Brief report: How adolescents with ASD process social information in complex scenes. Combining evidence from eye movements and verbal descriptions

M. Freeth[1], D. Ropar[2], P. Mitchell[3], P. Chapman[2], S. Loher[4]

[1] Psychology Department, University of Sheffield

Western Bank, Sheffield

S10 2TP

United Kingdom

[2] School of Psychology, University of Nottingham

University Park, Nottingham

NG7 2RD

United Kingdom

[3] School of Psychology, University of Nottingham Malaysia

Campus, Jalan Broga, 43500 Semenyih, Selangor Darul Ehsan,

Malysia

[4] Universität Bern – Institut für Psychologie

Muesmattstrasse 45

CH – 3000 Bern 9

Switzerland

Running Head: Processing complex scenes in ASD

Abstract

We investigated attention, encoding and processing of social aspects of complex photographic scenes. Twenty four high-functioning adolescents (aged 11-16) with ASD and 24 typically developing matched control participants viewed and then described a series of scenes, each containing a person. Analyses of eye movements and verbal descriptions provided converging evidence that both groups displayed general interest in the person in each scene but the salience of the person was reduced for the ASD participants. Nevertheless, the verbal descriptions revealed that participants with ASD frequently processed the observed person's emotion or mental state without prompting. They also often mentioned eye-gaze direction, and there was evidence from eye movements and verbal descriptions that gaze was followed accurately. The combination of evidence from eye movements and verbal descriptions provides a rich insight into the way stimuli are processed overall. The merits of using these methods within the same paradigm are discussed.

Keywords

Transcript analysis; eye tracking; autism; social scenes; gaze following; emotion processing

Corresponding Author E-Mail: m.freeth@sheffield.ac.uk

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Is the world perceived and interpreted in a fundamentally different way by individuals with ASD compared to typically developing individuals? It has been suggested that social stimuli are less salient to individuals with ASD (Jones & Klin, 2008). Eye tracking studies investigating attention allocation have demonstrated that this is true for both neutral stimuli (Riby & Hancock, 2008; Riby & Hancock, 2009; Freeth, Chapman, Ropar & Mitchell, 2010a) and stimuli with emotional content (Klin, Jones, Schultz, Volkmar & Cohen, 2002; Sasson, et al., 2007). Making inferences about mental states and processing others' emotions are often considered to be difficult for individuals with ASD (Baron-Cohen, Wheelwright, Hill, Raste & Plumb, 2001; Baron-Cohen, Wheelwright & Joliffe, 1997) and children with ASD tend to spontaneously comment on other's affective states less frequently than typically developing children in everyday conversation (Müller & Schuler, 2006).

Another aspect of social processing that is an issue for individuals with ASD is following another person's eye gaze direction. Typically developing individuals spontaneously follow the gaze direction of a person in a complex scene (Langton, O'Donnell, Riby & Ballantyne, 2006). Some researchers argue that by adolescence individuals with ASD still do not follow another person's gaze direction in a normal manner (e.g. Klin, Jones, Schultz & Volkmar, 2003; Ristic, Mottron, Friesen, Iarocci, Burack & Kingstone, 2005). However, others have shown that gaze direction can be spontaneously and accurately followed by high-functioning adolescents and adults with ASD (Fletcher-Watson, Leekam, Benson, Frank & Findlay, 2009; Freeth, Ropar, Chapman & Mitchell, 2010b). Further evidence is required to establish where similarities

and differences lie between groups with respect to attention allocation and processing of social information.

Though eye tracking studies provide important information about attention allocation and other experimental paradigms provide insight into cognitive processes, it has been argued that a highly structured experimental approach does not tell the whole story. Kingstone, Smilek, and Eastwood (2008) suggest that studies of human cognition should integrate measures of both objective behaviour (such as eye-tracking) as well as subjective experiences (such as verbal reports) in order to develop comprehensive accounts of cognitive processes. Verbal reports can provide insight into experiences and beliefs and can indicate not only that certain aspects of stimuli are noticed and attended to, but also that they are deemed important and relevant to the participant. Such reports have provided insight into cognitive processes beyond that found in eye-tracking data alone (Smilek, Birmingham, Cameron, Bischof & Kingstone, 2006). As noted by Ames and Fletcher-Watson (2010), complementing traditional behavioural measures with analysis of spontaneous reports may facilitate a broader understanding of ASD.

In the experiment reported in this paper a series of photographic scenes, each containing a person with a neutral expression, were presented to participants. Eye movements were tracked in order to measure participants' attention to various aspects of the scenes. In addition, transcripts of verbal descriptions of the scenes were analysed. The use of these two methods in concert can tell us which aspects of the scenes participants attended to, encoded, processed and deemed important. Task instructions were modelled on a study by Birmingham, Bischof and Kingstone (2007) who demonstrated that fixation patterns were not significantly different when participants freely-viewed scenes to fixation patterns when participants thought about how they could describe the scenes followed by a verbal description phase. We therefore predicted that patterns of fixations

would be similar to those observed in a free-viewing task using similar stimuli and the same participant cohort (Freeth et al. 2010a). We predicted that ASD participants would display a general interest in the person in each scene but they would be slower to first fixate the person. In addition, we predicted that the gaze direction of the person in each scene would be followed by participants in both groups, as also observed in studies using similar participant cohorts, Fletcher-Watson et al. 2009; Freeth et al. 2010b.

The novel purpose of the current research was to discover whether social aspects of the stimuli were encoded, processed and deemed important, as indicated by analysis of participants' verbal descriptions of the scenes. We predicted that although participants with ASD would display a general interest in the people in the scenes, the person would not feature as frequently in the descriptions. We predicted that comments on emotion/mental state would be lower in the ASD group but were interested to discover whether any such comments of this type would be produced. This analysis provides an indication of whether any attempts were made to infer emotions/mental states without prompting and without the presence of strong emotional cues. In addition, we predicted that evidence of gaze following would be found in the verbal descriptions but were unsure whether the object at the location of the person's gaze would increase in salience to the ASD participants as a result of the person's direction of gaze. Analysis of eye tracking data together with verbal descriptions of the same scenes should provide a clearer indication of how stimuli are processed overall.

Method

Participants

Twenty four 11-16 year old adolescents (21 males, 3 females) with an Autism Spectrum Disorder (ASD) - autism or Asperger syndrome - and 24 age, gender and IQ matched typically developing adolescents participated in the study. All of the participants

with ASD had been formally diagnosed by a mental health professional according to DSM-IV criteria (American Psychiatric Association, 1994) and as a result had a statement of Special Educational Needs for Autism or ASD. All participants were recruited through their schools, which were a mixture of UK mainstream and special schools. An Autism Spectrum Screening Questionnaire (Ehlers, Gillberg & Wing, 1999) was completed by a teacher of each participant giving an indication of current level of autistic features. An independent-samples *t*-test demonstrated a significant between group differences on ASSQ scores $t(46)=7.43$, $p<.001$, $d=2.19$. All participants completed the Wechsler Abbreviated Scale of Intelligence (WASI) providing measures of verbal IQ, performance IQ and full-scale IQ on which participants in the typically developing group and ASD group were matched. All participants had normal or corrected-to-normal visual acuity (see Table 1 for full participant details).

(Insert Table 1 about here)

Stimuli and Design

Eight sets of photos of different scenes containing one person were constructed. There were four photo versions in each set which enabled counterbalancing of person location (left vs. right [mirror reverse of left version]) and gaze direction (straight vs. towards an object in the scene) for each target scene between participants. The person's expression was neutral in all photos (see Figure 1 for examples). Eight filler photos were also constructed, each of an everyday scene containing one or more people. These were a mixture of indoor and outdoor scenes. Each photo had a resolution of 1024 x 512 pixels and was presented on a blank background. Four regions of interest were defined for each photo: top face; lower face (top face and lower face region were of equal area); body; main objects (3 main objects were present in each scene, one of which was looked at by the person in the scene). The regions were defined by 4 pixel co-ordinate points which

represented a rectangular area for each region. Objects/bodies that did not naturally fall within one rectangle were defined by two rectangles combined.

(Insert Figure 1 about here)

Apparatus

Photographs were presented sequentially on a computer monitor using E-Prime. Verbal descriptions of each photo were recorded using an Olympus Digital Voice Recorder (WS-205). Eye movements were recorded using a remote Tobii 1750 eye-tracker system. The frequency of recording was 50 Hz and was accurate to 1º of visual angle. Images were displayed on a 19" colour LCD monitor at a distance of approximately 60cms.

Procedure

Participants were sequentially presented with 16 scenes. Eight target scenes (one from each set, see Figure 1) were separated by 8 filler scenes. Filler scenes were included to distract participants from the general set-up of the target scenes. Participants were fully informed about the viewing and description procedure before commencing the experiment. For each of the 16 scenes, participants were requested to "have a good look at the photo" for 15 seconds. This duration was chosen as we wanted participants to have the opportunity to explore the images without time pressure before initiating their descriptions of the scenes – this was important for the verbal description aspect of our paradigm and follows the procedure used by Birmingham et al. (2007). During this time, participants' eye movements were tracked. Fixation locations and durations were recorded. Fixations were recordings of 80ms or more within 1.5 º visual angle. A screen prompt then requested that participants gave a "short" description of the scene. The scene was still visible in this phase. No time limit was administered. These instructions were repeated 16 times, until all scenes had been viewed and described.

Results

Verbal descriptions of the scenes were transcribed and transported into Nvivo 7 for theme identification analysis before statistical analysis was conducted. Mean length of utterance was compared between groups. There was one outlier whose data was removed from further verbal description analysis. This participant was from the typically developing group. An independent samples *t*-test found that mean length of utterance did not significantly differ between groups, $t(45)=0.59$, $p=.55$, $d=0.2$. A summary of the main verbal description results can be seen in Table 2.

Analysis of outliers in the eye tracking data found that four ASD participants and three typically developing participants had an average time to first fixate the scenes that was more than 2 standard deviation from the group mean (each outlier, mean time to first fixate images >150ms). It seems that these participants were not sufficiently attentive in the eye tracking phase and therefore they were excluded from the eye-tracking analyses. A summary of the main eye tracking results can be seen in Table 3, proportion of fixations on Regions of Interest (ROI) can be seen in Figure 2. There was no significant difference between groups in the time spent fixating the scenes overall, $t(39)=0.79$, $p=.43$, $d=0.3$ indicating that both groups were similarly attentive to the scenes.

(Insert Table 2 about here)

(Insert Table 3 about here)

(Insert Figure 2 about here)

General Interest in the Person in the Scene

The number of verbal descriptions in which the person in the scene was mentioned at least once (e.g. “the girl”; “the lady”; “she”; “her”) was compared between

groups. An independent samples *t*-test found no difference between groups, $t(46)=1.27$, $p=.21$, $d=0.4$, and both groups were close to ceiling. This demonstration of interest in the person was also apparent in the eye tracking data. Proportion of overall viewing time spent fixating the person was not significantly different between groups, $t(39)=0.62$, $p=.54$, $d=0.2$ (see Figure 2). Participants looked at the person's face for a significantly greater proportion of viewing time than would be expected if fixations had been distributed randomly, $t(40)=15.73$, $p<.001$, $d=2.2$. No significant difference between groups in the amount of time spent fixating the face of the person was found, $t(39)= 0.77$, $p=.44$, $d=0.2$, suggesting that both groups were interested in the person's face.

To take the investigation a step further, eye movement data from participants who showed differing interest in the person – as indicated by their verbal descriptions - was compared. Eye movement data from participants who failed to mention the person in two or more descriptions were compared to participants who mentioned the person in all, or all but one, descriptions. There was no significant difference in proportion of viewing time spent fixating the person between groups, $t(39)=0.85$, $p=.93$, $d=0.3$. Further, one ASD participant failed to mention the person on five occasions (two more than any other participant). This participant actually spent a greater proportion of their viewing time fixating the person than the rest of the participants (42.5% vs 25.6%); $t(39)=12.3$, $p<.001$. This participant was also as fast as the rest of the participants to first fixate the person, (ppt mean=375ms; group mean=389ms), $t(39)=0.30$, $p=.77$, $d=0.1$. These analyses indicate that although some participants did not frequently mention the person in their descriptions, they still fixated the person in the visual inspection stage. This finding demonstrates that consideration of eye tracking data in isolation may not provide a balanced overview of the aspects of the stimuli that are actually attended to, processed and deemed important.

Salience of the Person

The salience of the person in the descriptions was analysed by comparing the frequency with which the person was mentioned in each scene description. References to the person were split into nouns (e.g. "the guy"; "a lady"; "a person") and pronouns (personal – e.g. "he/she" and possessive "his/her"). This provided information about the way the person was referenced within the descriptions. A repeated measures ANCOVA (controlling for mean length of utterance) found a main effect of diagnosis, $F(1,44)=5.53$, $p=.023$, $\eta_p^2=0.11$. ASD participants mentioned the person less frequently than the typically developing participants. There was a main effect of noun type, $F(1,44)=6.48$, $p=.015$, $\eta_p^2=0.13$ as participants used pronouns more than nouns. There was no interaction between noun type and group, $F(1,44)=1.21$, $p=.28$, $\eta_p^2=0.03$ giving no reason to suppose that that the distribution of nouns and pronouns used in the descriptions differed between groups. This analysis suggests that the person was a more central feature in the typically developing participants' descriptions than in the ASD participants' descriptions.

Eye movement data supported this suggestion as typically developing participants were significantly faster than ASD participants to first fixate the person, Mann Whitney $U=113.5$, $N=41$, $p=.012$[1]. This pattern was also observed when only fixations on the face were considered - typically developing participants were significantly faster to first fixate the face-, Mann Whitney $U=89.0$, $N=40$, $p=.012$[1]. These analyses suggest that the salience of the person was reduced for the ASD participants as they did not prioritise attending to the person in the scene.

Reference to the person's emotion/mental state

[1] The data was positively skewed and as no transformations were able to reduce the skew to an acceptable level, a Mann Whitney test was performed rather than an independent samples *t*-test.

Approximately half of the participants made at least one reference to the mental state/emotion of the person in one of the scenes (11 ASD; 12 typically developing), examples included "…is thinking about…"; "she wants…"; "he looks happy". The number of photos in which the mental state or emotion of the person in the photo was mentioned was compared between groups using an independent samples *t*-test. There was no significant difference between groups, $t(46)=0.26$, $p=.80$, $d=0.08$, indicating that participants with ASD were just as likely to make reference to the person's emotions or mental state as the typically developing participants, when describing the photos. Further, the emotions/mental states that were mentioned were classified as describing either basic or complex emotions/mental states. Classifications proposed by Baron-Cohen et al. (2001) were used. *Basic* emotions were those which are recognised universally purely as emotions without the need to attribute a belief to a person, e.g. happy, sad, angry, afraid, disgust; *complex* emotions/mental states were those which involve an attribution of belief or intention, e.g. thinking, confident, boredom, displaying an interest. A mixed measures ANOVA (emotion type x group) found no main effect of emotion, $F(1,21)=2.57$, $p=.12$, $\eta_p^2=0.11$, and no significant interaction between factors, $F(1,21)=0.88$, $p=.36$, $\eta_p^2=0.04$ demonstrating that the nature of the emotion/mental state comments were similar in each group. The mean number of times participants mentioned an emotion/mental state was: ASD basic=0.82; ASD complex=1.45; Typical basic=0.67; Typical complex=0.83. These analyses indicate that the frequency with which emotions were mentioned between groups was similar and the nature of the descriptions was also similar.

Reference to gaze direction and evidence of gaze following

The number of photos in which the gaze direction of the person in the photo was mentioned was compared between groups. A gaze direction reference was coded when a phrase such as "is looking at"; "is gazing towards" was mentioned in the description. A

2x2 mixed measures ANOVA (gaze x diagnosis) revealed a significant main effect of gaze direction, $F(1,46)=50.55$, $p<.001$, $\eta_p^2=0.5$ as, perhaps unsurprisingly, participants tended to mention the gaze direction of the person in the photo more frequently in their descriptions of the 'gaze towards an object' photos than in their descriptions of the 'straight gaze' photos. There was no main effect of diagnosis, $F(1,46)=0.41$, $p=.53$, $\eta_p^2=0.01$. There was also no gaze x diagnosis interaction, $F(1,46)<0.001$, $p>.99$, $\eta_p^2<0.01$. These results demonstrate that the person's gaze direction was mentioned a similar amount by participants in each group.

The number of photos in which the participant mentioned the object that was being looked at (in the gaze object scenes) by the person in the scenes, was compared between groups. A 2x2 mixed measures ANOVA (gaze x diagnosis) showed that this object was mentioned significantly more frequently in the 'gaze object' scenes than in the 'straight gaze' scenes, $F(1,46)=5.36$, $p=.025$, $\eta_p^2=0.1$, indicating that participants' attention was drawn to the object that was looked at by the person in the scene. The ASD participants tended to mention the object less overall, $F(1,46)=5.29$, $p=.026$, $\eta_p^2=0.1$, but importantly there was no gaze x diagnosis interaction, $F(1,46)=1.34$, $p=.25$, $\eta_p^2=0.03$, which suggests that the gaze cue directed attention to the location of gaze to a similar extent in both the typically developing group and the ASD group.

Eye movement data showed that participants were significantly faster to first fixate the object in the 'gaze object' scenes, $F(1,38)=5.71$, $p=.022$, $\eta_p^2=0.1$, indicating that participants rapidly directed their attention towards the object (one outlier from the ASD group was removed prior to this analysis). No differences were found between groups, $F(1,38)=1.86$, $p=.18$, $\eta_p^2=0.05$, and no interaction was observed, $F(1,38)=.50$, $p=.48$, $\eta_p^2=0.01$. As a comparison, gaze direction of the person did not have an effect on time to first fixate the other two main objects in each scene that were never looked at,

$F(1,38)=-2.28$, $p=.14$, $\eta_p^2=0.06$; $F(1,38)=-2.05$, $p=.16$, $\eta_p^2=0.06$, demonstrating that there was no general increase in speed to look at the main objects in the scenes when the observed person's gaze was averted.

To take the investigation a step further, eye movement data from participants who showed differing interest in the target object of the person's gaze – as indicated in their verbal descriptions - was compared. Eye movement data from participants who mentioned the object in two or fewer descriptions were compared to participants who mentioned the object in three or four descriptions. There was no significant difference in total time spent fixating the objects between groups, $t(38)=0.06$, $p=.95$, $d=0.02$. In addition, two participants (1 ASD, 1 typically developing) did not mention the object being looked at in any of their descriptions. However, when comparing the amount of time they spent fixating the objects (1402ms) to the mean amount of time spent fixating the objects by the rest of the participants (1557ms), there was no significant difference ($t(38)=1.40$, $p=.17$, $d=0.5$). These analyses indicate that although some participants did not frequently mention the object that was looked at they still fixated these objects in the visual inspection stage. Thus, relying on eye movement data alone to infer what is attended to in a scene may be misleading. These findings demonstrate the importance of taking additional measures in combination with eye tracking (such as verbal descriptions) to better understand how stimuli are processed overall.

General Discussion

The aim of this experiment was to discover whether social aspects of images representing naturalistic scenes are attended to, encoded, processed and deemed important by high-functioning adolescents with ASD. Analysis of participants' verbal descriptions of scenes, and eye movements recorded whilst scenes were viewed, provided a broad

overview of how the scenes were interpreted. Both typically developing participants and those with ASD displayed general interest in the person, mentioning the person in the vast majority of their descriptions and spending a large portion of viewing time fixating the person. In addition, participants in both groups spent a similar amount of time fixating the face of the person. However, the results indicate that the saliency of the person in each scene was reduced for the ASD participants. The frequency with which the person was mentioned was significantly lower in the ASD group and their eye movements demonstrated that they were significantly slower to first fixate the person and the person's face. The nature of these eye tracking findings were similar to those observed in our recent investigation into the time-course of eye movements, completed by the same participants (Freeth et al., 2010a) and in a study conducted with a similar participant cohort reported by Fletcher-Watson et al. (2009). Findings of the verbal description analyses also demonstrate that there is general interest in the person in the scene but reduced saliency was also observed. Thus, a similar pattern for encoding and processing of information was observed as was found for allocation of attention. This supports Jones and Klin's (2008) theory that social saliency is generally reduced in ASD.

Evidence of reduced social saliency was found more strongly in a study reported by Riby and Hancock (2008) than in the current study. Riby and Hancock reported that ASD participants looked at the eye regions of people in scenes significantly less than typically developing individuals overall. It is possible that these results were driven by their stimuli being particularly social in nature, as their photographs contained up to four characters in social settings e.g. a wedding, sharing a meal, chatting. In the future it may be useful to vary the social content of stimuli and to vary the salience of people within stimuli. This will enable investigation into how these factors affect the extent to which social aspects of stimuli are attended to, processed and encoded by individuals with and

without ASD. Additionally, the differences between groups in terms of attention allocation to social aspects of the stimuli reported here were not as pronounced as in a study reported by Riby and Hancock (2009). In that study participants were presented with scenes onto which an embedded face was artificially pasted and were also presented with scrambled scenes containing face stimuli. It will be important in future to investigate whether individuals with ASD do better at attending to people and faces when presented in context rather than in more abstract stimuli. It may also be possible that particulars of the participant cohorts could explain the differences in the nature of findings between studies and this warrants further investigation.

Surprisingly, the number of references to the person's emotion or mental state was similar between groups in the current study. However, it is worth considering that the frequency with which a topic is mentioned may not indicate competence with this topic (Müller & Schuler, 2006). Ochs and Capps (2001) note that preoccupation with a certain topic may not be a reflection of mastery rather it may be a reflection that comprehension of this topic is still developing. It is possible that although the participants in this study referenced others' emotions and mental states, they may not be likely explanations of how the person was actually feeling or what they were thinking about when the photograph was taken. Nonetheless, it was interesting that descriptions frequently mentioned these topics, even though each person being photographed was asked to maintain a neutral expression when the stimuli were created.

Participants in both groups mentioned the person's gaze direction with similar frequency. An object was mentioned more frequently in participants' descriptions if the person in the scene was looking at that object. This pattern was found in both groups. Eye movement data supported these findings as the time to first fixate the object was significantly faster when the person in the scene was looking at it than when the person

was looking out of the scene. The verbal description and eye movement findings suggested a level of effective processing of gaze direction that is consistent with eye tracking data reported elsewhere (Fletcher-Watson et al. 2009; Freeth et al., 2010a). Indeed, the participants in the experiment reported here were the same who participated in Freeth et al. (2010a) Experiment 2, though different stimuli were presented. Evidence from a change blindness study reported by Freeth et al. (2010b) also demonstrated that a person's gaze direction can cue high-functioning adolescents with and without ASD to the exact location of gaze in a static scene. The experiment reported here extends previous findings, demonstrating that both typically developing individuals and individuals with ASD are able to verbally articulate what a person in a photo is looking at and this is done without being prompted to look towards the eyes or to follow a person's gaze direction.

The data reported here also demonstrate that relying on eye movement data alone may not reveal the whole story. It was found that participants who did not mention the object the person was looking at, in their descriptions of the scenes, did still look at these objects in the visual inspection phase. Thus, the data demonstrate that it would be unwise to rely on eye tracking data alone to infer the aspects of stimuli that participants attend to and deem important. Analysis of verbal descriptions in concert with eye movement data provides a broader overview of how stimuli are processed overall.

In conclusion, this study has demonstrated the merit of complementing established methods of investigation of cognitive processes, such as eye tracking, with exploratory techniques that investigate other aspects of cognitive processing, such as analysis of participants' verbal descriptions. The pattern of general interest in the person in the scene, but reduced saliency of the person overall, was observed in both the eye tracking data and the verbal description data. It is important to note that this pattern of reduced social

saliency was observed even though the ASD participants were high functioning and the stimuli did not contain complex social or rapidly changing information, as is the case in some other studies that have observed differences between groups (Klin et al. 2002; Riby and Hancock, 2008). Thus, this study demonstrates the robust nature of social processing differences in individuals with ASD. Using eye tracking and analysing verbal descriptions within the same paradigm, we have demonstrated not only that certain stimuli are attended to, but also that information about these stimuli is being encoded and processed in a meaningful way. In addition, we have demonstrated that analysis of verbal descriptions can reveal clues to differences in the way stimuli are processed that would be missed if eye tracking data is considered in isolation.

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Author Note

The authors are Megan Freeth, University of Sheffield – Department of Psychology, UK; Danielle Ropar, University of Nottingham - School of Psychology, UK; Peter Mitchell, University of Nottingham - School of Psychology, UK; Peter Chapman, University of Nottingham - School of Psychology, UK; Sarah Loher, - Universität Bern, Switzerland.

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Correspondence concerning this article should be addressed to Megan Freeth, University of Sheffield – Department of Psychology; Telephone: 0114 2226628; e-mail: m.freeth@sheffield.ac.uk

Table 1

Participant characteristics

	ASD participants	Typically developing participants
N	24	24
Age (years; months)		
Mean	14;11	14;9
SD	1.4	1.3
Verbal IQ		
Mean	96.0	97.0
SD	15.2	9.9
Performance IQ		
Mean	*106.9	*99.7
SD	11.3	8.0
Full-scale IQ		
Mean	101.3	98.3
SD	12.1	7.4
ASSQ		
Mean	21.1**	2.1**
SD	11.5	2.8
Range	2-43	0-9

*Significant difference between groups, $p<.05$

**Significant difference between groups, $p<.001$

Table 2

Summary of verbal description results

	ASD participants Mean (SD)	Typically developing participants Mean (SD)
Number of descriptions which mentioned the person (/8)	7.4 (1.25)	7.8 (0.72)
Number of times each participant mentioned the person in the scene	14.1 (8.2)*	19.1 (8.6)*
Number of descriptions which mentioned the emotion or mental state of the person (/8)	1.2	1.0
Number of descriptions which mentioned the person's gaze direction (/8)	2.9 (2.5)	3.3 (2.0)
Number of descriptions which mentioned an object when gaze was directed towards the object (/4) / out of the scene (/4)	2.9 (1.1) / 2.3 (1.5)	3.4 (1.1) / 3.2 (1.3)

*Significant difference between groups, $p<.05$

Table 3

Summary of eye tracking results

	ASD participants Mean (SD) ms	Typically developing participants Mean (SD) ms
Total fixation duration on each scene	10212 (2061)	10720 (2030)
Total fixation duration on the face per scene	2325 (1124)	2552 (727)
Time to first fixate the person	473 (374)*	307 (141)*
Time to first fixate the object when gaze was directed towards the object/ out of the scene	1320 (1841) / 2099 (1070)	1746 (929) / 2170 (1063)

*Significant difference between groups, $p<.05$

Figure Caption Sheet

Figure 1. Example stimuli from set 1: a) Person left, straight gaze b) Person left, gaze object

Example stimuli from set 2: c) Person left, straight gaze d) Person left, gaze object

Figure 2. Percentage of fixations in regions of interest – error bars represent standard error

Figure 1. TOP

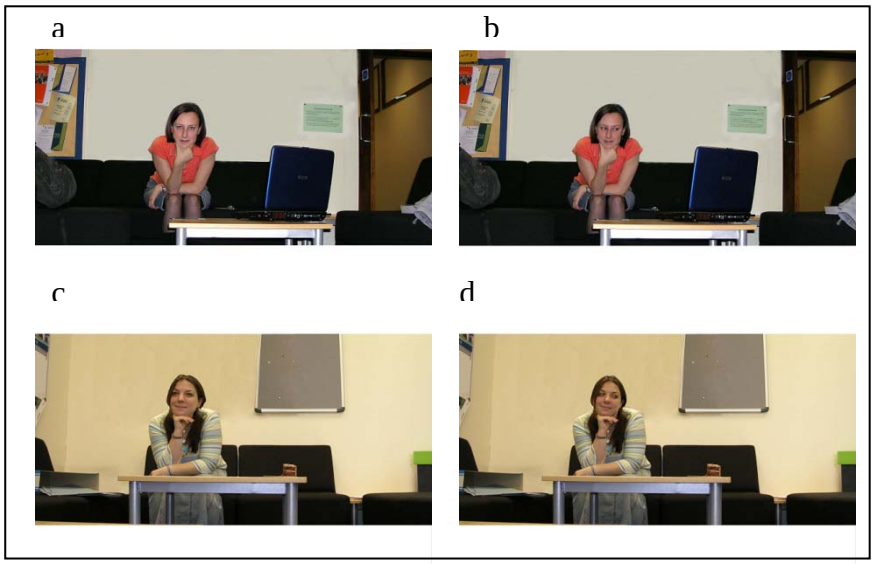
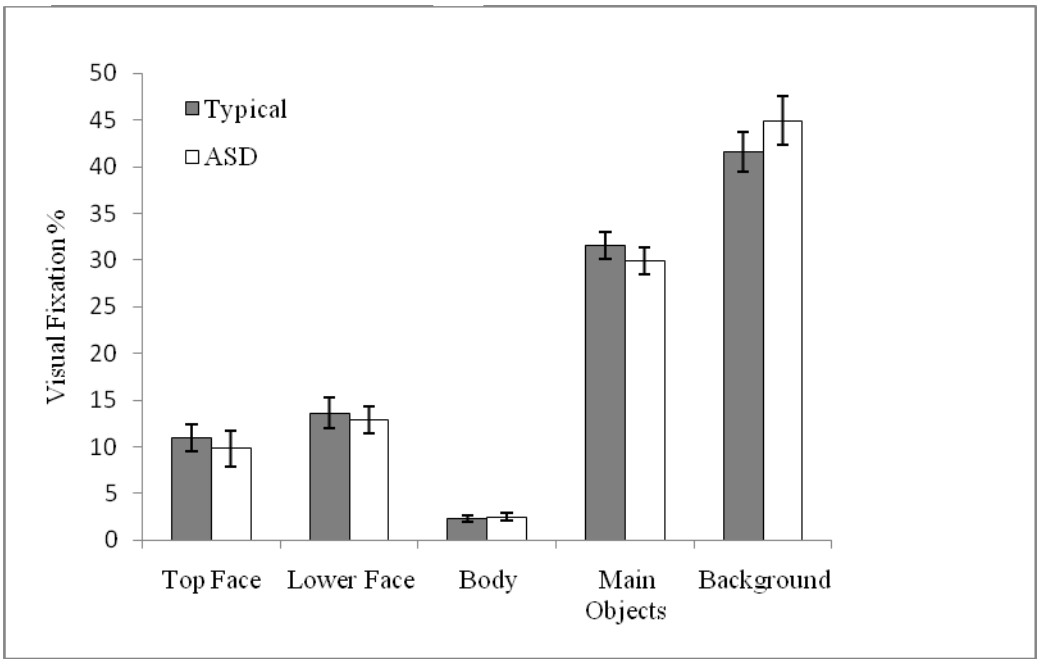


Figure 2. TOP


Typical
ASD
Visual Fixation %
50
45
40
35
30
25
20
15
10
5
0
Top Face
Lower Face
Body
Main Objects
Background