
RESPONSE:
We thank the reviewer for this comment. The adjective “recent” has been removed.

9. The abstract is hard to understand as a stand-alone without some description of the tasks.
RESPONSE:
We thank the reviewer for this comment, we have made amendments to the abstract to include a brief description of the task.

Autistic individuals often present atypicalities in adaptation – the continuous recalibration of perceptual systems driven by recent sensory experiences. Here, we examined such atypicalities in human biological motion. We used a dual-task paradigm, including a running-speed discrimination task (‘comparing the speed of two running silhouettes’) and a change-detection task (‘detecting fixation-point shrinkages’) assessing attention. We tested 19 school-age autistic and 19 age- and ability-matched typical participants, also recording eye-movements. The two groups presented comparable speed-discrimination abilities and, unexpectedly, comparable adaptation. Accuracy in the change-detection task and the scatter of eye-fixations around the fixation point were also similar across groups. Yet, the scatter of fixations reliably predicted the magnitude of adaptation, demonstrating the importance of controlling for attention in adaptation studies.

10. Person-first language would be preferable throughout.
RESPONSE:
We thank the reviewer for highlighting this issue. We acknowledge that person-first language (e.g., “children with autism”) is common in mainstream autism research but its use is in decline. Recent work by Gernsbacher (2017, JCPP) suggests that this particular linguistic style may be stigmatizing. Furthermore, data from a large sample (n>3,000) of the UK’s autism community on the terms that people use to describe autism (Kenny et al., 2016, Autism) suggested that, on the whole, autistic adults prefer the use of disability-first terms (“autistic individual”), rather than person-first terms (“person with autism”) because they feel that being autistic is central to their identity. Many parents also endorsed the use of the term “autistic” to describe their children. Our use of identity-first language was therefore deliberate – and respects the wishes of the autistic and broader autism communities and recent scholarly trends. This justification is included in a footnote in the new version of the manuscript (see pp. 2, 39).

Footnote:
We use ‘identify-first’ language (‘autistic person’) rather than person-first language (‘person with autism’), because it is the preferred term of autistic activists (e.g. Sinclair, 1999) and many autistic people and their families (Kenny et al., 2016) and is less associated with stigma (Gernsbacher, 2017).
Gernsbacher, M. A. (2017). The use of person-first language in scholarly writing may accentuate sigma. Journal of Child Psychology and Psychiatry, 58, 859–861.
Kenny, L., Hattersley, C., Molins, B., Buckley, C., Povey, C., et al. (2016). Which terms should be used to describe autism? Perspectives from the UK autism community. Autism, 20, 442–462.
Sinclair, J. (1999). Why I dislike ‘person-first’ language. Available at: http://autismmythbusters.com/general-public/autistic-vs-people-with-autism/jim-sinclair-why-i-dislike-person-first-language/ (accessed 1 September 2019).

11. What is "autistic perception"?

RESPONSE:
This term is used widely in the autism literature to refer to the often-different perception of autistic individuals. Example references using this term:
Pellicano, E., & Burr, D. (2012). When the world becomes too real: A Bayesian explanation of autistic perception. Trends in Cognitive Sciences, 16, 504–510.
Lawson, R. P., Rees, G., & Friston, K. J. (2014). An aberrant precision account of autism. Frontiers in human neuroscience, 8.

12. The General procedures and ethics section disrupts flow when presented after task methods. Perhaps move to subject section.
RESPONSE:
We thank the reviewer for this comment. The General procedure and ethics section have been moved to the Participants section.

13. What is PSERight (and PSELeft)? Please write out conceptually what these terms refer to.

RESPONSE:
We thank the reviewer for this comment.

We have included explanations for these two terms in our revised manuscript (p. 11). Additionally, the new Figure 2 helps understanding what these measures refer to.

The PSE corresponded to the value of the Test stimulus intensity (more precisely, the value of the log-transformed ratio speed of Test stimulus : speed of Reference stimulus) for which the judgements of participants in the speed-discrimination task were at chance levels, that is, participants responded that the Test PLD was faster than the Reference PLD with a probability of 0.5. For each participant, we derived PSE_Right and the PSE_Left using data from the Right and the Left condition, correspondingly. In our data, due to adaptation, PSE_Right tended to be higher than PSE_Left. This was as in the Left (Right) condition, the Test stimulus was presented after exposure to a slow (fast) adaptor and was thus perceived to be faster (slower), pushing (pulling) the psychometric curve to the left (right) (see Figure 2). To estimate the magnitude of the adaptation effect we calculated the distance PSE_Right – PSE_Left. We compared the magnitude of adaptation in the two matched groups with an independent samples t-tests. We also performed a complementary Bayesian independent samples t-test for this difference.

14. The section titled non-significant trend… on p13 does not describe any non-significant trend.
RESPONSE:
We thank the reviewer for this comment. We corrected the title of this section.

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Title page with all author contact information; Abstract with key words and corresponding author email

Adaptation to the Speed of Biological Motion in Autism

Themis Karaminis, Roberto Arrighi, Georgia Forth, David Burr & Elizabeth Pellicano

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Abstract

Autistic individuals often present atypicalities in adaptation – the continuous recalibration of perceptual systems driven by recent sensory experiences. Here, we examined such atypicalities in human biological motion. We used a dual-task paradigm, including a running-speed discrimination task ('comparing the speed of two running silhouettes') and a change-detection task ('detecting fixation-point shrinkages') assessing attention. We tested 19 school-age autistic and 19 age- and ability-matched typical participants, also recording eye-movements. The two groups presented comparable speed-discrimination abilities and, unexpectedly, comparable adaptation. Accuracy in the change-detection task and the scatter of eye-fixations around the fixation point were also similar across groups. Yet, the scatter of fixations reliably predicted the magnitude of adaptation, demonstrating the importance of controlling for attention in adaptation studies.

Keywords

autism; perception; adaptation; biological motion; running speed

TITLE: Adaptation to the Speed of Biological Motion in Autism

Abstract

Autistic individuals often present atypicalities in adaptation – the continuous recalibration of perceptual systems driven by recent sensory experiences. Here, we examined such atypicalities in human biological motion. We used a dual-task paradigm, including a running-speed discrimination task (‘comparing the speed of two running silhouettes’) and a change-detection task (‘detecting fixation-point shrinkages’) assessing attention. We tested 19 school-age autistic and 19 age- and ability-matched typical participants, also recording eye-movements. The two groups presented comparable speed-discrimination abilities and, unexpectedly, comparable adaptation. Accuracy in the change-detection task and the scatter of eye-fixations around the fixation point were also similar across groups. Yet, the scatter of fixations reliably predicted the magnitude of adaptation, demonstrating the importance of controlling for attention in adaptation studies.

TITLE: Adaptation to the Speed of Biological Motion in Autism

Introduction

Perceptual adaptation refers to the continuous recalibration of the response properties of perceptual and sensory systems driven by recent sensory experiences (Clifford and Rhodes 2005). For example, a quiet and continuous pure tone will be perceived to decrease in loudness over time (adaptation to loudness; see Lawson, Aylward, White and Rees 2015), while prolonged exposure to a face identity will cause a bias to perceive subsequently presented faces as dissimilar to it (adaptation to face identity; see Pellicano, Jeffery, Burr and Rhodes 2007). Such adaptation is a ubiquitous property of perception and is thought to offer many functional advantages (e.g., Kohn 2007), in particular with regards to the efficiency with which sensory systems distinguish relevant from irrelevant stimuli. Limitations in adaptation should imply increases in the transmission of redundant information and should render individuals less able to distinguish relevant from irrelevant stimuli (Barlow 1990; Clifford et al. 2007; Webster, Werner and Field 2005). Such limitations could therefore have profound effects on how individuals perceive and interpret incoming sensory information.

Adaptation is also pertinent to theoretical accounts of autistic perception aiming to account for a range of sensory atypicalities and symptoms in the condition (DSM-5; American Psychiatric Association 2013). Atypicalities in perceptual adaptation have been thought to reflect difficulties of autistic[1] individuals in deriving or using prior knowledge representations accrued from recent sensory experiences (Pellicano and Burr 2012). Within the Bayesian inference, or predictive-coding theoretical frameworks, which, in broad terms, suggest that the brain continually exploits the statistics of the world to predict current sensory input using a hierarchical and bidirectional processing system which aims to minimise prediction error within a cascade of cortical processing; Clark 2013; Friston 2010), adaptation may relate to the atypical encoding of precision in the perceptual hierarchy in autism

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(Lawson, Rees and Friston 2014) or the inability to process flexibly prediction errors (Van de Cruys et al. 2014).

Given the ubiquitous presence of adaptation in perception, an intriguing possibility is that autistic individuals' atypicalities in adaptation are pervasive across perceptual domains. The presence of domain-general atypicalities in adaptation could account for sensory issues in autistic people (e.g., why they might find certain sounds particularly disturbing), as well as core social difficulties, on the basis of a common neural mechanism (Lawson, Aylward, Roiser and Rees 2017).

With regard to social stimuli, attenuated adaptation in autism has been observed consistently within the face-processing domain, including, for example, for facial identity in autistic children (Ewing et al. 2013b; Pellicano et al. 2007) and relatives of autistic children (Fiorentini et al. 2012), for facial configuration (Ewing, Pellicano and Rhodes 2013) and eye-gaze direction in children (Pellicano, Rhodes and Calder 2013) and adults (Lawson et al. 2018), and for emotional expressions in children (Rhodes et al. 2018) and adults (Rutherford et al. 2012). van Boxtel, Dapretto and Lu (2016) also found that autistic children show reduced adaptation to action discrimination in biological motion (walking vs. running).

Turning to the processing of non-social stimuli, autistic children have been found to present attenuated adaptation to numerosity (Turi et al. 2015) and, in the auditory domain, autistic adults have been found to present attenuated adaptation to loudness (Lawson et al. 2015) and audiovisual integration (Turi et al. 2015). Three studies, however, have failed to find evidence of atypical adaptive-coding abilities, including Cook et al. (2014), who reported intact adaptation to facial expression and identity in autistic adults, Karaminis et al. (2015), who found that autistic and typical children did not differ in the degree of adaptation of perceptual causality, and Maule, Stanworth, Pellicano and Franklin (2018), who found that autistic and typical adults did not differ in the degree of adaptation to colour.

In this study, we contribute new evidence about the adaptive coding of the speed of biological motion in autistic children and adolescents. The examination of the adaptive coding of biological motion in autism is important for two reasons. First, the processing of biological motion is key for a wide range of social competencies, such as inferring other people’s emotions, mood, and intentions (e.g., Brooks et al. 2008). Previous research on the abilities of autistic individuals to process biological motion stimuli has produced mixed results. Autistic individuals have been found to present reduced sensitivity to biological motion and atypical brain activation patterns following the presentation of relevant biological stimuli in some studies (Annaz et al. 2010; Blake et al. 2013; Freitag et al. 2008; Klin et al. 2009; Koldewyn, Whitney and Rivera 2008; Nackaerts et al. 2012, Wang et al. 2015; see also Wang et al. 2018, for a recent behavioural genetics approach), but other studies have found no such difficulties (Cusack, Williams and Neri 2015; Edey et al. 2019; Jones et al. 2011; Murphy, Brady, Fitzgerald and Troje 2009; Saygin, Cook and Blakemore 2010; van Boxtel et al. 2016). With regard to the adaptive coding of biological motion in autism, van Boxtel et al. (2016) found attenuated adaptation to action discrimination in autistic children while action discrimination (per se) was intact. There are (to our knowledge) no other studies examining the adaptive coding of biological motion in autism beyond action discrimination (van Boxtel et al. 2016).

Second, it is important to examine the adaptive coding of biological motion in autism to establish whether findings for attenuated adaptation in autism during the processing of social stimuli are specific to faces or extend to other, high-level social stimuli. This could be likely as biological motion is supported by high-level neuronal mechanisms within the superior temporal gyrus (STS) and the fusiform and the lingua gyri (Gobbini et al. 2007; Vaina et al. 2001), that is, brain areas that are also involved in the processing of faces

(Grossman et al. 2000), as well as the extrastriate and fusiform body areas (EBA and FBA; Jastorff and Orban 2009).

In this study, we used a different paradigm for biological motion from that used in the study by van Boxtel et al. (2016). Our paradigm focuses on adaptive coding of the speed of running silhouettes presented with point light displays (PLDs). We employed child- and autism-friendly methodologies and we also aimed to account for participants' attention to the stimuli. This was important as earlier studies have shown that attention modulates the size of adaptation (Kreutzer, Fink and Weidner; 2015; Rhodes et al. 2011). Controlling for attention was achieved by employing a dual-task paradigm, in which the primary task measured the perception of biological motion and adaptive coding, while the secondary task motivated participants to attend to the middle of the screen and assessed their attention (see also Ewing et al. 2013b; Karaminis et al. 2015; Lawson et al. 2018; Rhodes et al. 2018). We also collected eye-movement data to quantify participants' looking preferences during the task.

Method

Participants

Participants demographics are shown in Table 1.

(Insert Table 1 about here)

Autistic participants

Nineteen autistic participants (6 girls) aged between 8.8 and 19.5 years (M = 14.15; SD = 2.84) were recruited via schools in London and community contacts. All autistic participants had an independent clinical diagnosis of an autism spectrum disorder (ASD) and met the criteria for autism on the Autism Diagnostic Observation Schedule − 2 (ADOS-2) (Lord et al. 2012; cut-off score = 7) or the Social Communication Questionnaire − Lifetime (SCQ) (Rutter et al. 2003; cut-off score = 15) (see Corsello et al. 2007). All autistic participants were considered to be cognitively able, achieving scores >= 70 in the Wechsler Abbreviated Scales of Intelligence-2nd edition (WASI-II; Wechsler 2011).

Typical participants

Nineteen typically developing participants (10 girls), recruited from local London schools, were selected from a pool of 63 participants to match the group of autistic participants for chronological age, t(36) = 0.23, p = 0.87, gender, X^2(2, N = 38) = 1.72, p = 0.18, as well as for performance IQ, t(36) = 0.20, p = 0.85; verbal IQ, t(36) = 0.19, p = 0.85; and full-scale IQ, t(33.66) = 0.26, p = 0.79, as measured by the Wechsler Abbreviated Scales of Intelligence – 2nd edition (WASI-II; Wechsler 2011). Parents of typical participants also completed the SCQ (n = 11). SCQ scores of typical participants ranged between 0 and 12 (M = 2.64, SD = 3.50), below the cut-off point for autism (score of 15; Rutter et al. 2003).

Exclusions

Seven additional participants (3 autistic, 4 typical) were tested but excluded because of poorly-fitting psychometric curves, as judged by two observers who were blind to any demographic details of the participants (exclusion criterion #1). One additional typical child was excluded due to an IQ score lower than the threshold of 70 in the WASI-II (Wechsler 2011) (exclusion criterion #2). Five additional autistic and two additional typical participants were excluded due to poor performance on the attentional task (exclusion criterion #3, see Data analysis). Finally, one additional autistic boy was excluded because he did not fixate centre-screen during the experimental task (exclusion criterion #4, see Data analysis).

General Procedure and Ethics

The study was conducted in accordance to the principles laid down in the Declaration of Helsinki. The [blinded for review] approved all procedures. Parents of all participants gave their informed written consent prior to their child’s participation in the study and participants gave their verbal assent. Participants were tested individually in a quiet room at the [blinded for review]. The WASI-II was administered on the same day, before or after the session. The ADOS-2 was administered either on the same day or on a separate occasion.

Stimuli and Apparatus

Adaptor and test stimuli (see Figure 1) were point-light displays (PLDs) comprising 10 dots of diameter 0.75° of visual angle and simulating running human figures. An original version of PLDs stimulus representing the running human silhouette was downloaded from an online database (http://astro.temple.edu/~tshipley/ptltarchive.html; Shipley 2012). This movie displayed a complete running cycle (starting with the left foot on the floor and ending with the left foot landing again) in 20 frames. Using customised interpolation scripts, we created 6000 points within each running cycle. We defined running speed as the number of running cycles completed within a second (in Hz).

(Insert Figure 1 about here**)**

Adaptor and test stimuli appeared on the left- or the right-hand side of the screen (centred 10° from the centre of the screen). The adaptor stimuli were two PLDs which appeared in grey colour and in pairs, simultaneously on the right- and left- hand side of the screen for 4.0 sec. The adaptor stimuli fitted a 10° height x 5° width frame (‘medium-sized’) and moved at a speed of either 0.5 Hz or 2 Hz.

The test stimuli were two PLDs, the Reference stimulus and the Test stimulus (see Figure 1). The Reference stimulus appeared in red colour on the left-hand side of the screen for 2.0 sec. It fitted a 10° x 5° frame (‘medium-sized’) and moved at a speed of 1 Hz. The Test stimulus appeared in blue colour on the right-hand side of the screen for 2.0 sec. It appeared in three possible sizes: small (within a frame of 8° height x 4° width), medium (10° x 5° frame), or large (12°x 6° frame) and at different speeds at the range 0.5 - 2Hz.

For the change-detection task, the main stimulus was a round dot subtending 1.0° in the centre of the screen, which occasionally shrank to a diameter of 0.75° twice during each adaptation period.

All stimuli were displayed on a 60 Hz TFT monitor measuring 50° x 28° when viewed at a distance of 57 cm, controlled by a Dell Desktop computer. The experiments were written in MatLab using routines of the Psychophysics Toolbox 3 (Brainard 1997; Pelli 1997; Kleiner et al. 2007). Eye-tracking data were collected using a Tobii-X300 eye tracker at 120 Hz and were processed with the Tobii Analytics Software Development Kit (SDK).

Procedure

We measured perceptual adaptation to the speed of biological motion using a developmentally-sensitive computer game, which combined a speed-discrimination task, assessing adaptation to the speed of biological motion, and a change-detection task, motivating participants to attend to the centre of the screen. The general theme of the game was that participants were ‘Space Running Trainers’ aiming to form a winning team for the ‘Space Olympics’. To do so, participants should choose the fastest runners using a ‘specialised viewing machine’ (which provided the PLDs). The task structure and the trial structure are presented in Figure 1.

Speed-discrimination task

The speed-discrimination task comprised two conditions, Right and Left (‘rounds’, counterbalanced across participants), each consisting of 40 trials presented in blocks (‘Levels’) of 13, 13, and 14 trials. Each trial included an adaptation phase, in which participants were exposed to adaptor stimuli, followed by a testing phase, in which participants judged the speed of test stimuli. The adaptation phase was differentiated in the Right and the Left condition so as to elicit adaptation aftereffects in two opposite directions (see also Measurements and Analysis). The two conditions of the speed-discrimination task thus implemented a so-called ‘push-pull’ adaptation protocol.

In the adaptation phase, which lasted 4.0 sec, participants watched the adaptor PLDs while they were encouraged to attend to the fixation point centre-screen (see also Change-detection task). In the Right condition, the speed of the right adaptor PLD was 2Hz, four times faster than the left adaptor (0.5 Hz). Conversely, in the Left condition, the right adaptor that ran at 0.5 Hz and the left at 2Hz.

In the test phase, participants were presented with the two test PLDs, first the Reference stimulus on the left-hand-side of the screen and then the Test stimulus on the right-hand-side of the screen, for 2.0 seconds each. They were asked to indicate which runner they thought was the fastest by pressing a corresponding red or blue key on the keyboard. Responses were not registered until both runners had finished running.

The speed of the Reference PLD always was set at 1.0 Hz. The speed of the Test PLD was chosen using two QUEST functions (Watson and Pelli 1983), one starting at 0.5 Hz and ascending and one starting at 2.0 Hz and descending. The two QUESTs homed in on the point where the speed of the two test stimuli appeared equal; to ensure a good distribution of durations to estimate discrimination thresholds, a random jitter of SD = 0.1 log units was also added to the QUEST estimates (Watson and Pelli 1983).

The Test stimulus appeared in three possible sizes, small (8° x 4°), medium (10° x 5°), and large (12°x 6°). This manipulation ensured that our participants could not solve the discrimination task by relying on the local speed of the dots constituting the PLDs (see also van Boxtel and Lu 2013). For example, let’s assume that the two test stimuli (Reference and Test) moved at the same speed (say, a gait cycle per second) and that the Test stimulus was small. Because of this size difference, the distance covered by the individual dots of the Test stimulus (e.g., the feet) during a cycle gait would be shorter than the distance covered by the corresponding dots of the Reference stimulus. Based on this difference, if participants relied on a local-speed response strategy, they should present a bias to respond that the Reference stimulus would be faster. By contrast, if participants relied on a global response strategy, they should not present this bias.

Change-detection task

In the change-detection task, participants were asked to respond to changes of the fixation ('viewing machine losing power') point by pressing the spacebar ('powering up the machine'). The fixation point returned to normal after a response. The change-detection task took place during the adaptation phase of the trials of the speed discrimination task. There were zero, one or two shrinkage events in each trial, each lasting 1 sec.

Practice trials and motivation

Participants were given visual and verbal instructions for both tasks at the start of the game, including practice on pressing the spacebar when the dot in the centre of the screen shrank. They also completed 8 practice trials, in which the speed of each of the running figures in the testing phase were very clearly different from each other (0.5 Hz vs. 1.5 Hz or 2.0 Hz). Practice trials were repeated if participants made more than three mistakes or if they responded that they needed more practice to proceed to the actual game. This happened only for two autistic participants and never more than once. Participants had the opportunity to take short breaks at the end of the testing blocks. They were regularly praised for their performance and, at the end of each round, they were shown a leaderboard. The experimenter encouraged them to attend to the centre of the screen throughout testing and monitored their attention.

Measurements and Analysis

Speed-discrimination task

Figure 2 shows example data from two of our participants from the speed-discrimination task. We fitted individual data from participants with cumulative Gaussian functions using bootstrapping (Efron and Tibshirani 1993) with 10 repetitions and a 'maximum likelihood' fitting method (Watson 1981). First, two observers, blind to any demographic details, judged the quality of the fitted curves. Participants with poorly fitting curves were excluded from the analysis. From the fitted curves, and for each condition, we derived Weber Fractions (the standard deviations of the fitted Gaussians or Just Noticeable Difference-JND divided by the PSE) and the points of subjective equality (PSEs) (the mean of the fitted Gaussians).

(Insert Figure 2 about here**)**

Weber Fractions provided an estimate of the precision with which participants judged the speed of the PLDs. We compared Weber Fractions using a repeated-measures ANOVA with Condition ('Left' vs. 'Right') as a between-participants factor and Group ('Autistic' vs. 'Typical').

The PSE corresponded to the value of the Test stimulus intensity (more precisely, the value of the log-transformed ratio *speed of Test stimulus : speed of Reference stimulus*) for which the judgements of participants in the speed-discrimination task were at chance levels, that is, participants responded that the Test PLD was faster than the Reference PLD with a probability of 0.5. For each participant, we derived *PSE_Right* and the *PSE_Left* using data from the Right and the Left condition, correspondingly. In our data, due to adaptation, *PSE_Right* tended to be higher than *PSE_Left.* This was as in the Left (Right) condition, the Test stimulus was presented after exposure to a slow (fast) adaptor and was thus perceived to be faster (slower), pushing (pulling) the psychometric curve to the left (right) (see Figure 2). To estimate the magnitude of the adaptation effect we calculated the distance *PSE_Right* – *PSE_Left*. We compared the magnitude of adaptation in the two matched groups with an independent samples t-tests. We also performed a complementary Bayesian independent samples t-test for this difference.

Change-detection task

For the change-detection task, we calculated mean accuracy (the proportion of detected shrinkages) in the change-detection task across both conditions. Participants with accuracy scores lower than 25% were excluded from the analysis. We also examined reaction times in the change-detection task (online measure).

Eye-tracking data

From the eye tracking data, we calculated the scatter of fixations around the centre of the screen (the standard deviation of average distance from the centre of the screen) during the adaptation and the testing phase. One autistic participant, with a scatter of fixation of 15.0 degrees of the visual angle was excluded from the analysis. We also calculated correlations between the scatter of fixations and adaptation in the speed-discrimination task.

Correlational analysis

In a secondary analysis, we examined correlations between adaptation to the speed of biological motion and precision in speed discrimination, as well as correlations between adaptation and demographic and eye-tracking variables.

Results

Similar speed-discrimination precision and similar adaptation to the speed of biological motion

First, we looked at precision in discriminating the speed of biological motion, expressed as Weber Fractions. Figure 3 shows Weber Fractions in the two conditions of the speed discrimination tasks [Left, autistic: M = 0.40, SD = 0.23; typical: M = 0.37, SD = 0.22; Right, autistic: M = 0.42, SD = 0.36; typical: M = 0.37, SD = 0.18]. We conducted a mixed-design ANOVA with Group (‘Autistic’ vs. ‘Typical’) as a between-participants factor and Condition (‘Left’ vs. ‘Right’) as a within-participants factor. There were no significant effects of Group, F(1, 36) = 0.39, p = 0.54, n_p^2 = 0.01; Condition, F(1, 36) = 0.01, p = 0.93, n_p^2 < 0.01; and no significant interaction between the two factors, F(1, 36) = 0.04, p = 0.84, n_p^2 = 0.001. Our analysis therefore suggested that autistic and typical participants presented similar precision in speed-discrimination.

(Insert Figure 3 about here**)**

Next, we examined the magnitude of adaptation, shown in Figure 4 [autistic participants: M = 0.60, SD = 0.20; typical participants: M = 0.55, SD = 0.26]. The magnitude of the adaptation effect was significantly higher than 0 in both groups of participants, as revealed by one-sample t-test [autistic participants: t(18) = 13.36, p < 0.001; typical participants: t(18) = 10.77, p < 0.001]. Importantly, and contrary to our prediction, there were no differences in adaptation between autistic and typical participants, t(36) = 0.50, p = 0.48, *d* = 0.20.

We also performed a Bayesian independent samples t-test using JASP software (Version 0.8.0.0; JASP Team 2016) and estimated a Bayes factor using Bayesian information criteria (Wagenmakers 2007), which allowed for a comparison of the fit of our data under the null hypothesis that there are no differences between autistic and typical children in the magnitude of the adaptation to the speed of biological motion, and the alternative hypothesis that adaptation differs in the two groups of participants. The Bayes factor (null/alternative-estimated using a Cauchy distribution prior with a scaling factor of 1) was 3.38, suggesting that our results were 3.38 times more likely to occur under the null hypothesis than under the alternative hypothesis. Our data, therefore, provided substantial evidence (Wetzels et al. 2011) that autistic and typical participants adapted to the speed of biological motion to a comparable degree.

(Insert Figure 4 about here**)**

Similar performance in the change-detection task

Turning to the change-detection task, Figure 5 shows accuracy rates in the two conditions of the task [Left, autistic: M = 0.78, SD = 0.17; typical: M = 0.79, SD = 0.17;

Right, autistic: M = 0.75, SD = 0.22; typical: M = 0.72, SD = 0.21]. A mixed-design ANOVA with Group (‘Autistic’ vs. ‘Typical’) as a between-participants factor and Condition (‘Left’ vs. ‘Right’) as a within-participants factor showed no effects of Group, F(1, 36) = 0.27, p = 0.87, n_p^2 = 0.001, a significant effect of Condition, F(1, 36) = 6.16, p = 0.02, n_p^2 = 0.15, and no significant interaction between Condition and Group, F(1, 36) = 0.99, p = 0.32, n_p^2 = 0.00. Autistic and typical participants performed similarly on the secondary task.

(Insert Figure 5 about here**)**

Similar reaction times in the change-detection task

For the change-detection task, we examined mean reaction times, shown in Figure 6 [Left, autistic: M = 2.84, SD = 0.94; typical: M = 2.74, SD = 0.83; Right, autistic: M = 2.74, SD = 0.83; typical: M = 2.47, SD = 0.52]. A mixed-design ANOVA with Group (‘Autistic’ vs. ‘Typical’) as the between-participants factor and Condition (‘Left’ vs. ‘Right’) as the within-participants factor showed no significant effects of Group, F(1, 36) = 2.40, p = 0.13, n_p^2 = 0.06, or Condition, F(1, 36) = 0.12, p = 0.73, n_p^2 = 0.003, or condition x group interaction, F(1, 36) = 0.36, p = 0.54, n_p^2 = 0.01. The results therefore suggested that autistic and typical participants did not differ in their reaction times.

(Insert Figure 6 about here**)**

Similar eye-movement data

We also examined eye-tracking data to obtain an objective measure of the extent to which participants attended to the centre of the screen (as motivated by the change-detection task, as well as by the experimenter during the testing session). Figure 7 shows the scatter of fixations around centre-screen in the two conditions (in degrees of the visual angle) [Left, autistic: M = 0.035, SD = 0.014; typical: M = 0.039, SD = 0.025; Right, autistic: M = 0.038, SD = 0.020; typical: M = 0.044, SD = 0.032]. Again, a mixed-design ANOVA with Group (‘Autistic’ vs. ‘Typical’) as a between-participants factor and Condition (‘Left’ vs. ‘Right’) as a within-participants factor and showed no significant effects of Group, F(1, 36) = 0.54 p = 0.47, n_p^2 = 0.02, Condition, F(1, 36) = 1.08, p = 0.31, n_p^2 = 0.03, and no significant interaction, F(1, 36) = 0.11, p = 0.74, n_p^2 = 0.00. Autistic and typical participants fixated to centre-screen to a comparable extent.

(Insert Figure 7 about here)

Correlational analysis

In a secondary correlational analysis, we examined the relationship between adaptation to the speed of biological motion and precision in speed discrimination, as well as between and adaptation demographic and eye-tracking variables (Figure 8). Correlations between adaptation to the speed of biological motion and precision were non-significant in either group of participants [autistic: r (19) = -0.17, p = 0.55; typical: r(19) = -0.36, p = 0.13]. Furthermore, in either group of participants, there were no significant correlations between adaptation and age [autistic: r (19) = 0.08, p = 0.78; typical: r(19) = 0.04, p = 0.99], and Performance-IQ [autistic: r (19) = 0.06, p = 0.79; typical: r (19) = 0.22, p = 0.36] and Verbal-IQ [autistic: r(19) = 0.36, p = 0.13; typical: r (19) = -0.18, p = 0.46]. Within the group autistic participants, there were also no significant correlations between the magnitude of adaptation and autistic features, as indexed by ADOS-2 calibrated severity scores, r(16) = -0.35, p = 0.18, or SCQ scores, r(17) = 0.23, p = 0.38. Correlations between the magnitude of adaptation and SCQ scores were also not significant when autistic and typical participants were considered as one group, r (28) = 0.08, p = 0.66.

(Insert Figure 8 about here)

Interestingly, there was a significant correlation between the magnitude of adaptation and the eye-tracking variable of the scatter of fixations in both autistic, r(19) = -0.62, p = 0.005, and typical participants, r(19) = -0.61, p = 0.01. As shown in Figure 8(h), the adaptation effect is less pronounced for participants who attended to a lesser extent to centre-screen. Note that correlations between the eye-movement measure and precision in speed-discrimination [autistic: r (19) = 0.15, p = 0.54; typical: r (19) = 0.34, p = 0.16] were non-significant.

Discussion

In this study, we compared autistic and typical participants, of similar age and ability, on the adaptive coding of the speed of biological motion. We hypothesised that autistic individuals' atypicalities in the adaptive coding of facial stimuli (Ewing et al. 2013a; Lawson et al. 2018; Pellicano et al. 2013; Rhodes et al. 2018; Rutherford et al. 2012) should generalise to non-facial social stimuli and predicted that autistic participants should show less adaptation to the speed of the PLDs of our task than the typical comparison participants. We found that both groups showed significant adaptation effects – but, contrary to our prediction, that the magnitude of adaptation was comparable in autistic and typical participants. This finding could not be attributed to group differences in attention or to looking differences, as both accuracy on the change-detection task and the scatter-of-fixations measure were similar across groups.

Furthermore, the lack of differences in adaptation between autistic and typical participants could not be due to differences in precision in speed discrimination. We found that the two groups were equally precise. This latter result is consistent with studies that do not find differences in the processing of biological motion in autism (Cusack et al. 2015; Jones et al. 2011; Murphy et al. 2009; Saygin et al. 2010; van Boxtel et al. 2016) rather than those that report reduced sensitivity and differences in the brain activation patterns to biological stimuli (Annaz et al. 2010; Blake et al. 2013; Freitag et al. 2008; Klin et al. 2009; Koldewyn et al. 2008; Nackaerts et al. 2012).

Our results are also inconsistent with the study on adaptation to biological motion by van Boxtel et al. (2016), which examined a similar number of autistic and typical children. It is possible that this discrepancy is due to the focus on different aspects of biological motion ("running speed" vs. discrimination of type of movement in van Boxtel et al. 2016). It is difficult to understand the origin of these discrepancies without further investigation of performance in different types of biological motion within the same individual. It would be interesting to replicate our and van Boxtel et al.'s methods, also considering other biological motion characteristics such as gender, which is more explicitly social and to which adaptation has previously been shown in non-autistic adults (Jordan et al. 2006; Troje et al. 2006).

Another factor that could be considered in future studies is the likely correspondence between the kinematics of the test stimuli and the kinematics of participants. One study has reported that autistic adults present atypical kinematics and that the degree of such atypicalities predicts performance in a biological motion perception task (Cook, Blakemore and Press 2013). It is possible that the perceptual similarity or dissimilarity between the kinematics of stimuli and participants could also affect the adaptive coding of biological motion.

One important methodological feature of our study is that it carefully examined differences in attention. This was achieved by including the secondary change-detection task and using eye-tracking. By contrast, in van Boxtel et al. (2016), where autistic children were found to present attenuated adaptation, "the experimenter monitored fixation throughout the experiment, providing reminders as deemed necessary" (p. 4). Arguably, the use of a change-detection task is a more robust method for directing participants' attention to the fixation point. Interestingly, the post-hoc analysis of the eye-tracking data showed that the more participants attended to the fixation point, the larger the magnitude of adaptation. Therefore, even though autistic participants did not differ on average from typical participants on the degree of adaptation, the scatter of fixation accounted for adaptation performance. This result raises the possibility that differences in adaptation in many studies could result from attention differences. It is thus also very important to control for attention in adaptation studies. To our knowledge, controlling for attention has been employed in earlier studies on adaptation in autism by Ewing et al. (2013b) on face identity, Karaminis et al. (2015) on perceptual causality, Lawson et al. (2018) on eye-gaze direction and Rhodes et al. (2018) on facial expression. Our study on adaptation to the running speed of biological motion in autism is novel in combining the use of a secondary attention task with eye-tracking.

Our study is not without its shortcomings. We applied four exclusion criteria and thus excluded a considerable number of participants from our initial dataset to obtain a dataset that would allow measuring the adaptive coding of biological motion. The dual-task paradigm was also demanding, especially for younger participants. Finally, adaptation to biological motion in participants who were not able to attend to stimuli was also not explored in this study.

Conclusion

Sensory differences have been included in the latest diagnostic criteria for autism (DSM-5; APA 2013) and represent some of the most puzzling features of the condition. The renewed interest in autistic sensory differences by researchers is prompted largely by the possibility that these and other non-social features of autism might be caused by fundamental differences in sensation and perception. Our results provide evidence that diminished adaptation, proposed to be one such fundamental difference, is not pervasive in autistic perception. Our findings demonstrate that more nuanced accounts of adaptation in autism are warranted, which address the potentially uneven adaptation profile in autism and its developmental implications (cf. Karaminis et al. 2015). The interplay between adaptation and attention is also important for a fuller understanding of autistic perception.

Compliance with Ethical Standards

This work was generously funded by grants from [blinded for review] and [blinded for review].

All authors declare that they have no conflict of interest of which they are aware.

All procedures performed in the study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Parents of all child/adolescent participants gave their informed written consent prior to their child’s participation in the study and young participants gave their informed verbal assent.

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Figure Captions

Figure 1. Trial structure and task design.

Figure 2. Sample data from an autistic and a typical participant and fitted psychometric curves. Adaptation is measured as the difference between the Points of Subjective Equality (PSE) in the Right and the Left condition.

Figure 3. Speed-discrimination abilities of autistic and typical participants in the ‘Left’ and the ‘Right’ condition. Boxplots show group averages (green circles) and medians (horizontal lines), dots show the performance of individual participants.

Figure 4. Adaptation to the speed of biological motion as measured by the difference between the Points of Subjective Equality (PSE) in the left and the right condition. Boxplots show group averages (green circles) and medians (horizontal lines), dots show performance of individual participants.

Figure 5. Accuracy in the change-detection task, in the two conditions. Boxplots show group averages (green circles) and medians (horizontal lines), dots show performance of individual participants.

Figure 6. Reaction times in the speed-discrimination task. Boxplots show group averages (green circles) and medians (horizontal lines), dots show the performance of individual participants.

Figure 7. Scatter of fixations in the two conditions of the speed-discrimination task. Boxplots show group averages (green circles) and medians (horizontal lines), dots show performance of individual participants.

Figure 8. Results of the secondary correlational analysis of individual variability. The analysis suggested that in both groups of participants, the magnitude of adaptation was smaller for participants with more scattered fixations (subplot h). Note that this relationship remained significant when the extreme value in the typical group was removed.

Figures

Figure 1

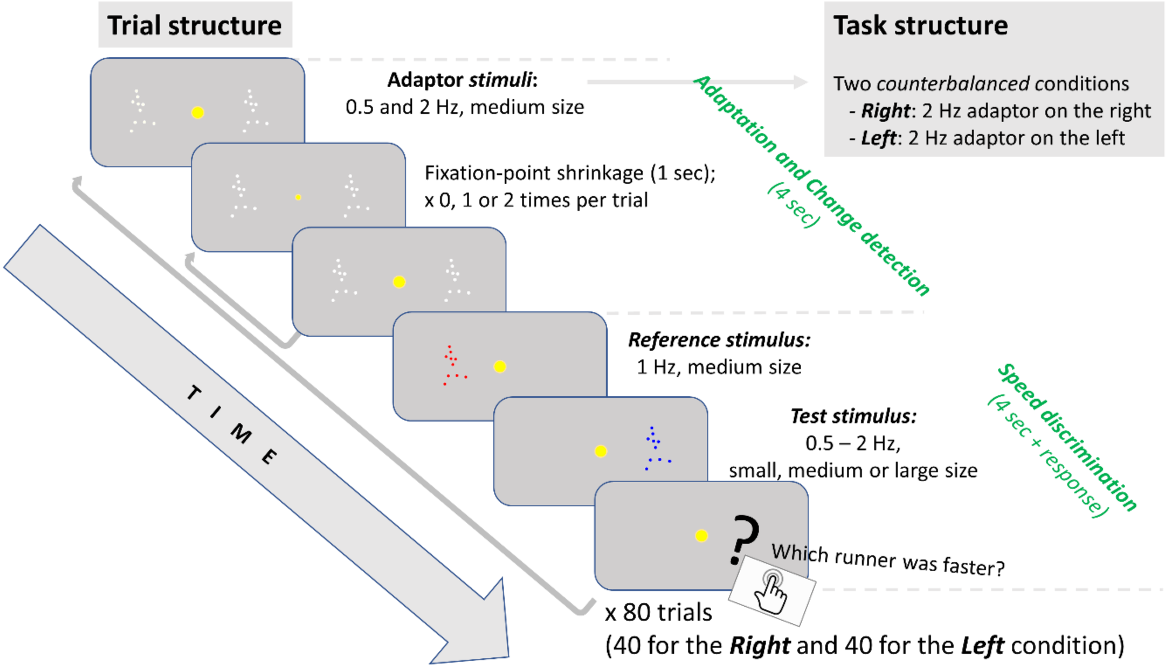

Trial structure
Adaptor stimuli:
0.5 and 2 Hz, medium size
Fixation-point shrinkage (1 sec);
x 0, 1 or 2 times per trial
Adaptation and Change detection
(4 sec)
Task structure
Two counterbalanced conditions
- Right: 2 Hz adaptor on the right
- Left: 2 Hz adaptor on the left
T I M E
Reference stimulus:
1 Hz, medium size
Test stimulus:
0.5 – 2 Hz,
small, medium or large size
Speed discrimination
(4 sec + response)
?
Which runner was faster?
x 80 trials
(40 for the Right and 40 for the Left condition)

Figure 2

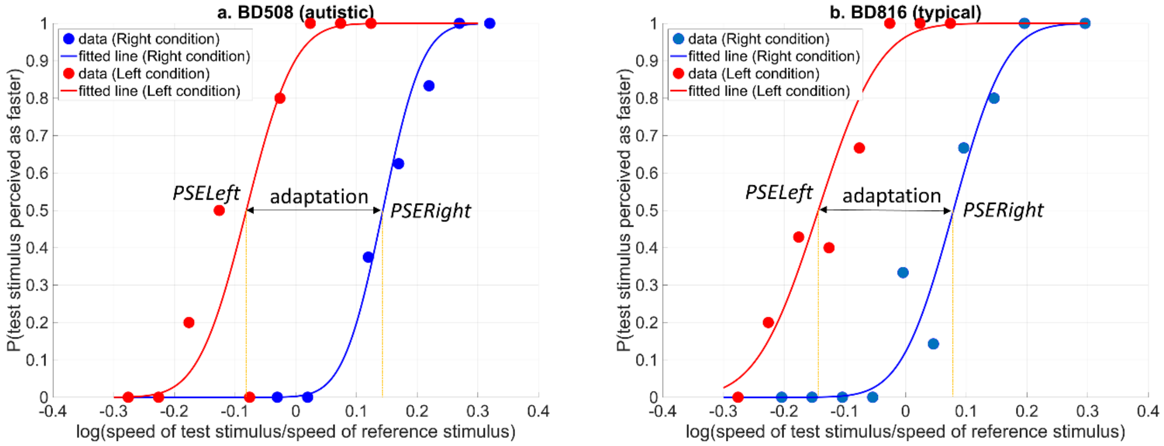

a. BD508 (autistic)
b. BD816 (typical)
data (Right condition)
fitted line (Right condition)
data (Left condition)
fitted line (Left condition)
PSELeft
adaptation
PSERight
P(test stimulus perceived as faster)
log(speed of test stimulus/speed of reference stimulus)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4

Figure 3

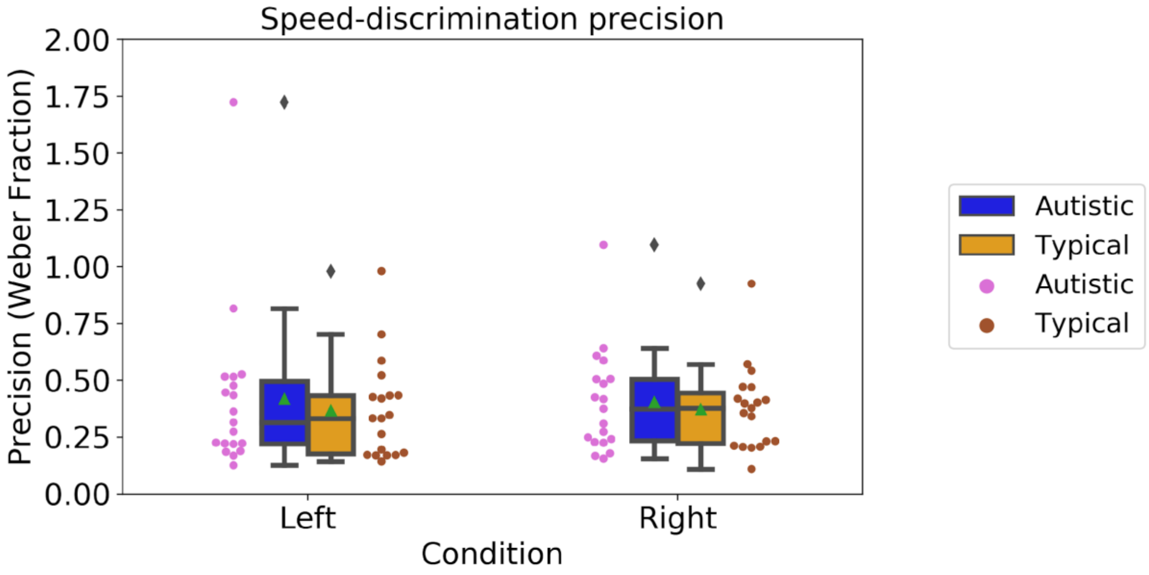

Speed-discrimination precision
Precision (Weber Fraction)
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Left
Right
Condition
Autistic
Typical
Autistic
Typical

Figure 4

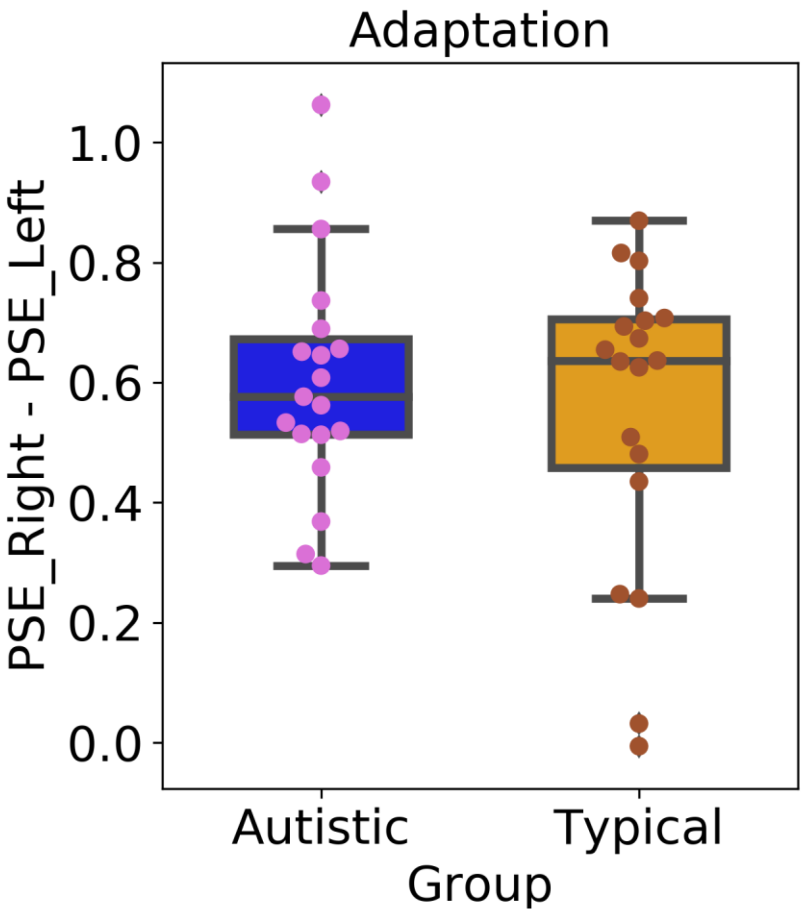

Adaptation
PSE_Right - PSE_Left
1.0
0.8
0.6
0.4
0.2
0.0
Autistic
Typical
Group

Figure 5

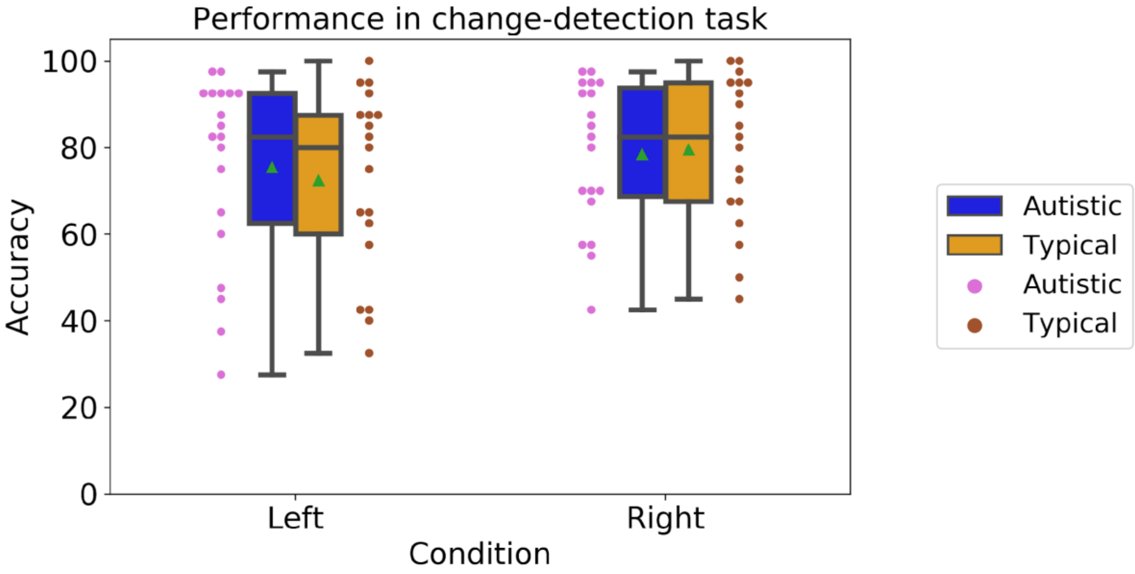

Performance in change-detection task
Accuracy
0
20
40
60
80
100
Left
Right
Condition
Autistic
Typical
Autistic
Typical

Figure 6

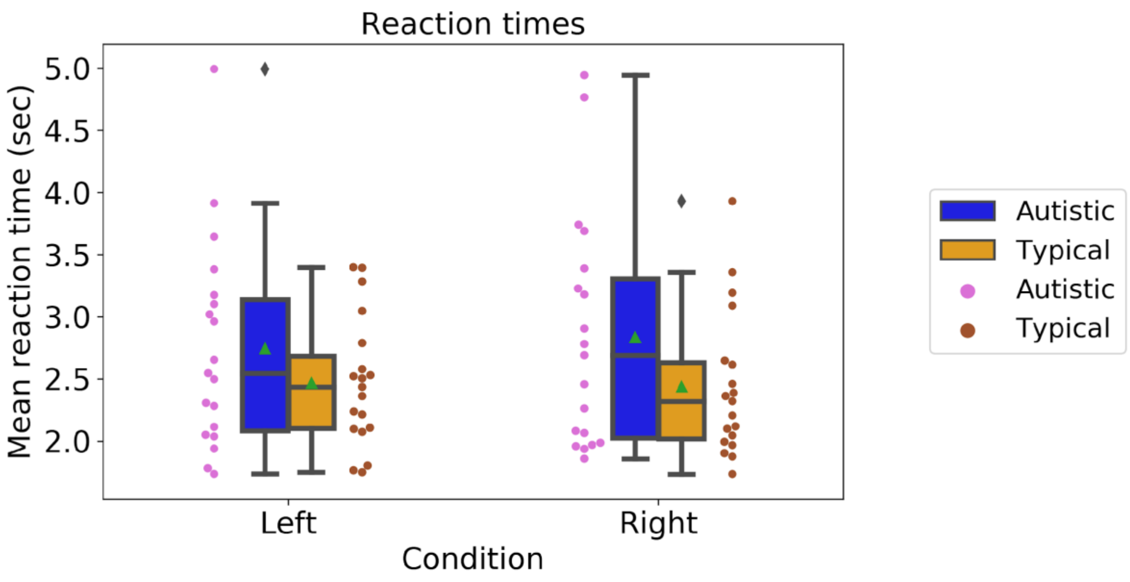

Reaction times
Mean reaction time (sec)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
Left
Right
Condition
Autistic
Typical
Autistic
Typical

Figure 7

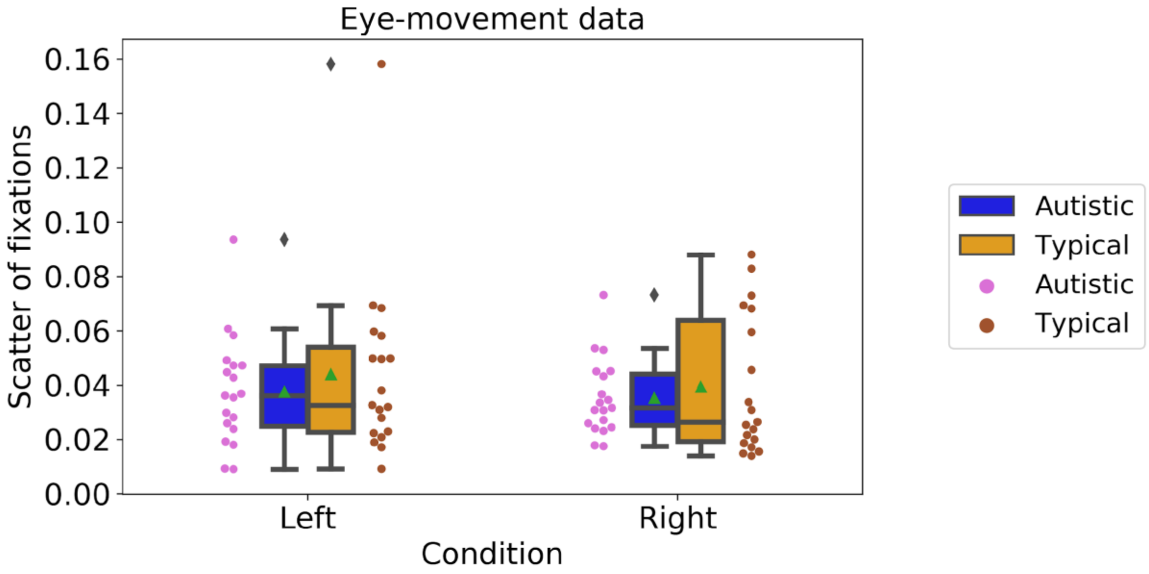
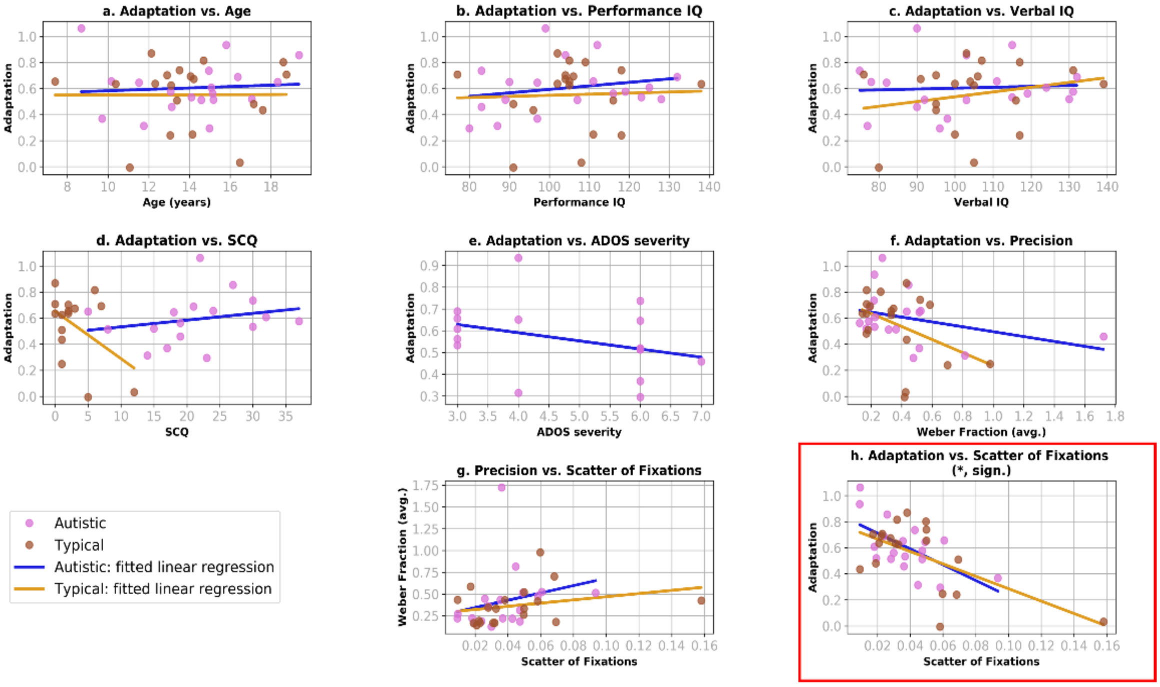

Eye-movement data
Scatter of fixations
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Left
Right
Condition
Autistic
Typical
Autistic
Typical

Figure 8


a. Adaptation vs. Age
Adaptation
Age (years)
0.0 0.2 0.4 0.6 0.8 1.0
8 10 12 14 16 18
b. Adaptation vs. Performance IQ
Performance IQ
80 90 100 110 120 130 140
c. Adaptation vs. Verbal IQ
Verbal IQ
80 90 100 110 120 130 140
d. Adaptation vs. SCQ
SCQ
0 5 10 15 20 25 30 35
e. Adaptation vs. ADOS severity
ADOS severity
0.3 0.4 0.5 0.6 0.7 0.8 0.9
3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0
f. Adaptation vs. Precision
Weber Fraction (avg.)
0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8
g. Precision vs. Scatter of Fixations
Weber Fraction (avg.)
0.25 0.50 0.75 1.00 1.25 1.50 1.75
Scatter of Fixations
0.02 0.04 0.06 0.08 0.10 0.12 0.14 0.16
h. Adaptation vs. Scatter of Fixations
(*, sign.)
Autistic
Typical
Autistic: fitted linear regression
Typical: fitted linear regression

Tables

Table 1. Descriptive statistics for developmental variables for autistic and typical participants.

Measures	*Autistic participants*	*Typical participants*	*Statistical comparison*
N	19	19	
Gender (n females : n males)	6 : 13	11 : 8	$X^2(2, N = 38) = 1.72, p = 0.18$
Age (years) **Mean (SD)** **Range**	14.15 (2.84) 8.68 – 19.37	13.93 (3.80) 7.40 – 18.75	$t(36) = 0.23$, $p = 0.87$
Verbal IQ[a] **Mean (SD)** **Range**	104.68 (14.21) 70 – 126	105.47 (10.91) 83 – 130	$t(36) = 0.19$, $p = 0.85$
Performance IQ[a] **Mean (SD)** **Range**	103.21 (18.94) 75 – 132	103.21 (18.95) 76 – 139	$t(36) = 0.20$, $p = 0.85$
Full-Scale IQ[a] **Mean (SD)** **Range**	104.32 (16.57) 80 – 132	105.58 (12.65) 77 – 138	$t(33.66) = 0.26$, $p = 0.79$
ADOS-2 calibrated severity score[b] **Mean (SD)** **Range**	(N = 16) 4.75 (1.48) 3 – 7	n/a	n/a
SCQ score[c] **Mean (SD)** **Range**	N = 17 21.24 (8.41) 5 – 37	N = 15 2.87 (3.35) 0 – 12	$t(21.44) = 8.29$, $p <.001$

Notes: [a]Verbal, Performance and Full-Scale IQ were measured using the Wechsler Abbreviated Scales of Intelligence – 2nd edition (WASI-II; Wechsler, 2011); [b]ADOS-2 calibrated severity scores obtained from Autism Diagnostic Observation Schedule – 2 (Lord et al., 2012), scores range from 1 – 10, higher scores reflect greater autism severity; [c]SCQ: Social Communication Questionnaire (score out of 40; Rutter, Bailey, & Lord, 2003).

Footnotes

[1] We use ‘identify-first’ language (‘autistic person’) rather than person-first language (‘person with autism’), because it is the preferred term of autistic activists (e.g., Sinclair, 1999) and many autistic people and their families (Kenny et al., 2016) and is less associated with stigma (Gernsbacher, 2017).

Figure 1

Click here to access/download;Figure;Figure1.png

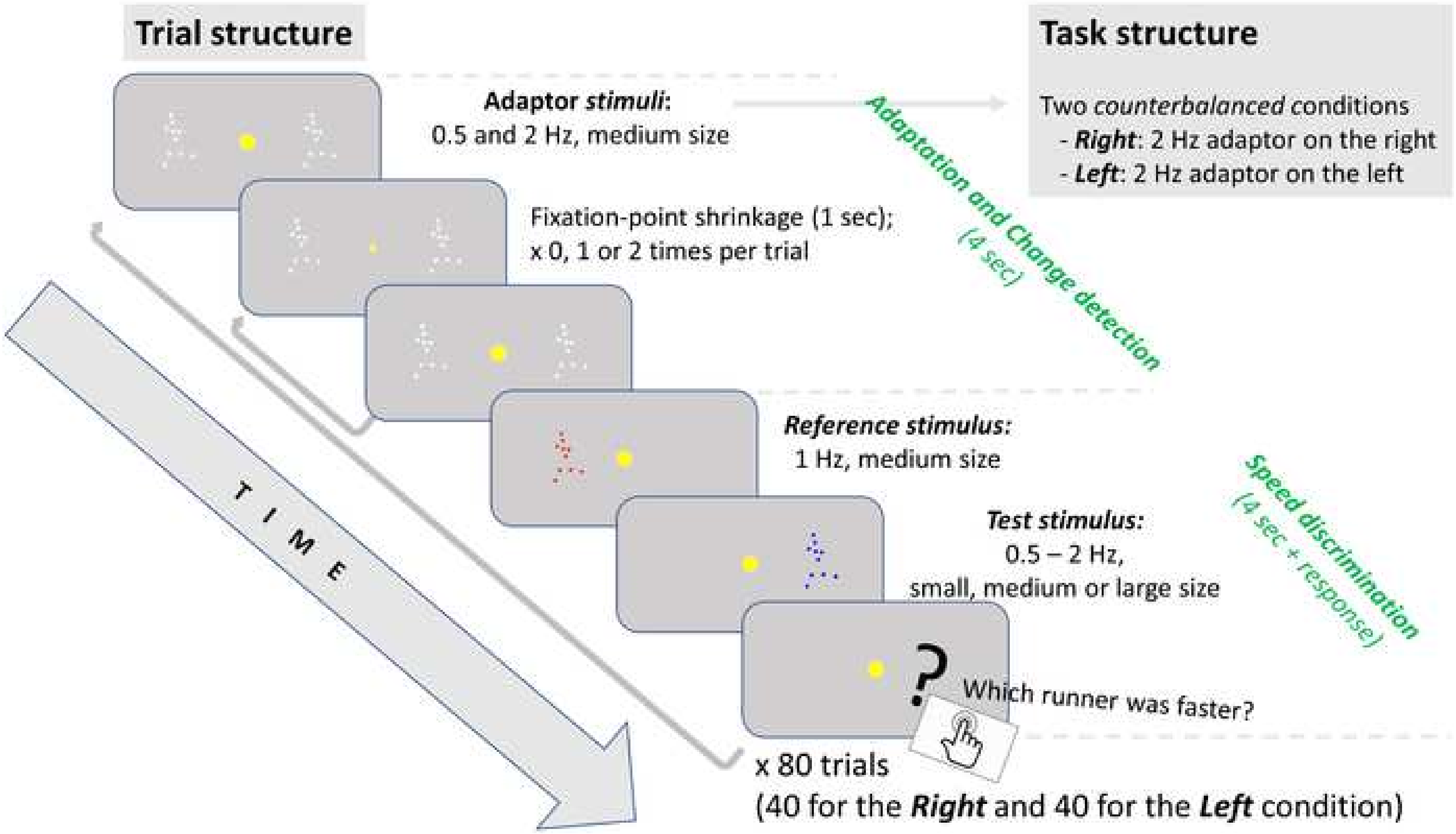
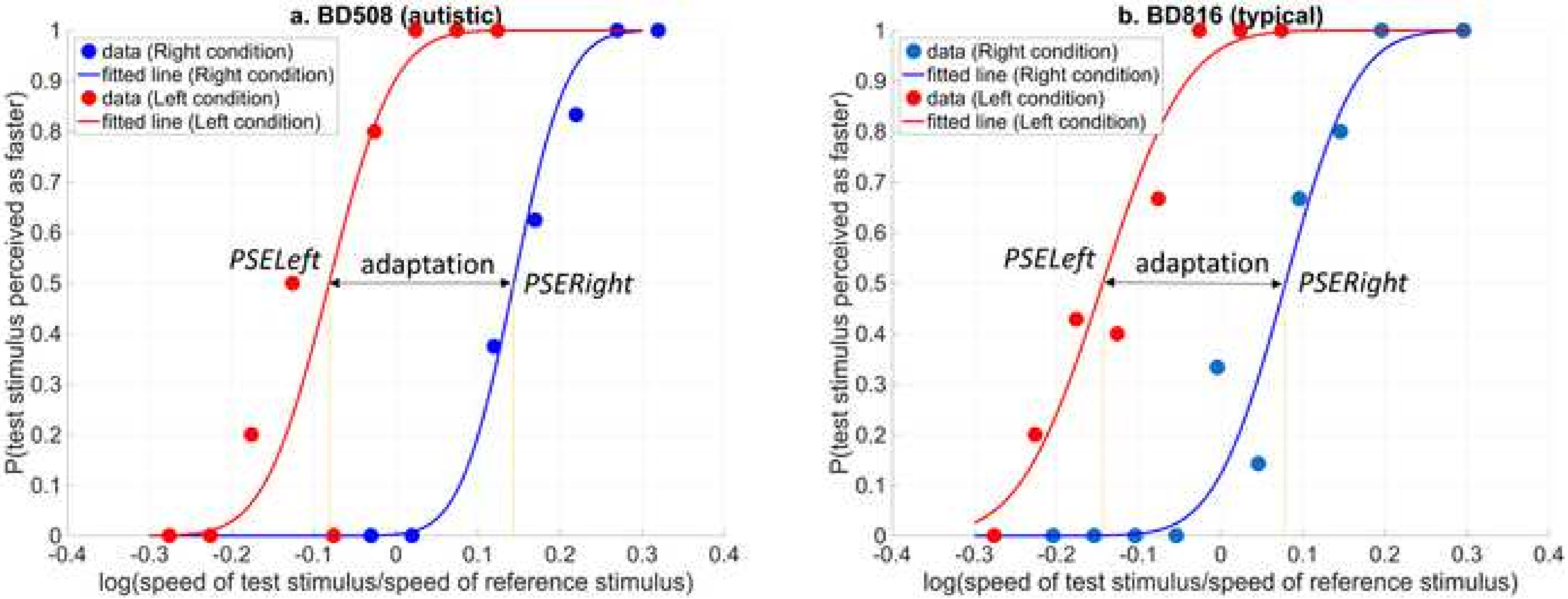
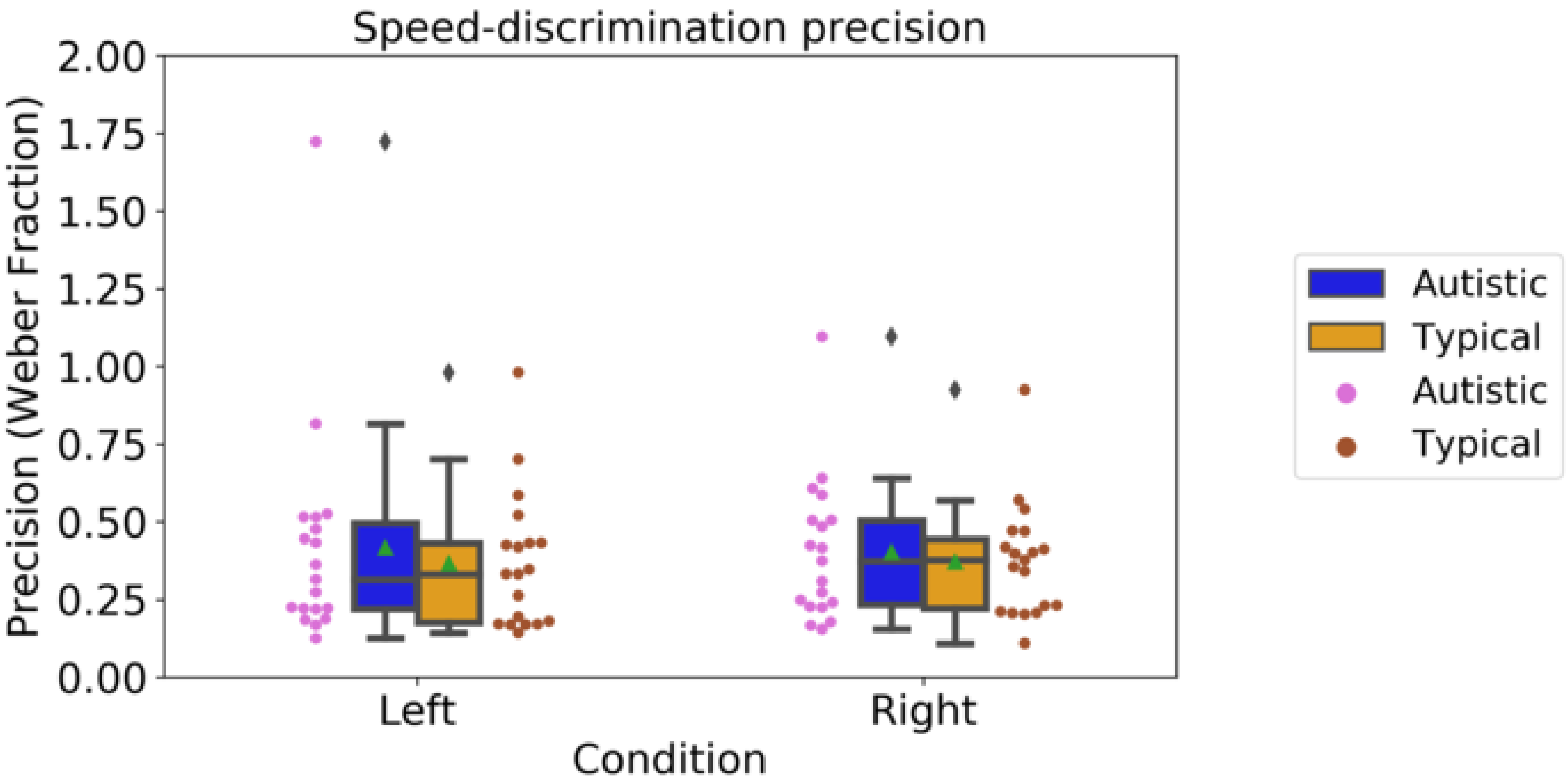
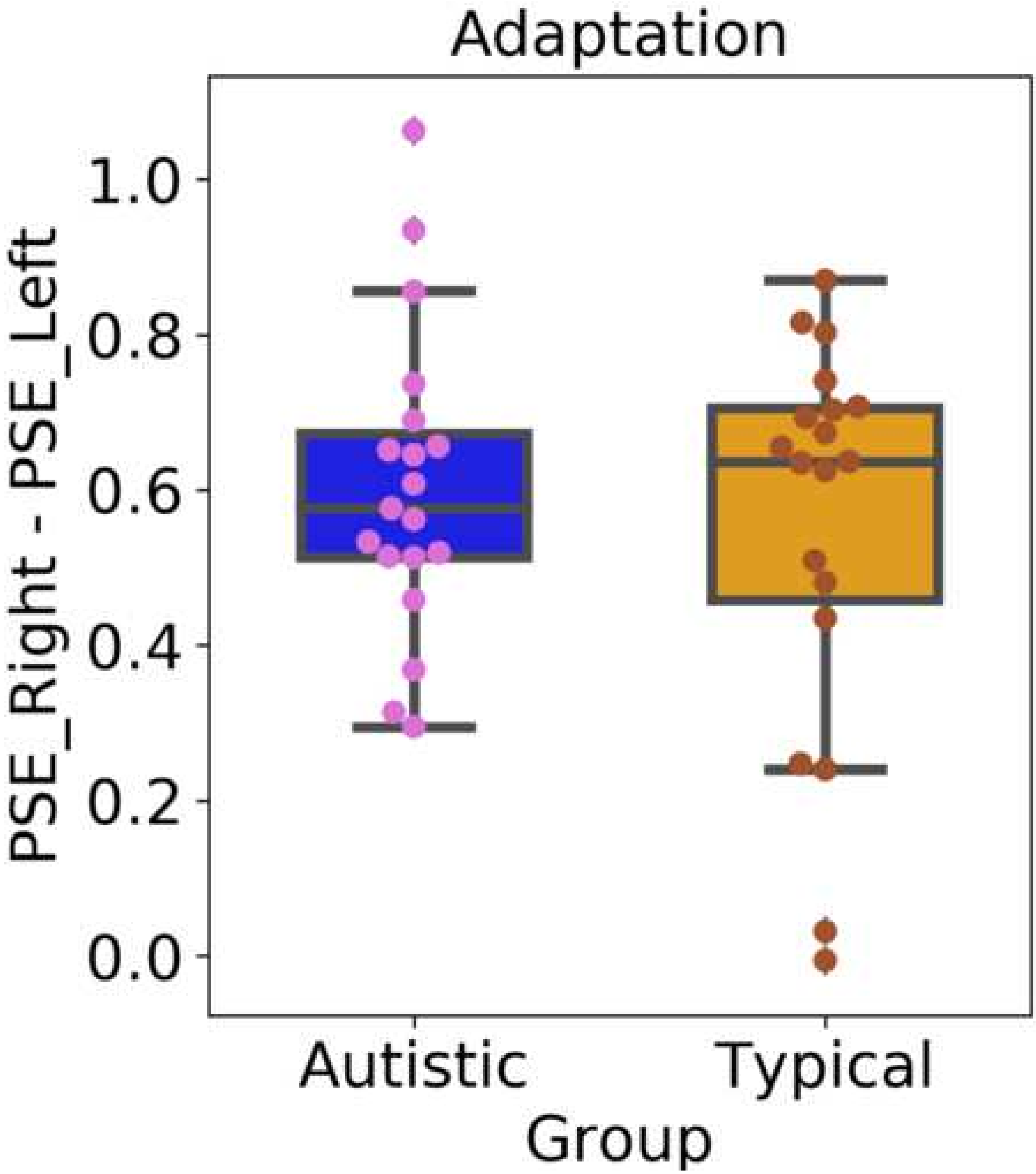

Trial structure
Adaptor stimuli:
0.5 and 2 Hz, medium size
Fixation-point shrinkage (1 sec);
x 0, 1 or 2 times per trial
Adaptation and Change detection
(4 sec)
Task structure
Two counterbalanced conditions
- Right: 2 Hz adaptor on the right
- Left: 2 Hz adaptor on the left
Reference stimulus:
1 Hz, medium size
Test stimulus:
0.5 – 2 Hz,
small, medium or large size
Speed discrimination
(4 sec + response)
?
Which runner was faster?
T I M E
x 80 trials
(40 for the Right and 40 for the Left condition)

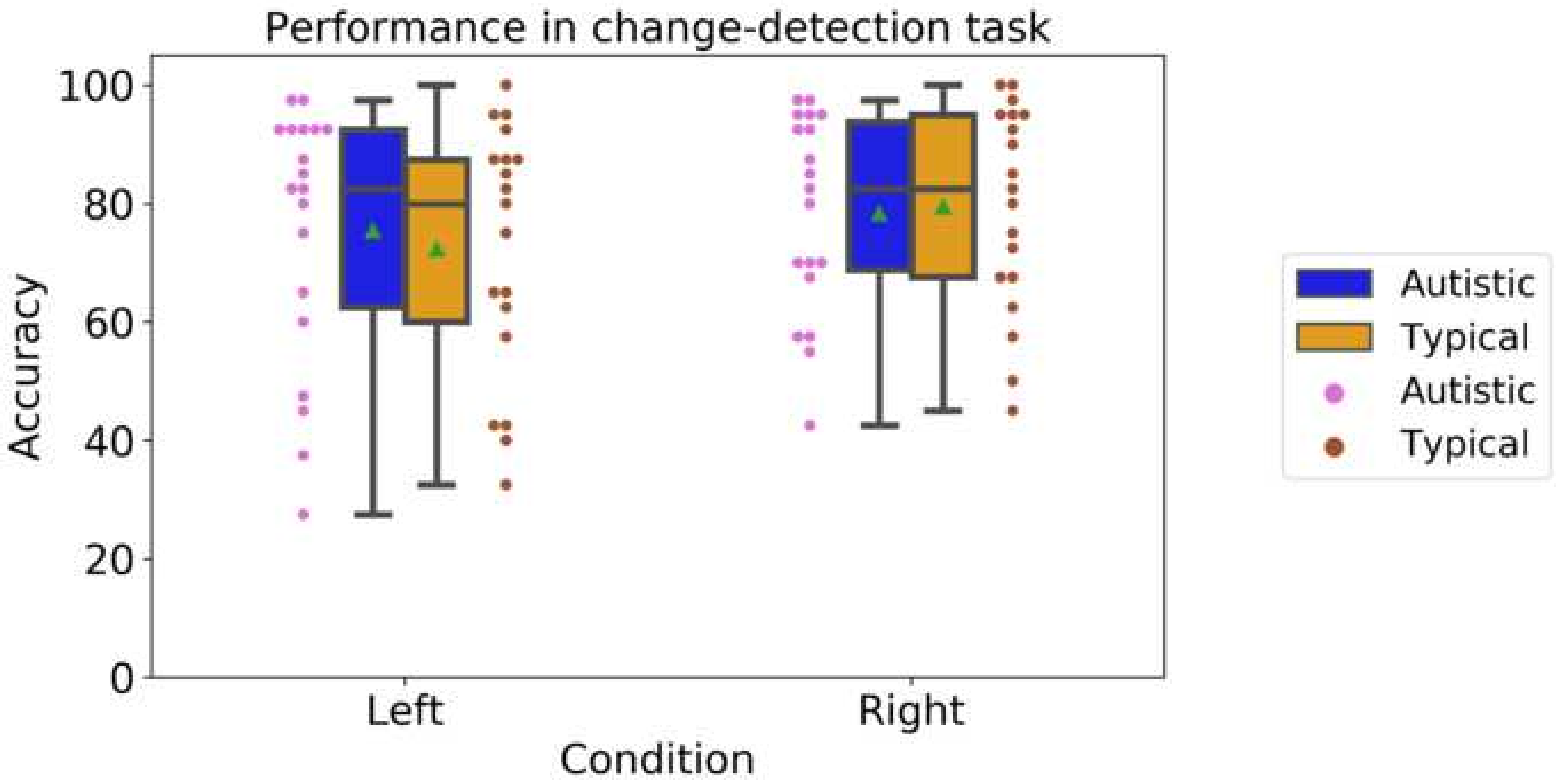
Figure 2 Click here to access/download;Figure;Figure2.png




Speed-discrimination precision
Precision (Weber Fraction)
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Left
Right
Condition
Autistic
Typical
Autistic
Typical


Adaptation
PSE_Right - PSE_Left
1.0
0.8
0.6
0.4
0.2
0.0
Autistic
Typical
Group

Click here to access/download;Figure;Figure5.png



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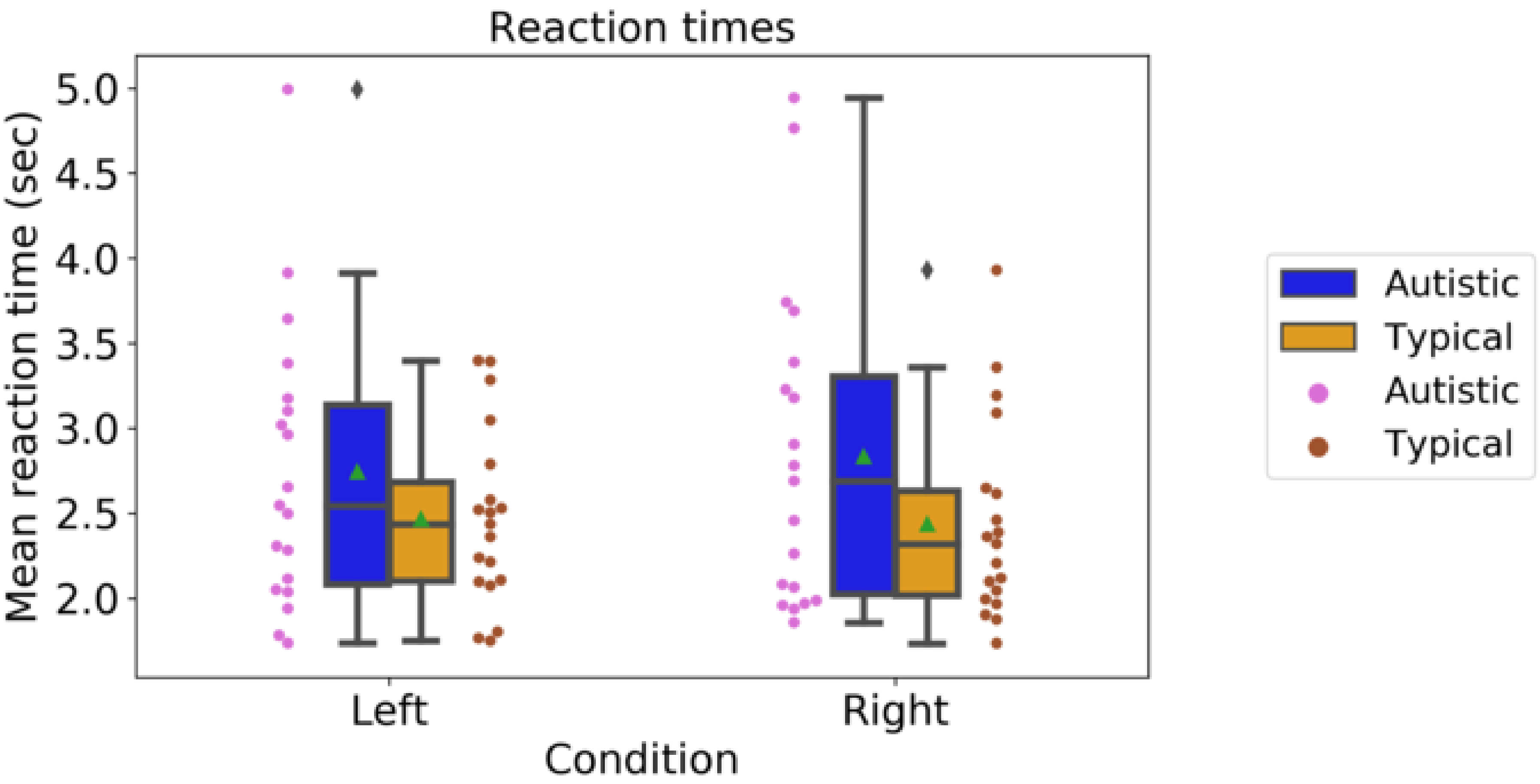

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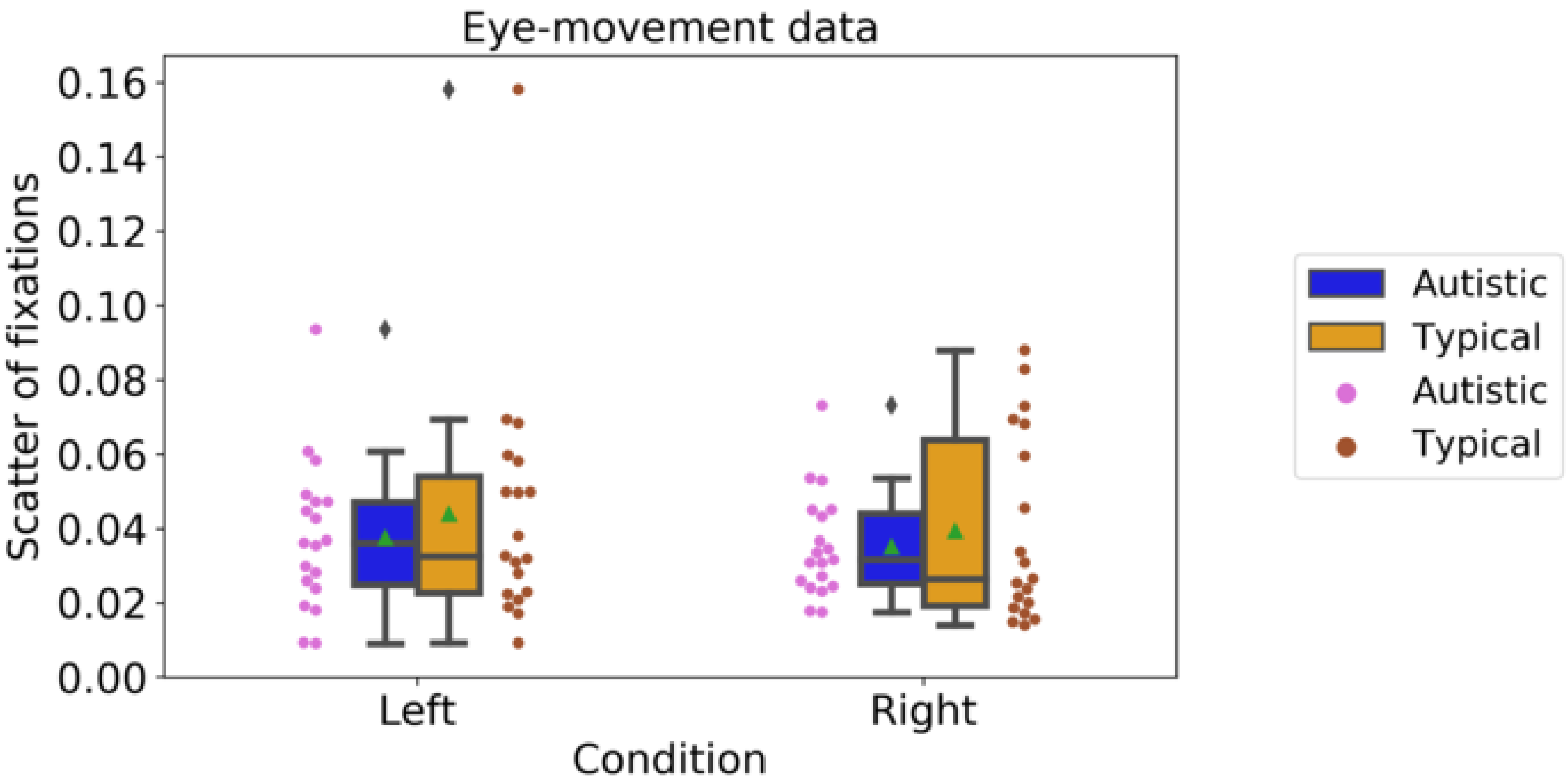

Figure 8

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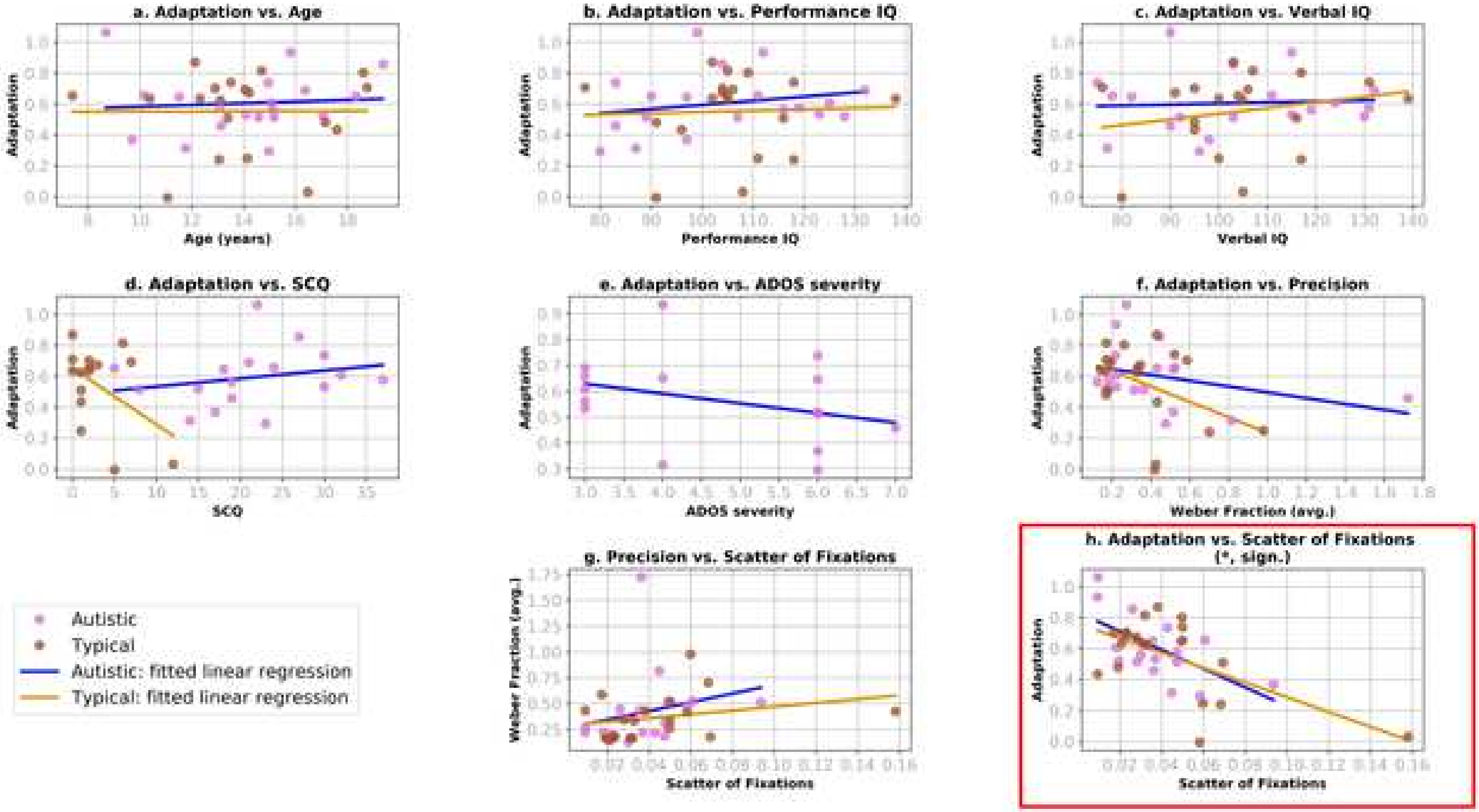

Author Note

At the time of the study Themis Karaminis was based at the Centre for Research in Autism and Education; UCL, London, UK. Roberto Arrighi was based at the Institute of Neuroscience, National Research Council, Pisa, Italy. Georgia Forth was based at the Centre for research in Autism and Education; UCL, London, UK. David Burr was based at the Institute of Neuroscience, National Research Council, Pisa, Italy. Elizabeth Pellicano was based at the Centre for research in Autism and Education; UCL, London, UK.

Themis Karaminis is now based at the Department of Psychology, Edge Hill University, Ormskirk, UK. Georgia Forth is now based at the Department of Child and Adolescent Psychiatry, Institute of Psychiatry, Psychology and Neuroscience, King's College London, London, UK. Elizabeth Pellicano is now based at the Department of Educational Studies, Macquarie University, Sydney, Australia.

Acknowledgments. We are very grateful to the young participants, families and school staff who kindly took part in this research. Thanks also to Lorcan Kenny, Katy Warren, and Hannah White for their help in collecting the data. This work was generously supported by a grant from the UK's Medical Research Council awarded to Elizabeth Pellicano and David Burr (MR/J013145/1) and also by the European Research Council (ERC advanced grants "STANIB" and "ECSPLAIN"). This work has also received funding from the EU Horizon 2020 research and innovation programme under Grant Agreement No 832813 'Spatio-temporal mechanisms of generative perception —GenPercept (to David Burr).

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