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ORIGINAL PAPER

Effects of Observing Eye Contact on Gaze Following in High-Functioning Autism

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Abstract Observing eye contact between others enhances the tendency to subsequently follow their gaze and has been suggested to function as a social signal that adds meaning to an upcoming action or event. The present study investigated effects of observed eye contact in high-functioning autism (HFA). Two faces on a screen either looked at or away from each other before providing congruent or incongruent gaze cues to one of two target locations. In contrast to control participants, HFA participants did not depict enhanced gaze following after observing eye contact. Individuals with autism, hence, do not seem to process observed mutual gaze as a social signal indicating the relevance of upcoming (gaze) behaviour. This may be based on the reduced tendency of individuals with HFA to engage in social gaze behavior themselves, and might underlie some of the characteristic deficiencies in social communicative behaviour in autism.

Keywords Gaze following · Joint attention · Social cognition · High-functioning autism

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Introduction

Communication and social interaction involve various instances in which we engage in eye contact, i.e. mutual gaze, with others or in which we jointly attend to the environment by coordinating our gaze (Baldwin 1995). People actively seek eye contact, direct others' attention to the environment, and detect objects or events by rapidly shifting attention according to others' gaze (Bakeman and Adamson 1984; Driver et al. 1999; Mundy et al. 2007; Farroni et al. 2002; Friesen and Kingstone 1998). Recent evidence suggests that initiating joint attention by directing someone else's gaze is associated with increased activity in reward-related neurocircuitry (Schilbach et al. 2010). Attending to and with others, in turn, plays an important role in the coordination of joint actions (Clark and Krych 2004; Richardson and Dale 2005; Sebanz et al. 2006), in social learning (Csibra and Gergely 2009; Striano et al. 2006), in communication (Tomasello et al. 2005; Tomasello and Carpenter 2007), and in the regulation of social relations (Ham and Tronick 2006).

More generally, joint attention constitutes a simple form of a social encounter and, as such, contributes to our understanding of other persons' inner experiences (including perceptions, thoughts, intentions to act) and their behaviour (Schilbach 2010; Schilbach et al. 2012, 2013). Attending with others has been argued to underlie the development of social skills by establishing an understanding of self and other as distinct agents who can have (different) mental states such as desires, beliefs, or goals (Baron-Cohen 1991; Barresi and Moore 1996; Reddy 2003).

Autism is a developmental disorder that is characterized by impairments of communication and social interaction and, specifically, a lack of the ability to intuitively infer other people's mental states (10th revision of the International Classification of Diseases, ICD-10, World Health Organization; Baron-Cohen 1995; Hill and Frith 2003). Individuals with autism also show a reduced motivation to share attention with others from their first years of life onward (Chevallier et al. 2012). While reflexive gaze following (see Frischen et al. for a review) seems relatively preserved in autism (Chawarska et al. 2003; Kylliäinen and Hietanen 2004; see Nation and Penny 2008 for a review), the neural mechanisms underlying this effect differ between individuals with and without autism (Greene et al. 2011). Also, individuals with autism initiate joint attention to a lesser extent (Mundy et al. 1994; Mundy 2003; Sigman and Ruskin 1999), are less sensitive to social gaze (Schilbach et al. 2011), and tend to avoid eye contact, which has been shown to increase arousal (increased skin conductance response) (Kylliäinen and Hietanen 2006). Besides being less prone (or even averse) to the direct experience of eye contact and gaze-based communication, individuals with autism show a reduced tendency to direct attention to the eyes of observed others (e.g. in video clips), particularly in dynamic social interactions (Speer et al. 2007).

A question that has not been addressed until now is how observed attentional relations between others are processed in autism and how this influences subsequent behavior. How is eye contact perceived and interpreted when it is merely observed between two agents? The aim of the present study was to investigate whether individuals with autism process observed attentional relations in similar ways as non-autistic individuals. For this purpose, we employed an established paradigm that targets the effect of observing eye contact between two persons on subsequent processing of gaze cues. In this task, two faces were depicted that provided gaze cues after they had established eye contact with each other or not (Böckler et al. 2011). Previous findings revealed that healthy participants showed an enhanced sensitivity to gaze cues when the two faces had looked at each other beforehand. This extended earlier findings of increased gaze following after being looked at oneself (Bristow et al. 2007; Senju and Csibra 2008) and suggests that both experienced and observed eye contact may act as 'ostensive cues', enhancing the perceived significance of subsequent (gaze) behavior (Csibra and Gergely 2009).[1]

Does observing mutual gaze in others also enhance the use of subsequent gaze cues in high-functioning individuals with autism (HFA)? The category HFA comprises people diagnosed with Asperger's syndrome and Childhood Autism with average or above-average IQ. High-functioning individuals may be better able to understand interactions that are merely observed (as compared to interactions they are involved in), since the observational stance might make the use of learned and rule-based compensatory strategies easier (e.g. counting words as an indicator of mood; Schilbach et al. 2011, 2013). Also, observed eye contact may not automatically elicit the same emotional consequences (increased arousal) in individuals with autism as being engaged in eye contact oneself and could, hence, constitute less arousing or less aversive social information. Previous studies have reported that individuals with autism process low-level social information (i.e. information that can be processed without higher-order theory of mind) in similar ways as non-autistic people. For instance, participants with high-functioning autism (HFA) showed an automatic understanding of others' different spatial perspective (Zwickel et al. 2010) and took certain aspects of a co-actor's task (e.g. stimulus and response location) into account, even though this was irrelevant for performing their own tasks (Sebanz et al. 2005). Accordingly, observed eye contact between others may be processed as a low-level social signal that attracts attention and highlights others' subsequent behaviour.

On the other hand, several studies have shown that individuals with autism are specifically impaired in understanding communicative signals (Baron-Cohen 1989; Baron-Cohen et al. 2000; Happé 1993) and make less use of gaze-based cues to infer others' intentions, predict their behaviour (Pierno et al. 2006), or form evaluative impressions of others (Kuzmanovic et al. 2011). The interpretation of observed eye contact as being communicatively meaningful might depend on previous experiences with such signals. Specifically, people may understand observed attentional relations as communicative by mapping them onto their own experiences of being engaged in such relations (Barresi and Moore 1996). Since individuals with autism experience difficulties with the understanding of communicative cues directed at them, it is possible that they also do not process the communicative aspect of mutual gaze when it is merely observed, or do so to a lesser extent.

The present study applied a third-person observation setting of shared attention in order to investigate the processing of observed eye contact in HFA participants. If HFA participants process observed eye contact as an indication for the relevance of the subsequent gaze cues (as do healthy subjects, see Böckler et al. 2011) we should find enhanced gaze cueing effects after the observation of eye

[1] Note that the term 'observed eye contact' refers to the observation of eye contact between other agents (not the experience of being looked at oneself).

contact. Conversely, if individuals with autism are not responsive to the social cue of observing eye contact in others we should not find an increase in gaze cueing subsequent to the observation of eye contact.

Methods

Participants

Twenty-seven persons who underwent an autism screening and were diagnosed with HFA (9 female; age range from 20 to 62 years, mean age 41 years) participated in the experiment. Their performance was compared to 25 control participants (10 female, age range from 21 to 63 years, mean age 41 years) who were matched with respect to age, gender, and years of education. All patients were diagnosed and recruited in the Autism Outpatient Clinic at the Department of Psychiatry at the University of Cologne (Germany). As part of a systematic assessment implemented in this clinic, diagnoses were made by two independent specialized clinicians corresponding to ICD-10 criteria and supplemented by an extensive neuropsychological assessment. Patients with the diagnosis of Asperger's syndrome (F84.5) and childhood autism (F84.0) were included when average or above-average IQ had been ascertained. All patients, therefore, belonged to the HFA population. Due to the fact that both diagnostic groups exhibit a comparable intellectual level of functioning and that differences in diagnostic criteria relate to language development in early childhood irrelevant for the adult level of social adaptation, the two diagnoses were subsumed under the term HFA. None of the participants received psychotropic medication. Control participants were tested at the Radboud University Nijmegen (the Netherlands).

Participants completed several questionnaires, including the AQ ("Autism Quotient", Baron-Cohen 2003), the EQ ("Empathy Quotient") and the SQ ("Systemizing Quotient", Wheelwright et al. 2006), and the BDI ("Beck Depression Inventory", Beck and Steer 1987) (see Table 1 for demographic and questionnaire data). Three of the autistic participants did not complete the EQ and the SQ. As depression is a common co-morbidity in HFA (e.g. Stewart et al. 2006) it does not come as a surprise that there was a significant difference in the BDI score for the control and the HFA group (see Table 1). Consistent with the clinical diagnoses, there were also significant differences in the AQ between the patient and the comparison group (see Table 1) (Wheelwright et al. 2006). The testing environments of the two sites (Cologne and Nijmegen) were kept as similar as possible. Participants were welcomed and instructed using a predefined script; they were then seated in front of a 17-in. TFT computer screen and performed a training session. When they had no more questions, the experimental session began. Light was kept at an ambient level. Questionnaires were filled in after the experimental session.

Stimuli and Procedure

Stimuli were presented using 'Presentation' software. Photographs of two horizontally aligned female faces were depicted in the centre of a screen (see Fig. 1). Two factors were manipulated in the present experiment: first, the two faces either looked at each other (attention shared) or away from each other (attention not shared) before providing gaze cues. Second, gaze cues were either congruent or incongruent with regard to the target location.

Each trial started with the presentation of the two faces with their eyes closed. After 900 ms, the two faces either looked at each other (attention shared; 50 % of the trials) or looked away from each other (attention not shared; 50 % of the trials). 900 ms later, a fixation cross appeared between the two faces for 500 ms so as to draw participants' attention to the centre of the screen. Subsequently, both faces simultaneously looked at one of the two target locations (towards the upper or towards the lower part of the screen). Following randomized stimulus onset asynchronies of 500, 600, or 700 ms, the target (an apple or a pear) was presented at one of the locations until participants responded (max. 2,000 ms). In half of the trials (both 'attention shared' trials and 'attention not shared' trials), the target appeared at the cued location (congruent; e.g. faces had looked up and the target appeared on the upper side of the screen) and in the other half of the trials, the target appeared at the non-cued location (incongruent; e.g. faces had looked up and the target appears on the lower side of the screen). Inter-trial intervals were 700 ms. Participants were instructed to respond as fast as possible to the identity of the fruit by pressing one of two response keys (two-choice task) with two fingers of their right hand (e.g. press index finger for apple and middle finger for pear). In order to exclude effects of stimulus–response compatibility, response buttons were aligned orthogonally to the target locations. The order of trials was randomized within blocks (7 blocks of 48 trials each).

Data Analysis

Reaction times (RTs) were analyzed by means of a repeated measures analysis of variance (ANOVA). A $2 \times 2 \times 2$ factorial design was applied with the between-subject factor Group (HFA vs. control) and the within-subject factors Attention (shared vs. not shared) and Gaze congruency (congruent vs. incongruent). Error rates were

Table 1 Demographic and questionnaire data

	HFA group		Control group		Statistics	
	M	SD	M	SD		
Gender	18:9		15:10		t(50) = .81	$p = .42$
Age	41.4	10.35	40.7	10.50	t(50) = .31	$p = .76$
Education (years)	17.5	5.06	16.1	4.74	t(46) = .68	$p = .51$
AQ	40.04	4.80	15.96	7.06	t(50) = 13.6	$p < .001$
EQ	16.50	9.29	41.71	11.33	t(47) = 8.15	$p < .001$
SQ	37.17	15.31	39.42	12.40	t(47) = .31	$p = .76$
BDI	16.42	11.93	5.76	4.19	t(50) = 4.38	$p < .001$

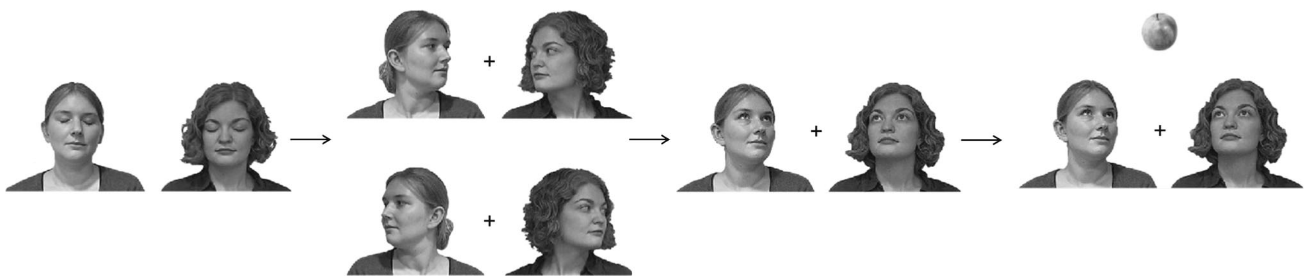

Fig. 1 Schematic illustration of the event sequence. After looking straight ahead, the two faces looked at each other or away from each other, and then simultaneously shifted their gaze up or down. After stimulus onset asynchronies of 500, 600, or 700 ms, the target (apple or pear) appeared at a location that was either congruent or incongruent in regard to the gaze cues. In the schematic image above the faces look at each other and the target (apple) appears at the gaze congruent location

not normally distributed and the Mann–Whitney-U-Test was employed for the non-parametric analysis.

Results

RTs

Results are displayed in Fig. 2. Only trials with correct responses were included in the analysis (error rate see below). The HFA group responded generally slower than the control group which was reflected in a significant main effect of Group [$F(1, 50) = 4.6, p < .05, \eta^2 = .084$]. Gaze congruency had a significant influence on RTs [$F(1, 50) = 5.0$, $p < .05$, $\eta^2 = .091$] with faster responses for congruent gaze cues.

The main focus of this study was the modulation of the effect of Gaze congruency by prior observation of eye contact between others. Crucially, there was a three-way interaction of Attention and Gaze congruency with the between-subject factor Group [$F(1, 50) = 7.3$, $p < .01$, $\eta^2 = .128$]. This was due to the fact that observed eye contact significantly enhanced the effect of Gaze congruency in the control group [$F(1, 24) = 4.5$, $p < .05$, $\eta^2 = .157$], but not in the HFA group [$F(1, 26) = 3.5$, $p = .072$, $\eta^2 = .119$]. In the control group, the congruency effect (faster RTs for congruent gaze cues) was larger after faces had looked at each other. By contrast, the congruency effect in the HFA group was not enhanced by prior shared attention, but was even numerically decreased after the faces had looked at each other [$p = .072$].

Gaze congruency interacted (trend) with the between-subject factor Group [$F(1, 50) = 3.3$, $p = .075$, $\eta^2 = .062$]. Subsequent analyses revealed that congruent gaze cues significantly speeded up responses in the control group [$F(1, 24) = 8.5$, $p < .01$, $\eta^2 = .262$], but not in the HFA group [$F(1, 26) < 1$, $\eta^2 = .003$].

Additional Analyses

The HFA group showed generally slower response times than the control group (see above). In an additional ANOVA we therefore included Speed (mean RTs) as a covariate. Results revealed that Speed did not interact with Attention, Gaze congruency, or the interaction of Attention $\times$ Gaze congruency [$Fs(1, 50) < 1$].

The HFA group in the present study had higher BDI scores than the control group. In order to investigate whether depression (partly) accounts for the current findings, BDI was included as covariate in an additional

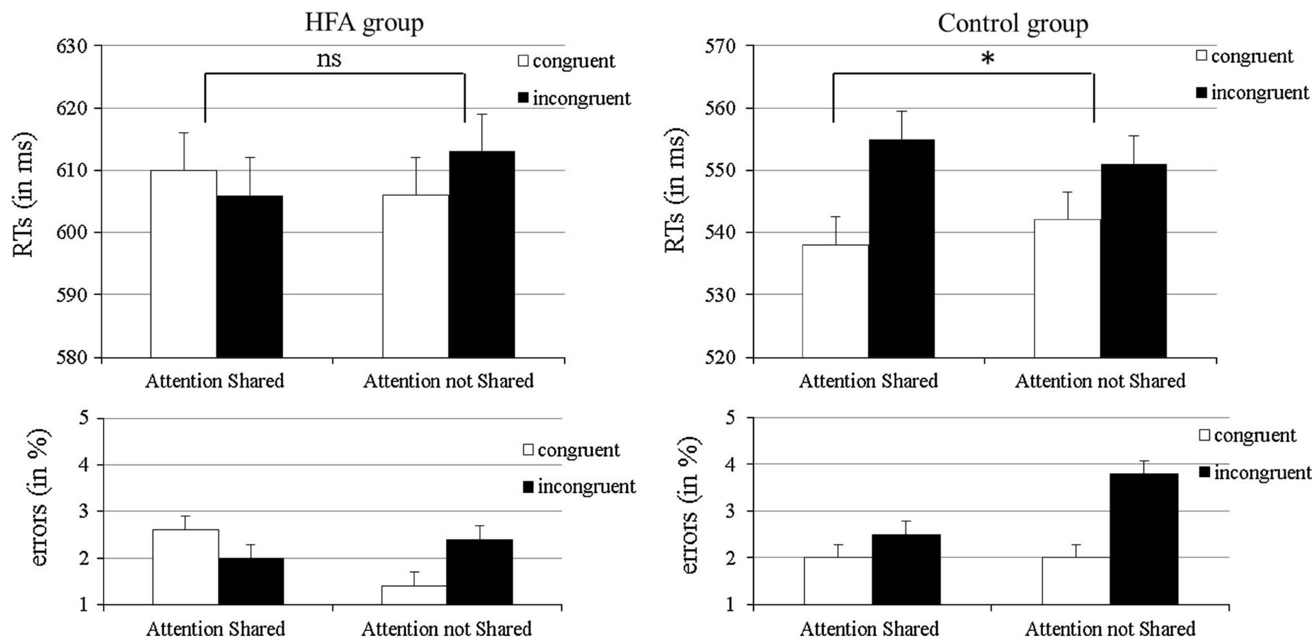

Fig. 2 Mean RTs (in ms) and errors rates (in %) for the HFA group (*left side*) and the control group (*right side*). Note that scales for RTs differ. *Error bars* display within-subjects confidence intervals based on Loftus and Masson 1994

ANOVA. Results revealed that BDI did not interact with Attention, Gaze congruency, or Attention × Gaze congruency [F(1, 50) < 1].[2]

Finally, the HFA group did not show an overall effect of Gaze congruency. In order to further explore the effect of Attention on Gaze congruency, we performed an analysis including only the 16 individuals of the patient group who showed an effect of Gaze congruency (faster RTs for gaze congruent trials). This sub-group showed a similar pattern as the complete HFA group and this time the interaction was significant [$F(1, 15) = 6.3$, $p < .05$; $\eta^2 = .295$]: the response time benefit for gaze congruent trials was larger after the two faces had not looked at each other.

Errors

Mean error rates were 2.3 %. Error rates were not normally distributed and the Mann–Whitney-U-Test was employed for the non-parametric analysis of error rates. This analysis revealed that HFA and control participants did not significantly differ concerning the effects of Attention, Gaze congruency, or the effect of Attention on the effect of Gaze congruency [$Z(1, 50) \leq 1.7$, $p \geq .09$].

Discussion

The present study investigated whether observing eye contact between others modulates responses to subsequently presented gaze cues in HFA and control participants. In contrast to healthy controls, HFA participants did not show enhanced responsiveness to gaze cues after observing eye contact and, hence, did not additionally benefit from congruent gaze cues subsequent to observing shared attention between others.

It has been suggested that eye contact constitutes a powerful social cue that is indicative of a communicative intent towards the addressee and highlights the importance of a subsequent action (Csibra and Gergely 2009; Schilbach et al. 2010, 2011). The enhanced sensitivity to gaze cues after observing eye contact in control participants replicates earlier findings (Böckler et al. 2011). It indicates that observed eye contact, although lacking a direct communicative intent towards the observer, highlights the significance of the observed individuals' subsequent actions (or gazes).[3] The absence of this pattern in autistic

[2] The control group entailed numerically more women than the HFA group and there are indications of larger gaze cueing effects in women (Bayliss et al. 2005). Though the HFA and control group did not differ significantly in terms of age and gender, both variables were included as covariates in additional analyses. Results revealed no interactions of Gender with any of the other factors or with any of the interactions [$Fs(1, 50) \leq 1.9$, $p \geq .16$, $\eta^2 \leq 0.038$] and no effect of Age with any of the factors or interactions [$Fs(1, 50) < 1$].

[3] It needs to be mentioned that the condition in which the two faces are looking at each other, as opposed to looking away, constitutes a situation in which (a) participants' attention is drawn to the centre of the screen and (b) the two faces are looking at something together with the participant. Control experiments in the original paper suggest that the enhanced gaze cueing effect after observing direct gaze is not

participants implies that they did not process observed eye contact between other agents in the same way, and may have failed to perceive eye contact as an ostensive cue. Even though individuals with autism appear to take into account certain social information such as others' gaze direction, spatial perspectives, or tasks (Chawarska et al. 2003; Sebanz et al. 2005; Zwickel et al. 2010), they did not respond to observed attentional relations in similar ways as non-autistic individuals. This study, hence, is the first to show that the processing of observed eye contact differs between people with and without HFA already at a reasonably early level. In HFA participants, the observation of eye contact did not affect subsequent gaze following, suggesting that they did not spontaneously interpret shared attention as a social signal that indicates the meaningfulness of a subsequent gaze cue.

Why was gaze following in individuals with HFA not increased after observing shared gaze? Mutual gaze constitutes a simple case of a communicative interaction, and understanding such social phenomena in observation may require experience in comparable situations that involve other mental agents with (communicative) intentions. Based on their own experiences, people form general predictions and apply them to understand observed social and communicative interactions of others (Clark 2013; Timmermans et al. 2012; Carhart-Harris and Friston 2010). In the specific case of observed eye contact, people may obtain an understanding by mapping the observed attentional relation between other agents onto their own previous experiences of mutual gaze with others (Barresi and Moore 1996). While non-autistic people appear to be highly motivated to and rewarded by engaging in joint attention (Schilbach 2010; Tomasello and Carpenter 2007), individuals with autism use communicative gaze to a lesser extent, possibly because of a lack of motivation to initiate experiences of joint attention or joint action (Chevallier et al. 2012). Hence, it is possible that their reduced responsiveness to observed eye contact arises from the lack of experience in communicating with eye contact or with gaze cues themselves. Future research may provide insight into the link between experiencing and observing eye contact by assessing whether the experience with communicative gaze behaviour predicts the sensitivity to observed communications (Schilbach et al. 2013). In a similar vein, it might prove interesting to address whether interactive trainings for individuals with autism (which would help establish social experiences that are comparable to non-autistic people) affect the interpretation of observed interactions as well.

Alternatively, the mechanism behind the enhanced gaze following effect in controls (but not in HFAs) after observing eye contact may be related to more general preferences in processing local versus global properties. Two faces looking at each other form a meaningful pattern, or 'Gestalt', that (non-autistic) people are well acquainted with. This may lead to the representation of faces looking at each other as a global 'joint attention' unit by the control participants, but not by the HFA participants. The reduced tendency of individuals with autism to integrate information into global representations may be at the bottom of their reduced sensitivity to the gaze cues provided by faces that had just looked at each other (Bölte et al. 2007).

The HFA group in the present study did not show an overall effect of gaze congruency. This is somewhat inconsistent with the majority of the literature, reporting gaze following in individuals with autism in standard computerized settings (see Nation and Penny 2008 for a review). A possible reason for the absence of this effect may be that our experiment employed a fixation cross after the two faces had looked at/away from each other (in order to draw attention to the centre of the screen in both conditions). This exogenous onset cue may have drawn attention away from the eyes of the faces altogether in the HFA group. In addition, it has been shown that individuals with autism, while showing similar behavioural gaze cueing effects as individuals without autism, process gaze cues differently on a neuronal level (Greene et al. 2011). The authors suggested that individuals with autism do not assign special social significance to gaze stimuli, but may be able to use lower-level properties of eye gaze to direct attention accordingly, at least in controlled settings. In more complex situations these mechanisms may not function as efficiently (Greene et al. 2011), which may also explain the absence of an overall gaze cueing effect in the present study. Importantly however, additional analyses including only HFA participants who showed the typical gaze follow effect, showed that gaze following in those participants was also not enhanced by observed eye contact. This indicates that the absence of an enhancement of gaze following after observing eye contact in the HFA group cannot be merely explained by the absence of an overall gaze cueing effect.

Contrary to the healthy control group, participants with HFA followed gaze less after observing eye contact (marginal effect in the entire HFA group, significant effect in the subsample showing overall gaze cueing). It is possible that HFA participants find eye contact between others harder to process than two faces looking away from each other, because eye contact requires understanding the relation of the two individuals gazing at each other, whereas faces looking away can be processed independently. This may be based on a general impairment of

Footnote 3 continued
due to either of these potential confounds. Enhanced gaze following was not found when participants' attention was directed towards the center by non-social cues or when one face looked at an object before providing gaze cues (Böckler et al., 2011).

parsing and understanding communicative cues (Baron-Cohen 1989; Baron-Cohen et al. 2000; Happé 1993) and could hinder gaze following in this condition by consuming attentional or cognitive resources. However, since the effect in the overall sample is only a trend, further research will be necessary to draw stronger conclusions.

Using and understanding communicative gaze signals plays an important role in successful social interactions, e.g. by helping the coordination of actions in space and time (Clark and Krych 2004; Richardson and Dale 2005; Schilbach et al. 2011, Autism) or by facilitating social learning (Csibra 2010; Wang et al. 2010; Yoon et al. 2008). Furthermore, engaging in attentional relations with others contributes to the understanding of others as independent mindful agents and may help to perceive and interpret attentional relations that are observed between others (Barresi and Moore 1996; Reddy 2003). We found that individuals with autism responded to observed attentional relations differently than healthy controls. While control subjects benefitted from congruent gaze cues particularly after observing eye contact, participants with HFA did not show an enhanced tendency to follow gaze after observing eye contact. These differences in processing observed attentional interactions may be related to differences between people with and without HFA in using and responding to social attention themselves. Taken together, the present findings are the first to show that in contrast to controls, high-functioning individuals with autism do not process observed eye contact as a social signal for the relevance of an upcoming (gaze) event. This difference in attentional processing might be related to many of the more apparent characteristics of social communicative behaviour in autism.

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