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Social partner gaze direction and conversational phase; factors affecting social attention during face-to-face conversations in autistic adults?

Running title: Eye-tracking conversations in autism

Abstract

Social attention is atypical in autism. However, the vast majority of evidence for this claim comes from studies where the social partner is not physically present and the participants are children. Consequently, to ensure acquisition of a comprehensive overview of social attention in autism, systematic analysis of factors known to influence face-to-face social attention in neurotypicals is necessary and evidence from adulthood is required. The current study assessed the influence of experimenter gaze direction (direct or averted) and conversational phase (speaking or listening) on social attention during a face-to-face conversation. Eye-tracking analyses indicated that when the experimenter looked directly at the participant, autistic adults looked at the experimenter's face less than did neurotypical adults. However, this between-group difference was significantly reduced when the experimenter's gaze was averted. Therefore, opportunities for reciprocal social gaze are missed by autistic adults when the social partner makes direct eye-contact. A greater proportion of time was spent fixating the experimenter's eye region when participants were speaking compared to listening in both neurotypical and autistic adults. Overall, this study provides a rich picture of the nature of social attention in face-to-face conversations adopted by autistic adults and demonstrates individual variation of social attention styles.

Keywords: social attention; autism; mobile eye-tracking; eye movements

Introduction

Prioritising attention towards other people, especially their faces, is an innate social mechanism (Johnson, Dziurawiec, Ellis & Morton, 1991; Goren, Sarty & Wu, 1975). This is an important aspect of social communication as the eyes of others convey an array of information, such as personal identity, thoughts and intentions, and emotional and mental state (Schyns, Bonnar & Gosselin, 2002; Baron-Cohen et al. 2001; Peterson & Eckstein, 2012). The focus of a social partner's attention can also typically be deciphered by looking at their eyes and subsequently following their gaze direction (Bayliss & Tipper, 2005; 2006; Langton & Bruce, 1999). Hence, there are a broad range of reasons why looking at the eye-region of a social partner is beneficial for understanding the current social dynamic. However, the current social dynamic is a fragile construct which can rapidly change. Therefore, to successfully engage in social interactions and social communication it is important that we monitor and continuously update our knowledge on the information afforded by others' eyes.

As humans, our visual system is well adapted for continuous social monitoring. Our natural tendency is to make saccadic eye movements to re-focus the location of our attention three to five times per second. When viewing social scenes, adults tend to spend a disproportionately large amount of time fixated on others' eyes (Hsiao & Cottrell, 2008; Birmingham, Bischof & Kingstone, 2008). This means that we are able to keep on top of the potentially changeable information which often characterises social situations. We tend to look directly at our conversational partner significantly more when listening compared to speaking (Cook, 1977; Argyle & Cook, 1976; Ehrlichman, 1981). This is thought to be reflective of a range of different social and cognitive demands. For example, gaze aversion tends to occur more in adults under high cognitive load, thus assisting with management of cognitive load

(Glenberg, Schroeder & Robertson, 1998); looking directly at the face of the social partner helps an individual to understand what is being said if information is ambiguous (Macdonald & Tatler, 2013); averted gaze acts as a social signal that a conversational turn has been taken (Ho, Foulsham & Kingstone, 2015). Overall, it has been proposed that social attention fulfils both a monitoring and regulating role during conversation (Kleinke, 1986). Therefore, the ability to modulate our social attention depending on the current demands of the conversation helps us to engage in successful social interaction.

For individuals with a diagnosis on the autism spectrum (hereafter termed "autistic"), a wealth of research has demonstrated differences in aspects of social attention when compared to individuals who do not have a diagnosis on the autism spectrum (hereafter termed "neurotypical"). A recent systematic review concluded that the ability to orient towards others' faces in an effective manner is affected in autistic individuals (Guillon, Hadjikhani, Baduel & Rogé, 2014) and a recent meta-analysis of eye-tracking studies assessing social attention in autism suggests an overall small but significant reduction in attention to the eyes, mouth and face of others (Chita-Tegmark, 2016). Differences begin to emerge at a young age (Chawarska, Macari & Shic, 2013; Jones & Klin, 2013; Pierce, Conant, Hazin, Stoner & Desmond 2011; Pierce et al., 2016) and socially complex stimuli elicit the clearest differences from neurotypical patterns of attention (Klin, Jones, Schultz, Volkmar & Cohen, 2002; Hanley, McPhillips, Mulhern & Riby, 2013). Systematic differences in the attentional priority that is given to faces has been observed via analysis of the timings of visual fixations (Fletcher-Watson, Leekam, Benson, Frank, Findlay, 2009; Freeth, Chapman, Ropar & Mitchell, 2010) and reduced visual exploration, assessed via analysis of spread of fixations over time, scan-path length and recursion, when viewing a scene containing a social stimulus, has been observed in those who are autistic (Heaton & Freeth, 2016). Reduced visual exploration, demonstrated via shorter and less frequent saccades, has also been observed in neurotypical individuals high in autistic traits during a face-to-face conversation (Vabalas & Freeth, 2016). It has been proposed that direct gaze does not capture attention in the same way in autistic individuals as it does in neurotypicals (Senju, Kikuchi, Hasegawa, Tojo & Osanai, 2008), with direct gaze tending to elicit heightened emotional approach-related arousal in those who are neurotypical but not those who are autistic (Kylliäinen, et al. 2012). Therefore, this body of research demonstrates that the mechanisms of social attention are different between autistic and neurotypical individuals.

However, the majority of social attention research to date has been conducted via studies where stimuli are presented on a computer screen. Concern has been raised that not all cognitive phenomena, particularly in relation to social attention, play out in the same way when in the presence of a social partner compared to when the social partner is not physically present (see Risko, Richardson & Kingstone, 2016; Risko, Laidlaw, Freeth, Foulshsm & Kingstone, 2012 for reviews). It is important to know whether the rules of social attention observed in computer-based studies hold for live face-to-face conversations. When viewing stimuli on a computer, pictures that are highly arousing (of both positive and negative valence) tend to capture attention to a greater extent than pictures that elicit lower levels of arousal (Vogt et al., 2008). However, in complex interactions with others, over stimulation often leads to withdrawal in order to conserve cognitive resources (Doherty-Sneddon et al. 2012). There has been suggestion that in face-to-face conversations the rules of social norms can profoundly affect behaviour as the social partner has the potential to judge a participant's behaviour (Laidlaw et al., 2011, Gobel et al., 2015). This potential for social interaction is absent from computer-based studies and therefore a key element that influences social attention is missing from computer-based social attention studies.

Recently, studies have begun to emerge that systematically analyse aspects of social attention in autism in live face-to-face situations using mobile eye-tracking devices. A study that compared attention distribution during a live interaction with an experimenter found that autistic children (aged 8-13 years) attended to the experimenter's face, particularly the eyes, significantly less than both a matched group of children diagnosed with Specific Language Impairment (SLI) and a group of neurotypical children (Hanley et al., 2014), see Noris et al. (2012) and Magrelli et al. (2013) for studies reporting concordant findings comparing social attention in autistic and neurotypical chilren. Further, Hutchins & Brien (2016) found reduced fixations to the eyes to be particularly pronounced when analysing eye movements of autistic children (aged 6-12 years) discussing "things that people feel" compared to "things that people do" during a Skype conversation. However, there are eye-tracking studies reporting no differences in the social attention patterns of autistic children and matched controls during face-to-face interactions (Nadig et al. 2010; Falck-Ytter, Carlström & Johansson, 2015), though these studies did not differentiate between fixations on the eyes and on the mouth, hence it is possible that differences in social attention did exist but the methodologies used did not have the precision to detect such differences.

Studies assessing social attention in autistic adults are more sparse. A study reporting on social attention patterns of autistic university students while engaged in a live interaction with an experimenter observed no reduction in attention to the experimenter's face overall (Hanley et al., 2015). However, when fixations were categorised into different facial regions, reduced fixations to the eye region and increased fixations on the mouth region were observed. Of methodological interest, the gaze direction of the experimenter was not systematically manipulated or analysed in this study, nor were potential differences between social attention according to conversational phase (speaking or listening) assessed. Hence, it is currently unknown whether these two factors influence social attention in autistic adults in a similar or different way to neurotypical adults.

In a systematic analysis of patterns of social attention during both a live face-to-face conversation and a conversation where the social partner was presented on a pre-recorded video, we found that whether the gaze direction of the social partner was direct or averted only influenced social attention during a live conversation but not during one which presented the social partner on a video (Freeth, Foulsham & Kingstone, 2013). Hence, it is important to assess factors that may impact social attention directly in face-to-face paradigms. In the current study the first main aim was to investigate whether adult participants' social attention when engaged in a conversation with a social partner who was looking directly at the participant differed between autistic individuals and neurotypical individuals, as has previously been observed in computer-based studies with autistic children (Senju et al. 2008; Kylliäinen, et al. 2012; Hutchins & Brien, 2016) and face-to-face studies with autistic children (Hanley et al. 2014; Magrelli et al. 2013). The second main aim was to investigate whether increased looking to the social partner's eyes when listening compared to speaking, widely observed in neurotypical individuals (e.g. Ehrlichman, 1981), would also be observed in autistic individuals. To this end an experimenter conducted one-to-one conversations with autistic adults, and age, gender and ability matched neurotypical adults. Social attention was monitored using a highly accurate mobile eye-tracking device allowing assessment of location of fixations on specific areas of interest within the visual array, including different facial regions. We predicted that when the experimenter looked directly at the participant's face, there would be increased attention to the experimenter's face by participants in the neurotypical group compared to the autistic group. We predicted that social attention differences between groups would be stronger when the experimenter looked directly at the participant compared to when the experimenter averted her gaze. We anticipated that we would observe increased looking to the experimenter's face while the participant was listening compared to speaking in neurotypical adults due to awareness of social norms (Laidlaw et al. 2011; Freeth et al. 2013). We predicted reduced modulation of attention across conversational phase in autistic adults; firstly due to reduced awareness of social norms, which is closely linked to the diagnostic criteria for autism (DSM 5, 2013), and secondly as we anticipated that arousal would be high, due to being asked to engage in a social interaction with an experimenter, both when speaking and listening for autistic adults hence there would be a tendency to avert gaze to reduce arousal in both phases (cf. Doherty-Sneddon et al. 2012). Finally, due to recent observations of reduced visual exploration when viewing social scenes (Heaton & Freeth, 2016) and reduced visual exploration during a face-to-face conversation in individuals high in autistic traits, but without a diagnosis of autism (Vabalas & Freeth, 2016), we predicted that reduced visual exploration during the face-to-face conversation, indicated by reduced fixation frequency and/or reduced frequency of shifts between different areas of interest, would be observed in the autistic participants in the current study.

Method

Participants

Thirteen adults with a diagnosis on the autism spectrum (11 males; 2 female) and 13 neurotypical adults (10 males; 3 females) participated in this study. Participants were matched one-to-one on age (within 5 years), verbal IQ and performance IQ assessed using the Wechsler Abbreviated Scale of Intelligence. For one participant in the autism group, although a high quality eye-tracking calibration was obtained, it was not possible to use the data produced in the interview due to the participant spending a large portion of the interview squinting, thus precluding fixation data being recorded. In addition, one participant in the autism group did not complete all aspects of the conversation due to finding the task challenging. However, the data collected from this participant was of high quality and the total amount of data collected was not significantly less than for the rest of the group so was therefore included in the analyses. Thus, the final sample of autistic adults comprised 12 individuals (see Table 1). All participants with a diagnosis on the autism spectrum had received an official diagnosis from a clinical psychologist in the UK based on DSM or ICD criteria. All participants completed the Autism Spectrum Quotient (AQ) as an indicator of current behavioural traits associated with autism. An independent samples *t*-test indicated a highly significant difference between groups on total AQ score, $t(23)=7.30$, $p<.001$, $d=3.04$.

Table 1. Participant characteristics

	Autism participants	Neurotypical participants
Gender (Male : Female)	11 : 1	10 : 3
Age		
Mean	35.1	34.8
SD	12.7	13.7
Range	22 – 57	19 – 57
Verbal IQ		
Mean	113.4	114.8
SD	13.9	8.8
Range	88 – 129	100 – 136
Performance IQ		
Mean	117.6	114.7
SD	10.9	10.3
Range	105 – 131	100 – 134
AQ		
Mean	35.3**	13.5**
SD	10.9	6.3
Range	21 – 45	6 – 28

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

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 resolution and up to 0.1° spatial resolution. This was combined with a recording from a 24Hz front view camera with a field of view: 60° horizontal, 46° vertical. In accordance with manufacturer recommendations, the eye-tracking device was fitted to each participant who then looked around the visual field for a couple of minutes before a one-point calibration was conducted. Participants were asked to fixate on a fixed point in the visual field, the tip of the experimenter's finger held adjacent to her face. The experimenter sat at the same distance from the participant for the calibration procedure and data collection (approximately 1m). The experimenter's face subtended approximately 12° of visual angle. Accuracy of calibration was assessed by observing the location of gaze fixation mapped on to the visual field view recording on the SMI-ETG laptop screen while the participant followed the experimenter's finger as she moved it to different positions. If a successful calibration was not achieved on the first attempt, up to two further attempts to calibrate were made. All participants were successfully calibrated within three attempts hence no participants needed to be excluded on this basis. Accuracy of calibration was checked by a second experimenter at the data coding phase. Fixations, saccades and blinks were defined by standard SMI algorithms. Viewing locations were coded using SMI BeGaze software. Fixation locations indicated by a marker on the video, recorded by front view camera, were manually mapped fixation-by-fixation onto a reference view (Figure 1a). The AOIs were eyes, mouth, outer face, body and background (all AOIs which were not on the experimenter were collapsed together for analysis purposes due to small proportions of fixations being on these areas) (see Figure 1b).

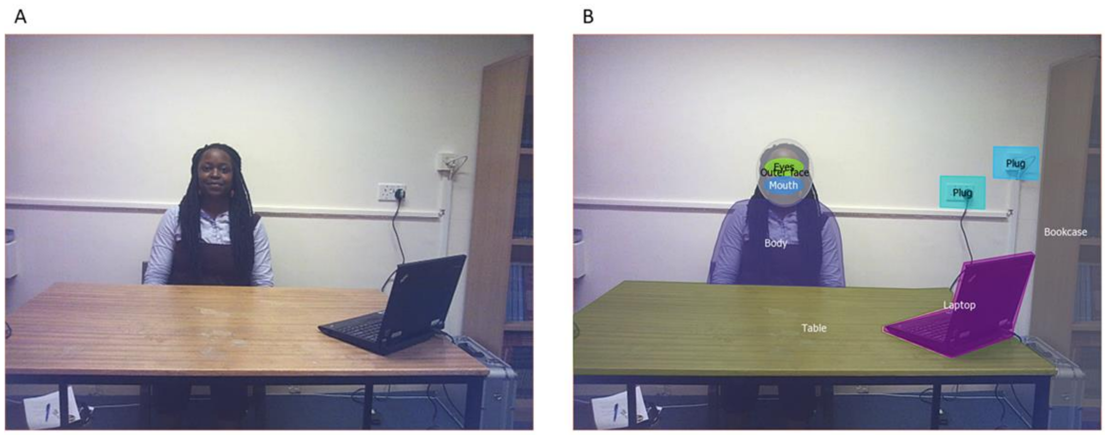

Figure 1. (a) A typical view seen by a participant during the experiment and (b) areas of interest.

All participants completed the Autism-spectrum Quotient (AQ) questionnaire. Scores on this 50 item self-report questionnaire provide an indicator of the degree to which an individual possesses traits associated with the autistic spectrum. The Baron-Cohen et al. (2001) collapsed scoring method was used: responses in the ‘‘autistic’’ direction were given a score of 1, and responses in the ‘‘non-autistic’’ direction were given a score of 0. Participants therefore received a score between 0 and 50, higher scores indicating the presence of more autistic traits.

Procedure

Participants sat across the desk from the female experimenter approximately one metre away. All participants completed a live, one-to-one informal conversation with the experimenter (for a typical view see Figure 1a). Before the task began, the experimenter fully explained and demonstrated to the participant how the eye-tracker worked and gave each participant the opportunity to put the eye-tracker on and take it off again to ensure they were comfortable with wearing it. During this phase, the experimenter tried to put the participant at ease as much as possible. Participants were told that during the conversation task they would discuss four topics with the experimenter and that the conversation about each topic will last for at least 30 seconds. Participants were informed that their responses did not need to be accurate but instead the goal of the task was to have an informal conversation and that there were no right or wrong answers. Participants were shown the four topics in advance of the formal start of the conversation while they were getting used to wearing the eye-tracker. The four topics were 1) "Living in XX - things that you like and don't like about living in XX"; 2) "Weekend plans – things that you did last weekend and any plans that you may have for this weekend"; 3) "National traits – things that you consider to be typically English and things that you consider to by typically French"; 4) "Hobbies – things that you like to do in your spare time". In the first phase of the conversation, the experimenter led the conversation. She introduced each of the four topics sequentially and in-between waited for the participant to speak about the topic. To ensure that the conversation was as naturalistic as possible, the experimenter commented on parts of the answer to encourage flow of conversation. If the experimenter felt that the participant may have spoken for less than 30 seconds, the experimenter prompted the participant to speak further on the topic by making ad-hoc comments or asking follow-up questions. The second phase of the conversation followed completion of phase one. In the second phase the experimenter told the participant that it was their turn to ask the questions.

The participant was reminded of the topics where necessary. The participant then proceeded to ask the experimenter to speak about each of the four topics sequentially.

Experimenter eye gaze direction was systematically manipulated between the different task phases from which eye-tracking data was analysed, but for the rest of the time was unconstrained. For both phase one and phase two of the task during two of the four topics the experimenter looked directly at the participant while introducing the topic and listening to the answer the participant gave. For the other two topics, the experimenter averted her gaze away from the participant's face. The experimenter's body position did not change depending on experimenter eye-contact. The order of these eye gaze direction manipulations were counterbalanced between participants but questions were always asked in the same order.

Thus, overall the task contained sixteen parts. In phase one the experimenter led the conversation. She asked about four different topics and then listened to the participant's answers to each of these four topics. For two of the topics, the experimenter looked directly at the participant's eyes. For the other two topics, the experimenter averted her gaze away from the participant's face and either looked downwards or to the side. In phase two the participant led the conversation. The participant asked about four different topics and listened to the experimenter's answers to each of these four topics. For two of the topics, the experimenter looked directly at the participant's face. For the other two topics, the experimenter averted her gaze. As for phase one, the order to experimenter eye-contact manipulation was counterbalanced between participants.

Eye-tracking data was recorded throughout the duration of the task. However, data was only coded, and analysed, for segments where the questions were being asked on each of the four topics and where the first 30 seconds of answers on each of the four topics were being given. Any comments from the experimenter when the participant was answering were not included in coding. Any comments from the participant when the experimenter was answering were not included in coding. The study was reviewed and approved by the University of Sheffield Ethics sub-committee.

Results

The amount of fixation data collected for participants in each group did not significantly differ, $t(23)=0.08$, $p=.93$, $d=0.03$ (mean autism group=145,904ms, SD=43,620; mean neurotypical group=144,486ms, SD=44,467). Nonetheless, as participants did inevitably contribute somewhat differing amounts of data, and we were interested in relative interest in the different AOIs, all total fixation data was converted into proportion data, i.e. total fixation duration on each AOI was divided by the total amount of data recorded for each participant in each phase so that each participant's relative attention capture by each AOI in each phase could be assessed. In the following sections as well as presenting results of standard parametric analyses, we also present results of bayesian analyses in order to indicate the strength and clarity of the evidence observed. BF_{H0} indicates the bayes factor value in favour of the null hypothesis; BF_{H1} indicates the bayes factor value in favour of the alternative hypothesis. BFs range from zero to infinity with higher values expressing stronger evidence for the respective hypothesis, with BFs>3 indicating substantial evidence (Wetzels and Wagenmakers, 2012). N.B. Bayes factors are only reported where error % was sufficiently low to indicate reliable analyses.

Eye-contact analysis

In order to investigate whether the gaze direction of the experimenter influenced the participant's distribution of social attention during the entire conversation task overall, proportion of time spent fixating the experimenter's face was assessed using a 2x2 (group x experimenter eye gaze direction) mixed-measures ANOVA. There was no main effect of experimenter eye gaze direction, $F(1,23)=0.36$, $p=.55$, $\eta\rho^2=.02$ ($BF_{H1}=0.31$; $BF_{H0}=3.26$;) indicating that overall participants did not look more or less at the experimenter's face depending on whether the experimenter was looking directly at their face or not. There was a trend for a main effect of group that approached significance, $F(1,23)=3.72$, $p=.066$, $\eta\rho^2=.14$ ($BF_{H1}=1.57$; $BF_{H0}=0.64$) as autistic participants tended to spend a smaller proportion of their time fixating the experimenter's face overall. However, importantly for the research hypothesis that experimenter eye gaze direction would differentially effect participants in each group, there was a significant group x eye gaze direction interaction, $F(1,23)=4.85$, $p=.038$, $\eta\rho^2=.17$ ($BF_{H1}=2.10$; $BF_{H0}=0.48$). Post-hoc *t*-tests indicated that when the experimenter made direct eye-contact, autistic participants spent a much smaller proportion of their time fixating on the experimenter's face than the neurotypical participants did, $t(13.5)=2.30$, $p=.038$, $d=1.0$[1] ($BF_{H1}=2.56$; $BF_{H1}=0.39$). However, there was no significant difference between groups in the proportion of time spent fixating the face when the experimenter's gaze was averted, $t(23)=1.25$, $p=.22$, $d=0.5$ ($BF_{H1}=0.65$; $BF_{H0}=1.54$)(see Figure 2a).

Levene's test for equality of variance indicated that when the experimenter looked directly at the participant, the proportion of time spent fixating the experiment's face was more variable for the autistic participants than for the neurotypical participants ($p<.001$). No such difference was observed for the data where the experimenter averted her gaze ($p=.15$). The increased variability in the autistic adults' data compared to the neurotypical adults' data for the direct eye gaze condition can be seen in Figure 2b. While some autistic adults spent a similar proportion of their viewing time fixating the experimenter's face when direct eye-contact was made, 5/12 participants spent a smaller proportion of time fixating on the experimenter's face

[1] Levene's test for equality of variances was significant hence values for equality of variances not assumed is reported.

than any of the neurotypical participants, indicating that clear evidence of reduced attention to the experimenter's face is evident in a subset of the autistic adult group, and that attention to the experimenter's face when direct eye-contact was made was highly variable in the autistic group.

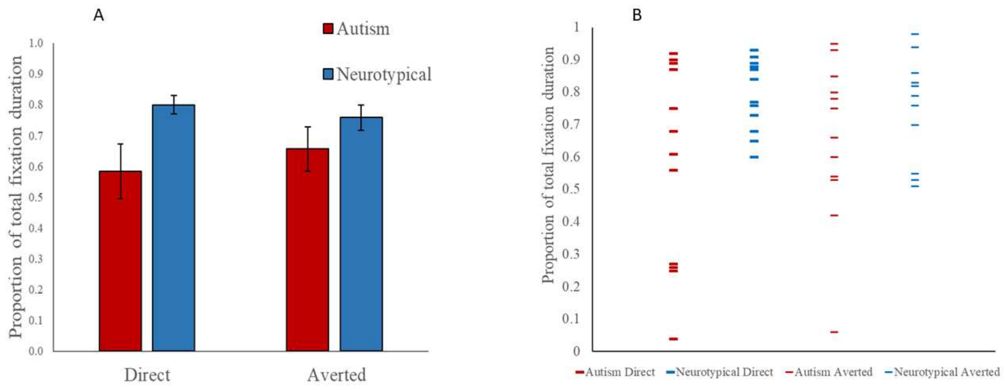

Figure 2. Proportion of total fixation duration on the experimenter's face: (a) group means per condition (error bars represent ±1 standard error) and (b) individual participant's data.

Face Region Analysis

Since a trend for an overall difference in proportion of fixations on the face was observed between groups, we were interested to discover whether this was associated with differences in proportion of fixations to the eyes or mouth, n.b. the area corresponding to "eyes" was exactly the same size as the area corresponding to "mouth" and these were a subset of overall face fixations (see Figure 1b). To that end, a 2x2x2 (group x experimenter eye gaze direction x face region) mixed measures ANOVA was conducted to assess whether there were differences in relation to proportion of fixations on the eye-region or the mouth region. There was a significant group x face region interaction, $F(2,46)=4.70$, $p=.041$, $\eta\rho^2=.17$[2]. As can be seen in Figure 3a, the neurotypical participants spent a greater proportion of their time fixating the experimenter's eye region than the mouth region, $t(12)=2.34$, $p=.037$, $d=0.91$ (($BF_{H1}=2.03$; $BF_{H0}=0.48$), this trend was not evident in the autistic participants, $t(11)=-0.70$, $p=.50$, $d=0.21$ ($BF_{H1}=0.36$; $BF_{H0}=2.82$). There was no significant 3-way interaction, $F(1,23)=0.19$, $p=.67$, $\eta\rho^2=.008$[2], indicating that experimenter eye-contact did not play a significant role in this pattern of differential fixations patterns between regions.

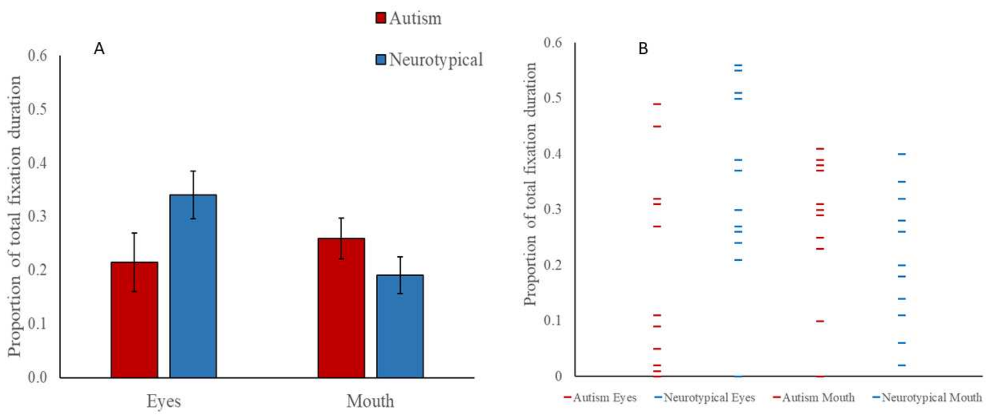

Figure 3. Proportion of total fixation duration on the experimenter's face regions: (a) group means per condition (error bars represent ±1 standard error) and (b) individual participant's data.

The effect of conversational phase on proportion of fixations on the eyes

In order to investigate whether the difference between groups in proportion of time spent fixating the eyes observed in the previous analysis was affected by conversational phase, the data were split further. The phases of the conversation where the participant was answering questions was split from the phases of the conversation where the participant was listening to questions being answered. A 2x2x2 (group x experimenter eye gaze direction x phase) mixed measures ANOVA found a significant main effect of conversational phase, $F(1,22)=7.98$,

[2] Bayes Factors were not reliable for this analysis

p=.010, $\eta\rho^2$=.27 (BF_{H1}=34.89; BF_{H0}=0.03), as participants tended to spend a greater proportion of their time fixating the experimenter's face when they were listening compared to when they were speaking (see Figure 4). There was also a significant experimenter eye gaze direction x phase interaction, F(1,22)=5.08, p=.035, $\eta\rho^2$=.19[3] (see Figure 4). Post-hoc t-tests indicated that participants tended to spend a reduced proportion of time fixating the eyes when speaking compared to listening when the experimenter's gaze was direct, t(23)=4.05, p<.001, d=0.88, (BF_{H1}=65.33; BF_{H0}=0.02) but this difference was not significant when the experimenter's gaze was averted, t(23)=1.21, p=.24, d=0.25, (BF_{H1}=0.42; BF_{H0}=2.40). There was no significant group x phase interaction, F(1,22)=0.06, p=.80, $\eta\rho^2$=.003[3], indicating that the tendency to reduce eye fixations when speaking compared to listening did not significantly differ between groups (see Figure 4). In addition, no significant 3-way interaction was observed, F(1,22)=0.16, p=.70, $\eta\rho^2$=.007[3]. As can be seen by comparing Figure 4a and b, the nature of the phase x experimenter eye gaze direction interaction is similar for the neurotypical participants and the autistic participants.

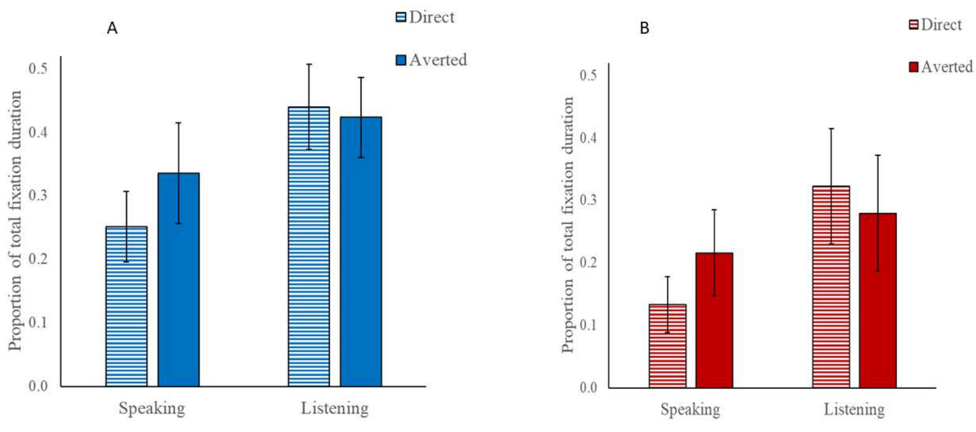

Figure 4. Proportion of total fixation duration on the experimenter's eyes (error bars represent ±1 standard error): (a) neurotypical participants and (b) autistic participants.

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[3] Bayes Factors were not reliable for this analysis

Visual exploration analysis

In order to test our hypothesis that autistic individuals would display reduced visual exploration, frequency of eye movements were compared between groups. Although there was a numerical trend for autistic participants to make less frequent eye movements than neurotypical participants, as indicated by longer mean fixation duration for autistic participants, this did not reach significance, $t(23)=1.16$, $p=.26$, $d=0.48$ ($BF_{H1}=0.60$; $BF_{H0}=1.67$) (see Figure 5). We also assessed whether participants in either group moved their point of fixation between different areas of interest more frequently. The frequency of shifts between areas of interest did not differ between groups (autistic group mean=1.87 shifts per second, $SD=0.38$; neurotypical group mean=2.08 shifts per second, $SD=0.76$), $t(23)=-0.87$, $p=.39$, $d=0.36$ ($BF_{H1}=0.49$; $BF_{H0}=2.06$), nor did frequency of shifts on and off the face differ between groups (autistic group mean=0.70 shifts per second, SD=0.30; neurotypical group mean=0.73 shifts per second), $t(23)=-0.21$, $p=.84$, $d=0.09$ ($BF_{H1}=0.37$; $BF_{H0}=2.68$). These results, therefore, did not support the hypothesis that autistic individuals would demonstrate significantly reduced visual exploration during the face-to-face conversation.

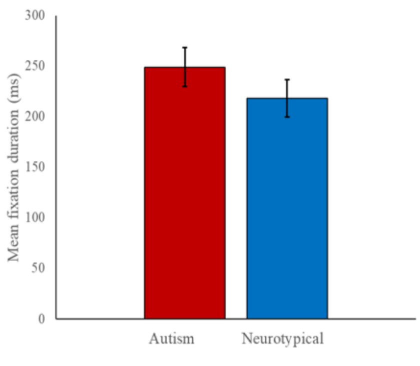

Figure 5. Mean fixation duration throughout the whole conversation task for each group (error bars represent ±1 standard error).

Discussion

The aim of the current study was to investigate whether the nature of social attention significantly differs between autistic individuals and neurotypical individuals during a face-to-face conversation with an experimenter and whether specific factors influence the social attention of autistic individuals in a similar or different manner to neurotypical individuals. We investigated whether the eye gaze direction of the social partner (direct or averted) had a differential effect on each group. In line with our hypothesis, we found that reduced attention to the face by the autistic participants was particularly pronounced when the social partner looked directly at the participant. The strength of this effect reduced when the social partner's gaze was averted. During the conversation, the regions of the face attended to significantly differed between groups. In accordance with previous research (Hanley et al. 2015), autistic adults displayed significantly reduced fixations to the eye-region but not the mouth-region compared to neurotypical adults. The second main factor of interest was the impact of conversational phase (i.e. when the participant was speaking or listening) on social attention. As expected, participants displayed significantly reduced attention to the experimenter's eyes when speaking compared to listening. The nature of this effect did not differ between groups suggesting that modulation of social attention depending on the conversational phase is something that both neurotypical and autistic individuals do, which did not support our hypothesis that autistic adults would display reduced social attention modulation in relation to conversational phase. Finally, we were interested to discover whether evidence of reduced visual exploration would be observed in the autistic group. We found no significant reduction in visual exploration as assessed by fixation frequency, or frequency of shifts between different areas of interest or shifts on and off the face, though due to the study sample size we only had sufficient statistical power to observe large between-group differences.

A clear finding from this study was that attention to the experimenter's face was significantly reduced in the autistic adults compared to the neurotypical adults when the experimenter looked directly at the participant. Reduced social attention in response to direct eye gaze means that autistic adults will have fewer opportunities for gaining the important information afforded by others' faces during conversations. Information missed includes opportunities for knowledge on the social partner's thoughts, intentions, and emotional and mental state (Schyns, Bonnar & Gosselin, 2002; Baron-Cohen et al. 2001; Peterson & Eckstein, 2012). In addition, if individuals aren't attending to the social partner's face, they will have reduced opportunity to decipher the focus of attention and to follow gaze direction cues (Bayliss & Tipper, 2005; 2006; Langton & Bruce, 1999). Three main reasons for reduced social attention in autism have been proposed. The first is reduced social motivation (Chevallier, Kohls, Troiani, Brodkin & Schulz, 2012), the second is finding faces, the eyes in particular, aversive (Tanaka & Sung, 2016; Kliemann, Dziobek, Hatri, Baudewig, Heekeren, 2012), the third is a lack of normative approach-related motivational response to eye contact (Kylliäinen, et al. 2012). Data from the current study does not support the first explanation as reduced social attention was only observed when the experimenter looked directly at the participant. If reduced social attention was solely due to reduced social motivation then the significant interaction between group and eye-contact on proportion of fixations on the face would not have been observed. Both the second and third explanation are plausible on the basis of the observed data. It is possible that one explanation is more relevant for certain individuals than others; investigating whether this is the case will be an important question for future research. Conversely, there could also be additional factors at play, such as perceived social rank of the experimenter or perceived dominance of the experimenter. If the social partner is perceived to be of a higher social rank, or to be holding a dominant posture, this can reduce social attention to that partner (Gobel, Kim & Richardson, 2015; Holland, Wolf, Looser, & Cuddy, 2017). Reduced social attention could also be due to participant concern that the experimenter may be monitoring their behaviour when the experimenter looks directly at the participant (Risko et al. 2016). Whether these factors influence the social attention of autistic adults has not yet been investigated but would be important future directions for gaining a better understanding of social attention modulation in autistic individuals.

In the current study, conversational phase had a clear effect on social attention. When listening participants spent a higher proportion of their time fixating the experimenter's face than when speaking. These findings are in line with a broad range of previous research (e.g. Ehrlichman, 1981; Argyle & Cook, 1976; Cook, 1977). However, this has not previously been assessed in autistic adults. A very similar pattern of results in relation to conversational phase was observed in the autistic adults as for the neurotypical adults indicating that autistic adults do modulate their social attention depending on the conversational phase, in a similar manner to neurotypical individuals. Increasing gaze aversion while speaking can serve a range of important functions, such as to reduce cognitive load (Doherty-Sneddon & Phelps, 2005), to facilitate understanding of ambiguous information (Macdonald et al. 2013) and to indicate that a conversational turn has been taken (Ho et al. 2015). It is therefore important to note that these effects were observed both in the autistic group and the neurotypical group.

Visual exploration was assessed in the current study in three different ways. Frequency of eye movements overall, the frequency of between area of interest shifts and the frequency of shifts between the face and other regions was assessed. On each measure there was a numerical trend for reduced visual exploration in the autistic group. However, none of these trends reached significance leading us to conclude that we did not find evidence for reduced visual exploration in the autistic group. This is in contrast to the nature of findings from other studies in which participants viewed static scenes containing a person (Heaton & Freeth,

2016) and findings from a face-to-face conversation where increased autistic traits in neurotypical adults were associated with reduced visual exploration (Vabalas & Freeth, 2016). However, we are cautious about drawing the conclusion that autistic adults do not display reduced visual exploration during a face-to-face conversation as due to the sample size of the current study we were only able to confidently observe large between-group differences. An important future direction will be to test whether small or medium-sized effect differences in visual exploration exist between autistic and neurotypical adults, as even small differences could have a profound impact on the type of information that can be gleaned from a rapidly changing social situation.

The high variability in proportion of fixations to the experimenter's face in the autistic group throughout the face-to-face conversation questions the feasibility of searching for clear rules that define autistic social attention, despite this being the goal of the vast majority of social attention in autism research (see Guillon et al. 2014 for a review). It was striking to observe that some autistic adults were in the neurotypical range with regards to proportion of time spent fixating the experimenter's face, though just below half of the autistic adults looked to the experimenter's face less than any individuals in the neurotypical group. In future work it will be important to investigate individual differences in social attention further, including analysis of whether factors that predict very low attention to a social partner's face in autistic adults can be identified, such as generalised anxiety, social anxiety or depression. It will also be important for social attention to be assessed in ecologically valid face-to-face contexts, particularly as previous research has demonstrated that the nature of findings can be different when a social partner is or is not physically present (Laidlaw et al. 2011; Freeth et al. 2013; Risko et al. 2016; Risko et al. 2012).

A limitation of the current study is that due to the sample size, it was only possible to detect large between group differences, leaving open the possibility that more subtle between group differences exist but could not be observed. Due to the complex nature of social attention and that small differences of attention can have a profound effect on cognition (Dawson, et al. 2004) future research designed to have the power to detect small between group differences would be beneficial.

In conclusion, the main findings of this study were that direct eye contact by the experimenter resulted in overall reduced proportion of fixations to the face in the autistic adults compared to neurotypical adults. However, there was striking variability in the data in the autistic group. Future research should investigate the predictors of this variability. Participants tended to look more to the experimenter's face while listening compared to speaking, the nature of this effect did not significantly differ between groups. Although there were numerical trends for reduced visual exploration in autistic adults compared to neurotypicals, this did not reach significance. Overall, the current study provides insight into the nature of social attention in autistic adults during face-to-face conversations and systematically investigated some of the factors that influence social attention.

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Tables

Table 1. Participant characteristics

	Autism participants	Neurotypical participants
Gender (Male : Female)	11 : 1	10 : 3
Age		
Mean	35.1	34.8
SD	12.7	13.7
Range	22 – 57	19 – 57
Verbal IQ		
Mean	113.4	114.8
SD	13.9	8.8
Range	88 – 129	100 – 136
Performance IQ		
Mean	117.6	114.7
SD	10.9	10.3
Range	105 – 131	100 – 134
AQ		
Mean	35.3**	13.5**
SD	10.9	6.3
Range	21 – 45	6 – 28

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