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Patterns of eye movements in face to face conversation are associated with autistic traits: Evidence from a student sample

Running title: Social attention in the BAP

Abstract

The current study investigated whether the amount of autistic traits shown by an individual is associated with viewing behaviour during a face-to-face interaction. The eye movements of 36 neurotypical university students were recorded using a mobile eye-tracking device. High amounts of autistic traits were neither associated with reduced looking to the social partner overall, nor with reduced looking to the face. However, individuals who were high in autistic traits exhibited reduced visual exploration during the face-to-face interaction overall, as demonstrated by shorter and less frequent saccades. Visual exploration was not related to social anxiety. This study suggests that there are systematic individual differences in visual exploration during social interactions and these are related to amount of autistic traits.

Keywords: social attention; mobile eye-tracking; eye movements; autistic traits

Introduction

In social situations people spend most of their time looking at the eyes of other individuals (e.g. Hsiao & Cottrell, 2008); this serves many cognitive and social purposes. Looking at the eyes is the most efficient way to determine identity, gender and emotional state (Peterson & Eckstein, 2012). It is also possible to draw inferences about others' mental states and their focus of attention by looking at their eyes and following their direction of gaze (Baron-Cohen et al., 2001a; Bayliss & Tipper, 2005; 2006). In addition, the eyes can provide signals of dominance, competence and intimacy (e.g. Argyle, 1988; Burgoon et al., 1985).

A diagnostic characteristic of Autism Spectrum Disorder (ASD) is atypical eye contact (American Psychiatric Association, DSM 5, 2013). Children with ASD are often found to look less to other people's faces compared to typically developing children, the eye region in particular (Klin et al., 2002; Nakano et al., 2010; Riby & Hancock, 2008). Some adult studies have also reported reduced looking to the eyes in individuals with ASD (e.g. Hernandez et al. 2009; Corden et al. 2008; Pelphrey et al. 2002). However, several studies have found no overall reduction in eye region viewing in ASD (e.g. McPartland et al., 2011; Freeth et al. 2010; Fletcher-Watson et al. 2009), suggesting that the association between ASD and social attention is complex. Some differences between studies may relate to differential social motivation elicited by different paradigms, e.g. Sasson and Touchstone (2014) found that children with ASD tended to look less to the faces when they were presented together with the objects of particular interest to the children with ASD, which competed for their attention. Alternatively, differential performance between paradigms may relate to social complexity, e.g. a study by Hanley et al. (2013) found that individuals with Asperger syndrome attended to the eyes less than typically developing individuals when faces were presented in social scenes containing two people, but not when a single face was viewed in isolation. In studies testing high functioning adolescents and adults with ASD differences in the timing of social attention are generally observed, such as being slower to orient attention to faces (Riby & Hancock, 2009), the eye region in particular (Freeth et al., 2010). A recent review concluded that the ability to orient towards others' faces in an effective manner is affected in ASD (Guillon et al. 2014).

Differences in attending to other people are more equivocal when considering neurotypical individuals with sub-clinical amounts of autistic traits (Broad Autism Phenotype, BAP). In a recent study where videos of speaking individuals were presented, neurotypical participants with more autistic traits showed less eye contact in response to direct gaze (Chen & Yoon, 2011). The same effect was found by Freeth et al., (2013a) when participants viewed a pre-recorded video of a person speaking and listening. However, no such simple relationship, of decreased looking at a social partner and increased autistic traits, was observed in a live face-to-face interaction. Individuals who were high in autistic traits looked to the social partner just as much as individuals who were low in autistic traits in the live interaction.

Indeed, social cognition in live situations, when another person is physically present, is often reported to be qualitatively and quantitatively different from social cognition when observing still or moving images of people (Risko et al., 2012). Structured experimental tasks that present static or video stimuli do not fully represent the complexity of a face-to-face interaction. However, only a small number of studies to date have used eye-tracking to assess patterns of visual attention during naturalistic face-to-face interactions in relation to autism or autistic traits. The findings of these studies are as follows: young children with ASD spent less time fixating a social partner's face compared to their typically developing peers during a live interaction (Hanley et al., 2014; Noris et al., 2012). No reduction in time spent looking at a social partner's face during a live interaction was found in pre-adolescents with high-functioning autism (Nadig et al., 2010). No relationship between time spent looking at a social partner during a live interaction and amount of autistic traits was found in adults (Freeth et al., 2013a). Laidlaw et al. (2011) also found no relationship between scores on the social skills sub-scale of the Autism-spectrum Quotient questionnaire (AQ, a self-report measure of autistic traits, Baron-Cohen et al., 2001b) and fixations on a potential social partner in a naturalistic situation.

Although recent studies have demonstrated that a simple relationship between increased autistic traits and reduced attention to a social partner in a face-to-face situation does not exist (Freeth et al., 2013a; Laidlaw et al. 2011), the potential for more subtle differences were not explored in these studies. Recent developments in eye-tracking technology now afford the possibility of assessing temporal aspects of eye movements in real-world tasks. Hence, a critical question to be answered by the current study was whether any temporal aspects of eye movements in a face-to-face interaction are related to the amount of autistic traits shown by an individual.

We had reason to predict that temporal aspects of eye movements would be related to the amount of autistic traits shown by an individual based on the autism literature using computer based eye-tracking tasks. Individuals with autism have been shown to demonstrate "sticky attention", exhibiting difficulty disengaging attention from an initial point of fixation on a range of tasks (Kikuchi et al., 2011; Landry & Bryson, 2004). In visual search tasks, poorer performance by those with ASD was associated with longer fixation durations in tasks where distracters were similar to targets (e.g. Kourkoulou et al., 2013). Lower saccade frequency in those with ASD was also evident when viewing novel, but not with frequently occurring, visual stimuli (Kemner et al., 1998).

There is little work in this area in relation to autistic traits or the broad autism phenotype. However research on ASD would predict that when presented with social stimuli, which can be characterised as complex and unpredictable (Dawson et al., 1998), more autistic traits will be associated with reduced saccadic activity (smaller and less frequent saccades). Smaller saccade amplitudes could be described as a tendency to view locations nearer to the previous ones and lower saccadic frequency as a tendency to view smaller number of locations in a visual field. Both of these eye movement characteristics signify reduced visual exploration. There are suggestions of reduced visual exploration when individuals with ASD view picture arrays (Sasson et al. 2008; Elison et al. 2012) but it is currently unclear whether this extends to real world attention.

Here we recorded eye movements during live, face-to-face, verbal interactions between each participant and the experimenter. A structured interview developed by Freeth et al. (2013a) was used. The experimenter asked participants to talk about four general topics and the participants gave answers. Participants were also required to ask the experimenter a set of pre-prepared questions and listen to answers given by the experimenter. It has previously been demonstrated that individuals use gaze aversion when processing cognitively demanding information (Doherty-Sneddon et al., 2002;

Doherty-Sneddon & Phelps, 2005; Glenberg et al., 1998). In a social interaction people show little gaze aversion when they are listening to another person speak, rather gaze aversion predominantly occurs when people are thinking about a response and when they are speaking (Doherty-Sneddon et al., 2002; Glenberg et al., 1998). The current experiment had two phases: when participants were speaking and when participants were listening. We predicted that during the speaking phase participants would avert gaze form the experimenter more than during listening phase of the experiment but did not predict specific differences in relation to autistic traits, though this will be tested in the current paradigm.

Mobile eye-tracking equipment was used which, in addition to an AOI analysis, enabled detailed temporal eye-movement analysis. The study firstly aimed to establish whether the Freeth et al. (2013a) finding, that increased autistic traits were not associated with reduced looking to the face, would be replicated. Secondly, we predicted that having more autistic traits would be associated with reduced visual exploration (less frequent and shorter saccades). In addition, we predicted that participants would avert gaze away from the experimenter more when speaking compared to listening.

Method

Participants

Thirty six student volunteers (27 female) participated in this study. Participants ranged in age from 18 to 31, (M=20.4, SD=3.0). Participants provided full written informed consent prior to participating in the study. All participants completed the Broad Autism Phenotype Questionnaire (BAPQ; Hurley et al., 2007). The distribution of BAPQ scores (totalling scores on all 36 items) was M=98.3, SD=19.3, range 58-133. Further details on this measure are provided in the following section. The study was reviewed and approved by the University of Sheffield Psychology Department Ethics sub-committee.

Apparatus, Materials and Measures

SMI (Senso Motoric Instruments, Teltow, Germany, www.smivision.com) eye tracking glasses were used for data recording. Two small cameras on the rim of the glasses captured the eye movements of the wearer and the recorded gaze fixations were mapped onto the scene camera video coinciding with the participant's line of sight. The range of eye tracking was 80° horizontal, 60° vertical with a binocular 30Hz temporal and up to 0.1° spatial resolution combined with 24Hz front view camera with a field of view: 60° horizontal, 46° vertical. In accordance with manufacturer recommendations a one-point calibration procedure was used. Participants were asked to fixate on a point in the visual field - the tip of the experimenter's finger held adjacent to his face. The experimenter sat at the same distance from the participant for calibration procedure and data collection. Real-time accuracy of calibration was assessed by observing the location of gaze fixation mapped onto visual field view recording (circular cursor on SMI-ETG laptop screen). Fixations, saccades and blinks were defined by standard SMI algorithms. Viewing locations were coded using SMI BeGaze software. Fixation locations indicated by a circular cursor on the video recorded by front view camera were manually mapped frame-by-frame onto a reference view (Figure 1, A). The AOIs were upper face (broadly defined as upper part of the head), lower face (broadly defined as lower part of the head), body and background (any area except upper face/lower face/body). To account for the tolerance of the spatial accuracy of the eye tracking glasses the AOIs were slightly protruding into the background (see Figure 1 B).

The BAPQ (Hurley et al. 2007) was administered in order to assess the amount of autistic traits shown by an individual. This measure was chosen as it was specifically designed to assess autistic traits in the general population, as opposed to the AQ (Baron-Cohen et al. 2001b) which was intended as a screening measure to identify clinical relevance. Recently the BAPQ was also demonstrated to be a superior measure of the BAP compared to the AQ and the SRS (Social Responsiveness Scale-A, Constantino & Gruber, 2002) in terms of internal consistency, criterion and incremental validity in non-clinical adult populations (Ingersoll et al. 2011). The BAPQ has reliable sub-scales which are termed "aloof" (cronbach's α=.94), "rigid" (cronbach's α=.91) and "pragmatic language" (cronbach's α=.85) (Hurley et al. 2007). The range of possible scores on the BAPQ is 36 to 216 with an expected mean score for neurotypical individuals being 99. A cut-off of 108 categorises individuals with and without BAP with 67% sensitivity and 63% specificity when used as a self-report scale, (Hurley et al., 2007).

The Liebowitz Social Anxiety Scale (LSAS; Liebowitz 1987), a self-report questionnaire assessing social anxiety, was also administered to check whether any viewing behaviour associated with autistic traits could be explained by social anxiety.

Procedure

Participants sat across the desk from the male experimenter approximately one metre away and were fitted with mobile eye tracking glasses. All participants completed a live, one-to-one interaction with the experimenter. For the whole duration of the interaction the experimenter looked directly at the participant (for a typical view see Figure 1A).

(Insert Figure 1 about here)

First, participants were verbally instructed: “I am going to ask you to talk about four general topics and your responses should be about half a minute in length”. The four topics were 1) Tell me some things you like about living in Sheffield and some things you dislike about living in Sheffield; 2) Tell me about some things that you did last weekend and some things that you plan to do next weekend; 3) Describe a few things you consider to be typically English and a few things you consider to be typically American; 4) Tell me about some things you do in your spare time; then pick one sport or activity of your choice and either describe some of the rules or tell me how you would go about doing that sport or activity.

Participants were then given a sheet of paper containing the same topics printed out and were verbally instructed: “The second part of the experiment is similar to the first one but instead of me asking questions you are required to ask them one-by-one, in the same order, from the first to the fourth one. Read each question for yourself first and don’t look at the sheet of paper while asking”.

Topics were presented in a random order for each participant. The average duration of participants' responses was 34.2 s (SD=10.2). There was no relationship between the average duration of response and BAPQ scores, $r(34)=.18$, $p=.307$, and only the first 30 seconds of long answers were used for analyses so that each participant contributed a similar amount of data (cf. Freeth et al., 2013a). Experimenter's responses to the questions were prepared in advance. Each participant also completed the BAPQ and LSAS.

Results

A median split by BAPQ score categorised each participant as being High/Low in autistic traits (Table 1).

(Insert Table 1 about here)

Proportion of fixations on Areas of Interest (AOIs)

A three-way mixed measures ANOVA (Phase of the experiment (Listening/Speaking) * AOI (Upper face/Lower face/Body/Background) * BAPQ (Low/High)) on proportions of fixations to AOIs was conducted, the results of which are organised by topic below.

Area of interest analysis. There was a main effect of AOI, $F(1.71,58.46)=17.04$, $p<.001$, $\eta\rho^2=0.33$. Post-hoc t-tests, using Bonferroni corrected alpha levels of 0.0083, indicated that participants fixated more on the experimenter's upper face than body, $t(34)=6.94$, $p<.001$, $d=1.87$, and more on the upper face than the background, $t(34)=3.20$, $p=.003$, $d=0.93$. Participants also fixated less on the body than the lower face, $t(34)=5.94$, $p<.001$, $d=1.33$, and less on body than background, $t(34)=6.23$, $p<.001$, $d=1.27$, (Figure 2A,C).

The effect of speaking and listening on viewing behaviour. There was a significant interaction between experiment phase (speaking/listening) and AOI, $F(2.52,85.80)=33.13$, $p<.001$, $\eta\rho^2=0.49$, indicating that participants distributed their viewing behaviour differently while speaking and listening. Simple effects analysis indicated that while speaking participants looked less at the upper face, $F(1,35)=8.76$, $p=.005$, $\eta\rho^2=0.20$, and lower face, $F(1,35)=29.07$, $p<.001$, $\eta\rho^2=0.45$, and more to the background, $F(1,35)=74.64$, $p<.001$, $\eta\rho^2=0.68$, compared to listening. There was no difference in looking to the body, $F(1,35)=.09$, $p=.763$, $\eta\rho^2=.00$, (Figure 2B).

The effect of autistic traits on viewing behaviour. The interaction between autistic traits and proportion of fixations on AOIs was non-significant, $F(1.72,63.0)=.71$, $p=.475$, $\eta\rho^2=0.02$. A main between subjects effect of autistic traits could not be observed in this analysis because proportions of fixations for each participant summed to 1. To address this issue a separate ANOVA was performed with background AOI omitted. There was no main effect of autistic traits $F(1,34)=1.91$, $p=.176$, $\eta\rho^2=0.05$. These findings demonstrate that proportion of fixations were distributed similarly in each group. As can be seen in Figure 2C, there was no trend for reduced fixations on the social partner by the high autistic traits group in these data thus replicating the findings of Freeth et al. (2013a).

(Insert Figure 2 about here)

Eye movements

A two-way mixed measures ANOVA ((Phase of the experiment (Listening/Speaking) * BAPQ (Low/High)) on saccade amplitude was conducted. A main effect of autistic traits, $F(1,34)=4.20$, $p=.048$, $\eta\rho^2=0.11$, indicated that individuals high in autistic traits made saccades smaller in amplitude compared to individuals low in autistic traits (Figure 3A). A Pearson's bivariate correlation revealed a negative correlation between BAPQ scores and mean saccade amplitudes, $r(34)=-.35$, $p=.037$, (Figure 3, B). Confirming the presence of the previously observed trend reported above using the BAPQ as a continuous variable, a main effect of experiment phase, $F(1,34)=6.91$, $p=.013$, $\eta\rho^2=0.17$, showed that participants made saccades smaller in amplitude while listening compared to speaking. The interaction between phase and autistic traits was not significant, $F(1,34)=1.36$, $p=.252$, $\eta\rho^2=0.04$.

A two-way mixed measures ANOVA ((Phase of the experiment (Listening/Speaking) * BAPQ (Low/High)) on saccade frequency was also conducted. A main effect of autistic traits, $F(1,34)=4.53$, $p=.041$, $\eta\rho^2=0.12$, indicated that individuals high in autistic traits made less frequent saccades compared to individuals low in autistic traits (Figure 3C). A Pearson's bivariate correlation revealed a negative correlation between saccade frequency and BAPQ, $r(34)=-.36$, $p=.032$, (Figure 3D). Neither a main effect of experiment phase, F(1,34)=1.96, p=.169, $\eta\rho^2$=0.06, nor the interaction between phase and autistic traits, F(1,34)=0.62, p=.438, $\eta\rho^2$=0.02, were significant.

These findings support our hypotheses that increased autistic traits would be associated with reduced visual exploration, as indicated by less frequent and smaller saccades.

(Insert Figure 3 about here)

We were also interested to discover whether specific aspects of autistic traits were differentially related to reduced visual exploration. Pearson's bivariate correlations of each of the three BAPQ subscales with saccade amplitude and frequency were conducted. As can be seen in Table 2 increased scores on the "rigid" BAPQ subscale were associated with both reduced saccade amplitude and reduced saccade frequency. Increased scores on the "aloof" subscale were associated with reduced saccade frequency only and scores on the "pragmatic language" subscale were not associated with either saccade amplitude or saccade frequency. Three partial correlations established the unique portion of variance accounted for by each subscale independently (unique correlations of a particular subscale with the other two partialled out; see Table 2). Overall these results indicate that the autistic trait of rigid behaviour best predicted reduced visual exploration during the social interaction with higher scores on the aloof subscale, suggesting low social motivation, also being associated with less frequent eye movements.

(Insert Table 2 about here)

Pearson's bivariate correlations indicated that social anxiety, measured via the LSAS, was not significantly correlated with mean saccade amplitude, r(34)=-.24, p=.156, or saccade frequency, r(34)=-.25, p=.139. Partial correlations also revealed that when controlling for scores on the BAPQ, the LSAS did not explain a significant portion of the variance for saccade amplitude r(33)=-.06, p=.721 (unique portion of variance = 0.40%) or saccade frequency r(33)=-.07, p=.696 (unique portion of variance = 0.46%).

Discussion

The aim of the current study was to discover whether looking behaviour during a face-to-face interaction differs depending on the amount of autistic traits an individual shows. The main findings can be summarised as follows: 1) consistent with previous findings, higher autistic traits were not associated with reduced looking to the social partner; 2) as predicted, differences were apparent in the temporal domain. Individuals who were high in autistic traits exhibited reduced visual exploration, making smaller and less frequent saccades during the face-to-face social interaction; 3) analyses of autistic trait subscales indicated that reduced visual exploration was associated with having a more "rigid" personality, i.e. having little interest in change or difficulty adjusting to change. Less frequent eye movements were also associated with having a more "aloof" personality, i.e. having a lack of interest in or enjoyment of social interaction. Having difficulty with pragmatic language, i.e. social aspects of language, was not associated with visual exploration behaviour; 4) social anxiety did not account for the observed relationship between increased autistic traits and reduced visual exploration; 5) more gaze aversion from the experimenter occurred when participants were speaking compared to listening.

Overall during the interaction participants spent most of the time looking to the face of the social partner - 70.5% (upper face - 44.1%, lower face - 26.4%). A greater proportion of time looking to the face was observed when participants were listening to the social partner speak - 84.5% compared to when participants were speaking themselves - 54.9%. Consistent with previous research (Doherty-Sneddon et al.; Glenberg et al., 1998), this potentially occurred due to speaking being more cognitively demanding than listening with gaze aversion serving as means to reduce processing costs of potentially distracting or resource demanding visual social signals.

The proportions of time spent looking to the upper face, lower face or body of a social partner were not different between individuals with more or fewer autistic traits, indicating that participants who were high in autistic traits did not display any aversion or lack of interest in attending to the social partner. This absence of a relationship between autistic traits and amount of time spent looking directly at the experimenter was also observed in a face-to-face interaction by Freeth et al. (2013a) and when there was potential for a social interaction by Laidlaw et al (2011). The nature of this finding is different to the reduced attention to faces often observed in children with autism (e.g. Klin et al. 2002; Nakano et al., 2010; Riby & Hancock, 2008), but is in-line with recent findings that observed no overall reduction in eye-region viewing in older, high functioning individuals with autism when only one face or person was present in the each visual stimulus (Fletcher-Watson et al. 2009; Freeth et al. 2010). Findings from this new cohort of participants replicated previous findings, from Freeth et al. (2013a) and Laidlaw et al. (2011), using equipment enabling a much more fine-grained temporal and spatial analysis of eye-movements compared to these previous studies and indicate that individuals with more autistic traits are focussing on socially relevant areas within their visual field as much as individuals who show fewer autistic traits, providing the opportunity to effectively spot and process any subtle social cues that may be produced by the social partner. In contrast to the current findings, when participants viewed a video presentation of the experimenter asking questions and listening to answers in the study by Freeth et al. (2013a), a simple relationship was found between reduced looking to the experimenter and more autistic traits. Overall, this body of research highlights the importance of conducting social attention research in face-to-face situations (as was the case in the current study) as well as in more controlled computer-based experiments as fundamentally differing results may be observed when comparing social attention when watching videos compared to social attention in real life (see Chevallier et al. 2015 for further discussion).

In the current experiment, individuals with more autistic traits exhibited reduced visual exploration; they executed smaller and less frequent saccades. Smaller saccades indicate that individuals with more autistic traits tended to explore locations nearer to the previous ones in a visual field, while lower saccade frequency indicate that they also explored fewer locations in a visual field. This pattern of behaviour has previously been observed when individuals with autism viewed static picture arrays (Elison et al. 2012; Sasson et al. 2008) and suggests that visual persistence may also be associated with the broad autism phenotype. In future, it will be important to investigate whether individuals with ASD also display reduced visual exploration in live face-to-face interactions as this may partially explain differences in social information processing, and provide a better understanding of how individuals with ASD view their environment. However, it would be premature to speculate that these eye movement characteristics signifying reduced visual exploration directly lead to individuals with more autistic traits processing social information less efficiently or missing socially important data. These would be questions for future work. Less frequent and more local shifts of attention also could mean that individuals with more autistic traits paid greater attention to detail in local areas but not necessarily that this strategy was less efficient for information processing.

Although previous research has generally used less ecologically valid paradigms compared to the current study, the existence of reduced eye movements and poorer performance in association with autism has previously been observed in cognitively demanding experimental tasks. Regarding saccadic activity, evidence suggests that at rest and in visual tasks requiring little effort, autism is associated with greater saccadic frequency. However with novel, more demanding tasks the opposite relationship exists (Kemmer et al., 1998). In support of this, Goldberg et al. (2002) used a battery of cognitive tasks to investigate eye movements in individuals with autism and found longer latencies to saccade in a memory guided saccade task and in all conditions of a gap/overlap task when compared to a neurotypical control group. In visual search tasks, where target and distracter objects are dissimilar and spatial attention is likely driven by object salience, individuals with ASD often demonstrate faster performance (e.g. O'Riordan, 2004; O'Riordan et al., 2001; Plaisted et al., 1998). However, heightened visual search ability has not been unanimously demonstrated. In tasks where target and distracter objects are similar and participants are able to make use of context, individuals with autism exhibit slower search performance (Barnes et al., 2008; Brown et al., 2010; Kourkoulou et al., 2013). Longer search time in such tasks was found to be driven by longer duration of fixations (Kourkoulou et al., 2013). It therefore seems that overall individuals with autism tend to exhibit reduced saccadic activity when task demands are high. In the current study individuals high in autistic traits exhibited reduced eye movements in accordance with our hypothesis, based on findings from research with individuals with ASD, suggesting that observed behaviour in ASD may extend to those who show high autistic traits. However, further research is needed to investigate whether reduced eye movements are associated with compromised processing of social stimuli and whether reduced eye movements in those high in autistic traits are limited only to social situations or are also apparent when viewing other types of complex visual stimuli. A further factor that it will be important to investigate in future work is gender. In the current study each participant interacted with the same experimenter who was male and 75% of the participant cohort was female. In future work it will be important to systematically vary the gender of the social partner and participant to establish whether gender is an influential factor when considering the relationship between social attention and autistic traits.

In neurotypical adults autistic traits were previously found to be related to social anxiety (r=0.51; Freeth et al., 2013b). In the current study, the association between reduced visual exploration and autistic traits was not explained by social anxiety. From the three subscales of the BAPQ, the rigid personality subscale accounted for the largest unique proportion of variance in both saccade amplitude and saccade frequency. The definition of rigid personality as "little interest in change or difficulty adjusting to change" (Hurley et al., 2007) certainly seems conceptually aligned with reduced visual exploration. It will be an important future direction to explore other potential implications of exhibiting rigid behaviour, both in terms of social attention and in relation to other aspects of social behaviour. It was also interesting to note that the "aloof" subscale, indicating a lack of interest in social interaction, was associated with reduced saccade frequency. It will be an important future direction to further investigate the role of social motivation on patterns of social attention as social motivation is proposed to play a central role in autism (Chevallier et al. 2012). Indeed, there are recent suggestions of motivation impacting social attention in autism if individuals are faced with a range of stimuli which compete to capture attention (Sasson & Touchstone, 2014). However, it is important to note that only a small proportion of the variance in visual exploration was associated with aspects of the BAP, with the majority of the variance in visual exploration remaining unexplained. An important future direction will be to aim to better understand the predictors of individual differences in visual exploration.

Overall, the current study demonstrated that high amounts of autistic traits are not associated with reduced looking to the face of a social partner but are associated with reduced visual exploration, manifested by a tendency to view places nearer to each other in a visual field and by shifting attention between different places less frequently. Future detailed time-course analyses of visual exploration strategies used by individuals high in autistic traits or with ASD are needed to investigate whether differences could influence aspects of social information processing.

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Table 1. Low and High BAPQ scoring sample characteristics.

** denotes significant between group difference, $p < .001$

	Low BAPQ scores	High BAPQ scores
Sample size (male;female)	4;14	5;13
Mean age (SD)	18.9 (0.9)	21.8 (3.6)
Mean BAPQ score (SD)	83.3 (12.9)**	113.2 (11.2)**
Mean LSAS score (SD)	85.6 (16.1)	93.9 (19.8)

Table 2. Correlation (left) and unique relationship (right) between BAPQ subscales and eye movement measures.* p<.05.

	Pearson's bivariate correlation		Unique proportion of variance (partial correlation r^2)	
	Saccade amplitude	Saccade frequency	Saccade amplitude	Saccade frequency
BAPQ Rigid subscale	-0.38*	-0.37*	8.53%	6.50%
BAPQ Aloof subscale	-0.28	-0.35*	1.23%	5.38%
BAPQ Pragmatic language subscale	-0.18	-0.14	0.25%	1.54%

Figure caption sheet

Figure 1.A: a typical view seen by a participant during the experiment, B: defined AOIs.

Figure 2.A: Percentage of fixations to AOIs. B: Proportion of fixations to the AOIs. ** $p<.001$

Figure 3.A: Comparison of mean saccade amplitude between individuals high and low scoring on the BAPQ. B: Correlation between saccade amplitude and BAPQ. C: Comparison of saccade frequency between individuals high and low scoring on the BAPQ. D: Correlation between saccade frequency and BAPQ. * $p<.05$.

Figure 1. TOP

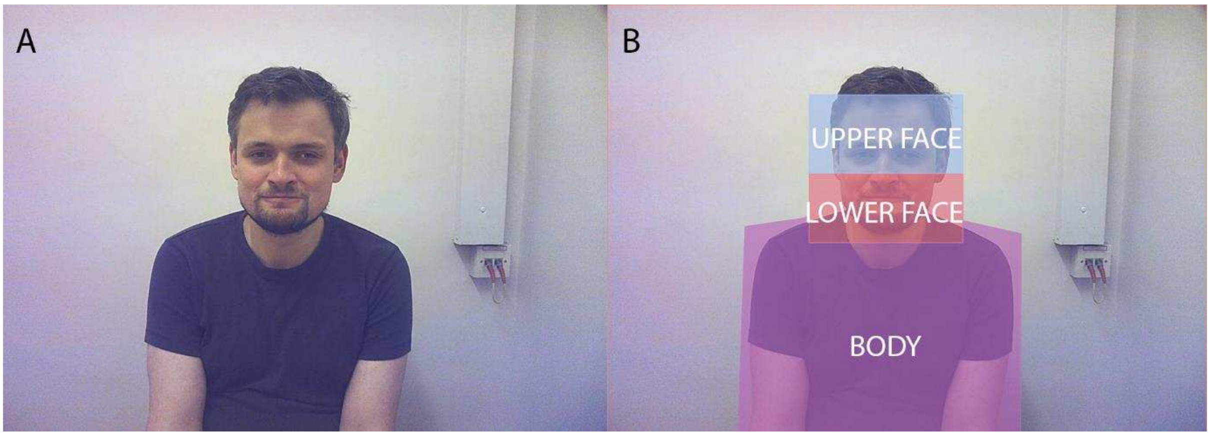


Figure 2: TOP

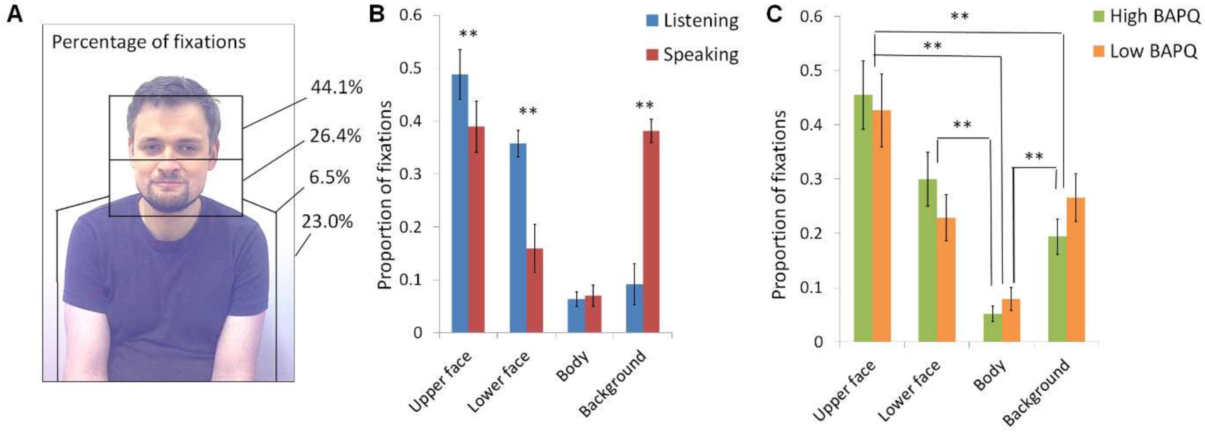
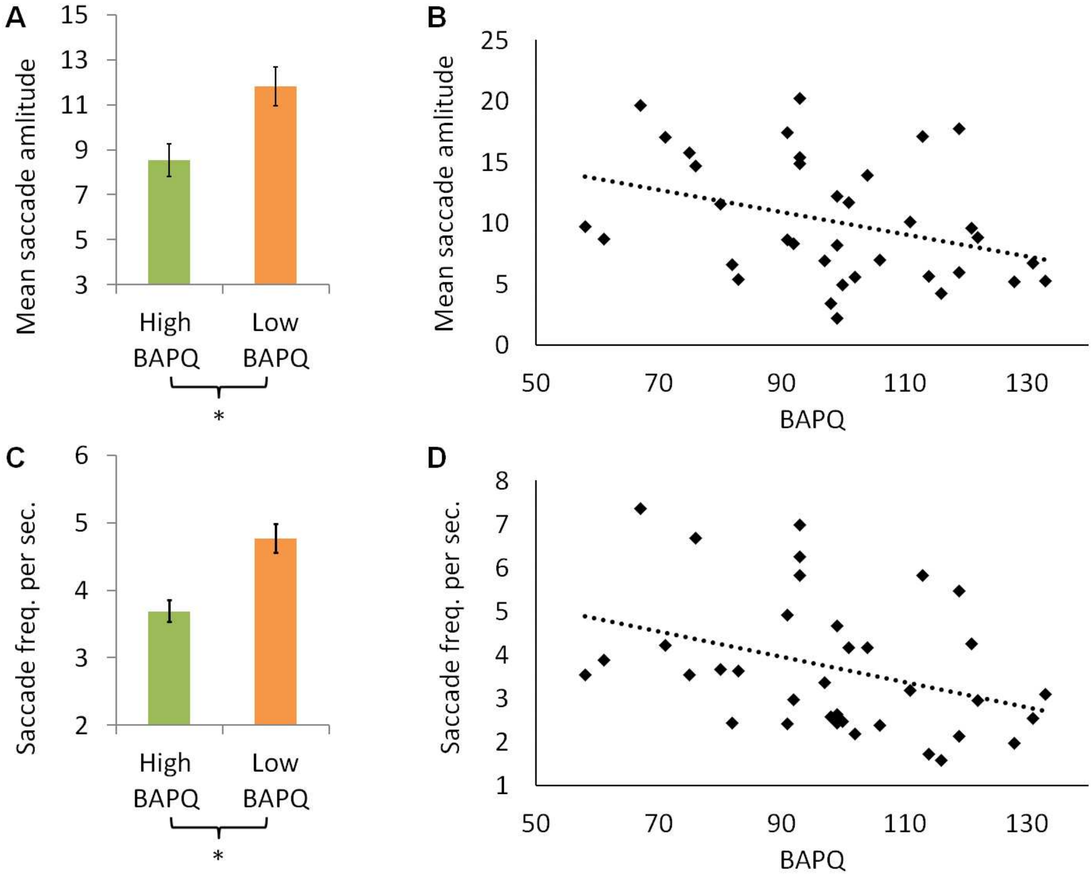

A
Percentage of fixations
44.1%
26.4%
6.5%
23.0%
B
Listening
Speaking
Proportion of fixations
Upper face
Lower face
Body
Background
C
High BAPQ
Low BAPQ
Proportion of fixations
Upper face
Lower face
Body
Background

Figure 3: TOP



A
Mean saccade amlitude
15
13
11
9
7
5
3
High BAPQ
Low BAPQ
*
B
Mean saccade amlitude
25
20
15
10
5
0
50
70
90
110
130
BAPQ
C
Saccade freq. per sec.
6
5
4
3
2
High BAPQ
Low BAPQ
*
D
Saccade freq. per sec.
8
7
6
5
4
3
2
1
50
70
90
110
130
BAPQ

Author note

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