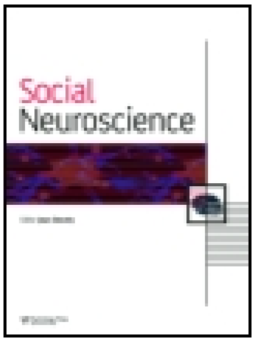

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Positive and negative gaze perception in autism spectrum conditions

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Eyes are key social features providing a wealth of information about the attention, interest, emotion, and intention of others. Humans are typically very adept at detecting gaze direction, but there is a large decrement in gaze discrimination ability when eye images change from positive to negative polarity. This is thought to show an expert system for gaze perception that applies a contrast-specific heuristic to determine where someone else is looking. Autism spectrum conditions (ASC) are characterized by social deficits including difficulties in face-processing and in the social use of gaze. People with ASC are thought to have less expertise for gaze processing compared to typical controls, though little research has tested this. We investigated gaze direction perception in typical males and females, and males with ASC using facial stimuli with positive or negative polarity of the eyes. Results showed that the ASC group was worse at judging gaze direction with positive stimuli, and showed less of a decrement in performance when eye stimuli changed from positive to negative polarity. The differences in gaze perception for the ASC group were most evident when information from the eyes was more difficult and ambiguous. Typical females performed better at gaze direction detection with positive polarity than typical males, who in turn performed better than males with ASC. This latter finding is consistent with the extreme male brain theory of autism, and with the idea that people with ASC have less gaze expertise.

Keywords: Gaze; Gaze Perception; Social Attention; Autism; Asperger Syndrome; Sex Differences.

INTRODUCTION

Faces are a rich source of information about others (Darwin, 1872/1998; Young, 1998). The eyes, in particular, convey important social signals about an animal's focus of attention and interest (Baron-Cohen, 1995; Emery, 2000). Eye direction can communicate different types of information. For example, direct eye contact can be a sign of threat in some instances, or it can be an indication of interest to initiate a conversation. Similarly, averted eyes may reflect submissive behaviour, or

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that the person is reflecting on something. The accurate perception of gaze direction is important in decoding the intentions of others and is therefore a key component in using a ''theory of mind'' (ToM) (Baron-Cohen, 1995). People who can easily read social cues from the eyes would have an advantage in navigating the social world compared to those with difficulty discriminating gaze direction information.

Sensitivity to gaze direction is evident in newborns and provides an important foundation for later social development (Batki, Baron-Cohen, Wheelwright, Connellan, & Ahluwalia, 2001; Farroni, Johnson, & Csibra, 2004). The ability to perceive the gaze of others tends to be quite accurate, with studies showing adults can detect gaze deviations as little as 1.4° from 1 m away (Cline, 1967; Gibson & Pick, 1963). Research involving visual search and oddball tasks using eye stimuli have shown that direct eye stimuli are found more quickly and accurately among an array of averted eyes compared to averted eyes within straight eyes, showing the human sensitivity to direct gaze (Senju, Kikuchi, Hasegawa, Tojo, & Osanai, 2008; von Grunau & Anston, 1995).

There are perceptual cues that help in reading gaze, as human eyes have evolved in unique ways compared to those of other primates (Langton, Watt, & Bruce, 2000). Humans are the only primates with eyes composed of a white sclera and a dark pupil, and this unique morphology of the human eye allows for easier detection of gaze direction (Kobayashi & Kohshima, 1997). This may have developed in humans because if another person makes direct eye contact, this often signals that they wish to speak to a listener—a prosocial signal. In other primates, if another animal makes direct eye contact this signals that it has you in its sights, potentially to attack you—an antisocial signal. Natural selection in other primates would have operated to favor animals with a dark sclera, either to make it harder for another animal to detect that it is being watched, or to minimize the risk that another animal might think it is about to be attacked. Natural selection in humans would have operated to favor individuals with white scleras, to facilitate reading the communicative intent of others.

Experiments have shown the importance of the luminance differences between the white sclera and dark pupil for judgments of gaze direction (Anstis, Mayhew, & Morley, 1969; Emery, 2000). For example, the ''bloodshot illusion'' occurs when the white sclera on one side of the iris in an eye gazing straight ahead is darkened. This leads to the impression that the gaze is now shifted to the side that was darkened. This effect occurs even though the actual iris does not change—only the luminance of the sclera. Another experiment showing the importance of luminance contrast is the ''Bogart illusion''. This effect occurs when pictures of people with gaze averted towards one side appear to be gazing towards the opposite side when the contrast polarity of the picture is reversed from positive to negative (Sinha, 2000). This occurs even though the ''perceived iris'' (the dark spot in the negative polarity eye) is a different shape and size than the actual iris would be. These authors suggest that humans use a simple heuristic for gaze detection: the position of the dark iris reflects the direction of gaze. It appears that this heuristic is automatic and very difficult to overcome (Sinha, 2000).

A study by Ricciardelli, Baylis, and Driver (2000) looked at the effect of contrast polarity in gaze perception across a variety of head and eye deviations. They asked participants to judge the gaze direction in photographs where the eyes and head of a ''looker'' had different orientations: left, right, or straight ahead (see Figure 1). They found that the ability to judge gaze direction is markedly reduced when eye polarity is changed from positive to negative, and this occurs even though the perceived iris is a different size and shape than an actual iris would be. This suggests that the visual system uses an inflexible rule involving the contrast between the dark iris and the white sclera to work out the gaze direction of others. The gaze detection rule is ''cognitively impenetrable'' (Pylyshyn, 1999), and cannot override cognitive judgments about the size and shape of the iris and sclera (Sinha, 2000).

In the study by Ricciardelli and colleagues, gaze detection was worst in conditions where the head was averted and the eyes were either straight ahead or congruent with head direction. These conditions were more ambiguous and difficult than others, as they involved white sclera on both sides of the dark iris. Thus participants had to make a gaze direction judgment involving more subtle differences in the amount of sclera on either side of the iris. These conditions involve averted head orientations, and the direction of the head is known to affect gaze direction perception (Langton & Bruce, 2000). Ricciardelli et al. (2000) suggested that the gaze polarity paradigm may

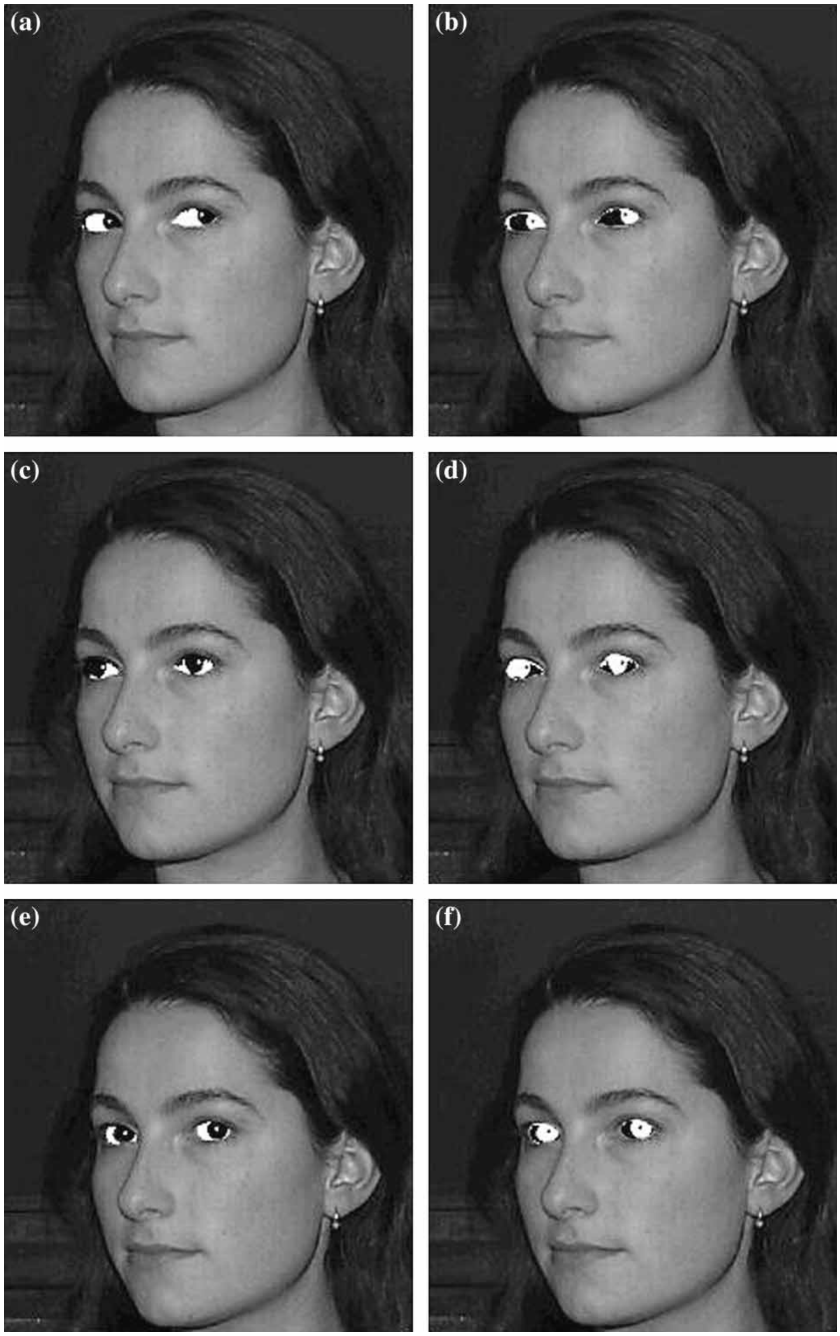

Figure 1. Examples of stimuli used in the experiment. (a) Positive polarity eyes, with the head averted 30° to the observer's left and the gaze averted 30° right; (b) the same as in (a) but with negative eye polarity; (c) positive polarity eyes, with the head and eyes both averted 30° to the observer's left; (d) same as in (c) but with negative eye polarity; (e) positive polarity eyes, with the head directed 30° to the observer's left and the eyes straight; (f) same as in (e) but with negative eye polarity.

serve to test whether the contrast-specific expertise in gaze perception might be lacking in a condition characterized by social impairments, such as autism.

Autism and Asperger syndrome (AS) are autism spectrum conditions (ASC) involving deficits in social functioning and communication, and repetitive behaviour and narrow interests (American Psychiatric Association (APA), 1994). One of the more striking characteristics of ASC involves abnormalities in the social use of gaze (Hutt & Ounsted, 1970; Kanner, 1943; Tinbergen & Tinbergen, 1983). Home movies of children later diagnosed with ASC reveal impairments in social attention and gaze behaviour within the first two years of life (Adrien et al., 1993; Osterling & Dawson, 1994). Studies of face-processing have shown that people with ASC look less in the eye region compared to controls, instead showing a preference to look more at mouths (Hobson, Ouston, & Lee, 1988; Joseph & Tanaka, 2003; Klin, Jones, Schultz, Volkmar, & Cohen, 2002). A lack of normal gaze following (joint attention) is one of the earliest signs of autism (Baird et al., 2000; Baron-Cohen, 1989; Sigman, Mundy, Ungerer, & Sherman, 1986). Joint attention abnormalities are thought to be a key component of ASC and central to the profound difficulties in language, social development, and ToM seen in these conditions (Baron-Cohen, 1995; Charman, 2003; Dawson et al., 2004).

Many of the studies related to gaze detection in autism have investigated higher-level abilities such as inferring the intentions of others by ‘‘reading the eyes’’. This research has consistently shown impairments in using the eyes to decode another's mental states or predict their behaviour (Baron-Cohen, 1995; Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001; Baron-Cohen, Wheelwright, & Jolliffe, 1997; Volkmar & Mayes, 1990). A few experiments have investigated basic gaze perception abilities in autism, with mixed results. Baron-Cohen and Cross (1992) used pairs of pictures of gaze and asked participants to choose the one showing direct gaze. They found no deficit in the autism group. However, other studies have reported impairments by people with ASC in detecting direct gaze (Howard et al., 2000; Swettenham, 2001), and a lack of facilitated detection of direct gaze normally seen in controls (Senju, Yaguchi, Tojo, & Hasegawa, 2003). This difference may result because those with ASC are relying more on featural information when processing gaze (Senju et al., 2008).

While differences have been reported in the perception of gaze in ASC, a number of studies have shown that the basic orienting reflex to the gaze of others is actually intact in children and adults with ASC. The gaze cuing effect involves detecting whether gaze is averted to one side or the other and does not require an explicit judgment about direction (Kylliainen & Hietanen, 2004; Senju et al., 2004; Swettenham, Condie, Campbell, Milne, & Coleman, 2003). Additionally, children with autism are successfully able to determine the gaze direction of others towards target pegs (Leekam, Baron-Cohen, Brown, Perrett, & Milders, 1997), showing that some basic abilities for processing the gaze of others in ASC are intact. Although it is suggested that even when intact gaze ability is evident in ASC they may be using atypical strategies (Nation & Penny, 2008).

Research investigating the neural processing of gaze in ASC has found abnormal brain activity compared to controls. One study looked at event-related potentials in the brain while children judged direct and averted gaze and reported differences in the laterality of activation during gaze perception in those with ASC (Senju, Tojo, Yaguchi, & Hasegawa, 2005). An fMRI study reported atypical activity of the superior temporal sulcus (STS) in people with ASC while they viewed the gaze of others (Pelphrey, Morris, & McCarthy, 2005). This is consistent with a number of other studies reporting abnormal STS activation (Castelli, Frith, Happe, & Frith, 2002; Ohnishi et al., 2000) and volume (Boddaert et al., 2004) in ASC. The STS and the inferior parietal lobe (IPL) are core regions of the brain involved in gaze perception (Haxby, Hoffman, & Gobbini, 2000; Hoffman & Haxby, 2000). Not surprisingly, the STS is thought to be one of the key brain regions implicated in ASC (Pelphrey, Adolphs, & Morris, 2004a; Zilbovicius et al., 2006), although this suggests that deficits in gaze direction processing in ASC should be more evident than currently reported, at least under more difficult conditions.

The empathizing–systemizing (E-S) theory of psychological sex differences (Baron-Cohen, 2002, 2003) proposes that males on average perform better on tasks of systemizing, which are highly rule-based and detail-oriented. Conversely, females on average perform better on tasks of empathizing, which involve attributing mental states and emotions to others and responding with appropriate affect. Relevant to the current study, empathizing occurs when we read the mind of others from their gaze (Baron-Cohen, 1995). Consistent with this proposed sex difference, females are better than males at identifying mental states from the eyes of others (Baron-Cohen et al., 2001), and a recent study found stronger gaze cuing effects in females compared to males (Bayliss & Tipper, 2005). An extension of the E-S theory is the ‘‘extreme male brain’’ (EMB) theory of autism (Baron-Cohen, 2002; Baron-Cohen & Hammer, 1997), which proposes that those on the autistic spectrum are an extreme of the male profile. The EMB theory would therefore predict greater expertise for gaze detection by females compared to males, who in turn should be better than those with ASC. To date, no studies have looked directly at differences in gaze detection involving the contrast polarity effect in ASC or between the sexes.

The present study investigated gaze perception in adult males with and without ASC using the gaze polarity paradigm developed by Ricciardelli et al. (2000). Experiment 1 of that study used images with negative and positive polarity of the eyes and included almost all female participants (7 females and 1 male), who generally do better on such social tasks (Baron-Cohen, 1995, 2003; Bayliss & Tipper, 2005). We tested whether the same effects of gaze polarity would be seen in a group consisting solely of typical males, and also whether the effect might differ in people with ASC. If people with ASC have not developed the typical heuristic for gaze direction perception seen in adult controls, they might show less of a decrement in gaze detection performance compared to controls when eye polarity is reversed from positive to negative. Adults with ASC may use compensatory mechanisms to process social information, perhaps by relying on different explicit rules (Baron-Cohen, 2003; Frith, 2003). While many of the conditions in the present experiment involve the iris being more easily detected in the middle or to one side of the sclera, the conditions with the head averted and eyes either straight ahead or averted in the same direction as the head contain more ambiguous information. In conditions with the head facing straight ahead, the iris is more clearly visible as being in the middle or completely to one side or the other (see Figure 1a). In conditions where the head direction is averted to the left or right and the eyes are looking congruently or straight, the information is more ambiguous as white sclera is visible on either side of the dark iris (see Figure 1c and 1e). If people with an ASC are relying more on conscious explicit rules than on intuitive expertise for gaze processing, we might expect to find normal judgments in conditions where rule-based information is clearly evident. This intact performance would occur alongside impaired performance in conditions where information from the eyes about gaze direction is more ambiguous and difficult.

The aims of the present study were: (1) to replicate the findings of Ricciardelli et al. (2000) in a group of adult male controls; (2) to investigate gaze direction perception ability in a group of high-functioning male adults with ASC using eye stimuli with positive polarity; (3) to test whether the ASC group would show less of a decrement in gaze perception when the eye stimuli changes from positive to negative polarity; and (4) to use data involving female participants from Ricciardelli et al. (2000) to test whether the EMB theory applies to performance of gaze perception ability between typical females, typical males, and males with ASC.

We predicted that: (1) the adult male control group would show a gaze polarity effect similar to previous research (Ricciardelli et al., 2000), with significantly reduced gaze perception for negative contrast polarity of eyes compared to positive; (2) the ASC group would show impaired gaze perception compared to the males when eyes had positive polarity, particularly in the most difficult conditions involving an averted head and eyes directed either straight or in the same direction as the head; (3) the ASC group would show less of a decrement in performance when the eye stimuli changed from positive to negative polarity; and (4) based on the E-S theory, in an analysis using the data from females reported by Ricciardelli et al. (2000), females in the present study would show the greatest decrement in performance from positive to negative gaze polarity compared to both the control males and participants with ASC. Further, we expected the ASC group to show a reduced decrement in performance compared to males and females, suggesting reduced gaze direction expertise compared to typical controls.

METHOD

Participants

We recruited 15 male adult control participants (mean age $\pm$ standard deviation, 27.6 ± 6.3; full-scale IQ, 120.1 ± 13.8) with no history of psychiatric conditions from the general population through advertisements. We also recruited 15 adult male participants (mean age $\pm$ standard deviation, 29.9 ± 9.1; full-scale IQ, 117.9 ± 18.2) who had a formal diagnosis of high-functioning autism (HFA; $N = 2$) or Asperger syndrome (AS; $N = 13$) according to international criteria (APA, 1994). Every participant except for one in each group completed an assessment of intelligence (Wechsler, 1999), and all of the participants with ASC completed the Autism-Spectrum Quotient

(AQ) (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001). The AQ scores of the participants with ASC ($N = 15$, mean AQ score = 35.3, $SD = 5.2$, 80% scoring 32+) matched very closely to those found previously in Baron-Cohen et al. (2001) ($N = 58$, mean AQ score = 35.8, $SD = 6.5$, 80% scoring 32+).

Materials

The stimuli consisted of a series of monochrome photographs of the same actress gazing towards different positions: 30° left, 30° right, or straight ahead. Independent of these gaze directions, the looker's head could face straight, to the left by 30°, or to the right by 30°. In half the displays, the two-tone eyes had normal "positive" contrast involving a black iris within a white sclera (see Figure 1a, 1c, and 1e). In the other half of the displays the same pictures appeared but with "negative" contrast for the eye region, involving a white iris within a black sclera (see Figure 1b, 1d, and 1f).

Design and procedure

The participants were tested individually in a quiet and dimly lit room. They were seated approximately 1 m from the computer screen in a comfortable chair whose height could be adjusted so the participant's eyes were positioned at the center of the screen. Prior to the experiment participants saw an example of each condition together with the correct response. Participants were then presented with 384 trials divided into six equal blocks, with the 18 conditions being randomly shown within each block. Participants were told that some of the gaze stimuli might look unusual, but they were simply to indicate the perceived direction of gaze by pressing one of three buttons on a response box. The testing session began with 18 practice trials to ensure that the participant understood the task.

Each trial began with the presentation of a central asterisk which served as a warning signal and fixation point at the center of the screen for 448 ms. This was followed by one of the displays with the looker gazing towards one of the three possible different positions (while facing towards any one of these). The image was displayed until the participant's response or for a maximum of 1112 ms. Responses were followed by a blank delay of 500 ms preceding the fixation stimulus of the next trial.

Statistical design

The data were arcsin transformed and subjected to a general linear model (GLM) repeated measures analysis of variance (ANOVA) with Head Direction (left vs. straight vs. right), Gaze Direction (left vs. straight vs. right) and Polarity (positive vs. negative) as the within-group factors and Group (controls vs. autism) as the between-subject factor. Post-hoc comparisons were done where appropriate and Bonferroni corrected for multiple comparisons.

Since the stimuli and experimental procedures were exactly the same between our study and that of Ricciardelli and colleagues (2000), we used data from both studies in a further analysis to test differences between typical females, typical males, and males with AS. Since fewer participants were run in the original Ricciardelli study ($N = 8$), and we were mainly interested in the effect of positive versus negative polarity on gaze direction detection, we included only polarity as a within-group factor for this analysis. The arcsin-transformed data were analyzed using a GLM repeated measures ANOVA with Polarity (positive vs. negative) as the within-group factor and Group (typical females vs. typical males vs. ASC) as the between-group factor, and Bonferroni corrected post-hoc comparisons were carried out where appropriate.

Results

There were no significant differences between the groups for age, $t(28) = 0.49$, or for IQ, $t(26) = 0.36$. Statistics on the accuracy data revealed there was no main effect for Group, $F(1, 28) = 2.12$, $MSE = 6.73$, *ns*, showing that both groups understood the task and that general performance did not differ.

There was a large influence of contrast polarity (see Figure 2), with worse performance for negative eye stimuli by both the control group (65.0% correct overall versus 86.5% for positives) and the autism group (60.7% correct overall versus 74.0% for positives). This was confirmed by a main effect of polarity, $F(1, 28) = 95.3$, $MSE = 34.81$, $p < .001$, showing that changing the polarity to negative had a significant effect on performance (see Figure 2).

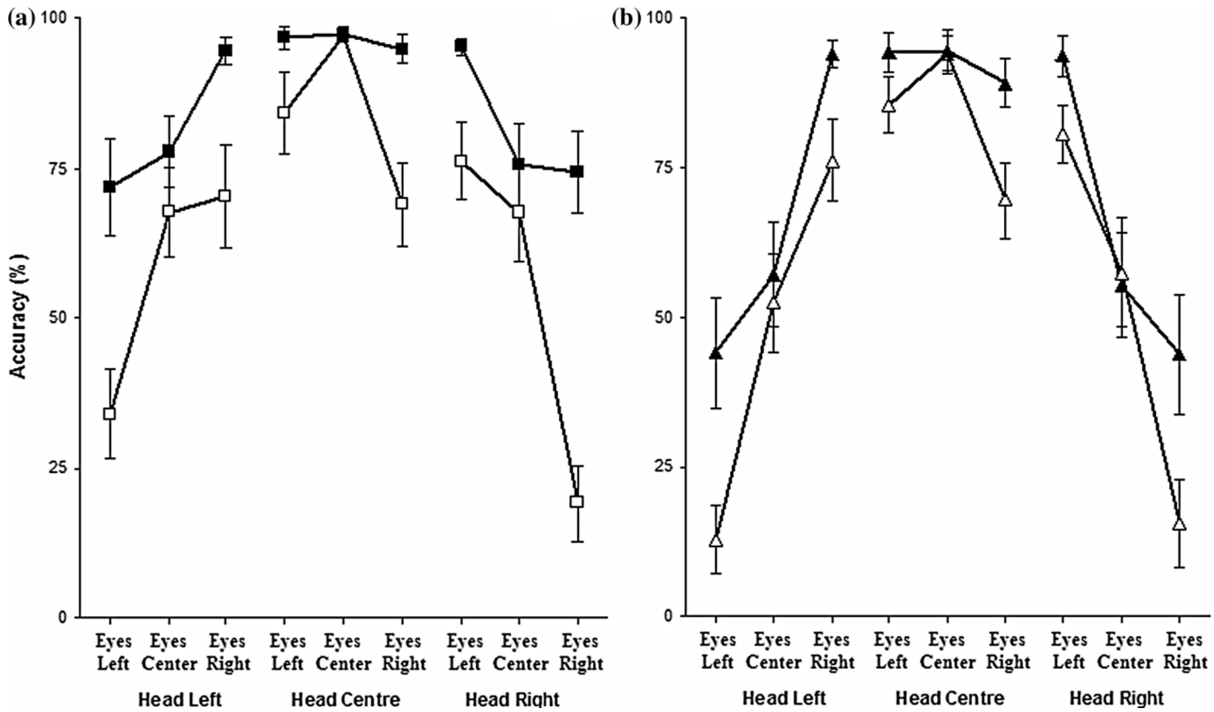

Figure 2. Accuracy results with standard errors for (a) control males and (b) males with autism, across all head and eye directions and positive and negative eye polarity.

However, there was an interaction between group and polarity, $F(1, 28) = 4.27$, $MSE = 1.56$, $p < .05$, revealing that the difference between positive and negative trials was less for the autism group than it was for the control group (see Figure 3). Post-hoc independent samples *t*-tests showed that the control group performed significantly better on the positive polarity trials than

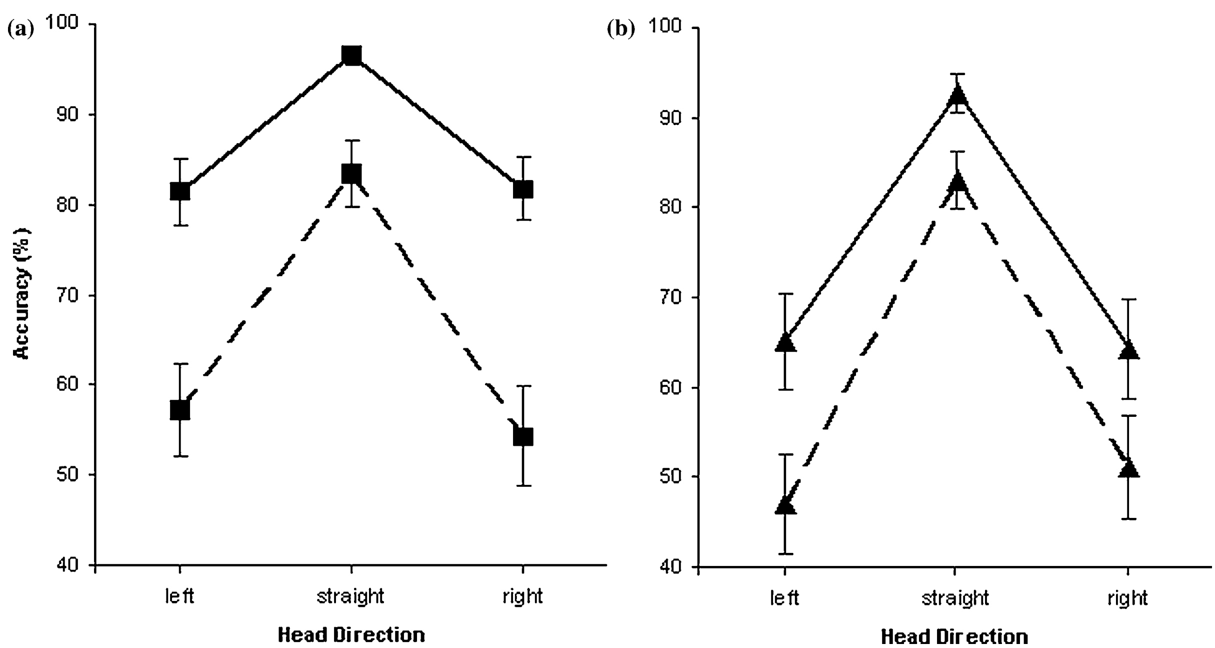

Figure 3. Accuracy results with standard errors for (a) control males and (b) males with autism, for positive eye polarity trials (solid lines) and negative eye polarity (broken lines) across different head directions.

the autism group, $t(268) = 3.69$, $p < .001$, while there was no group differences for the negative polarity trials, $t(268) = 0.98$.

Planned comparisons involving independent samples *t*-tests with Bonferroni corrections were carried out on the positive polarity conditions between the groups and revealed that the ASC group performed significantly worse than the control group in the Head Left/Eyes Left, $t(28) = 2.25$, $p < .05$, and Head Right/Eyes Right conditions, $t(28) = 2.52$, $p < .02$. In addition, the Head Left/Eyes Straight and Head Right/Eyes Straight just missed significance ($p = .065$ and $p = .079$ respectively), with the control group once again performing better than the ASC group. There were no significant differences for any of the other conditions ($p > .05$ for all).

There was a significant interaction between polarity, head direction and group, $F(2, 27) = 3.51$, $MSE = 0.14$, $p < .05$. Post hoc independent samples t-tests between groups for the positive and negative trials across the Left, Straight, and Right Head direction conditions showed the controls performed better than the ASC group on the Head Left Positive trials, $t(88) = 2.42$, $p < .02$, and the Head Right Positive trials, $t(88) = 2.33$, $p < .05$. The groups did not show any other significant differences for positive or negative trials in any of the other Head Direction conditions (all $p > .05$).

Further within-group planned comparisons showed that the control group was significantly worse for each of the negative conditions compared to the corresponding positive conditions for every case except the Direct Gaze/Straight Head condition ($p < .05$). The autism group also showed no difference between positive and negative trials for the direct gaze/straight head condition, like the controls. However, unlike the controls they also showed no significant difference between positive and negative trials in the Head Right/ Eyes Center and the Head Left/Eyes Center conditions ($p < .05$). The rest of the conditions showed no significant differences for the ASC group. Analysis of the data involving the three groups (typical females, typical males, and ASC) revealed a significant main effect of polarity, $F(1, 339) = 309.94$, $MSE = 84.74$, $p < .001$. More importantly, there was a crucial interaction between group and polarity, $F(2, 339) = 25.79$, $MSE = 7.05$, $p < .001$. Post-hoc independent sample *t*-tests on the positive polarity data showed that females were significantly better than both the control males, $t(205) = 3.17$, $p < .01$, and the males with ASC, $t(205) = 5.05$, $p < .001$, while the control males performed better than the males with ASC, $t(268) = 3.37$, $p < .01$ (see Figure 4). Post-hoc independent sample *t*-tests on the negative polarity data revealed that the males performed significantly better than the females, $t(205) = 2.01$, $p < .05$. There were no other significant differences ($p > .05$ for all). These results show that the females had the steepest slope line between positive and negative polarity gaze perception with the greatest decrement in performance, followed by control males, and then the ASC group with the flattest line and smallest decrement in performance from positive to negative polarity.

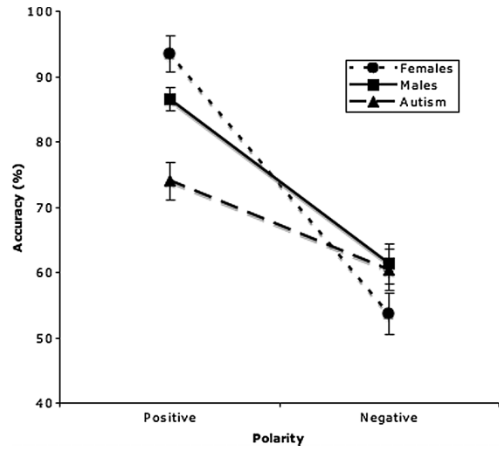

Figure 4. Accuracy results with standard errors for control males, control females, and males with autism across positive and negative eye polarity.

DISCUSSION

In the present study typical males showed significantly worse performance in gaze direction perception when contrast polarity of the eyes was changed from positive to negative, consistent with previous findings involving mainly female participants (Ricciardelli et al., 2000). Importantly, males with ASC showed significantly worse gaze direction detection than controls when contrast polarity of eyes was positive, and less of a decrement in performance when the eyes in the images changed to negative contrast polarity. These findings show that high-functioning adults with ASC have decreased expertise in gaze direction perception, and suggest they do not use the typical gaze heuristic in the same way as normally developed adults to work out where others are looking.

Control males showed a large decrement in gaze perception ability when eye stimuli were changed from positive to negative contrast polarity. This was true for all conditions for the typical males apart from the Head Straight/Eyes Straight condition, and is consistent with previous work showing a large decrement in gaze detection performance with a change in polarity in a control group composed almost entirely of female participants. This drop in performance with polarity change is thought to emerge because humans have developed an expert system that utilises a contrast-specific heuristic for processing the gaze direction of others, and the present study shows these findings are true also for typical males. While the ASC group also showed a decrement in gaze perception performance for images with negative contrast polarity of the eyes, there were some important differences compared to controls. The ASC group showed impaired gaze direction detection even when eyes had positive polarity, consistent with deficits in ASC for perceiving the gaze of others in images or everyday life (Baron-Cohen, 1995; Howard et al., 2000; Kanner, 1943; Swettenham, 2001; Wallace, Coleman, Pascalis, & Bailey, 2006). The decreased expertise for gaze perception would be expected to play a role in the development of deficits seen in higher-level social–emotional abilities involving joint attention and reading mental states from the eyes (Baron-Cohen, 1995).

If people with ASC have reduced expertise for gaze and are using a more online (i.e. conscious) and rule-based style of processing utilizing featural information from the eyes, we should expect to see relatively good performance in conditions where information is less ambiguous and easily perceivable. At the same time we should expect to see impaired performance in more ambiguous conditions that may require a more holistic type of processing. This was generally confirmed, as the biggest differences in performance by the ASC group were found in conditions when the poser in the photos had an averted head combined with eyes that were either averted congruent with the head direction, or looking straight ahead. These are the most difficult and ambiguous conditions as some amount of white sclera is visible on either side of the iris, and since the head is averted makes it difficult to judge whether the person is looking straight ahead or to the side—particularly when a quick, intuitive judgement is required. Conversely, the ASC group did well on trials where explicit rules could easily and quickly be applied about the position of the iris, such as when the head was straight and the eyes were either straight or averted. Therefore the lack of expertise in ASC is most evident when information about gaze direction is most difficult and ambiguous. We speculate that this emerges from a more effortful online style of processing for social information in those with ASC that relies on a different heuristic for judging gaze direction than control participants, who instead use a more intuitive and expert system for gaze perception. The atypical social processing in ASC has less interference on gaze judgments compared to controls when contrast polarity of the eyes is shifted from positive to negative.

Although knowledge about the brain mechanisms for gaze processing in typical controls has grown considerably, the understanding about differences in these neural mechanisms in ASC is lacking. Neuroimaging studies with controls have shown that the STS and IPL are key brain areas for perceiving the gaze directions of others (Haxby at al., 2000; Hoffman & Haxby, 2000; Materna, Dicke, & Thier, 2008; Pelphrey, Singerman, Allison, & McCarthy, 2003; Wicker, Michel, Henaff, & Decety, 1998). The posterior part of the STS (pSTS) is reported to be more involved in reading intentionality from social information like gaze direction (Pelphrey, Morris, & McCarthy, 2004b; Saxe & Kanwisher, 2003; Saxe & Powell, 2006; Saxe, Xiao, Kovacs, Perrett, & Kanwisher, 2004), while the anterior STS (aSTS) is associated more with perceptual coding of different gaze directions (Calder et al., 2007). Atypical activation of the pSTS has been reported in ASC during a task of gaze direction perception involving inferences about intentionality (Pelphrey et al., 2005), which is thought to show the STS doesn't correctly code the mental significance of gaze direction in those with ASC. This is consistent with a recent fMRI study showing greater activation of the aSTS and the IPL in those with ASC while viewing real-life videos of posers shifting their gaze direction (Ashwin et al., submitted for publication). The findings of differences in aSTS activation in ASC are thought to reflect a greater effort in judging the gaze direction of others in real-life videos, due to reduced gaze expertise and a greater reliance on detailed perceptual information from the eyes. Another neuroimaging study of gaze processing showed that people with ASC failed to recruit higher-level brain areas for cognitive control when viewing incongruent gaze shifts (Dichter

& Belger, 2007). Together these neuroimaging findings suggest that the mechanisms underlying reduced expertise for gaze direction processing in ASC are associated with greater perception of detailed local information alongside a reduced ability to intuitively discriminate more ambiguous and difficult gaze direction information and to read mental states from the eyes. Further work with neuroimaging paradigms is needed to better understand the neural underpinnings of differences in gaze perception and understanding in ASC.

The present results are consistent with the EMB theory of autism, which predicts that people with ASC will have difficulties with more ambiguous and difficult social–emotional information, and will show intact or superior performance in processing visual–spatial information that is highly geometrical and rule-based. The EMB theory further predicts that females will perform better on empathizing compared to males, who in turn will be better than people with autism. This pattern of results was confirmed in our study. Female controls performed significantly better at gaze detection with positive polarity compared to control males and those with ASC, and had a larger decrement in performance than both groups when images had negative contrast polarity of the eyes. Males with ASC were significantly impaired relative to both control males and females with positive polarity, and showed the least decline in performance when images contained eyes with negative polarity. Therefore the control females had the greatest decrement in performance from positive to negative polarity, followed by the control males, and then the ASC group. These results are consistent with recent findings of sex differences for eye gaze effects (Bayliss & Tipper, 2005), and with the literature showing that females often perform better than males on social–emotional tasks (Baron-Cohen, 2003; Hall, 1978). However, given the small number of females in the present analysis, further work is needed to test this effect in larger samples.

CONCLUSION

Typical males showed a large decrement in gaze detection performance when eyes were changed from positive to negative polarity, consistent with previous results with control females. Males with ASC were impaired in detecting gaze direction with positive polarity compared to controls, and showed less of a decrement in performance when eye stimuli changed from positive to negative polarity. Further analyses including previous data showed that females performed better than both groups of males with positive polarity eyes and showed a greater decrement in gaze detection when images of eyes were changed to negative polarity. Control males were better with positive polarity gaze than males with ASC and had a greater decrement in performance when eye images were switched to negative polarity. The results are consistent with the extreme male brain theory of autism and show decreased expertise with gaze in ASC. These findings suggest people with autism do not use the typical gaze detection heuristic, or use it in an abnormal way, when working out where others are looking.

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