Article:

Pirrone, Angelo, Wen, Wen, Li, Sheng et al. (2 more authors) (2018) Autistic traits in the neurotypical population do not predict increased response conservativeness in perceptual decision making. Perception. pp. 1081-1096. ISSN: 0301-0066

https://doi.org/10.1177/0301006618802689

Autistic traits in the neurotypical population do not predict increased response conservativeness in perceptual decision making

Journal:	*Perception*
Manuscript ID	PEC-18-0050.R1
Manuscript Type:	Article
Date Submitted by the Author:	15-Aug-2018
Complete List of Authors:	Pirrone, Angelo Wen, Wen; Peking Univerity, School of Psychological and Cognitive Sciences Li, Sheng; Peking University, School of Psychological and Cognitive Sciences Baker, Daniel; University of York, Milne, Elizabeth; University of Sheffield, Department of Psychology
Keywords:	autism, decision making, response conservativeness, AQ
Abstract:	Recent research has shown that adults and children with autism spectrum disorders (ASD) have a more conservative decision criterion in perceptual decision making compared to neurotypical (NT) individuals, meaning that autistic participants prioritise accuracy over speed of a decision. Here, we test whether autistic traits in the NT population correlate with increased response conservativeness. We employed three different tasks; for two tasks we recruited participants from China (N=39) and for one task from the UK (N=37). Our results show that autistic traits in the NT population do not predict variation in response criterion. We also failed to replicate previous work showing a relationship between autistic traits and sensitivity to coherent motion and static orientation. Following the argument proposed by Gregory and Plaisted-Grant (2016), we discuss why perceptual differences between autistic and NT participants do not necessarily predict perceptual differences between NT participants with high and low autistic traits.

RUNNING HEAD: Autistic traits and response conservativeness

Autistic traits in the neurotypical population do not predict increased response conservativeness in perceptual decision making

Angelo Pirrone [1,2,3,4], Wen Wen [1,2,3,4], Sheng Li [1,2,3,4], Daniel H. Baker [5], Elizabeth Milne [6]

(1) School of Psychological and Cognitive Sciences, Peking University, Beijing 100871, China
(2) Beijing Key Laboratory of Behavior and Mental Health, Peking University, Beijing, 100871, China.
(3) PKU-IDG/McGovern Institute for Brain Research, Peking University, Beijing, 100871, China.
(4) Key Laboratory of Machine Perception (Ministry of Education), Peking University, Beijing, 100871, China.
(5) Department of Psychology, University of York (UK)
(6) Department of Psychology, The University of Sheffield (UK)

Abstract

Recent research has shown that adults and children with autism spectrum disorders (ASD) have a more conservative decision criterion in perceptual decision making compared to neurotypical (NT) individuals, meaning that autistic participants prioritise accuracy over speed of a decision. Here, we test whether autistic traits in the NT population correlate with increased response conservativeness. We employed three different tasks; for two tasks we recruited participants from China (N=39) and for one task from the UK (N=37). Our results show that autistic traits in the NT population do not predict variation in response criterion. We also failed to replicate previous work showing a relationship between autistic traits and sensitivity to coherent motion and static orientation. Following the argument proposed by Gregory and Plaisted-Grant (2016), we discuss why perceptual differences between autistic and NT participants do not necessarily predict perceptual differences between NT participants with high and low autistic traits.

Keywords: autism, decision making, response conservativeness, AQ

Acknowledgements: This work was supported by Beijing Municipal Science & Technology Commission (Z171100000117015); National Key Research and Development Program of China (2017YFB1002503); National Natural Science Foundation of China (31470974). The funding source had no role other than financial support. All authors declare that they have no conflict of interest.

Correspondence concerning this article should be addressed to Angelo Pirrone, School of Psychological and Cognitive Sciences, Peking University, Beijing 100871, China. E-mail: angelopirrone@gmail.com.

Introduction

When making a ‘simple’ binary perceptual decision, such as deciding whether a pattern on the road is an animal or the shadow of a tree, we quickly sample information for one option over the other until a certain decision boundary is reached and a decision is made in favour of the alternative that received most support (Gold & Shadlen, 2007). A number of factors are known to affect our decisions: (1) the difficulty of the task – ‘easy’ discriminations are made faster and more accurately compared to ‘difficult’ discriminations, (2) participants’ sensitivity – those who are ‘better’ at discriminations are faster and more accurate, (3) the response conservativeness (i.e., the distance between the two boundaries for a decision) – participants can decide to be fast in the decision (hence more inaccurate) or accurate (hence slower), (4) the bias for a response – with regards to the above example, on a road with few trees but many farms, subjects might be more likely to answer for the option ‘animal’ compared to the option ‘tree’, (5) the time to execute the motor response – once decided that the stimulus is an animal, a young driver might be faster moving the car away from it, compared to an older individual, given the speed difference in motor response between younger and older individuals (Ratcliff & McKoon, 2008).

Pirrone, Dickinson, Gomez, Stafford and Milne (2017) have shown that, in deciding whether a stimulus is oriented clockwise or anticlockwise, adults with Autism Spectrum Disorder (ASD), compared to neurotypical (NT) participants, adopt a more conservative response criterion and take longer to execute the motor response. The authors used a computational model of decision making, the Drift Diffusion Model (Ratcliff & McKoon, 2008) that enables the extraction of estimates for each of the parameters that contribute to the output of a simple perceptual decision. Pirrone, Johnson, Stafford and Milne (under review) have replicated the results of increased response conservativeness in children with ASD performing an orientation discrimination task. Interestingly, in both studies, the sensitivity of the participants to the stimulus did not differ between autistic participants and controls. As widely discussed in the two above mentioned papers, this result has important consequences for studies that, on the basis of RTs and/or accuracy differences alone, have proposed perceptual enhancement or impairments in ASD. Furthermore, given that the conservativeness hypothesis may explain previous findings in autism this result has led to a number of research projects that are the focus of current and future research.

It has been proposed that ASD is an extreme case of a continuum of traits also observable in the NT population (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001). Autistic traits are commonly measured using the autism-spectrum quotient questionnaire (AQ; Baron-Cohen et al, 2001). The AQ is a 50 item questionnaire which assesses five different domains that are associated with ASD: social skill, attention switching, attention to detail, communication and imagination. Some studies have reported performance similarities between participants with high AQ scores and individuals with ASD in a variety of perceptual tasks (Stewart et al., 2009; Grinter et al.,2009; Almeida et al.,2010; Bayliss & Kritikos, 2011) and the AQ has been used to test predictions about ASD on NT populations (Stewart, M. E., & Ota, 2008; Auyeung, Baron□Cohen, Ashwin, Knickmeyer, Taylor, & Hackett, 2009), although this approach can be considered to be controversial (see Gregory & Plaisted-Grant, 2016).

To date, no studies have investigated the link between response conservativeness and autistic traits in the neurotypical population. This is the aim of the current study as we investigate whether increased response conservativeness is predicted by AQ scores. We used three classical perceptual tasks: an orientation discrimination task similar to the one used in the studies cited above; a motion discrimination task; and an attention-cuing task. The choice of the orientation task is motivated by the fact that this experimental paradigm was adopted by Pirrone et al. (2017) and Pirrone et al. (under review) for our previous investigations of decision making in autistic adults and children. Coherent motion perception was also included as there are a large number of studies showing differences in the way in which participants with autism perceive coherent motion, although results are not always consistent (for a review see Milne, Swettenham & Campbell, 2005). Furthermore, previous studies have shown that motion coherence and orientation discrimination are correlated with AQ scores (see, Dickinson, Jones and Milne, 2014; Jackson et al, 2013). Attention-cuing is another controversial topic within ASD research, for which conflicting results have been reported (see, Landry & Parker 2013). Inclusion of three different tasks enabled us to investigate decision criteria under different task demands. We recruited participants in two different countries, China (for the orientation and the motion discrimination task) and UK (for the attention-cuing task).

One difference with the studies of Pirrone et al. (2017) and Pirrone et al. (under review) is that here, for the orientation and motion experiment we also added speed and accuracy instructions, meaning that participants were instructed either to be fast or to be accurate, depending on the specific experimental block. This manipulation allowed us to test whether any potential differences in response criterion between low and high AQ scorers are consistent across speed and accuracy instructions, or whether potential differences in response criterion are specific only for one type of instruction, or whether the ability to flexibly adjust response criterion between the two instructions correlate with AQ scores. The nature of the current investigation was exploratory; however, if a correlation between AQ and response conservativeness was to be found, we expected a positive correlation, indicating that higher AQ scores are associated with increased response conservativeness.

Methods

Motion and orientation discrimination

Participants

Thirty-nine participants (22 females) took part in the study; their mean age was 21.56 and ranged from 18 to 26 years. Participants were university students recruited through online advertisements who were naive to the purpose of the experiment. All participants had normal or corrected-to-normal vision. Participants did not have a history of psychiatric, neurological or medical disorders and did not have first degree relatives with ASD. Their participation was voluntary and rewarded monetarily with 90 ¥ (about 13.5 $). Ethical approval was granted by the ethics committee of the School of Psychological and Cognitive Sciences of Peking University and informed consent was obtained from each subject.

AQ and IQ measures

In random order, either before or after the perceptual experiment, participants performed the Chinese version of the Autism Spectrum Quotient test (Baron-Cohen et al, 2001; Chan & Liu, 2008) and the Raven Matrix non-verbal reasoning test (Raven, Court & Raven, 1995). The test order was randomized across participants, but they were both presented either before or after the perceptual experiment. In this study we controlled for non-verbal IQ given that some studies (but not all, see

Dutilh et al., 2017) have reported that IQ correlates with drift rate (Ratcliff, Thapar & McKoon, 2010) and in some cases also with response criterion in decision making tasks (Wagenmakers, 2009).

The average raw IQ score (number of correct responses out of 72 items) was 68.51 (range 54-72); the average standardised IQ score (Angoff, 1984) was 100 (range 75 -135).The average AQ score was 21.18 (range 11-36). The distribution plots of Figure 1 show how our samples are distributed; recall that an AQ score of 32 is the clinical cut-off for autism, and 16.4 is the average score in the NT population in the UK (Baron-Cohen et al, 2001).

Insert Figure 1 about here

Fig. 1. Distribution plots for the AQ scores in the orientation and motion discrimination task (top) and the attention-cuing task (bottom). The red line represents the best fit of a non-parametric kernel smoothing distribution. Our distributions are reasonably centred around the expected values for the NT population (16.4) with a low number of extreme cases.

Design of the experiment

The stimuli were generated on a personal computer using PsychoPy (Peirce, 2007) and presented on a 36 x 27 cm CRT screen with a refresh rate of 100 Hz at a viewing distance of 57 cm where the head of the subject was positioned on a chin rest. The experiment consisted of two sessions, one with speed and one with accuracy instructions, the order of which was randomized across participants. Within each block participants performed an orientation and a motion discrimination task, the order of which was randomized across participants. During the motion experiment, participants were presented a random dot kinematogram (RDK) stimulus centred on the screen and with a diameter of 5 deg. The stimulus consisted of 90 dots; each dot had a size of 3 pixels and a speed of .03 deg/frame. Each dot had a lifetime of 3 frames after which it was re-drawn in a random location; within the 3 frames lifetime the dots assigned to the noise and those assigned to the signal were the same. Noise dots had a constant, random direction within the 3 frames lifespan. The percentage of coherently moving dots could be 4, 6 or 8% and was pseudo-randomly selected on each trial. On average, on half of the trials the dots were moving left, on the other half they were moving right.

The orientation discrimination was similar to that performed in Pirrone et al. (2017) and Pirrone et al. (under review). The task consisted of a sine wave grating stimulus with a spatial frequency of 4 cycles per degree, windowed by a Gaussian spatial envelope to have a diameter of 10 degrees. The orientation could be .2, .4 or .6 degrees clockwise or anticlockwise with regards to an imaginary vertical line. Setting such a low difference in angle was justified by previous pilot studies, in which we found that with a vertical standard the task becomes particularly easy as compared to non-cardinal standards.

For both tasks, participants, using their second and third finger of their right hand, had to press left (anticklockwise) or right (clockwise) on a keyboard to indicate the response. Throughout the experiment, participants were instructed to maintain fixation on a red dot at the centre of the screen (0.9 deg diameter), and minimize eye movements as much as possible. After the presentation of each trial, participants were presented a 10 by 10 degrees white noise texture for 450 ms. Each block consisted of 198 trials. After each block, participants could take a self-paced break during which they were presented with their mean accuracy or mean RT for the block and reminded to be either as fast or as accurate as possible. Before the RDK and before the orientation task, participants performed 6 practise trials to familiarize themselves with the task. For each task participants performed 3 blocks for a total of 594 trials for the motion discrimination task and 594 trials for the orientation task in each session.

Attention-cuing task

Participants

Thirty-seven participants (17 female), with a mean age of 21 (range 18-23) completed the experiment. Participants were university students recruited through online advertisements. All provided written informed consent, and ethical approval was granted by the ethics committee of the Department of Psychology at the University of York. We measured AQ for all participants, with a mean of 16.86 (range 5-44). IQ was not measured for this cohort.

Design of the experiment

Participants each completed 800 trials of a spatially cued contrast discrimination task. On each trial a cue stimulus was first presented for 200ms in the centre of the screen where the participants were instructed to fixate. This consisted of an identity-averaged (mean of 22 examples, digitally averaged using morphing software) female face (6 degrees wide by 10 degrees high) with the eyes digitally altered to look to either the left or the right. A random duration blank interval (400-600ms) then preceded a 200ms presentation of a single target grating, located 8 degrees to either the left or the right of fixation. The target was a 2c/deg horizontal sine wave grating with a diameter of 4 degrees. One half (top or bottom) of the grating had a contrast of 50%, the other half had a contrast of 60%. Participants indicated which half of the stimulus (top or bottom) appeared higher in contrast using the arrow keys on the keyboard. The validity of the cue was 0.75, such that on 600 trials the stimulus appeared in the cued location (where the eyes were looking), and on 200 trials it appeared in the uncued location (where the eyes were not looking). Cue direction was balanced and randomized across left/right. All stimuli were presented on a gamma-corrected ViewPixx monitor running at 120Hz, controlled by an Apple Macintosh computer, and viewed from a distance of 57cm. EEG data were collected contemporaneously, but are not reported here.

Results

Motion and orientation discrimination

Insert Figure 2 about here

Fig. 2. Top: mean correct reaction time (RT) and accuracy for the motion discrimination task. Bottom: mean RT and accuracy for the orientation discrimination task. For both tasks, we report RT and accuracy for when participants were instructed to be fast (asterisk symbols) or accurate (circle symbols). Bars represent standard error of the mean.

Figure 2 shows the presence of a typical speed-accuracy trade-off. Participants were faster and less accurate when they were instructed to be fast, and slower but more accurate when instructed to be accurate. Furthermore, as the difficulty of the discrimination to be made increased, accuracy decreased and correct reaction time (cRT) increased.

We run analyses using the free and open-source software JASP (JASP Team, 2017). For the Bayesian ANOVAs we report results from Bayesian model averaging (Hoeting, Madigan, Raftery, & Volinsky, 1999). This method averages across all models that could have generated the data and, through the Bayes Factor for inclusion (BFi), it provides succinct information of the likelihood for inclusion of a specific term for the explanation of the observed data. For the correlation analyses, we instead report the Bayes Factor (BF) which quantifies the amount of evidence for the null hypothesis relative to the alternative hypothesis (for details see Lee & Wagenmakers, 2014). For BFi and BF we used the classification scheme adopted by JASP that is adjusted from Jeffreys (1961), as reported in Table 1.

Bayes Factor	**Evidence category**
> 100	Extreme evidence for H1
30 - 100	Very strong evidence for H1
10 -30	Strong evidence for H1
3 - 10	Moderate evidence for H1
1 - 3	Anecdotal evidence for H1
1	No evidence
1/3 - 1	Anecdotal evidence for H0
1/10 – 1/3	Moderate evidence for H0
1/30 – 1/10	Strong evidence for H0
1/100 – 1/30	Very strong evidence for H0
< 1/100	Extreme evidence for H0

Table 1: Classification scheme of Bayes Factor, taken from Lee & Wagenmakers (2014), adjusted from Jeffreys (1961).

For the orientation discrimination task, a Bayesian ANOVA on correct RTs, with instruction (speed vs accuracy) and difficulty as factors, and AQ and raw IQ scores as covariates, showed that instructions had a BFi indistinguishable from infinite (i.e., above the upper limit value in JASP), difficulty had a BFi of .09, their interaction had BFi of .048 while IQ and AQ had a BFi of respectively .349 and .454 . Regarding the motion discrimination task, instructions had a BFi > 10^{15}, difficulty had a BFi of .303, their interaction had BFi of .204 while IQ and AQ had a BFi of respectively .243 and .271 .

A Bayesian ANOVA on accuracy for the orientation discrimination task showed that instructions had a BFi > 10^{14}, difficulty had an infinite BFi, their interaction had BFi of 43.99 while IQ and AQ had a BFi of .538 and .319. The very strong BFi for the interaction is due to the fact that for the most difficult discrimination there was not a difference in accuracy between speed and accuracy instructions, while for medium and easy discriminations, decisions were less accurate when instruction stressed speed compared to accuracy. For the motion discrimination task, instructions had a BFi > 10^{14}, difficulty had a BFi of 10^{14}, their interaction had BFi of .711 while IQ and AQ had a BFi of respectively .413 and .432 . Overall, the BFi for AQ provides anecdotal to moderate support for the null hypothesis (i.e., that AQ does not affect RT or accuracy), while instruction and difficulty affected the behavioural pattern as expected by our manipulation.

Figure 3 shows scatter-plots with AQ against all of the measures and manipulations of our experiment (i.e., accuracy and RTs for two tasks, three levels of difficulty and two types of instructions). AQ did not correlate with any of the measures (lowest BF .199 - highest BF .55). AQ did not correlate with any of the measures also while controlling for IQ; in JASP it is not possible to calculate BF for partial correlations, so we report the p-values for frequentist partial correlations between AQ and any of the other measures of the study, with all $p > .145$.

Insert Figure 3 here (fullpage)

Fig. 3. Scatterplots showing the relationship between AQ and accuracy, and between AQ and reaction times for all manipulations involved in the study, for when the instructions stressed speed (Fig 3a, top) or accuracy (Fig 3b, bottom). For the subplots title, the label 'orientation' or 'motion' indicates whether the task was the orientation discrimination or the motion discrimination. The numbers in the end refers to the difficulty of the discrimination, in particular .2, .3 and .6 degrees of difference for the orientation discrimination task, and 4%, 6% and 8% coherence level for the motion discrimination task. In all cases the BF for the correlation between the two measures supported the null hypothesis.

Attention-cuing task

Insert Figure 4 about here

Fig. 4. Mean correct reaction time and accuracy for the cue-congruent and the cue-incongruent conditions. Bars represent standard error of the mean.

Figure 4 shows the effect of cueing on correct RTs and accuracy. Cue congruency can be seen to affect both RTs , BFi = 9717 and accuracy BFi = 36.

Figure 5 shows scatter-plots with AQ against accuracy and RTs for the cue-congruent and cue-incongruent condition. Also in this case, AQ did not correlate with any of the measures. When the cue was congruent, the BF for the correlation between AQ and accuracy was .339, and for RTs it was .208; when the cue was incongruent, the BF for the correlation between AQ and accuracy was .276, while the BF for the correlation between AQ and RTs was .247.

Insert Figure 5 about here

Fig. 5. Scatterplots showing (top) the relationship between AQ and accuracy for the cue-congruent an cue-incongruent conditions and (bottom) the relationship between AQ and RTs for the cue-congruent an cue-incongruent conditions. In all cases there was not a correlation between the two variables under consideration.

Model fitting

Given that AQ did not affect accuracy or RTs, we believe that the fitting results would also show that AQ does not affect the DDM parameters. Here we report the results from the fitting with regards to our measure of interest, AQ. We performed the fitting using the Diffusion Model Analysis Toolbox (DMAT; Vandekerckhove & Tuerlinckx, 2007) for MATLAB. In order to estimate the parameters, data were grouped using the .1, .3, .5, .7 and .9 quantiles that divide the correct and error distributions and a chi-square fitting routine was selected among the options available using DMAT. In order to avoid overfitting, we constrained the model fitted to our data, by making theoretically plausible assumptions. For the motion and orientation discrimination study, we fitted an unbiased model in which all parameters could vary by instruction (this is equivalent to fit the speed and accuracy instructions separately), drift rate could vary by difficulty for each task since this parameter exactly captures the difficulty of the task, while all other parameters (boundary separation, non-decision time, variability in non-decision time and variability in drift) were kept constant within each task. For the attention-cuing task, we fit a model in which cue congruency could affect the difficulty of the task, the non-decision time and its variability, while all other parameters (boundary separation and variability in drift) were kept constant. Recall that in the attention-cuing task, there was no relation between stimulus location (left or right) and response category (up or down); for this reason we selected an unbiased model also in this case, given that stimulus location could not interfere with response category – this assumption was corroborated by a visual inspection of data that did not show a response bias.

Estimated DDM parameters are reported in Table 2. In particular, we report for the three experiments, the values of the estimated parameters averaged across participants. In line with the behavioural analyses, the BFi showed anecdotal to moderate support for the null hypothesis for a correlation between AQ and any of the decision parameters (BF ranging from .884 to .199 for the motion and orientation discrimination tasks, BF range .436 - .205 for the attention-cuing task). In particular, with regards to our parameter of interest, boundary separation, for both tasks there was moderate support for the null hypothesis concerning a correlation with AQ scores (BF = .252 for the speed instruction of the motion task, BF = .274 for the speed session of the orientation task, while for the accuracy sessions the BF were .199 and .208; for the attention-cuing task BF = .319), as also can be seen from Figure 6 and Figure 7. Furthermore, AQ did not correlate with the ability to flexibly change the decision boundary across instructions (i.e., difference between boundary separation for the accuracy and speed instructions) in the orientation (BF = .202) and motion discrimination tasks (BF = .214).

task	session	difficulty or cue-congruency	parameter	estimated DDM parameter
motion	speed		boundary	.163
orientation	speed		boundary	.137
motion	speed		non decision time	.405
orientation	speed		non decision time	.341
motion	speed		variab. drift	.120
orientation	speed		variab. drift	.084
motion	speed		variab. non decision time	.210
orientation	speed		variab. non decision time	.216
motion	speed	coherence 4%	drift	.043
motion	speed	coherence 6%	drift	.053
motion	speed	coherence 8%	drift	.076
orientation	speed	degree diff 2	drift	.036
orientation	speed	degree diff 4	drift	.062
orientation	speed	degree diff 6	drift	.092
motion	accuracy		boundary	.316
orientation	accuracy		boundary	.253
motion	accuracy		non decision time	.353
orientation	accuracy		non decision time	.333
motion	accuracy		variab. drift	.143
orientation	accuracy		variab. drift	.196
motion	accuracy		variab. non decision time	.194
orientation	accuracy		variab. non decision time	.168
motion	accuracy	coherence 4%	drift	.042
motion	accuracy	coherence 6%	drift	.053
motion	accuracy	coherence 8%	drift	.082
orientation	accuracy	degree diff 2	drift	.070
orientation	accuracy	degree diff 4	drift	.115
orientation	accuracy	degree diff 6	drift	.163
attention-cuing			boundary	.129
attention-cuing		incongruent	non decision time	.393
attention-cuing		congruent	non decision time	.351
attention-cuing			variab. drift	.091
attention-cuing		incongruent	variab. non decision time	.161

attention-cuing		congruent	variab. non decision time	.180
attention-cuing		incongruent	drift	.417
attention-cuing		congruent	drift	.443

Tab. 2. Estimated parameters for the three experiments, averaged across participants. Recall that only for the motion and orientation discrimination task there was a speed-accuracy manipulation. Difficulty (or cue-congruency) is only reported for the parameters that were allowed to vary with respect to difficulty (or cue-congruency). All the other parameters were kept fixed across difficulty (or cue-congruency) conditions.

Insert Figure 6 about here

Fig. 6. Scatterplots showing correlation (continuous line) between AQ and boundary separation for the orientation and the motion discrimination task, for both speed and accuracy instructions. In all cases there was not a correlation between the two variables under consideration.

Insert Figure 7 about here

Fig. 7. Scatterplots showing correlation (continuous line) between AQ and boundary separation for the attention-cuing task. The BF provides evidence for the null hypothesis of a correlation between AQ and boundary separation.

Discussion

In three experimental paradigms, involving classic stimuli and procedures adopted in perceptual decision making research, we investigated whether autistic traits predict response conservativeness.

We predicted that there may be an interaction between AQ score and boundary separation given previous findings that autistic children and adults show increased boundary separation when performing an orientation discrimination task (Pirrone et al., 2017; Pirrone et al., *under review*). For all experiments, the manipulations of interest (difficulty of the task, speed-accuracy instructions and cue-validity) clearly elicited typical results suggesting that our tasks were valid. However, AQ scores did not predict RTs or accuracy, nor differences in any of the parameters that underlie a decision, either in the motion and orientation discrimination tasks or in the attentional cueing task.

While it could be argued that a larger sample size might change this result, our current results do not show even a specific trend to suggest that an increase in sample size may overturn the results in favour of an effect of AQ. Furthermore, in our investigation the BF shows support for the null hypothesis. Previous studies have found relationships between coherent motion discrimination and orientation discrimination and AQ score (Dickinson et al. 2014 and Jackson et al. 2013), although these findings were not replicated here. It remains to be seen whether drift diffusion modelling of a dataset in which a relationship between perceptual decision making and AQ scores is seen would reveal an association between response conservativeness and AQ score as was predicted here. Furthermore, a future interesting project could involve a (Bayesian) reanalysis and DDM decomposition of data that have reported relationships between coherent motion discrimination and orientation discrimination and AQ (Dickinson et al. 2014 and Jackson et al. 2013).

Our findings can be interpreted as supporting two alternative conclusions. On the one hand, it could be argued that while performance on these tasks, including DDM parameters, is unrelated to the variables are that are measured by the AQ, our result does not actually tell us anything about ASD. Interestingly, we did not find similar findings to previous works in terms of relationship between AQ score and either motion perception or orientation discrimination (Dickinson et al. 2014 and Jackson et al. 2013) – hence this conclusion is warranted by the data.

On the other hand, assuming that the AQ is a good proxy for autism, then this study does not support our previous findings and cast doubts on the conservativness hypothesis of autism. However, here we fully embrace the argument reported in Gregory and Plaisted-Grant (2016) and their argument against using AQ as a proxy for ASD. In Gregory & Plaisted-Grant, authors were interested in visual search but their argument is a general one and can be also applied to our case. To quote the words of the authors "the connection between the surface features of ASC as assessed by the AQ (e.g. social skill, repetitive interests and communicative difficulties) and the profile on our visual search task exists *only where that relationship is mediated by the syndrome of autism*" meaning that there are no a priori reasons to expect that high AQ in the NT population can be linked to variations in perceptual performances, as the mediating factor, autism, is absent.

Here, we consider the case of the speed-accuracy trade-off in perceptual decision making and how participants adjust their boundary separation. Forstmann et al. (2008) investigated the neural basis of the speed-accuracy trade-off, with NT participants performing a motion discrimination task while undergoing an fMRI scan. Before the presentation of each RDK stimulus participants were presented with cues emphasizing either speed, accuracy or both speed and accuracy. Results showed that speed instructions engaged the striatum and the pre-supplementary motor area and that inter-individual variations in this area were associated with threshold adjustments for speeded choices. In a second study (Forstmann et al., 2010), participants performed a RDK task and before the presentation of the stimulus were presented with cues emphasizing either speed or accuracy. In a separate session, participants underwent two structural MRI scans. Here, the authors found, in two independent studies, that the flexibility with which participants adjust their threshold in a motion discrimination task is associated with the strength of white matter tracts from striatum to pre-supplementary motor area. This result strengthens the results presented in Forstmann et al. (2008) and supports the *striatal hypothesis of the speed-accuracy trade-off* according to which, decrease in threshold is described by an increased activation from cortex to striatum that releases inhibition, disinhibiting the cortex and allowing a faster response.

Striatum alterations are known to be associated with ASD and to play an important role in one of the features commonly associated with ASD: repetitive behaviours (Schuetze, Park, Cho, MacMaster, Chakravarty, & Bray, 2016; Fuccillo, 2016; Kohls, Yerys & Schultz, 2014). Therefore, differences in response conservativeness between ASD and NT participants may be caused by structural and/or functional differences in striatum activation; such differences are documented, and the striatum is known to play a role in response conservativeness, hence we believe that this could be a fruitful line of research for future neuroimaging studies of ASD. However, to paraphrase the argument of Gregory and Plaisted-Grant (2016), if a participants has ASD, she will score high on the AQ *and* have increased response conservativeness; both these phenomena are related to one single underlying factor: *autism.* Therefore while some neurotypical participants would score high on the AQ questionnaire, on the basis of the data presented here, on no grounds we can propose that high AQ is associated with striatum alterations in the NT population. Hence the finding that autistic traits do not predict response conservativeness in the NT population is not at odds with the finding that ASD does indeed predict more conservative decision thresholds in decision making. While ASD and autism traits are related for the five dimensions measured by the AQ (social skill, attention switching, attention to detail, communication and imagination), assuming that the correlation should extend to other areas, is an arbitrary assumption. In other words, assuming that autism traits and ASD are *the same*, is an untested, arbitrary hypothesis that does not take into consideration the factor that differentiates NT and ASD populations, the clinical condition of autism. The lack of correlation between AQ and response conservativeness does not cast doubts on the conservativeness hypothesis of ASD, unless we introduce an unsubstantiated assumption between the domains measured by the AQ and the perceptual and decision making anomalies in ASD. Similarly, a positive correlation between AQ and response conservativeness would not have allowed us to claim whether the causes underlying the same behavioural pattern in high AQ individuals and in ASD individuals are the same.

In conclusion, our investigation highlights important empirical and theoretical differences between AQ scores and ASD; while participants with ASD show increased response criterion in decision making which may be related to striatum alterations, AQ per se does not predict response conservativeness differences, nor it can be assumed to correlate with striatum alterations in the neurotypical population.

Compliance with Ethical Standards

Ethical approval: all procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration or comparable ethical standards.

Informed consent: informed consent was obtained from all individual participants included in the study.

References

Almeida, R. A., Dickinson, J. E., Maybery, M. T., Badcock, J. C., & Badcock, D. R. (2010). A new step towards understanding Embedded Figures Test performance in the autism spectrum: The radial frequency search task. *Neuropsychologia*, *48*(2), 374-381.

Angoff, W. H. (1984). *Scales, norms, and equivalent scores*. Educational Testing Service.

Auyeung, B., Baron□Cohen, S., Ashwin, E., Knickmeyer, R., Taylor, K., & Hackett, G. (2009). Fetal testosterone and autistic traits. *British Journal of Psychology*, *100*(1), 1-22.

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The autism-spectrum quotient (AQ): Evidence from asperger syndrome/high-functioning autism, malesand females, scientists and mathematicians. *Journal of autism and developmental disorders*, *31*(1), 5-17.

Bayliss, A. P., & Kritikos, A. (2011). Brief report: Perceptual load and the autism spectrum in typically developed individuals. *Journal of Autism and Developmental Disorders*, *41*(11), 1573-1578.

Gold, J. I., & Shadlen, M. N. (2007). The neural basis of decision making. *Annu. Rev. Neurosci.*, *30*, 535-574.

Dickinson, A., Jones, M., & Milne, E. (2014). Oblique orientation discrimination thresholds are superior in those with a high level of autistic traits. Journal of autism and developmental disorders, 44(11), 2844-2850.

Dutilh, G., Vandekerckhove, J., Ly, A., Matzke, D., Pedroni, A., Frey, R., ... & Wagenmakers, E. J. (2017). A test of the diffusion model explanation for the worst performance rule using preregistration and blinding. *Attention, Perception, & Psychophysics*, *79*(3), 713-725.

Fuccillo, M. V. (2016). Striatal circuits as a common node for autism pathophysiology. *Frontiers in neuroscience*, *10*.

Hoeting, J. A., Madigan, D., Raftery, A. E., & Volinsky, C. T. (1999). Bayesian model averaging: a tutorial. *Statistical science*, 382-401.

Forstmann, B. U., Dutilh, G., Brown, S., Neumann, J., Von Cramon, D. Y., Ridderinkhof, K. R., & Wagenmakers, E. J. (2008). Striatum and pre-SMA facilitate decision-making under time pressure. *Proceedings of the National Academy of Sciences*,*105*(45), 17538-17542.

Forstmann, B. U., Anwander, A., Schäfer, A., Neumann, J., Brown, S., Wagenmakers, E. J., Bogacz, R. & Turner, R. (2010). Cortico-striatal connections predict control over speed and accuracy in perceptual decision making.*Proceedings of the National Academy of Sciences*,*107*(36), 15916-15920.

Gold, J. I., & Shadlen, M. N. (2007). The neural basis of decision making. Annu. Rev. Neurosci., 30, 535-574.

Gregory, B. L., & Plaisted-Grant, K. C. (2016). The autism-spectrum quotient and visual search: Shallow and deep autistic endophenotypes. *Journal of autism and developmental disorders*, *46*(5), 1503-1512.

Grinter, E. J., Maybery, M. T., Van Beek, P. L., Pellicano, E., Badcock, J. C., & Badcock, D. R. (2009). Global visual processing and self-rated autistic-like traits. *Journal of autism and developmental disorders*, *39*(9), 1278-1290.

Jackson, B. L., Blackwood, E. M., Blum, J., Carruthers, S. P., Nemorin, S., Pryor, B. A., ... & Crewther, D. P. (2013). Magno-and parvocellular contrast responses in varying degrees of autistic trait. *PLoS One*, *8*(6), e66797.

JASP Team (2018). JASP (Version 0.9)[Computer software].

Jeffreys, H. (1961). Theory of probability. Oxford University Press, Oxford.

Kohls, G., Yerys, B., & Schultz, R. T. (2014). Striatal development in autism: repetitive behaviors and the reward circuitry. *Biological psychiatry*, *76*(5), 358.

Landry, O., & Parker, A. (2013). A meta-analysis of visual orienting in autism. *Frontiers in human neuroscience*, *7*.

Lee, M. D., & Wagenmakers, E. J. (2014). *Bayesian cognitive modeling: A practical course*. Cambridge university press.

Milne, E., Swettenham, J., & Campbell, R. (2005). Motion perception and autistic spectrum disorder: a review. *Current Psychology of Cognition*, *23*(1/2), 3.

Peirce, J. W. (2007). PsychoPy—psychophysics software in Python. *Journal of neuroscience methods*, *162*(1), 8-13.

Pirrone, A., Dickinson, A., Gomez, R., Stafford, T., & Milne, E. (2017). Understanding perceptual judgment in autism spectrum disorder using the drift diffusion model. *Neuropsychology*, *31*(2), 173.

Pirrone, A., Johnson, I., Stafford, T., & Milne, E. (under review). A diffusion model decomposition of orientation discrimination in children with Autism Spectrum Disorder (ASD)

Ratcliff, R., & McKoon, G. (2008). The diffusion decision model: theory and data for two-choice decision tasks. *Neural computation*, *20*(4), 873-922.

Ratcliff, R, Thapar, A, & McKoon, G (2010). Individual differences, aging, and IQ in two-choice tasks. *Cognitive Psychology*, *60*, 127–157.

Raven, J. C., JH Court, & Raven, J. (1995). Manual for Raven's Progressive Matrices and Vocabulary Scales by JC Raven, JH Court and J. Raven; Section2; Coloured Progressive Matrices. Oxford Psychologist Press.

Schuetze, M., Park, M. T. M., Cho, I. Y., MacMaster, F. P., Chakravarty, M. M., & Bray, S. L. (2016). Morphological alterations in the thalamus, striatum, and pallidum in autism spectrum disorder. *Neuropsychopharmacology*, *41*(11), 2627.

Stewart, M. E., Watson, J., Allcock, A. J., & Yaqoob, T. (2009). Autistic traits predict performance on the block design. *Autism*, *13*(2), 133-142.

Stewart, M. E., & Ota, M. (2008). Lexical effects on speech perception in individuals with "autistic" traits. *Cognition*, *109*(1), 157-162.

Vandekerckhove, J., & Tuerlinckx, F. (2007). Fitting the Ratcliff diffusion model to experimental data. *Psychonomic bulletin & review*, *14*(6), 1011-1026.

Wagenmakers, E. J. (2009). Methodological and empirical developments for the Ratcliff diffusion model of response times and accuracy. *European Journal of Cognitive Psychology*, *21*(5), 641-671.

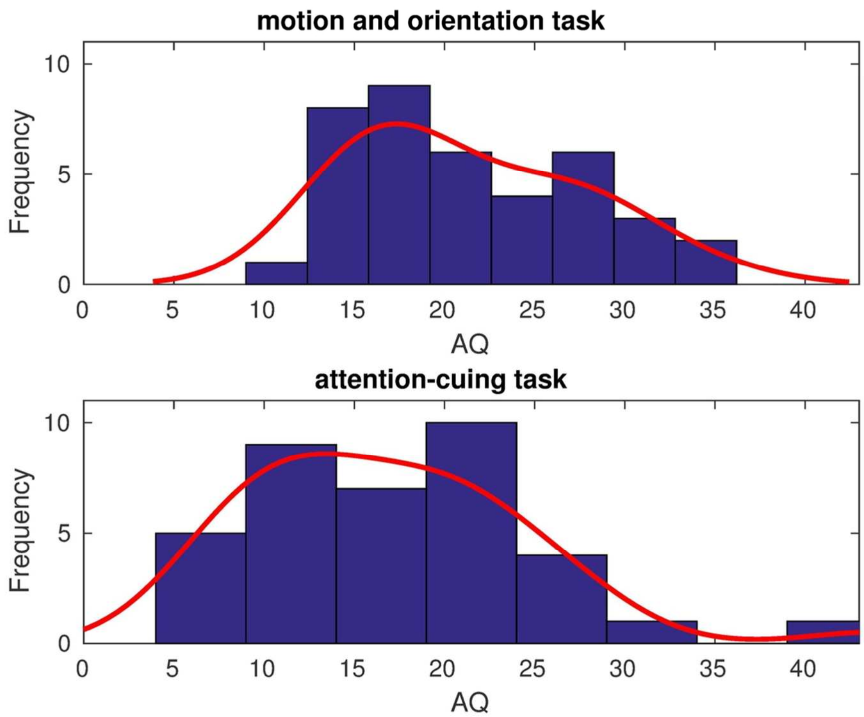

Figure 1

110x83mm (300 x 300 DPI)

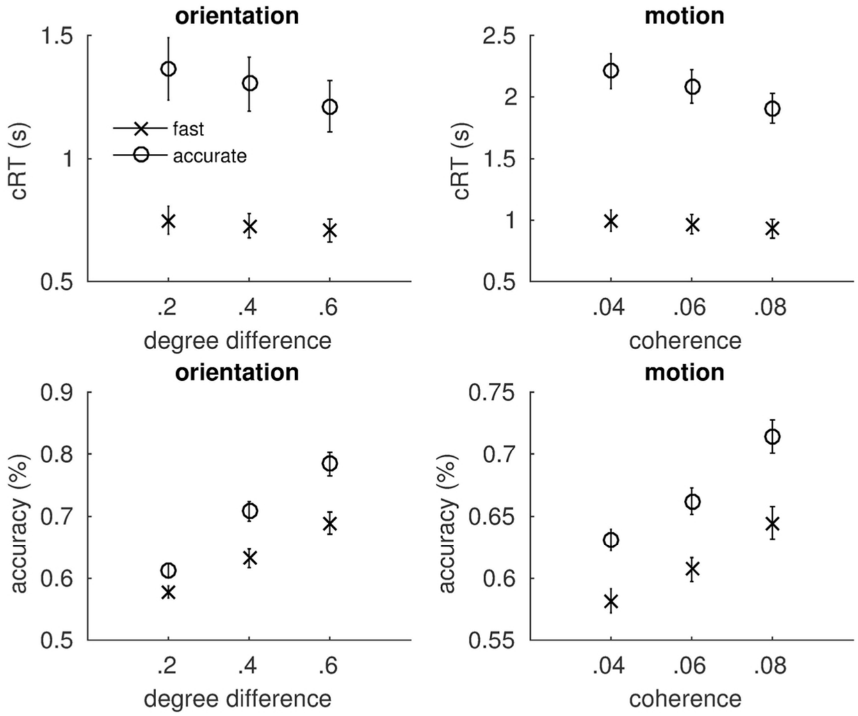

Figure 2

110x83mm (300 x 300 DPI)

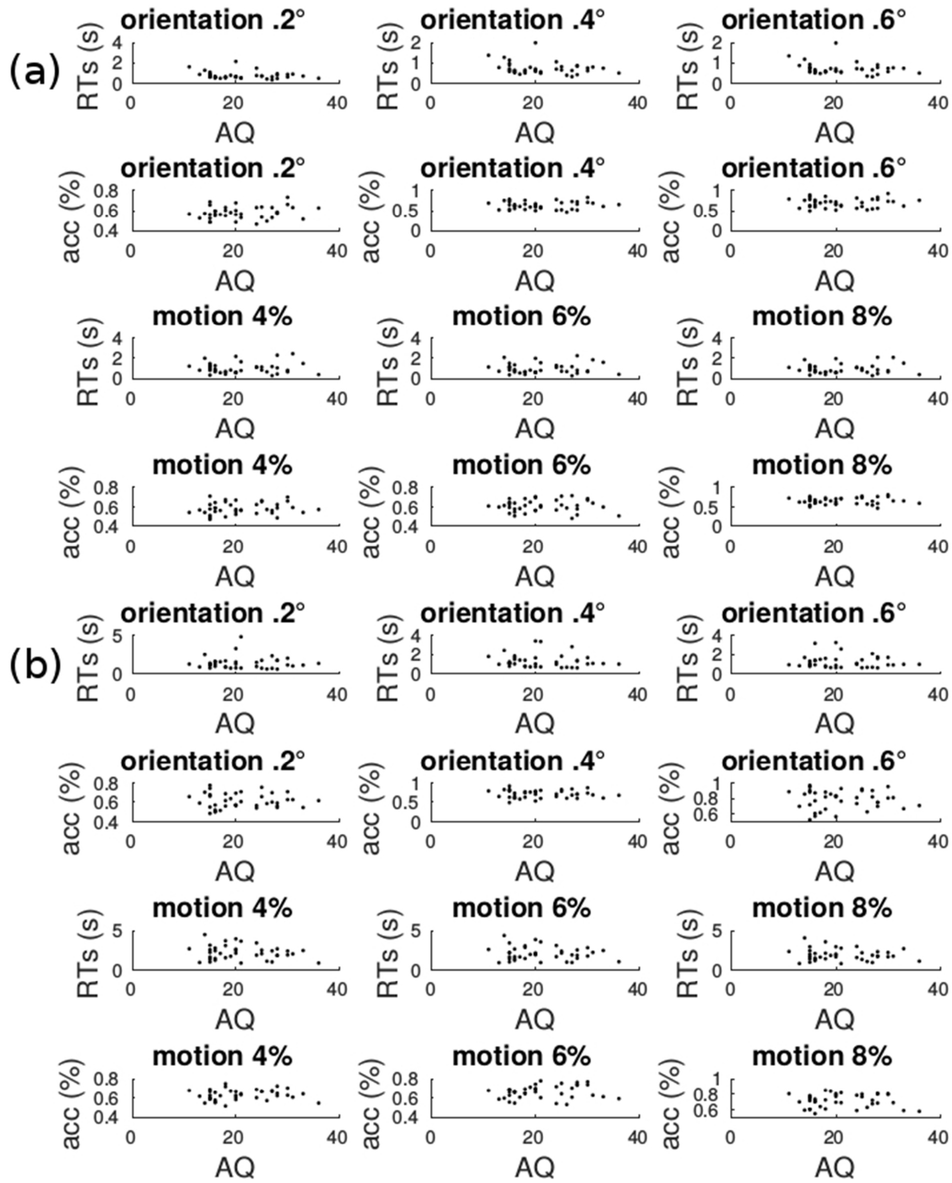
(a)
orientation .2°
orientation .4°
orientation .6°
motion 4%
motion 6%
motion 8%
(b)
RTs (s)
acc (%)
AQ

Figure 3

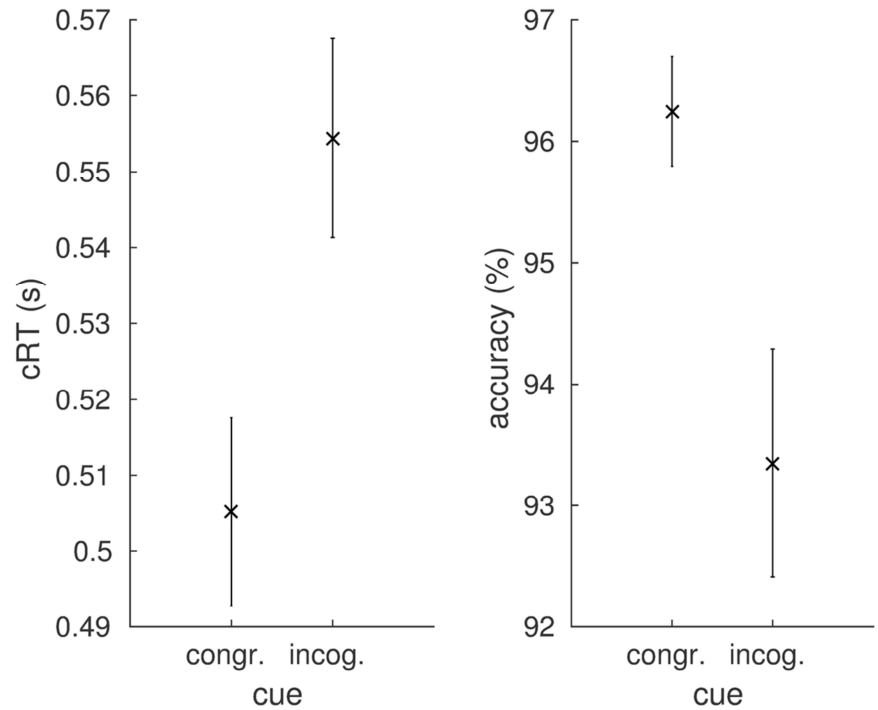

Figure 4

111x83mm (300 x 300 DPI)

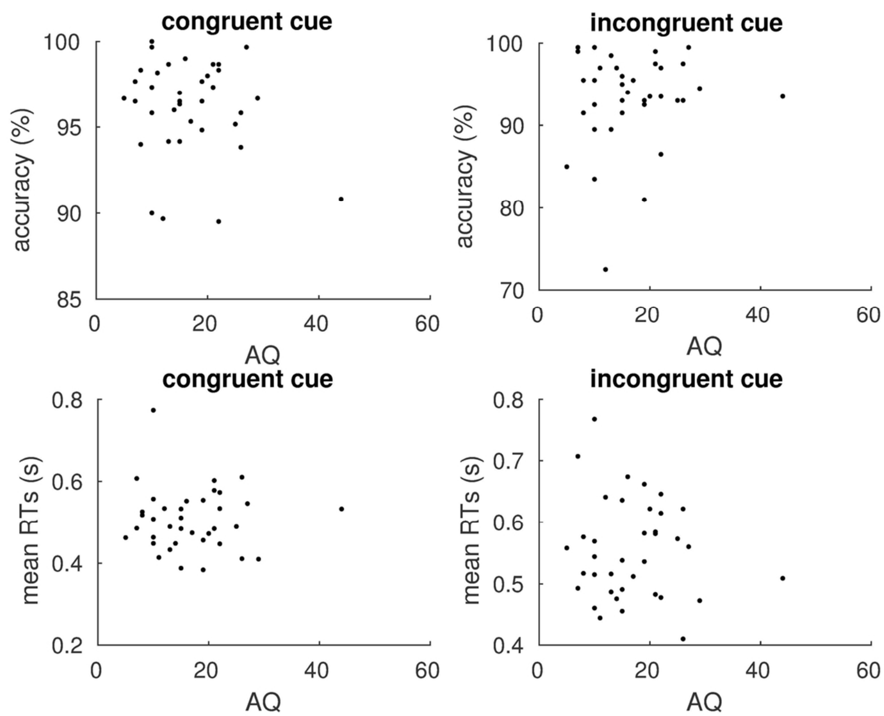

Figure 5

117x87mm (300 x 300 DPI)

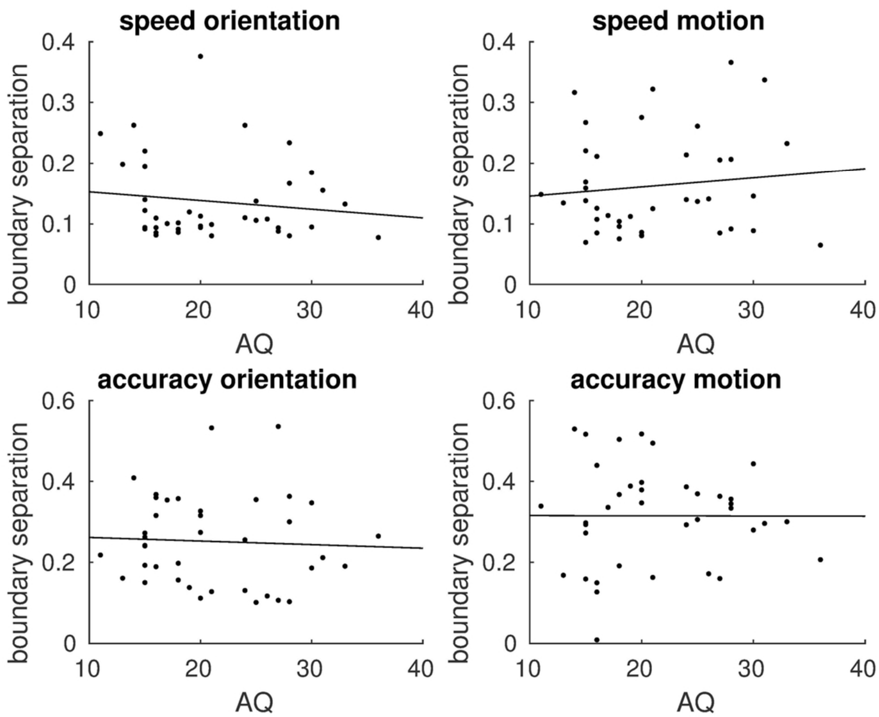

Figure 6

110x83mm (300 x 300 DPI)

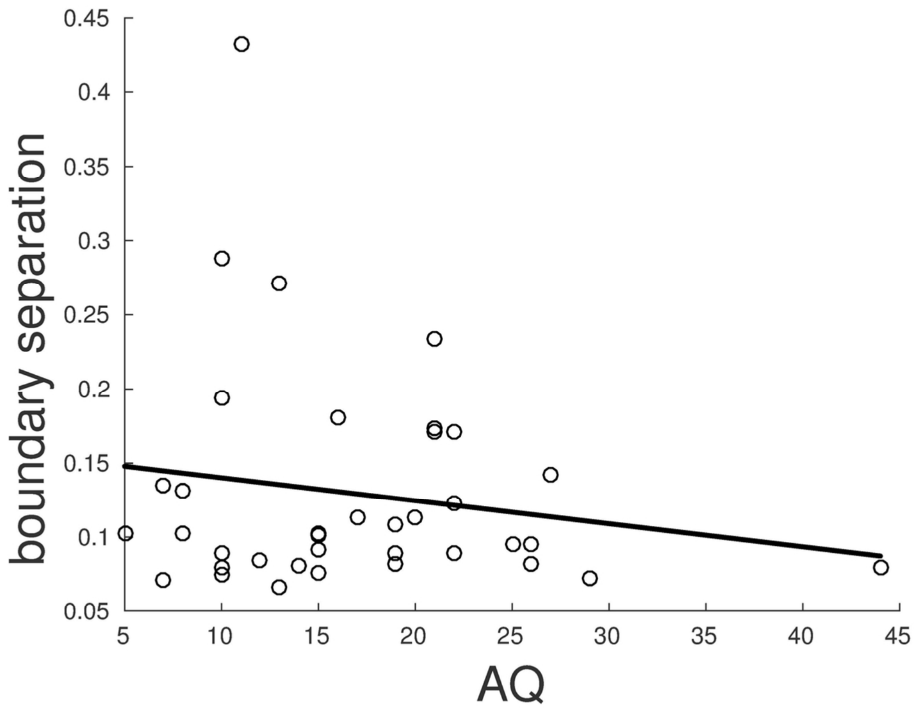

Figure 7

111x83mm (300 x 300 DPI)