Reduced distractor interference in neurotypical adults with high expression of autistic traits irrespective of stimulus type

Muller Spaniol, Mayra; Shalev, Lilach; Mevorach, Carmel

DOI:
10.1002/aur.2005

Title: **Reduced distractor interference in neurotypical adults with high expression of autistic traits irrespective of stimulus type**

Running title: **Distractor interference in high vs. low AQ**

[Accepted for publication in ***Autism Research***]

Authors: Mayra Muller Spaniol[1,*,&], Lilach Shalev[2,3], Carmel Mevorach[1,4,&]

Affiliations:

1. School of Psychology, The University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK.
2. School of Education, Tel-Aviv University, Israel.
3. Sagol School of Neuroscience, Tel-Aviv University, Israel.
4. Centre for Human Brain Health, The University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK.

* Current address: Developmental Disorders Program, Universidade Presbiteriana Mackenzie, São Paulo, Brazil.

& Correspondence and requests for materials should be addressed to: M.M.S. (email: mayramspaniol@gmail.com) and/or to C.M. (email: C.Mevorach@bham.ac.uk).

Acknowledgments: Mayra Muller Spaniol was supported by the Coordination for the Improvement of Higher Education Personnel during this research (CAPES; BEX: 2903/13-0).

Conflict of Interest: All authors declare that there is no conflict of interest.

Lay Summary

In the present study we show that neurotypical adults with high autistic traits are better able to avoid distraction from conspicuous (but completely irrelevant) distractors when told in

advance to do so. This ability is not affected by the type of visual input (for instance whether the distractor is a face or whether small rather than large letters should be reported). This finding could be important in better understanding the way attention is utilized in Autism.

Key words

Autism Spectrum Disorder, Broader Autism Phenotype, Attention, Distractor Suppression, Perceptual Bias.

Abstract

Attention atypicality is evident in Autism Spectrum Disorder (ASD) and its broader phenotype with previous studies suggesting that in some cases participants can be more efficient at ignoring distracting irrelevant information. However, it is not clear to what extent this improved filtering capacity is driven by perceptual atypicality such as local bias or atypical face processing, which is also sometimes reported in these populations. For instance, better ability to ignore the global aspect of a display could stem from a local perceptual bias rather than from improved distractor inhibition. To test whether distractor suppression per se. is associated with high expression of autistic traits, in the present study a large cohort of neurotypical participants (n=218), in whom expression of autistic traits was assessed, performed two non-spatial attention selection tasks with different categories of stimuli (Global/Local and Face/Scene). Importantly, both tasks involved a conflict with one aspect of the stimuli designated as the target and the other designated as the distractor. Across the two experiments adults with high autistic traits were overall better able to ignore distractors than adults with low autistic traits, irrespective of the type of perceptual processing involved. These results support the notion that autistic tendencies are associated with increased attention filtering (at least when target and distractor remain constant) which is not dependent on perceptual biases. Thus, future work in the Broader Autism Phenotype should explicitly consider the effect played by attention mechanisms in this population.

Introduction

Top down attention control is a fundamental cognitive mechanism important for efficient interaction with the environment. Since bottom-up signals tend to dominate selection, top-down control is required to override such signals to guide attention according to behavioural goals. While attention is not regarded as a core component of Autism Spectrum Disorder (ASD) or the Broader Autism Phenotype (BAP), previous investigations have repeatedly highlighted atypical top-down control of attention in these cohorts (Ames & Fletcher-Watson, 2010). Specifically, investigations focused on top-down distractor inhibition (which tends to be considered within executive functions that are thought to be impaired in autism; Hill, 2004), have yielded mixed findings with different studies showing inhibition to be intact (Lipszyc & Schachar, 2010; Ozonoff & Jensen, 1999), impaired (specifically inhibition of prepotent responses; Hill, 2004) or even potentially improved in ASD (Riby & Hancock, 2009). For instance, Greenaway and Plaisted (2005) have used a spatial-cuing task to demonstrate reduced attentional allocation to non-targets that match the top-down attention cue (similar to contingent capture; Folk et al., 1992) in children with ASD. This finding was interpreted as impaired top-down attention allocation but could also be regarded as improved ability to avoid attention capture by non-targets, and therefore reduced distractor interference. Perhaps more direct evidence for reduced distractor interference was documented by Riby & Hancock (2009) who found that an incongruent (social) stimulus was more easily ignored by ASD participants compared to neurotypical control participants. Such improved ability to ignore face stimuli may also relate to improved attention disengagement from faces in ASD, demonstrated in the gap-overlap task (Kikuchi et al., 2011).

However, one aspect that seems to be intertwined with the various investigations into attention atypicalities in ASD is the degree to which such differences are mediated by the type of stimuli being perceived. Differences in performance are often seen when social stimuli (and particularly faces) are presented. For instance, differences in attention selection were observed in individuals with autism who did not automatically and rapidly fixate on faces compared to controls (Freeth et al., 2011). Furthermore, the pattern of attention allocation to face components can also be atypical (Klin et al., 2002) with increased fixations on the mouth compared to typically developing (TD) controls (Neumann et al., 2006). Consequently, ASD participants seem to have difficulties in judging complex information coming from the eyes, but not the mouth (Baron-Cohen, 1997) although discriminating between faces tends to be comparable to controls (Adolphs et al., 2006; Humphreys et al., 2006).

Further support for the notion that social (and specifically face) stimuli may underlie the attention atypicalities in ASD come from studies measuring participants' ability to switch away from or avoid processing of face stimuli. Participants with ASD were better able to switch their attention from a distracting face to a different non-social target compared to TD controls (Kikuchi et al., 2009), especially when the face is depicting an emotional state which is naturally salient, as "fear" (Hsu & Pessoa, 2007). Similarly, ASD participants showed better attention disengagement from a centrally presented face compared with TD participants (Kikuchi et al., 2011) and were also less affected by the presence of an irrelevant face (Riby & Hancock, 2009). It is therefore possible that such atypical attention performance in autism is attributed to the reduced salience incorporated in social stimuli for ASD participants compared to controls (Bird et al., 2006), rather than to differences in the attention mechanisms themselves. This conjecture is also supported by findings showing typical performance in ASD participants when explicitly instructed to allocate attention to the eye region (Kikuchi, et al., 2011; Kikuchi, et al., 2009) indicating that typical attention mechanisms are available but perhaps not used in the absence of explicit instructions.

Another example of possible perceptual differences that mediate attention behavior in autism relates to the preference sometimes documented in ASD for local processing. Participants with ASD seem to show an advantage when performing tasks requiring attention to details (Happé & Frith, 2006; Pellicano et al., 2006). While they are able to process the global level of information when required, they tend to show a preference or advantage when attention to local elements of stimuli is needed (Koldewyn et al., 2013; Mottron & Belleville, 1993; Plaisted et al., 1999; Wang et al., 2007). These effects are also evident in neurotypical participants with high self-reported autistic traits who show faster performance in the embedded figures test (EFT), which is thought to rely on local processing capacity (Grinter et al., 2009). The same result was found amongst parents of children with autism, who showed faster reaction times in the same EFT, suggesting that enhanced performance and possible local bias may be present in the BAP (Bölte & Poustka, 2006). Importantly, previous findings show not only increased local bias but also reduced global interference when the global information is irrelevant. In a study measuring biological motion, Van Boxtel and Lu (2013) found that neurotypical participants with low expression of autistic traits were automatically drawn to process the global distractors present in the periphery. Conversely, this was not evident in the group with high expression of autistic traits who were better able to ignore the global distractor. Here too, however, it is plausible that global information does not carry its typical precedence over local information (Navon, 1977) in the BAP and therefore it is easier to inhibit. Indeed, when directed to process and respond to global stimuli, ASD and BAP participants seem to demonstrate comparable performance to controls (Almeida et al., 2013; Wang et al., 2007). Thus, these results suggest that rather than a fundamental difference in top-down attention control processes, a perceptual bias may explain atypicalities in people with ASD and the BAP.

In contrast, the notion that a local bias lies at the heart of improved performance in the EFT in autism and the BAP was recently challenged by Almeida et al. (2013). In their study, neurotypical participants with high and low expression of autistic traits were asked to perform several visual search tasks involving either local or global aspects. Importantly, their findings indicated superior search performance in the group with high autistic traits irrespective of whether local or global features had to be selected. Furthermore, performance on the EFT task was also recorded and was found to correlate with the visual search performance (Almeida et al., 2013). This suggests that performance differences in people with high vs. low autistic traits are not necessarily attributed to a local bias but rather to a general enhanced top-down visual search ability. Effectively, these findings raise the possibility that performance is driven by reduced distractibility by irrelevant non-target information (Joseph et al., 2009; Kemner et al., 2008, Van Boxtel & Lu, 2013), which is not necessarily associated with differences in perceptual bias (e.g., Almeida et al., 2013).

To test these notions further, in the present study stimulus type (global/local, faces/scenes) was pitted against top-down attention selection and suppression in a large cohort of neurotypical adults, in whom the expression of autistic traits was measured. We utilized two non-spatial top-down attention control tasks while relative physical salience of the target and distractors was manipulated. In the first experiment, a hierarchical letter task (global/local; Mevorach et al., 2009) was used while in the second experiment, superimposed face and scene stimuli were presented. Specifically, we ask whether high expression of autistic traits is associated with reduced interference from distractors in general or rather with a perceptual bias that may lead to improved ability to ignore only perceptually unfavorable distractors. If the latter holds, we expect participants with high rates of autistic traits to be better able to ignore the global information in the first experiment (but not the local) and the faces in the second experiment. If the former holds, then improved ability to ignore distractors should be documented across both experiments irrespective of the type of stimulus that needs to be selected/ignored.

Autistic traits are present in the neurotypical population in varying degrees and studies point to a genetic link between autism and autism-like traits, indicating that the cut-off for a disorder might be arbitrary (Constantino & Todd, 2003). Over the past decade, more research has been done investigating the mechanisms underlying the BAP, including instruments such as the Autism Quotient questionnaire (AQ) measuring autistic traits (Baron-Cohen et al., 2001), and family members of persons with autism (Sucksmith et al., 2011). Therefore, the AQ test was used in this study to measure autistic traits in a relatively large cohort of neurotypical participants to assess its relation to task performance.

Methods

Participants

Two hundred eighteen neurotypical individuals from the University of Birmingham participated in the study, being naïve to its purpose (mean age: 21.4; standard deviation: 4.2; age range: 18-31). The data initially consisted of 50 male and 168 female individuals. Participants were excluded from the study if they had a history of psychiatric illness, epilepsy, neurological disorders, suffered brain injury or lost consciousness for more than five minutes. Participants who performed at 50% accuracy or less on the global/local and/or the face/scene tasks were removed from further analysis. Based on these exclusion criteria, 7 participants were excluded from the global/local experiment, and 17 from the face/scene experiment. The data presented in this report is from the remaining 211 participants on the global/local task, and 201 participants on the face/scene task. Data from the same basic cohort was previously reported in Abu-Akel et al. (2016). Participants signed an informed consent before taking part in the study which was approved by the STEM Ethics Review Committee of the University of Birmingham.

General Procedure

Participants signed a consent form and completed a short demographics questionnaire. They then performed the two tasks: a global/local and a face/scene task. Following the completion of the tasks, participants had to complete the Autism-Spectrum Quotient questionnaire - AQ (Baron-Cohen et al., 2001) and the Community Assessment of Psychic Experiences – CAPE (Stefanis et al., 2002). CAPE data were collected for a different investigation (Abu-Akel et al., 2016). The session lasted 60 minutes.

The Global/Local Task

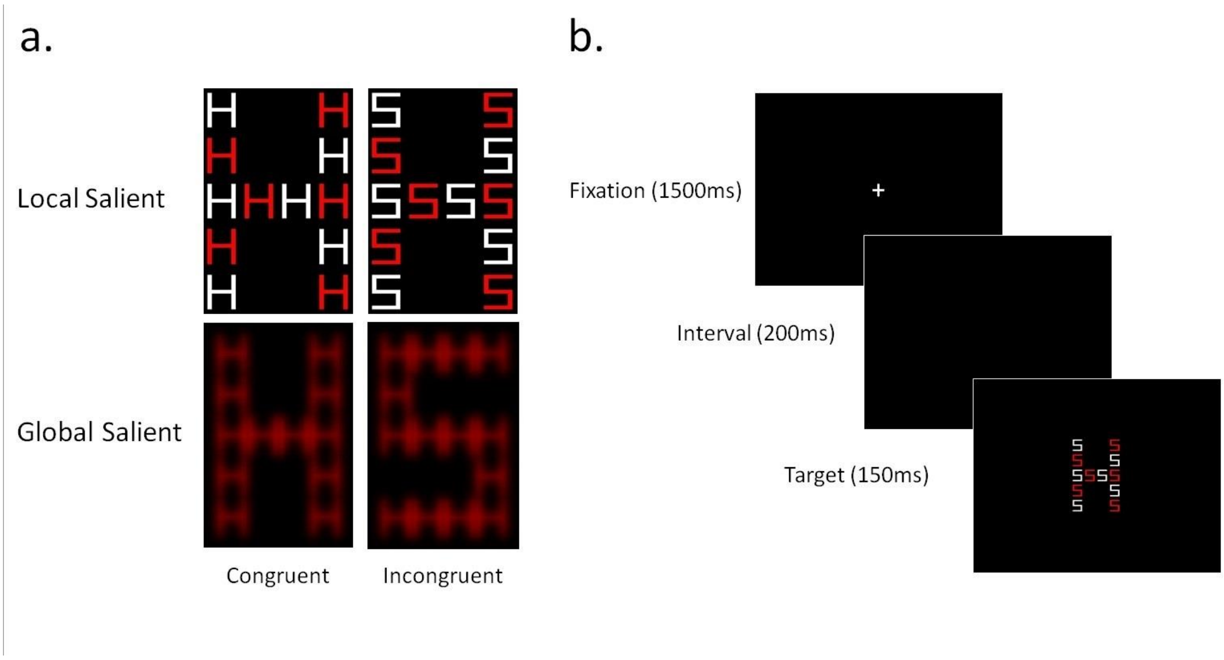

Figure 1: Stimuli and procedure for the Global/Local task. a) Example stimuli depicting global-more-salient and local-more-salient displays (top and bottom, respectively) and congruent and incongruent displays (left and right, respectively). b) A schematic presentation of a trial sequence.

Global-Local Stimuli

Participants were seated approximately 60 cm from a 17-inch monitor so that each centimeter on the screen represented ~0.96 degrees of visual angle. All the stimuli appeared against a black background. Two different displays depicting a compound letter (Navon, 1977) were used: one with high global saliency and another with high local saliency (Figure 1a). For both displays, the stimuli were created from the orthogonal combination of the letters H and S at the global and local levels. For the display with high local saliency, alternately colored (red and white) local letters were used, each subtending a visual angle of 1.348° and 1.068° in width and height, respectively. The global letter subtended 8.268° and 5.388° of visual angle (in width and height, respectively). The inter-element distance was 0.388°. In the display with high global saliency, only red local letters were used, which subtended 1.348° and 1.068° of visual angle (in width and height, respectively) and the global letter subtended 5.668° and 4.518° of visual angle (in width and height, respectively). The distance between local elements was 0.0968°. These letters underwent a blur procedure in Paint Shop Pro 7.0 with factor = 7. A white cross (0.578°) served as fixation and was presented in the center of the screen (Mevorach et al., 2009).

Global-Local Procedure

The task consisted of 4 blocks containing 32 trials each for a total of 128 trials. The four blocks corresponded to the four possible conditions – 2 (identify the global or the local letters) x 2 (global salient or local salient displays). Two seconds prior to the beginning of each block, instructions were presented on the screen to either identify the *local* or *global* level throughout the block. Participants had to respond to letters H or S by pressing the ‘K’ or ‘M’ keys on the keyboard respectively. In half of the trials in each block the same letter (H or S) appeared in the local and global aspect of the compound letter (congruent trials) and on the other half different letters appeared (incongruent trials). Each trial began with a 1500msec fixation cross. The stimuli then appeared for 150msec following a 200msec interval (Figure 1b). Participants were asked to respond to the presented letter as quickly and as accurately as possible. Key presses recorded the participants' responses in accuracy and reaction times. The task was presented using Presentation® (Neurobehavioral Systems). Participants had a practice block before task initiation and a paper sheet with instructions and visual information was available before and during task execution to avert memory constraints.

The Face/Scene Task

The face/scene task was developed in accordance to the global/local task but with social (face) and non-social (outdoor scene) stimulus. Participants were required to identify either the face or the scene, which were superimposed on each other. Here too the relative saliency of the face and the scene was manipulated to induce scene more salient and face more salient displays. In contrast to the global/local task, here we also included a neutral condition, in which the target (face or scene) was superimposed on a scrambled version of the non-target (scene or face). The neutral condition was included to provide a more direct measure of perceptual processes, irrespective of top-down attention (in this display there is no distractor and therefore no requirement to inhibit it). Relative salience was similarly manipulated for this condition with face or scene (or their scrambled version) being more salient.

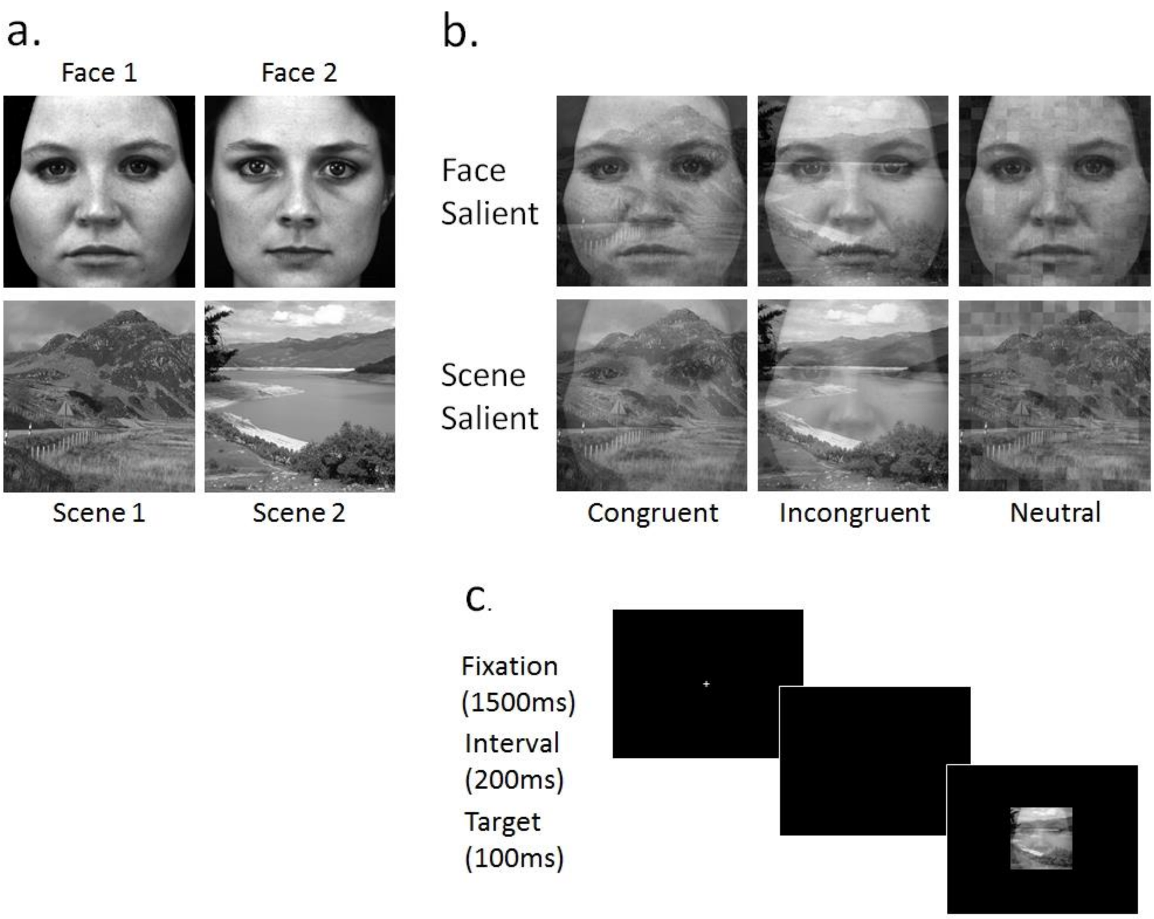

Figure 2. Stimuli and procedure for the Face/Scene task: a) The two face stimuli (face 1 and 2) and two scene stimuli (scene 1 and 2) used in the Face/Scene task. Face 1 and Scene 1 were mapped on to the same response ('K' on the keyboard) and so were Face 2 and Scene 2 ('M' on the keyboard). b) Superimposed faces and scenes stimuli – faces are depicted in a higher contrast compared to scenes in the top row (Face Salient) and in a lower contrast in the bottom row (Scene Salient). Congruent and incongruent displays represent response congruency, where the face and scene are mapped on the same (congruent) or different (incongruent) key responses. Neutral displays are also presented where a face is superimposed over a scrambled scene (top row) and a scene over a scrambled face (bottom row). c) Typical trial display sequence for the Face/Scene task.

Face-Scene Stimuli

A pair of superimposed photos of a face and an outdoor scene (or a scrambled version) taken from a set of two female faces and two outdoor scenes (Figure 2), appeared at the center of the screen in each trial. All photos were the same size and subtended a visual angle of ~12.88^{O} horizontally and ~12.79^{O} vertically. The opacity of one of the photos was always set to 30% while the other was set to 70%. This created two types of displays – face salient (where the opacity of the face was set to 70%) and scene salient (where the opacity of the scene was set to 70%). To create the neutral condition each face and scene picture was divided into 288 squares that were then randomly repositioned to create a scrambled version. This scrambled picture was then combined with a target picture (e.g., a scrambled face was superimposed with a non-scrambled scene) using the same opacity values as above.

Face/Scene Procedure

The two possible faces and two possible scenes were associated with the ‘K’ and ‘M’ keys on the keyboard (Figure 2a). Thus, and similarly to the global/local task, each face/scene display could be response-congruent (both the face and the scene were mapped to the same response) or response-incongruent (the face and the scene were mapped onto competing responses). To avoid memory constraints, a sheet depicting these associations was placed in front of the participant whilst performing the task. 12 blocks of 12 trials each were included for a total of 144 trials, equally divided between congruent, incongruent and neutral conditions. Four block types were used (each randomly repeated three times) – 2 (identify face or scene) x 2 (face salient or scene salient displays). Each block was preceded with an instruction to identify faces or scenes, which remained on the screen for 5 seconds. Each trial then began with a 1500 ms fixation cross, and following a 200 ms interval, the face/scene pair appeared for 100 ms (see Figure 2c for a typical display sequence). Participants were seated approximately 60cm from a 17-inch monitor and were asked to identify the presented faces or scenes as quickly and as accurately as possible. Key presses recorded the participants’ responses and reaction times. Participants had a short practice block before task initiation. The task was presented using Presentation®.

The Autism-Spectrum Quotient Questionnaire (AQ)

The AQ questionnaire (Baron-Cohen et al., 2001) measures the degree to which an adult with normal intelligence has traits associated with ASD. The AQ is a self-administered instrument consisting of 50 questions corresponding to 5 different sub-scales: social skills, communication, imagination, attention switching and attention to details. Participants answered from "Definitely agree" to "Definitely disagree" to questions 1 to 50. The overall AQ score ranged from 0 to 50. A higher score means prevalence of autistic traits, while lower scores indicate individuals with low autistic traits. While the AQ questionnaire is not a diagnostic tool, previously it was reported that eighty percent of those diagnosed with autism or a related disorder (including Asperger Syndrome) had an AQ score of 32 or higher (Baron-Cohen, 2001). The AQ's internal consistency in this study is good (Cronbach's $\alpha = .82$) and comparable to the values reported in other studies (e.g., Austin, 2005).

Data analysis

For both tasks, the inverse efficiency scores were used (reaction time (RT)/accuracy), generating an adjusted measure, AdjRT. This is recommended for tasks in which the accuracy is above 80%, allowing the use of reaction time and accuracy in one single measure and in accordance to previous studies using the same paradigms (Mevorach et al., 2006, Mevorach et al., 2009). Overall, accuracy was 96.5% and 92.3% for the global/local task and the face/scene task, respectively. All subsequent data was analyzed using the AdjRT with SPSS software. The means ± standard error of the mean (SEM) are reported. Significance level was set at $p<0.05$. Effect sizes are reported as partial eta squared (η_p^2) for ANOVAs and Hedges' g (Hedges, 1981; Hentschke & Stuttgen, 2011) or Cohen's d for t-tests (when statistically significant).

To evaluate differences in performance according to the quantity of autistic traits (low vs. high), participants' scores on the Autism Quotient (AQ) were independently divided into two groups with low and high autistic traits, using K-means cluster analysis. Cluster analysis is useful in the process of organizing a heterogeneous sample into relatively homogeneous groups, especially for large quantities of information (Clatworthy et al., 2005). This enabled analysis to be carried using the whole dataset of participants. Also, grouping the AQs to its nearest mean guarantees each group is more similar to its own and different from the next, being a good representation of low vs high autistic traits.

Results

Global-local task

The 211 participants were split into high and low AQ groups using K-means clusters (see Table 1). Importantly, age (t(209)=-1.54, p=.125) and sex (χ^2= .62, df=1, p=.43) did not differ significantly between the two groups.

Table 1: Distribution of participants according to scores in the AQ, age and sex in the Global/Local task

	ALL (N=211)	HIGH AQ (N=65)	LOW AQ (N=146)
Sex (males, females)	49, 162	16, 49	33, 113
Age (mean, std. deviation**)**	21.53; 4.11	21.55; 3.32	21.51; 4.43
AQ (mean; std. deviation; range)	16.01; 6.35; 4-37	23.60; 4.05; 19-37	12.64; 3.73; 4-18

AdjRT was analyzed using repeated measures analysis of variance (ANOVA) with target level (global vs. local), saliency (target salient vs. distractor salient) and congruency (congruent vs. incongruent) as within subject factors and the AQ group (high vs. low AQ) as between-subjects factor. The analysis revealed a main effect for congruency (F(1,209)=416.2; p<.001, η_p^2=.66) as participants were overall better at identifying the target in the congruent (555±9), compared with incongruent (636±8.5; Figure 3a) condition. There was a main effect for saliency ($F(1,209)=263.34$; $p<.001$, $\eta_p^2=.56$), with overall better performance when the target was salient (558±9) than when the distractor was salient (633±9). Significant two-way interactions were found between congruency and level ($F(1,209)=50.37$; $p<.001$, $\eta_p^2=.194$), and congruency and salience ($F(1,209)=12.35$, $p=.001$, $\eta_p^2=.056$). However, these interactions were further qualified by a significant three-way interaction between level, saliency and congruency ($F(1,209)=12.35$; $p=.001$, $\eta_p^2=.056$). To test whether this interaction was driven by differences in the congruency effect we repeated the ANOVA using the congruency effect as the dependent measure. This analysis revealed a two-way interaction between level and saliency ($F(1,209)=12.35$; $p=.001$, $\eta_p^2=.056$), which was driven by a larger effect of saliency on the congruency effect for global identification (target salient = 61±9; distractor salient = 146±11; 85 difference) than for local identification (target salient = 38±10; distractor salient = 76±11; 38 difference; $t(210)=-4.33$, $p<.001$, Cohen's $d=0.554$; Figure 3a). This shows that the increase in congruency effect from target salient to distractor salient displays was more pronounced when participants identified the global level than when they identified the local level. These effects resemble previous reports using a similar task (e.g., Mevorach et al., 2009, 2016).

More important for our purposes, there was an interaction between AQ groups and congruency ($F(1,209)=5.03$; $p=.026$, $\eta_p^2=.023$). Simple effects revealed a significantly smaller congruency effect (incongruent – congruent) in the high AQ group (72±6) in comparison to the low AQ group (89±4; $t(209)=2.24$, $p=.026$, $G_{Hedges}=0.33$; Figure 3b). In other words, individuals with high AQ exhibited less interference from the distracting information for the global and local stimuli, indicating less distraction in this group. Interestingly, the interaction between group and level, which may point to an overall difference in perceptual tendencies across the two groups did not reach significance ($F(1,209)=1.47$; $p=.226$, $\eta_p^2=.007$). None of the other main effects or interactions involving the group factor reached significance (all ps > .165). Thus, this result highlights a link between autistic traits and attention control in general, irrespective of whether global or local information had to be ignored (Figure 3b).

To further explore the notion that higher expression of autistic traits leads to better ability to ignore distractors in this task, we conducted a post-hoc analysis in which we divided up the cohort into 3 groups (rather than 2) based on K-means clustering of the AQ score. Using a one-way ANOVA we found a significant linear effect of group on the congruency difference ($F(1,208) = 5.828$, $p=0.017$) with the low, medium and high AQ groups showing increasingly better ability to ignore distractors (93.86, 78.58 and 71.22 congruency difference for the low AQ, medium AQ and high AQ groups, respectively). Pairwise comparisons revealed significant difference between the low and high AQ groups ($t(124)=2.135$, $p=0.035$, $G_{Hedges}= 0.43$) and a marginally significant difference between the low and medium AQ groups ($t(174)=1.888$, $p=0.061$, $G_{Hedges}= 0.28$) but no significant difference between medium and high AQ groups ($t<1$). This post-hoc analysis further supports the notion that people with higher expression of autistic traits (as measured by AQ) show different attentional performance than people with lower trait expression.

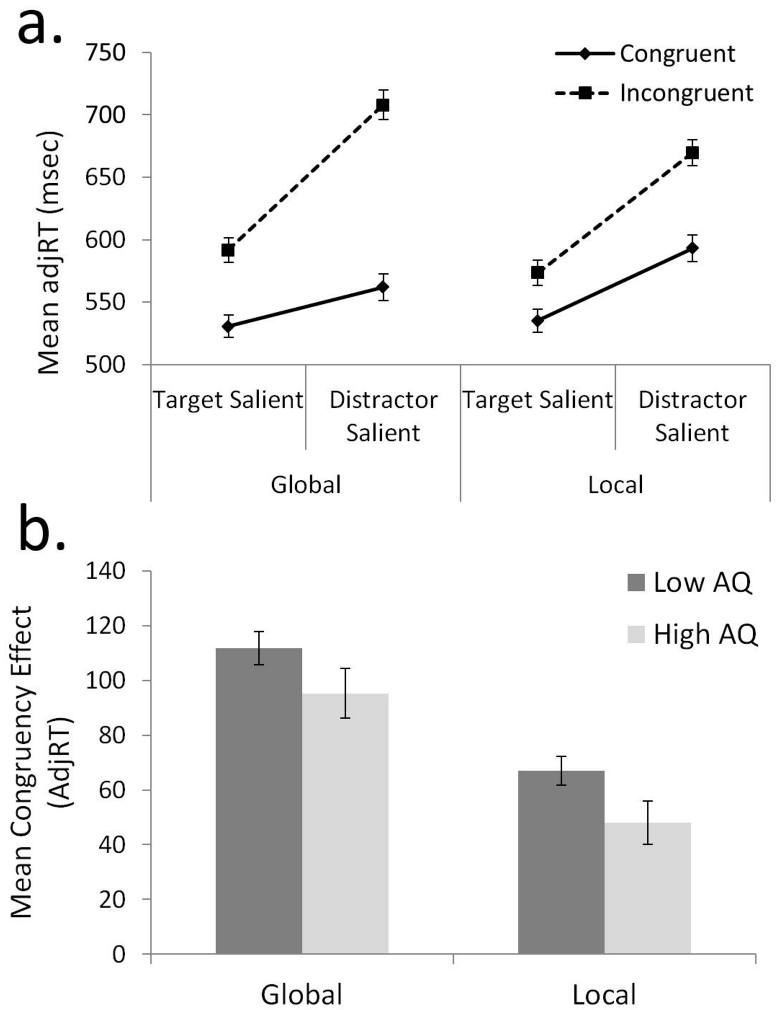

Figure 3: Performance in the global-local task. a. Overall performance (across the entire cohort) depicting mean AdjRT (±SEM) as a function of level, salience and congruency. For both global and local identification, performance under conditions of distractor saliency resulted with increased distractor interference (increased congruency difference). b. Congruency effect (incongruent - congruent) for the two AQ groups. The high AQ group showed consistently smaller congruency effects (smaller distractor interference) regardless of whether the global or the local aspects had to be identified. The target level (global or local) did not interact with group.

Face-scene task

AQ groups were divided into high and low autistic traits using K-means cluster analysis (Table 2). There were no age or sex differences across the two groups ($t(199)=-.614$, $p=.54$; $\chi^2=.194$, $df=1$, $p=.65$, respectively). AdjRT for the face/scene task was analysed using a repeated measures ANOVA with target (face vs. scene), saliency (target salient vs.

distractor salient) and congruency (congruent, incongruent and neutral) as within subject factors and AQ group (high vs. low AQ) as a between subjects factor.

Table 2: Age, sex and AQ for the whole cohort and the split groups in the Face/Scene task

	ALL (N=201)	HIGH AQ (N=66)	LOW AQ (N=135)
Sex (males, females)	43, 158	15, 51	28, 107
Age (mean, std. deviation)	21.38; 4.31	21.65; 3.73	21.24; 4.58
AQ (mean; std. deviation; range)	16.32; 6.38; 4-37	23.59; 4.06; 19-37	12.76; 3.74; 4-18

The analysis revealed a statistically significant main effect of target F(1,199)=49.46; p<.001, η_p^2=.199) whereby performance was overall better when identifying scenes (626±9) compared to faces (752±18). A main effect of saliency was also obtained as participants performed better when the target was salient (579±8) compared to when the distractor was salient (799±16; F(1,199)=312.52; p<.001, η_p^2=.611), and performance was also affected by congruency (F(2,398)=45.21; p<.001, η_p^2=.185) as participants were generally worse for the incongruent (760±16), compared to congruent (653±11; t(200)=-8.32, p<.001, Cohen's d=0.54) and neutral (661±9; t(200)=8.41, p<.001, Cohen's d=0.57) conditions. There were significant 2-way interactions between target and saliency (F(1,199)=36.31.53; p<.001, η_p^2=.154), target and congruency (F(2,398)=33.3; p<.001, η_p^2=.143) and saliency and congruency (F(2,398)=38.32; p<.001, η_p^2=.161). However, they were further qualified by a three-way interaction between target, saliency and congruency (F(2,398)=28.93; p<.001, η_p^2=.127; Figure 4a). This interaction pointed to difficulties performing the incongruent condition when identifying faces in distractor salient displays (Figure 4a). Consequently, the cost (incongruent – neutral) under distractor salient displays, exhibited in the face task (353±42) was substantially larger than the cost for the scene task (4±13; t(200)=8.136, p

<0.001, Cohen's d=0.799). Interestingly, the group factor interacted significantly with congruency ($F(2,398)=3.3$; $p=.038$, $\eta_p^2=.016$) similar to the finding in the global/local task, with target and saliency ($F(1,199)=5.27$; $p=.023$, $\eta_p^2=.026$) and with target and congruency ($F(2,398)=4.9$; $p=.008$, $\eta_p^2=.024$). Importantly, however, these interactions were further qualified by a 4-way interaction of group, target, saliency and congruency ($F(2,398)=4.61$; $p=.011$, $\eta_p^2=.023$; Figure 4b). To investigate this interaction, partial ANOVAs were conducted with face and scene targets separately. While the ANOVA for scene target revealed no significant interaction of group, saliency and congruency ($F(2,398)=1.26$; $p=.285$, $\eta_p^2=.006$), this interaction was significant for the face targets ($F(2,398)=3.38$; $p=.035$, $\eta_p^2=.017$). This 3-way interaction was then investigated using partial ANOVAs on target salient and distractor salient conditions separately. It was then established that a group by congruency interaction was only evident for distractor salient displays ($F(2,398)=4.04$; $p=.018$, $\eta_p^2=.020$) but not for target salient displays ($F(2,398)=1.59$; $p=.205$, $\eta_p^2=.008$). Pairwise comparisons revealed that in the incongruent condition the high AQ group performed significantly better (1002±46) than the low AQ group (1220±69; $t(199)=2.64$, $p=.009$, $G_{Hedges}=0.33$) but there was no group difference for the congruent (low AQ: 806±41; high AQ: 777±34; $t(199)=.466$, $p=.642$) or neutral (low AQ: 601±14; high AQ: 596±14; $t(199)=.375$, $p=.708$) conditions (see Figure 4b). Thus, these results point to improved distractor suppression in the high AQ group as a function of stimulus category. Critically however, the improvement was only visible when the participants had to identify a low salient face and ignore a high salience response-incompatible scene which was the most difficult condition in this task.

As for the Global/Local task here too we conducted a post-hoc analysis in which the cohort was divided up into 3 groups (rather than 2) based on K-means clustering of the AQ score. A one-way ANOVA revealed once again a significant linear effect of group (low, medium and high AQ) on the participants performance in the incongruent trials of the face identification condition under distractor salient displays ($F(1,198)=5.248$, $p=0.023$) with the low, medium and high AQ groups showing increasingly better performance in this condition (1268, 1145 and 954 for the low AQ, medium AQ and high AQ groups, respectively). Pairwise comparisons revealed significant difference between the low and high AQ groups ($t(109)=2.192$, $p=0.031$, $G_{Hedges}= 0.43$) and a marginally significant difference between the medium and high AQ groups ($t(129)=1.810$, $p=0.073$, $G_{Hedges}= 0.34$) but no significant difference between low and medium AQ groups ($t(158)=1.024$, $p=0.308$). This post-hoc analysis once again supports the notion that people with higher expression of autistic traits (as measured by AQ) show different attentional performance than people with lower trait expression.

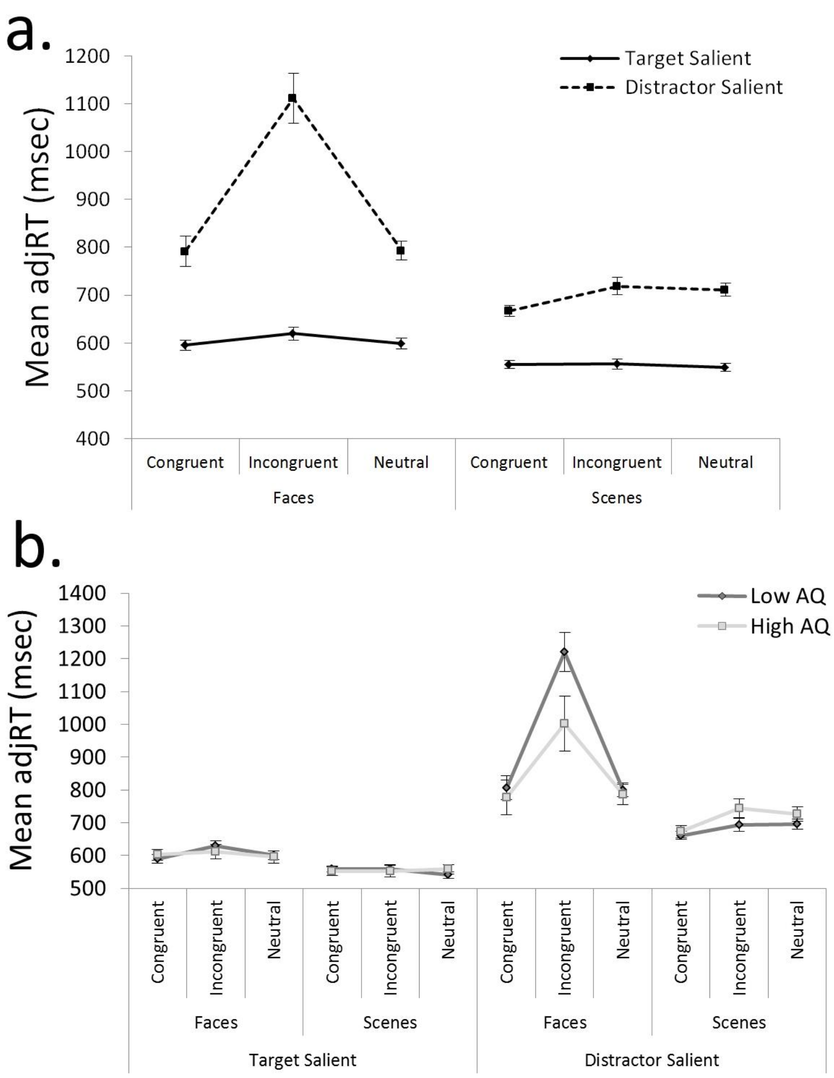

Figure 4: Performance in the face-scene task. a. Overall performance (mean adjRT ± SEM) across the entire cohort is presented. Response congruency affected performance more substantially in distractor salient displays (dashed line) and specifically when faces had to be identified (left side of figure). b. Performance in the face-scene task (mean AdjRT ± SEM) as a function of group (high vs. low AQ groups). Clear group differences are seen when participants had to identify a low salience face and ignore a competing (incongruent) high salience scene, where participants with high expression of autistic traits show better performance than those with low expression. Also of note is the lack of group difference in the neutral displays (when a face or a scene appeared on a background of noise).

Discussion

In this study we aimed at investigating whether self-reported expression of autistic traits in neurotypical young adults will be associated with top-down attention control (distractor interference) or rather with perceptual biases that in turn modulate attention control. Overall and across the two tasks, we found that participants exhibiting higher expressions of autistic traits showed *increased* ability to filter out distractors, which was manifested in a smaller interference effect for the high AQ group. Importantly, this improved capacity for distractor suppression did not seem to be directly modulated by the type of stimuli that had to be suppressed. In the global/local task, performance differences between the low and high AQ groups held across both local and global processing – in both cases participants with high AQ showed reduced distractor interference (indexed by a smaller congruency effect in AdjRT). While in the face/scene task group differences were only visible for face identification, this effect contrasts with what would be expected based on perceptual biases. If differences in performance are associated with processing the faces in this task we would have expected the high AQ group to be better at ignoring faces (which are potentially less salient to them). In fact, our findings were the opposite. There were no group differences when participants had to ignore the face but a substantial difference between the groups was evident when participants had to ignore the scene. Once again, participants in the high AQ group were considerably better at ignoring the distractor scene (especially in the incongruent condition). Thus, our high AQ group outperformed the low AQ group and showed reduced distractor interference which could not be explained by reduced sensitivity to social content.

A further support for the notion that performance differences in the groups were not attributed to perceptual differences comes from performance in the neutral condition in the face/scene task. If perceptual differences between the groups existed, they should have been manifested in the neutral condition, which reduces the demand for attention control while maintaining the perceptual difficulty of the stimulus. However, we found no evidence for such a difference across both face and scene stimuli. Group differences emerged only when competition from distracting stimuli existed in the display and consequently attention control was called upon.

Atypical (but improved) attention selection and distractor filtering in autism was also recently described by Robertson et al. (2013), who suggested that a sharper focus of spatial attention could explain improved performance. Measuring the spatial extent of the attention focus in autism, Robertson et al. (2013) documented a sharper spatial focus of attention, limited to the proximity of stimuli, with performance decreasing rapidly as exogenous spatial cues appeared further away from the target. Such a finding could explain superior performance in search, where a sharper gradient of attention would facilitate the inhibition of surrounding distractors, as well as interference from incongruent stimuli (Robertson et al., 2013). Our findings suggest that the enhanced focusing ability is not confined to spatial selective attention but perhaps reflects a broader ability to control attention and to restrict it to the relevant aspect of the visual field, even when the task requires to segregate between stimuli that occupy the same space.

As several obvious methodological differences exist between the two tasks used here it remains an open question why salience played a more pronounced role in the face/scene compared to the global/local task. Perhaps the most plausible account is that only when task demands are high enough, group differences emerge (i.e., in the face/scene task, faces were significantly more difficult to identify in comparison to scenes and the distractor interference in this condition was much more pronounced). It is possible that better performance when identifying faces and inhibiting scenes was due to more immediately obvious differences in the scenes compared to the faces. It is therefore likely that these results will reverse if the scene category was, for instance two different mountain scenes which were more similar to each other or if the face category had more pronounced differences such as a male and female face. Another difference between the tasks worth mentioning is the use of longer blocks in the Global/Local compared to the Face/Scene task. Such a difference may imply increase in fatigue experienced in the Global/Local task (or reduced fatigue in the Face/Scene task). It might therefore also be the case that reduced fatigue has helped participants deal with distractor interference in the easier condition of the scene identification and therefore prevented group differences from emerging. Importantly, however, the performance differences we documented in both experiments point towards more effective top-down control of attention in participants with higher expression of autistic traits (Almeida et al., 2010; Almeida et al., 2013).

In contrast to the findings we report here, previous research in ASD and the BAP has also pointed to increased distractor interference or increased sensitivity to salience seen in this population in certain conditions (Leader et al., 2009). For instance, in a recent study using EEG to record brain potentials, Dunn et al., (2016) identified reduced Pd (which is thought to represent distractor suppression) in individuals with high autistic traits compared to those with low autistic traits. This also fits with other finding suggesting a failure of participants with ASD to suppress a salient distractor (e.g., Russell et al., 1991) or examples where behavior is dominated by the salient stimulus in ASD (e.g., Leader et al., 2009). While the reason for such discrepancy between previous findings needs to be further investigated (regardless of the various methodological differences across studies), we can still speculate about a possible difference which is noteworthy. In both tasks in this study, full information of what constitutes a target and a distractor was given in advance and this remained constant throughout a block of trials. As such, participants in our study could have used top-down control in a preparatory manner (c.f., Mevorach et al., 2009 for the contribution of the left parietal cortex to such a preparatory process). Indeed, previous research has shown that when encouraged to use such control strategy – for instance when given full instruction in terms of which part of a face to attend, atypicalities in face processing in ASD can be overcome (Kikuchi, et al., 2011; Kikuchi, et al., 2009). Similarly, in Dunn et al. (2016) the reported smaller Pd amplitude associated with reduced distractor suppression was evidenced later in the process - after stimuli presentation, which may point to reactive suppression rather than a preparatory one. It is therefore plausible to speculate that increased distractor suppression (as we report here) in the BAP is associated with enhanced preparatory top-down control. However, when reactive or dynamic control is called upon (such as when participants need to voluntarily switch from one element to another only following their appearance) performance can be impaired.

One important limitation that is worth noting here is the generalizability of our findings to clinical ASD population. We note that our cohort had a majority of female participants which is not typical in clinical cohorts of ASD (Loomes et al., 2017). Importantly, however, sex did not mediate the effects we report and it is therefore not likely that the inclusion of female participants underlies the increased distractor suppression we record in the group with high expression of autistic traits. It is also worth highlighting that there is growing evidence that a significant minority of ASD diagnoses are associated with de novo genetic mutations (Iossifov et al., 2014), and thus may have different etiologies, neural and behavioral phenotypes. It may well be that the results we report here bare less relevance for this subset of ASD.

We conclude based on our findings that neurotypicals with a higher expression of autistic traits demonstrate enhanced distractor filtering and attentional focus irrespective of the type of stimulus that need to be selected or suppressed. As such, it challenges previous conjectures that performance differences in ASD and BAP are solely associated with atypicalities in local/global processing or reduced sensitivity to social stimuli. We speculate that this enhanced distractor suppression may be especially visible when top-down selection and suppression can be utilized proactively without the need to dynamically change the focus of attention selection. This highlights a testable prediction that the benefit for high autistic traits we find here might disappear when suppression cannot be achieved through a preparatory top-down mechanism.

References

Abu-Akel, A., Apperly, I. A., Wood, S. J., Hansen, P. C., & Mevorach, C. (2016). Autism tendencies and psychosis proneness interactively modulate saliency cost. *Schizophrenia bulletin*, *43*(1), 142-151.

Adolphs, R., Sears, L., Piven, J. (2006). Abnormal Processing of Social Information from Faces in Autism. *Journal of Cognitive Neuroscience*, 13(2), 232-240.

Almeida, R. A., Dickinson, J. E., Maybery, M. T., Badcock, J. C., & Badcock, D. R. (2013). Visual search targeting either local or global perceptual processes differs as a function of autistic-like traits in the typically developing population. *Journal of autism and developmental disorders*, 43(6), 1272-1286.

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.

Ames, C., Fletcher-Watson, S. (2010). A review of methods in the study of attention in autism. *Developmental Review*, 30(1), 52-73.

Apperly, I. A., Carroll, D. J., Samson, D., Humphreys, G. W., Qureshi, A., Moffitt, G. (2010). Why are there limits on theory of mind use? Evidence from adults' ability to follow instructions from an ignorant speaker. *The Quarterly Journal of Experimental Psychology*, 63(6), 1201-1217.

Austin, E. J. (2005). Personality correlates of the broader autism phenotype as assessed by the Autism Spectrum Quotient (AQ). *Personality and Individual Differences*, 38(2), 451-460.

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., Clubley, E. (2001). The Autism-Spectrum Quotient (AQ): Evidence from Asperger Syndrome/High-Functioning

Autism, Males and Females, Scientists and Mathematicians. *Journal of Autism and Developmental Disorders*, 3(1), 5-17.

Baron-Cohen S. (1997). *Mindblindness: An essay on autism and theory of mind.* Cambridge, MA: MIT Press.

Behrmann, M., Thomas, C., Humphreys, K. (2006). Seeing it differently: visual processing in autism. *Trends in Cognitive Sciences*, 10(6), 258-264.

Belmonte, M. K., Allen, G., Beckel-Mitchener, A., Boulanger, L. M., Carper, R. A., & Webb, S. J. (2004). Autism and abnormal development of brain connectivity. *The Journal of Neuroscience*, 24(42), 9228-9231.

Bird G., Catmur C., Silani G., Frith C., Frith U. (2006) Attention does not modulate neural responses to social stimuli in autism spectrum disorders. *Neuroimage*, (31), 1614–1624.

Bölte, S., & Poustka, F. (2006). The broader cognitive phenotype of autism in parents: how specific is the tendency for local processing and executive dysfunction?. *Journal of Child Psychology and Psychiatry*, 47(6), 639-645.

Brock, J., Xu, J. Y., & Brooks, K. R. (2011). Individual differences in visual search: Relationship to autistic traits, discrimination thresholds, and speed of processing. *Perception*, 40(6), 739-742.

Castelhano, M., Wieth, M., Henderson, J. (2007) I see what you see: eye movements in real-world scenes are affected by perceived direction of gaze. *Attention in Cognitive Systems*, 48(40), 251-262.

Chang, D. H., Mevorach, C., Kourtzi, Z., & Welchman, A. E. (2014). Training transfers the limits on perception from parietal to ventral cortex. *Current Biology*, 24(20), 2445-2450.

Clatworthy, J., Buick, D., Hankins, M., Weinman, J., & Horne, R. (2005). The use and reporting of cluster analysis in health psychology: A review. *British journal of health psychology*, 10(3), 329-358.

Constantino, J. N., & Todd, R. D. (2003). Autistic traits in the general population: a twin study. *Archives of general psychiatry*, 60(5), 524-530.

Davis, J., McKone, E., Zirnsak, M., Moore, T., O'Kearney, R., Apthorp, D., & Palermo, R. (2017). Social and attention-to-detail subclusters of autistic traits differentially predict looking at eyes and face identity recognition ability. *British Journal of Psychology,* 108(1), 191-219.

Dunn, S. A., Freeth, M., & Milne, E. (2016). Electrophysiological Evidence of Atypical Spatial Attention in Those with a High Level of Self-reported Autistic Traits. *Journal of autism and developmental disorders*, 46(6), 2199-2210.

Eaton, W. W., Smith, C., Ybarra, M., Muntaner, C., & Tien, A. (2004). Center for Epidemiologic Studies Depression Scale: review and revision (CESD and CESD-R).

Elsabbagh et al. (2009). Visual orienting in the early broader autism phenotype: disengagement and facilitation. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, 50, 637–642.

Fischer, J., Koldewyn, K., Jiang, Y. V., & Kanwisher, N. (2014). Unimpaired attentional disengagement and social orienting in children with autism. *Clinical Psychological Science*, *2*(2), 214-223.

Folk, C. L., Remington, R. W., & Johnston, J. C. (1992). Involuntary covert orienting is contingent on attentional control settings. *Journal of Experimental Psychology Human Perception and Performance, 18,* 1030-1030.

Freeth, M., Foulsham, T., Chapman, P. (2011). The influence of visual saliency on fixation patterns in individuals with Autism Spectrum Disorders. *Neuropsychologia,* 49(1), 156–160.

Greenaway, R., Plaisted, K. (2005). Top-down attentional modulation in autistic spectrum disorders is stimulus-specific. *Psychological Science*, 16 (12), 987–994.

Grinter, E. J., Maybery, M. T., Van Beek, P. L., Pellicano, E., Badcock, J. C., & Badcock, D. R. (2009). Global visual processing and self-related autistic-like traits. *Journal of Autism and Developmental Disorders,* 39, 1278–1290.

Halliday, D. W., MacDonald, S. W., Sherf, S. K., & Tanaka, J. W. (2014). A reciprocal model of face recognition and autistic traits: evidence from an individual differences perspective. *PloS one,* 9(5), e94013.

Happé, F., & Frith, U. (2006). The weak coherence account: Detail-focused cognitive style in autism spectrum disorders. *Journal of autism and developmental disorders*, 36(1), 5-25.

Hentschke, H., & Stüttgen, M. C. (2011). Computation of measures of effect size for neuroscience data sets. *European Journal of Neuroscience*, *34*(12), 1887-1894.

Hill, E. L. (2004). Executive dysfunction in autism. *Trends in cognitive sciences,* 8(1), 26-32.

Holmboe, K., Elsabbagh, M., Volein, A., Tucker, L. A., Baron-Cohen, S., Bolton, P., ... & Johnson, M. H. (2010). Frontal cortex functioning in the infant broader autism phenotype. *Infant Behavior and Development*, 33(4), 482-491.

Hsu, S. M., Pessoa, L. (2007). Dissociable effects of bottom-up and top-down factors on the processing of unattended fearful faces. *Neuropsychologia*, 45(13), 3075–3086.

Humphreys, K., Minshew, N., Leonard, G. L., & Behrmann, M. (2007). A fine-grained analysis of facial expression processing in high-functioning adults with autism. *Neuropsychologia*, *45*(4), 685-695.

Iossifov, I., O'roak, B. J., Sanders, S. J., Ronemus, M., Krumm, N., Levy, D., ... & Smith, J. D. (2014). The contribution of de novo coding mutations to autism spectrum disorder. *Nature*, 515(7526), 216.

Joseph, R. M., Keehn, B., Connolly, C., Wolfe, J. M., & Horowitz, T. S. (2009). Why is visual search superior in autism spectrum disorder?. *Developmental science*, 12(6), 1083-1096.

Kaldy, Z., Giserman, I., Carter, A. S., & Blaser, E. (2016). The mechanisms underlying the ASD advantage in visual search. Journal of autism and developmental disorders, 46(5), 1513-1527.

Kana, R. K., Liu, Y., Williams, D. L., Keller, T. A., Schipul, S. E., Minshew, N. J., & Just, M. A. (2013). The local, global, and neural aspects of visuospatial processing in autism spectrum disorders. *Neuropsychologia*, 51(14), 2995-3003.

Kemner, C., van Ewijk, L., van Engeland, H., & Hooge, I. (2008). Brief report: eye movements during visual search tasks indicate enhanced stimulus discriminability in subjects with PDD. *Journal of Autism and Developmental Disorders*, 38 (3), 553–557.

Kenworthy, L., Yerys, B. E., Weinblatt, R., Abrams, D. N., & Wallace, G. L. (2013). Motor demands impact speed of information processing in autism spectrum disorders. *Neuropsychology*, 27(5), 529.

Kikuchi, Y., Senju, A., Akechi, H., Tojo, Y., Osanai, H., & Hasegawa, T. (2011). Atypical disengagement from faces and its modulation by the control of eye fixation in children with autism spectrum disorder. *Journal of autism and developmental disorders*, 41(5), 629-645.

Kikuchi, Y., Senju, A., Tojo, Y., Osanai, H., & Hasegawa, T. (2009). Faces do not capture special attention in children with autism spectrum disorder: A change blindness study. *Child Development*, 80(5), 1421-1433.

Klin, A., Jones, W., Schultz, R., Volkmar, F., & Cohen, D. (2002). Visual fixation patterns during viewing of naturalistic social situations as predictors of social competence in individuals with autism. *Archives of general psychiatry*, *59*(9), 809-816.

Koldewyn, K., Jiang, Y. V., Weigelt, S., & Kanwisher, N. (2013). Global/local processing in autism: Not a disability, but a disinclination. *Journal of autism and developmental disorders*, 43(10), 2329-2340.

Lahaie, A., Mottron, L., Arguin, M., Berthiaume, C., Jemel, B., & Saumier, D. (2006). Face perception in high-functioning autistic adults: evidence for superior processing of face parts, not for a configural face-processing deficit. *Neuropsychology*, 20(1), 30.

Lipszyc, J., & Schachar, R. (2010). Inhibitory control and psychopathology: a meta-analysis of studies using the stop signal task. *Journal of the International Neuropsychological Society*, 16(06), 1064-1076.

Loomes, R., Hull, L., & Mandy, W. P. L. (2017). What is the male-to-female ratio in autism spectrum disorder? A systematic review and meta-analysis. *Journal of the American Academy of Child & Adolescent Psychiatry*, 56(6), 466-474.

Loth, E., Gómez, J. C., Happé, F. (2010). When seeing depends on knowing: Adults with Autism Spectrum Conditions show diminished top-down processes in the visual perception of degraded faces but not degraded objects. *Neuropsychologia*, 48, 1227–1236.

Mevorach, C., Humphreys, G. W., & Shalev, L. (2006). Opposite biases in salience-based selection for the left and right posterior parietal cortex. *Nature Neuroscience*, 9, 740–742.

Mevorach, C., Humphreys, G. W., & Shalev, L. (2009). Reflexive and preparatory selection and suppression of salient information in the right and left posterior parietal cortex. *Journal of Cognitive Neuroscience*, *21*(6), 1204-1214.

Mevorach, C., Hodsoll, J., Allen, H., Shalev, L., & Humphreys, G. (2010). Ignoring the elephant in the room: a neural circuit to downregulate salience. *Journal of Neuroscience*, *30*(17), 6072-6079.

Milne, E., Dunn, S. A., Freeth, M., & Rosas-Martinez, L. (2013). Visual search performance is predicted by the degree to which selective attention to features modulates the ERP between 350 and 600ms. *Neuropsychologia*, *51*(6), 1109-1118.

Mottron, L., & Belleville, S. (1993). A study of perceptual analysis in a high-level autistic subject with exceptional graphic abilities. *Brain and Cognition*, 23(2), 279–309.

Mottron, L., Dawson, M., Soulieres, I., Hubert, B., Burack, J., (2006). Enhanced perceptual functioning in autism: an update, and eight principles of autistic perception. *Journal of Autism and Developmental Disorders*, 36, 27–43.

Murphy, C. M., Christakou, A., Daly, E. M., Ecker, C., Giampietro, V., Brammer, M., ... & Rubia, K. (2014). Abnormal functional activation and maturation of fronto-striato-temporal and cerebellar regions during sustained attention in autism spectrum disorder. *American Journal of Psychiatry*, *171*(10), 1107-1116.

Neumann, D., Spezio, M. L., Piven, J., & Adolphs, R. (2006). Looking you in the mouth: abnormal gaze in autism resulting from impaired top-down modulation of visual attention. *Social cognitive and affective neuroscience*, *1*(3), 194-202.

Ozonoff, S., & Jensen, J. (1999). Brief report: Specific executive function profiles in three neurodevelopmental disorders. *Journal of autism and developmental disorders*, *29*(2), 171-177.

Pellicano, E., Maybery, M., Durkin, K., & Maley, A. (2006). Multiple cognitive capabilities/deficits in children with an autism spectrum disorder:“Weak” central coherence and its relationship to theory of mind and executive control. *Development and psychopathology*, 18(01), 77-98.

Pelphrey, K. A., Morris, J. P., & McCarthy, G. (2005). Neural basis of eye gaze processing deficits in autism. *Brain, 128*(5), 1038-1048.

Plaisted, K., Swetteham, J., & Rees L. (1999). Children with autism show local processing in a divided attention task and global precedence in a selective attention task. *Journal of Child Psychology and Psychiatry, 40*, 733-742.

Remington, A., Swettenham, J., Campbell, R., & Coleman, M. (2009). Selective attention and perceptual load in autism spectrum disorder. *Psychological Science*, 20(11), 1388-1393.

Rhodes, G., Jeffery, L., Taylor, L., & Ewing, L. (2013). Autistic traits are linked to reduced adaptive coding of face identity and selectively poorer face recognition in men but not women. *Neuropsychologia,* 51(13), 2702-2708.

Riby, D. M., & Hancock, P. J. (2009). Do faces capture the attention of individuals with Williams syndrome or autism? Evidence from tracking eye movements. *Journal of autism and developmental disorders, 39*(3), 421-431.

Rinehart, N. J., Bradshaw, J. L., Moss, S. A., Brereton, A. V., & Tonge, B. J. (2001). A deficit in shifting attention present in high-functioning autism but not Asperger’s disorder. *Autism*, 5(1), 67-80.

Robertson, C. E., Kravitz, D. J., Freyberg, J., Baron-Cohen, S., & Baker, C. I. (2013). Tunnel vision: sharper gradient of spatial attention in autism. *The Journal of Neuroscience,* 33(16), 6776-6781.

Ronconi, L., Facoetti, A., Bulf, H., Franchin, L., Bettoni, R., & Valenza, E. (2014). Paternal autistic traits are predictive of infants visual attention. *Journal of autism and developmental disorders*, 44(7), 1556-1564.

Stefanis, N. C., Hanssen, M., Smirnis, N. K., Avramopoulos, D. A., Evdokimidis, I. K., Stefanis, C. N., ... & Van Os, J. (2002). Evidence that three dimensions of psychosis have a distribution in the general population. *Psychological medicine*, *32*(02), 347-358.

Sucksmith, E., Roth, I., & Hoekstra, R. A. (2011). Autistic traits below the clinical threshold: re-examining the broader autism phenotype in the 21st century. *Neuropsychology review*, 21(4), 360-389.

Van Boxtel, J. J., & Lu, H. (2013). Impaired global, and compensatory local, biological motion processing in people with high levels of autistic traits. *Frontiers in psychology*, 4, 209.

Wang, L., Mottron, L., Peng, D., Berthiaume, C., & Dawson, M. (2007). Local bias and local-to-global interference without global deficit: A robust finding in autism under various conditions of attention, exposure time, and visual angle. *Cognitive Neuropsychology*, 24(5), 550-574.

Wilson, C. E., Freeman, P., Brock, J., Burton, A. M., & Palermo, R. (2010). Facial identity recognition in the broader autism phenotype. *PLoS One*, 5(9), e12876.