The Role of Gaze Direction in Face Memory in Autism Spectrum Disorder

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We tested the hypothesis that the direction of gaze of target faces may play a role in reported face recognition deficits in those with an autism spectrum disorder (ASD). In previous studies, typically developing children and adults better remembered faces in which the eyes were gazing directly at them compared with faces in which the eyes were averted. In the current study, high-functioning children and adolescents with an ASD and age- and IQ-matched typically developing controls were shown a series of pictures of faces in a study phase. These pictures were of individuals whose gaze was either directed straight ahead or whose gaze was averted to one side. We tested the memory for these study faces in a recognition task in which the faces were shown with their eyes closed. The typically developing group better remembered the direct-gaze faces, whereas the ASD participants did not show this effect. These results imply that there may be an important link between gaze direction and face recognition abilities in ASD. ***Autism Res** 2013, ••: ••–••.*

Keywords: autism spectrum disorder; face recognition; eye-contact; face-processing; gaze

Face processing is a pivotal component of human communication and interaction. There is evidence that people with an autism spectrum disorder (ASD), a disorder characterized by impairments in social interaction and communication as well as restricted range of interests and behaviors [e.g. Frith, 2003; Klin, Jones, Schultz, Volkmar, & Cohen, 2002], show impaired face-processing abilities and differences in neural responses to faces. For example, whereas event-related potential (ERP) recordings early in life from children with an ASD indicate differential responding to a familiar vs. unfamiliar toy, ERP patterns suggest that these children fail to respond differentially to their mother's face compared with an unfamiliar face [Dawson et al., 2002]. Behaviorally, there have been many studies examining face recognition and face processing in ASD. Face recognition and face-processing deficits have been found in a large number of studies [for review, see: Dawson, Webb, & McPartland, 2005; Sasson, 2006] although not all studies have demonstrated impairment. Given the huge scope of this area of research and the variability in methods and ASD samples, it is not surprising that there are conflicting findings regarding face processing in ASD. The variability in study results has led some researchers to question the notion of a face-specific processing deficit in ASD [for review, see: Jemel, Mottron, & Dawson, 2006].

One potential way to explain the findings that have supported impaired face recognition in ASD is within the framework of understanding face processing as a form of expertise. In contrast to a hypothesis which assumes that we have specialized innate mechanisms responsible for the recognition of faces [e.g. Duchaine, 2000; Farah, 1996; Farah, Levinson, & Klein, 1995; Farah, Rabionitz, Quinn, & Liu, 2000], proponents of the expertise hypothesis have argued that face recognition is "special" because we become expert at fine-level discriminations needed to recognize differences between faces [Gauthier, Behrmann, & Tarr, 1999; Gauthier, Skudlarski, Gore, & Anderson, 2000; Gauthier & Tarr, 2002; Tanaka, Gauthier, Goldstone, Medin, & Schyns, 1997]. According to this framework, individuals with an ASD may not develop expertise in face perception because they might spend less time looking at faces [e.g. Grelotti, Gauthier, & Schultz, 2002]. Consistent with this idea, a number of studies have indeed suggested that children with ASD do not pay attention to faces in the same way that typically developing children do. For example, an elegant retrospective study of children's first birthdays showed that those who were later diagnosed with ASD spent significantly less time looking at the faces of other people at their first birthday party [Osterling & Dawson, 1994].

Thus, it is possible that a lack of social interest underlies face recognition deficits in autism. A related, but slightly different, hypothesis is that aversion to eye contact, a common feature of ASD [Dalton, Nacewicz, & Johnstone, 2005; Joseph, Ehrman, McNally, & Keehn, 2008;

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Kylliäinen, Braeutigam, Hietanen, Swithenby, & Bailey, 2006; Kylliäinen & Hietanen, 2006], may play a role in reported face recognition deficits. That is, if children with an ASD avoid eye contact, this might lead to different exposure to faces than typically developing children experience, which in turn might lead to impoverished face-processing skills. Consistent with this hypothesis, some studies suggest that children with an ASD tend to focus less time on the eyes than other the parts of the face. Joseph and Tanaka [2003] demonstrated that high-functioning children with autism were much better at judging facial identity from the mouth alone rather than from the eyes alone. More importantly, and in comparison to age- and IQ-matched controls, these children were impaired at judging facial identity from the eyes alone. In fact, some eye-tracking studies support these findings, in that high-functioning children and adults with an ASD, unlike their age-and IQ-matched controls, allocate more attention to the mouth than to the eyes during the viewing of dynamic and static facial stimuli [Klin et al., 2002; Pelphrey et al., 2002]. Other studies, however, have indicated similar patterns of looking behavior in children with ASD and typically developing controls [Rutherford & Towns, 2008; van der Geest, Kemner, Camfferman, Verbaten, & van Engeland, 2002].

So why do children with ASD tend to look away from the eyes? Is it an active avoidance or simply lack of interest for the information that the eyes provide? Clinicians familiar with ASD and those with a diagnosis of ASD often describe a discomfort associated with eye contact. A recent brain imaging study suggests that the amygdala is hyperactive in children with ASD when they are gazing directly at the eyes [Dalton et al., 2005]. Furthermore, two studies [Joseph et al., 2008; Kylliäinen & Hietanen, 2006] employed galvanic skin response to examine arousal to direct-gaze and averted-gaze faces in ASD and typically developing controls. Kylliäinen and Hietanen [2006] showed greater arousal to direct-gaze faces compared with averted-gaze faces in the ASD sample, but no differential arousal in the control group. In addition, Joseph et al. [2008] reported that arousal in response to direct-gaze faces, but not averted-gaze faces, correlated negatively with face recognition accuracy for the ASD sample. Together, these studies indicate that direct gaze is arousing for people with ASD, which supports the idea that eye contact is aversive for children on the autism spectrum. Therefore, an intriguing alternative to the disinterest or lack of social motivation hypothesis is that overarousal, and associated aversion, to direct eye contact may be driving the face recognition deficit in autistic individuals.

To test this notion, we employed a social cognitive paradigm [Hood, Macrae, Cole-Davies, & Dias, 2003; Hood, Macrae, Flom, Lee, & Muir, 2007; Mason, Hood, & Macrae, 2004; Smith, Hood, & Hector, 2006]. In this paradigm, participants study a series of faces of different individuals. Half the faces in the study phase are shown with their eyes averted and the other half are shown with a direct gaze. In one of the conditions, the test phase consists of a set of photographs of individuals with their eyes closed. Some of the photographs in this test phase are of individuals shown in the study phase, and the participants' task is to decide whether they have seen that particular individual before. The result obtained in a number of studies, involving typically developing children, and adults, is that participants better remembered the faces that had a direct gaze during the study phase. There are no published reports of the use of this paradigm with ASD participants. However, this paradigm is ideal for testing the hypothesis that eye gaze aversion may play a role in the face recognition deficits that are reported in ASD. Specifically, it allows for the testing of the hypothesis that participants with ASD would not demonstrate a recognition advantage for direct gaze, relative to averted gaze, and thus would perform worse than controls on recognition memory for direct-gaze faces. Furthermore, in this paradigm, we can also test whether participants with ASD differ from control participants with regard to their recognition of averted-gaze faces. In the first experiment, we attempted to replicate this effect of recognition advantage for direct-gaze faces in college-aged students. In the second, we employed this paradigm to examine recognition of direct- and averted-gaze faces in children and adolescents with an ASD and age- and IQ-matched controls.

Experiment 1

In Experiment 1, we sought to replicate the effects of direct gaze on face memory [Hood et al., 2003, 2007; Mason et al., 2004; Smith et al., 2006] with our stimulus set before testing our target group. This replication was important given the changes that we made to various aspects of the stimuli used previously in this paradigm. That is, we opted to crop out nonface information such as hair, clothing, etc., to provide a more pure measure of face memory. Given these changes, Experiment 1 was aimed at testing whether or not this set of stimuli produced the advantage for direct-gaze faces in typically developing adults that has been previously reported.

Method

Participants. Twenty-six undergraduates at Williams College, a highly selective liberal arts college in Williamstown, Massachusetts, participated for course credit. The participants ranged in age between 18 and 22. Of the 26 participants, 16 were female and 10 were male.

Stimuli. The stimuli consisted of colored photographs of 18–21 year olds, each of whom posed for a direct gaze,

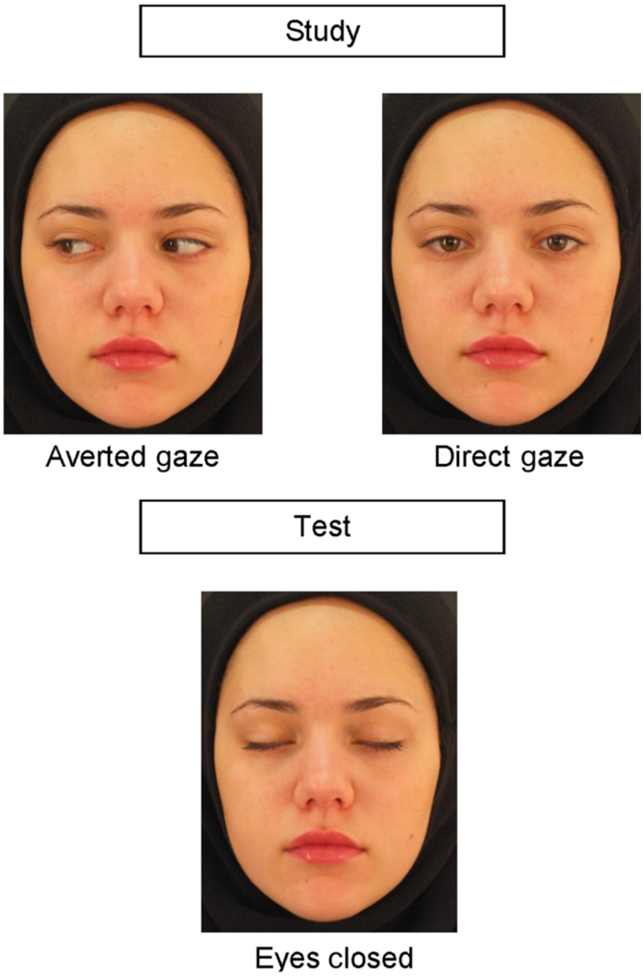

Figure 1. Example of stimuli used in the experiments.

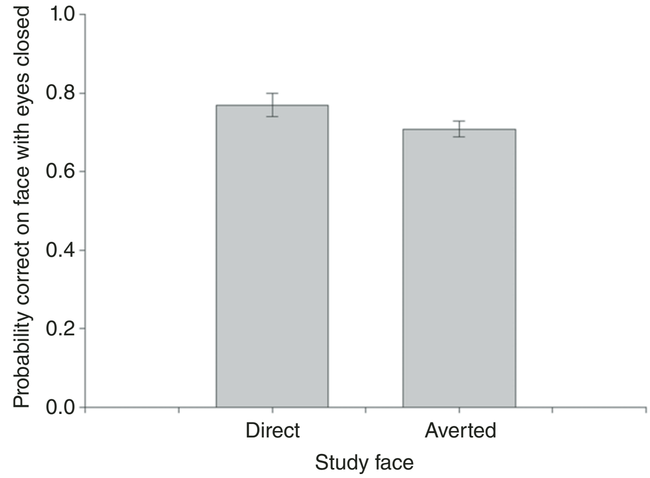

Figure 2. Mean probability correct for the direct-gaze and averted-gaze faces in Experiment 1. Error bars represent standard error of the mean.

eyes averted, and eyes closed condition. Half the pictures were of females and half were of males. Individuals in the photographs wore a hood to conceal hair and other identifying information. The pictures were cropped around the face to remove idiosyncratic nonface information. An example of the stimuli used in the experiment is given in Figure 1.

Procedure. The procedure consisted of a study phase followed by a test phase. In the study phase, participants saw 20 individual faces. Each individual's picture in this phase was shown with either an averted gaze or a direct gaze. The particular direction of gaze of each individual was randomized across subjects with the constraint that half of the pictures were shown with an averted gaze and half were shown with a direct gaze. Each face was presented for 10 sec, and the participant was simply asked to look carefully at each face. We increased the exposure duration from the 5 sec used in previous studies [e.g. Hood et al., 2003] to 10 sec because our stimuli lacked the extra information (such as hair, etc.) and were therefore more difficult to remember. Indeed, pilot testing suggested that this longer exposure was needed to obtain reasonable accuracy rates for these stimuli. The faces appeared on black background at the center of the screen and subtended 12.2° of visual angle horizontally and 16.3° vertically at a viewing distance of 65 cm. This reflects the size of a real face at a distance of about 65 cm [cf. Henderson, Williams, & Falk, 2005]. We opted to use relatively large stimuli so as to simulate a close conversational distance. We reasoned that we stood a better chance of finding effects of gaze aversion in an ASD sample when the distance between the observer and the face was potentially uncomfortably close.

In the test phase, the participants were shown 20 new faces and the 20 faces of people shown in the first phase in a random order. All faces in this phase were presented with their eyes closed. The participants' task was to indicate whether they had seen that particular person before. They indicated their choice by pressing the appropriately labeled key on the keyboard. The face remained on the screen until the participant made a response. No feedback was given. The selection of the particular items for study and test was randomly determined for each participant.

Results and Discussion

Figure 2 shows the probability correct responses for the two different types of gaze stimuli. As expected, participants were more accurate when recognizing faces that were studied with a direct gaze (0.77) than those faces studied with an averted gaze (0.71), $t(24) = 2.13$, $P = 0.043$, $\eta^2 = 0.16$. These results replicate the findings of Hood et al. [2003] with the current stimuli.

Table 1. **Mean and Standard Deviation of Age, WASI, and SRS for the ASD and Control Participants**

	ASD ($n = 31$) 27 M/4F	Controls ($n = 31$) 27 M/4F	t-value	P-value
Age (years)	13.1 (2.8) Range = 9–17	13.1 (2.4) Range = 9–17	0.12	0.90
WASI four subtest IQ	111.7 (13.7) Range = 73–142	111.8 (12.2) Range = 89–140	−0.04	0.97
SRS (t-score)	81.8 (9.3) Range = 57–90	42.1 (4.7) Range = 34–53	19.3	<0.001

ASD, autism spectrum disorder; SRS, Social Responsiveness Scale [Constantino et al., 2003]; WASI, Wechsler Abbreviated Scale of Intelligence [Wechsler, 1999].

Experiment 2

The main question of interest in this study was the performance of individuals with ASD on the old-new recognition task employed in Experiment 1. In Experiment 2, we compared performance of participants with ASD to typically developing controls. We expected the controls to demonstrate the same pattern of performance as in Experiment 1, where faces that are studied with a direct gaze when tested with their eyes closed would be recognized better than those that had averted gaze during the study phase. However, if direct gaze plays a role in face memory in ASD, we expected participants with ASD to show lower recognition rates for the test items studied with a direct gaze relative to those studied with an averted gaze.

Method

Participants. The participants were 31 high-functioning children and adolescents with an ASD (4 female and 27 male), ages 9–17, and 31 typically developing sex-, age-, and IQ-matched controls. Table 1 provides summary information of the participants' characteristics. Participants in the ASD group were diagnosed by the autism team at the regional health center or by a professional in the community (e.g. a psychologist or psychiatrist). Evidence-based assessment protocols incorporating the Autism Diagnostic Observation Schedule [Lord, Rutter, DiLavore, & Risi, 2008] and/or the Autism Diagnostic Interview-Revised [Rutter, LeCouteur, & Lord, 2003] were used by clinicians providing the ASD diagnosis or by the laboratory of one of the authors (S.J.) to confirm diagnosis. Control participants were recruited from the community using flyers, newspapers, and internet-based advertisements. For both groups, participants were excluded if they had an estimated IQ of less than 70 [Wechsler Abbreviated Scale of Intelligence; Wechsler, 1999], a history of a traumatic brain injury, significant neurological disorder, or systemic condition that might affect the central nervous system. Control participants were also excluded if they had a past or present diagnosis of any psychiatric disorder (including ASD). There were no significant differences between groups for sex, age, or IQ (see Table 1). A parent of each participant was asked to complete the Social Responsiveness Scale [SRS; Constantino et al., 2003]; 25 parents of ASD participants and 26 parents of controls completed the SRS. The t-score of the ASD group was significantly higher, indicating more ASD features/symptoms, than that of the control group.

Stimuli. The stimuli consisted of the same photographs used in Experiment 1.

Procedure. The procedure for the old-new recognition task was identical to Experiment 1. In addition, after the completion of the old-new recognition task, participants completed a face discrimination task. In this task, two faces were presented simultaneously on the screen and the participants' task was to indicate whether the faces were of the same individual. The faces subtended 10.5° of visual angle horizontally and 13.8° vertically at a viewing distance of 65 cm. The faces presented during this task had eyes closed, direct gaze, and averted gaze and were randomly selected for the 60 trials that each participant completed, with the constraint that half of the face pairs were images of the same person and half of the face pairs were images of different people. In addition, equal numbers of faces were shown with their eyes closed, direct gaze, and averted gaze. We included this task in order to rule out the possibility that poor memory performance was due to poor face discrimination.

Results

Figure 3 provides the mean correct probabilities in the old-new recognition task for the control and ASD participants. A group by condition (direct gaze, averted gaze) mixed model analysis of variance (ANOVA) revealed a group by condition interaction, $F(1, 60) = 8.41$, $P = 0.005$, $\eta_p^2 = 0.12$. There was no main effect of group ($F(1, 60) = 1.66$, $P = 0.20$, $\eta_p^2 = 0.03$) or condition ($F(1,

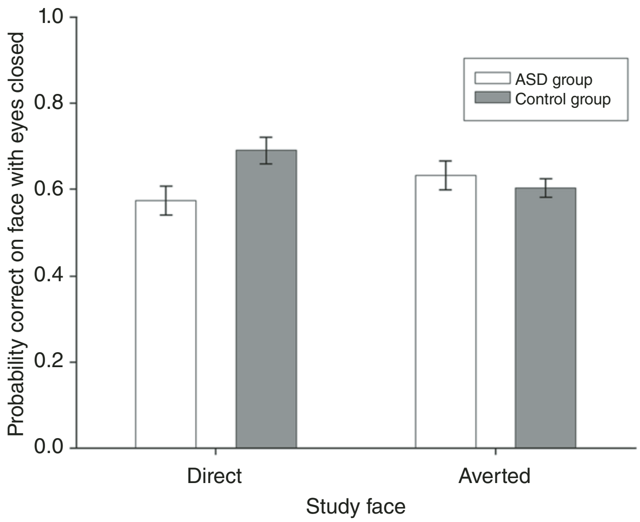

Figure 3. Mean probability correct for control and autism spectrum disorder (ASD) groups for the direct- and averted-gaze faces in Experiment 2. Error bars represent standard error of the mean.

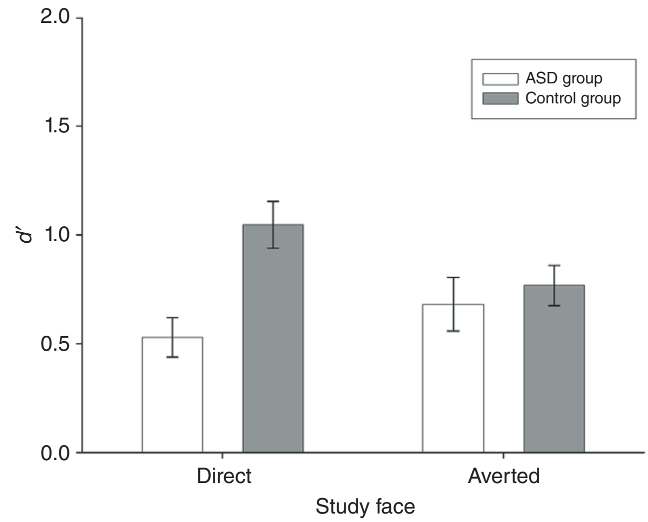

Figure 4. Sensitivity (d') for control and autism spectrum disorder (ASD) groups for the direct- and averted-gaze faces in Experiment 2. Error bars represent standard error of the mean.

$60) = 0.336$, $P = 0.56$, $\eta_p^2 = 0.01$). Consistent with previous findings, the typically developing group better remembered direct gaze compared with averted-gaze faces, $t(30) = 2.98$, $P = 0.01$, $\eta^2 = 0.23$. The ASD participants showed the reverse numerical pattern, but this difference was not statistically significant, $t(30) = 1.43$, $P = 0.16$, $\eta^2 = 0.06$. The differences between groups for recognition of faces with averted gaze was also not significant (controls = 0.60, ASD = 0.63; $t(60) = 0.74$, $P = 0.46$, $\eta^2 = 0.01$), whereas accuracy for direct gaze was significantly better for controls (controls = 0.69, ASD = 0.57, $t(60) = 2.59$, $P = 0.01$, $\eta^2 = 0.10$). Finally, the control group was marginally significantly more accurate at rejecting the foils, $t(60) = 1.98$, $P = 0.05$, $\eta^2 = 0.06$.

The marginally higher level of false recognition of the foils by the ASD group raised the interesting possibility of different criterion settings for the two sets of participants. Signal detection analysis [Green & Swets, 1966] is ideal for separating a participant's tendency to use either the new or old categories (measured as criterion) from their true ability to discriminate between new and old items (measured as sensitivity or d'). For an excellent primer on this method, see Macmillan and Creelman [1991]. To address the potential differences between groups in terms of criterion setting and to provide a metric of true sensitivity in recognizing the faces, we conducted a signal detection analysis of our results.

We calculated d' for each of the two test items types (targets previously presented with averted and direct gaze) by using the same proportion of false alarm to the foils. In order to complete the analysis, proportions of 0 were converted to 1/(2N), and proportions of 1 were converted to 1-1/(2N), where N is the number of observations per cell, given that 0 and 1 are undefined in z-space [Macmillan & Creelman, 1991]. We used c as a measure of criterion. Criterion did not differ significantly between the two groups (ASD = 0.01, controls = 0.05), $t(60) = 0.54$, $P = 0.59$, $\eta^2 = 0.00$.

Figure 4 displays d' values for the control and ASD participants in each of the two conditions. Signal-detection estimates can be somewhat unstable when there are relatively few observations per cell as in the present case and so they must be interpreted with some caution [Wickens, 2002]. Nonetheless, the general pattern we observed in accuracy was reflected in the d' prime analyses. That is, a group by condition (direct gaze, averted gaze) mixed model ANOVA on d' revealed a group by condition interaction, $F(1, 60) = 8.86$, $P = 0.004$, $\eta^2 = 0.13$, but no main effect of gaze direction, $F(1, 60) = 0.77$, $P = 0.38$, $\eta_p^2 = 0.01$. The d' analysis also indicated a main effect of group $F(1, 60) = 5.38$, $P = 0.02$, $\eta_p^2 = 0.08$, with higher overall sensitivity for the control group. Consistent with the analysis of accuracy, the d' analysis indicated that the typically developing group better remembered direct compared with averted-gaze faces, $t(30) = 3.32$, $P = 0.002$, $\eta^2 = 0.27$. Again, although the means were in the opposite direction for the ASD participants, the difference between performance on direct compared with averted-gaze faces did not approach significance $t(30) = 1.29$, $P = 0.21$, $\eta^2 = 0.05$. The control group was significantly better than the ASD group at recognizing the direct-gaze faces, $t(60) = 3.64$, $P = 0.001$, $\eta^2 = 0.18$, but there was no group difference in d' for averted-gaze faces, $t(60) = 0.56$, $P = 0.57$, $\eta^2 = 0.00$.

Finally, we computed probability correct on the face discrimination task for the two groups. There was no difference between accuracy of the control group (0.97) and the ASD group, (0.97), $t(60) = 0.19$, $P = 0.85$, $\eta^2 = 0.00$.

General Discussion

In two experiments, we investigated the effects of gaze direction on memory for faces in typical young adults, typically developing children, and children with ASD. The first experiment replicated previous findings, indicating that college-aged students better remembered the faces that were studied with a direct gaze when tested with the same face shown with eyes closed. The second experiment revealed that, although there was no difference in overall recognition accuracy between groups, in contrast to typically developing children who also derived a recognition boost from encountering a face with direct gaze, the ASD group did not. These results provide evidence that differences in the way that gaze direction is processed may play an important role in the poor face recognition abilities often exhibited by those with an ASD [see Pellicano & Macrae, 2009, for a similar result involving sex categorization in ASD as a function of gaze direction].

What underlies the difference in performance between the ASD participants and controls? The answer to this question must depend in part on our understanding of the underlying cause of enhanced face memory for direct-gaze faces in the normal population, but also on our understanding of the underlying mechanisms that contribute to atypical eye contact in ASD [see Senju & Johnson, 2009 for a recent review]. From these two literatures, a number of possibilities emerge.

One possibility, potentially the least interesting, is that in a typically developing group, averted gaze simply directs attention away from the face. We know, for example, that participants with an ASD fail to use eye direction to infer mental states [Baron-Cohen, Campbell, Karmiloff-Smith, & Grant, 1995]. In addition, whereas typically developing children prefer to use eye direction as opposed to an artificial cue to infer mental states, children with an ASD do not. Therefore, if the finding that the averted-gaze face disadvantage in a typically developing group is due to the directing of subjects' attention away from that face (i.e. gaze following), impoverished gaze-following in autistic individuals would predict that individuals with an ASD would not show an averted-gaze face deficit. To our knowledge, eye-tracking methods have not been employed to determine whether or not gaze-following accounts for the difference between recognition of direct- and averted-gaze faces in typically developing individuals. However, in a recent study of adult control participants, we [Goodman, Phelan, & Johnson, 2012] employed a centrally located attention probe during the learning phase of this task. We hypothesized that if participants were following gaze on averted gaze trials, detection of probes would be worse and response times would be slower compared with the performance on direct-gaze trials. Our findings indicated that an accuracy of detection and response times to the attention probe did not differ for direct- and averted-gaze faces. Although this provides some evidence against this possibility, there are limitations with this paradigm.

A second possibility that motivated the current research is that eye contact is aversive to individuals with an ASD. Abnormal eye contact has been described as an important clinical feature of ASD since the earliest descriptions of autism. The idea that direct eye contact is aversive to people with ASD is bolstered by findings that show a heightened emotional response to direct eye gaze [e.g. Dalton et al., 2005]. Interestingly, Joseph et al. [2008] found that amplitude of the skin conductance responses to direct gaze was negatively correlated to face recognition accuracy in children with ASD. In addition, Kylliäinen and Hietanen [2006] found stronger galvanic skin responses to direct-gaze faces compared with averted-gaze faces in children with ASD, but no difference in responses to direct- and averted-gaze faces in typically developing children. These findings support the notion that direct gaze may be overly arousing for people with ASD. The theory that children with ASD are overaroused while looking at faces with direct gaze makes two predictions with regard to our experiment. The first is that the ASD group should not show the recognition advantage for direct-gaze faces, and this was in line with our results. The second prediction is that the ASD group would perform more poorly on the direct-gaze faces than the averted-gaze faces. We did not find evidence for this second prediction, and so our data did not support the aversion hypothesis.

A third possibility, stated very generally, is that there is something *special* about direct gaze that triggers a different sort of processing, and that somehow this type of processing is impaired in ASD. There are a number of theories that fall into this general class. For example, Baron-Cohen [1995] suggested the existence of a specialized mechanism for eye-direction detection, and argued that links between this mechanism and other key mechanisms responsible for theory of mind may be impaired in autism. A related theory states that direct gaze activates "mutual gaze detectors" [i.e. a neural system attuned to detect if eyes are looking toward the observer; Mason et al., 2004; Smith et al., 2006]. These detectors are thought to increase arousal, which subsequently triggers elaborate encoding of faces with direct gaze. Smith et al. [2006] stated that this increased arousal is necessary because it may lead to more thorough evaluation of socially relevant stimuli (i.e. mutual gaze implies social relevance). Finally, in their *fast-track modulator model*, Senju and Johnson [2009] posit that a subcortical face detection pathway is responsible for processing eye contact separately from the cortical processing of faces. Although these theories have different key components, at their core is the idea that the special processing of direct gaze observed in a typical population is impaired in autism. Therefore, these models predict that people with ASD would not demonstrate a recognition advantage for direct-gaze faces, which is in line with the findings of the current study.

Eye-tracking studies employing the current paradigm will be important for elucidating the underlying causes of the pattern of data reported in this study. Although several studies have shown that individuals with ASD tend not to look at the eyes [e.g. Klin et al., 2002; Pelphrey et al., 2002], they also appear to be more efficient at detecting direct than averted gaze [Senju, Kikuchi, Hasegawa, Tojo, & Osanai, 2008]. One question that arises is whether there is any difference in looking behavior in response to direct- and averted-gaze faces in an ASD sample, relative to controls. This is not testable within the current data set because we did not monitor where participants looked when observing the face stimuli. Future studies involving eye tracking would allow us to investigate whether there is less time spent looking at the eyes in faces with direct-gaze faces, for example, by an ASD sample relative to a control sample, and whether this type of looking behavior might predict performance in the memory task.

In summary, the current results provide a strong demonstration that direction of gaze does not play the same role in face recognition memory in high-functioning ASD as it does in typically developing individuals. To determine the generalizability of these findings across the autism spectrum, future studies examining the role of gaze direction in face recognition should include participants with a wide range of ability levels. Our findings are also important in light of the fact that many previous face-processing studies of participants with an ASD have been conducted with direct-gaze faces as stimuli. Thus, conclusions about face-processing abilities drawn from these previous studies are likely only specific to recognition or processing of direct-gaze faces, which, given the different patterns of face recognition observed in this study, appears to not represent face-processing abilities more generally.

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