Does perceived direct gaze boost detection in adults and children with and without autism? The stare-in-the-crowd effect revisited

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This study extended that of von Grünau and Anston (1995) and explored whether perceived direct gaze is easily detected by individuals with and without autism, utilizing a visual-search paradigm. Participants detected target faces with either direct gaze or averted gaze. Laterally averted faces were used to eliminate the involvement of lower perceptual characteristics such as symmetry, which were inherent with the ''straight gaze'' used by von Grünau and Anston. Both typically developed adults and children detected targets with direct gaze more quickly than those with averted gaze, but face inversion distorted this asymmetrical performance, suggesting the contribution of configurative facial processing. In contrast, children with autism were not affected by the gaze direction presented by realistic facial stimuli. They were, however, faster to detect straight gaze defined solely by local features, which suggests that their impairment might be specific to the detection of direct gaze presented within a facial context.

The direction of another's gaze reveals his or her current attention and intention, and thus serves as a crucial signal in social interaction and communication. In particular, direct gaze indicates another's intentions towards the perceiver and may alert him or her to potential threats (e.g., a predator, an enemy) or rewards (a social and/or sexual partner). It follows that there may be evolutionarily
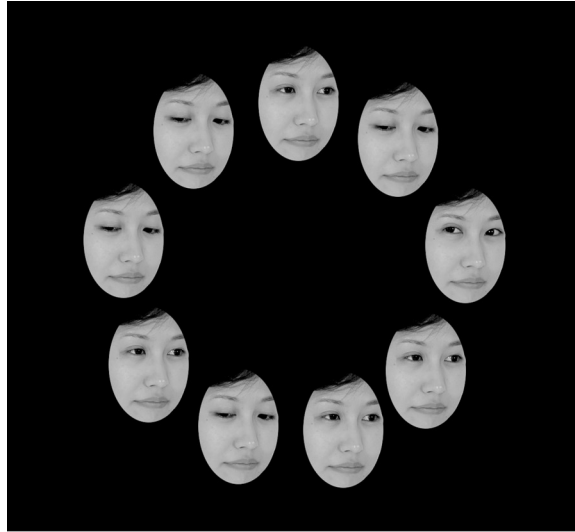
equipped perceptual or cognitive mechanisms that are specialized for detecting and attending to another's direct gaze; such mechanisms may have led to reproductive success in the course of human evolution. Recent advances in cognitive neuroscience have revealed that eye gaze is processed in specific brain regions, such as the superior temporal sulcus (STS; Hoffman & Haxby, 2000; Pelphrey, Singerman, Allison, & McCarthy, 2003; Puce, Allison, Bentin, Gore, & McCarthy, 1998) or the amygdala (Kawashima et al., 1999), supporting the evolutionary significance of gaze processing.

Behavioural findings have revealed the significance of direct gaze for human cognition and behaviour. As early as a few days after birth, neonates discriminate direct eye gaze from closed eyes or averted eye gaze, and prefer the former to the latter (Batki, Baron-Cohen, Wheelwright, Connellan, & Ahluwalia, 2000; Farroni, Csibra, Simion, & Johnson, 2002). These studies strongly suggest that humans have an innate mechanism to detect and attend to another's direct eye gaze. This innate tendency to prefer direct gaze may facilitate mother–infant interactions (Robson, 1967; Robson, Pedersen, & Moss, 1969) as well as infant learning about the characteristics of the human face (Morton & Johnson, 1991). In adults, another's direct gaze is reported to increase levels of arousal (Gale, Nissim, Lucas, & Harpham, 1972; Nichols & Champness, 1971) and to enhance facial recognition (Hood, Macrae, Cole-Davies, & Dias, 2003; Macrae, Hood, Milne, Rowe, & Mason, 2002).
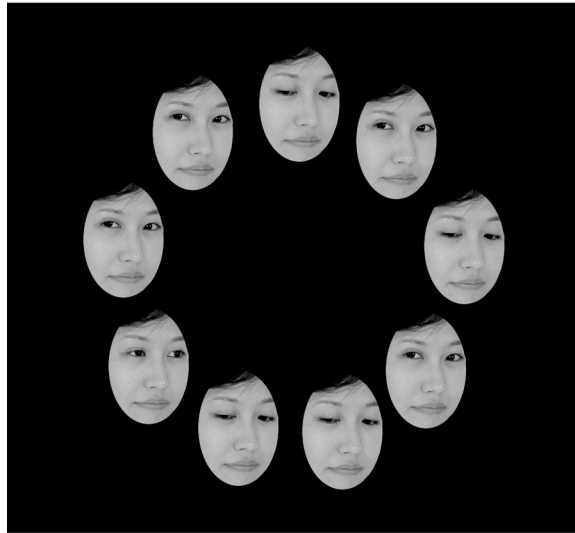
In addition, such sensitivities to the perceived gaze direction can be impaired in the case of atypical social development such as autism. Autism is a developmental disorder that is characterized by an impairment in social interaction and communication, and the presence of ritualistic, stereotypic, and limited behaviour, and interest (American Psychiatric Association, 1994; Baron-Cohen, 1995). Atypical mutual gaze behaviour is one of the major characteristics in individuals with autism (American Psychiatric Association, 1994). It appears very early in development (Osterling & Dawson, 1994; Osterling, Dawson, & Munson, 2002). In the later stages of development, although they show some intact gaze processing, such as the estimation of the direction of others' eye gaze (Leekam, Baron-Cohen, Perrett, Milders, & Brown, 1997) and reflexive orienting to the direction of others' eye gaze (Chawarska, Klin, & Volkmar, 2003; Neely, 2001; Okada et al., 2002; Senju, Tojo, Dairoku, & Hasegawa, 2004; Swettenham, Condie, Campbell, Milne, & Coleman, 2003), individuals with autism have impairments in joint attention behaviour (Leekam et al., 1997; Loveland & Landry, 1986; Mundy, Sigman, Ungerer, & Sherman, 1986) or in the inference of another's mental state from another's eye region (Baron-Cohen, Campbell, Karmiloff-Smith, Grant, & Walker, 1995; Baron-Cohen, Wheelwright, & Jolliffe, 1997). Furthermore, a study that we conducted recently revealed that children with autism were not affected by the gaze direction of a centrally presented face in an oddball paradigm (Senju, Yaguchi, Tojo, & Hasegawa, 2003).

Since another's direct gaze tells us about that individual's current intentions towards ourselves, swift detection of another's direct gaze from the surrounding environment would be of great benefit, enabling a faster reaction. Faster direct gaze detection was first examined by a series of elegant experiments conducted by von Grünau and Anston (1995). They adopted a visual search paradigm and demonstrated the relative salience of direct gaze. In their experiments, realistically drawn or schematic eyes (upper and lower lids, iris, and pupil) with various gaze direction (central gaze, iris and pupil having a centre position in the socket; leftward-looking gaze, iris and pupil having the leftmost position in the socket; rightward-looking gaze, iris and pupil having the rightmost position in the socket) were presented, and participants were instructed to detect targets with each eye direction among distractors, which consisted of the eyes with the other two gaze direction. In this experiment, participants were faster at detecting eyes with a central (staring) gaze among distractors with leftward- or rightward-looking eyes than they were at detecting eyes with an averted gaze among their other distractors. These results suggested that the detection of staring gaze was easier relative to averted gaze. However, as they pointed out in their paper, one major limitation of their study was that they only used eye-only stimuli and thus '''straight gaze' and 'eyes looking at the observer' were confounded'' (p. 1311). For example, an averted face with the eye gaze averted in the opposite direction to the face orientation can create ''direct gaze'' but not ''straight gaze''. Since straight gaze inevitably differs from averted gaze in basic features such as bilateral symmetry, which itself may affect search efficiency, it is important to investigate whether the ''directedness'' of eye gaze alone is sufficient to lead to faster detection latencies.

The present study investigated whether perceived direct gaze was easier to detect among averted gaze distractors than vice versa. To eliminate the possibility that lower-level perceptual features, such as bilateral symmetry in the eye region, might interfere with the results, we employed laterally averted (i.e., three-quarter) faces with varying eye directions (see Figure 1). Because another's direct gaze is a critical social signal in human interaction, we predicted that the detection of faces with direct gaze from among those with averted gaze would be faster than the detection of those with averted gaze, resulting in a relative difference in search efficiency. In addition, we included inverted facial stimuli as well as upright ones. In our stimuli, direct gaze can only be perceived with reference to the degree of head diversion. Such interaction of eye and head direction may require configurative facial processing (Bruce & Young, 1986; Langton, Watt, & Bruce, 2000). Because facial inversion is known to distort configurative facial processing (the facial inversion effect: *OLE_LINK7Valentine, 1988; Yin, 1969*OLE_LINK7), the relative salience of direct gaze may be diminished in inverted faces. Consequently, we predicted that search efficiency would not differ in that condition.

(a)

(b)

Figure 1. Examples of a stimulus display with a display size of 9 for Experiments 1 and 2. (a) The direct-gaze condition with a target (direct gaze, appeared to the right position of the stimulus array) present among distractors (rightward gaze and downward gaze). (b) The averted-gaze condition with a target (rightward gaze, appeared to the lower left area of stimulus array) present among distractors (direct gaze and downward gaze).

Further aim of the current study was to explore the relative salience of another's direct gaze for individuals with autism. In previous studies we have reported atypical responses to perceived eye gaze in individuals with autism (Senju et al., 2003, 2004). It is possible that individuals with autism would not exhibit relatively faster detection of another's direct gaze, compared to averted gaze, in a visual search paradigm: The ''stare-in-the-crowd'' effect (von Grünau & Anston, 1995). To date, several previous studies have employed a visual search paradigm for individuals with autism (O'Riordan, Plaisted, Driver, & Baron-Cohen, 2001; Plaisted, O'Riordan, & Baron-Cohen, 1998). However, since they only used nonsocial stimuli, it is still unknown how the ''social'' properties of the stimuli would impact on search performance.

EXPERIMENT 1

This experiment was designed to investigate the relative saliency of perceived direct gaze in a typically developed population, utilizing a visual search paradigm. The stimuli were laterally averted faces with varying degrees of eye direction, and the targets were either faces with direct gaze or those with averted gaze (see Figure 1). Facial stimuli were presented either upright or upside-down. There were two predictions: First, if direct gaze is relatively salient for the human observer, it should be detected faster and more efficiently than gaze-averted targets (i.e., there should be a decrease in search time per item, creating a ''search asymmetry'' in the slope of the search function; Wolfe, 2001). Second, if direct gaze perception relies on configurative facial processing (Bruce & Young, 1986), facial inversion should interfere with gaze perception and eliminate the faster detection of perceived direct gaze, since facial inversion is known to distort configurative facial processing (Valentine, 1988; Yin, 1969).

Method

Participants.   Eight graduates and undergraduates of the University of Tokyo (five female, three male) volunteered to participate in the experiment. All had normal or corrected-to-normal visual acuity.

Apparatus and stimuli.   The experiment was conducted on a laptop PC with a 12-inch colour LCD monitor, using Cedrus SuperLab Pro software. The participants were seated approximately 67 cm from the monitor. Their reaction times (RT) and accuracy were measured from their keyboard responses.

A fixation point consisting of a central cross that subtended 1° appeared on the screen, on which the participants were instructed to fixate before the experiment started. Each stimulus display consisted of five or nine female faces with varying eye directions. Faces were presented on an imaginary circle, which centred on the central fixation point and subtended approximately 12.5° (Figure 1). Colour photographs of the faces were cut into ovals (2.5° wide and 3.5° high)

to produce the stimulus elements in the eye direction condition. All the faces were laterally averted (three-quarter) aiming at eliminating the lower perceptual feature, such as bilateral symmetry in the eye region, which might affect the results. These consisted of a face with direct gaze, a face with averted gaze, and a downward-looking face (Figure 1). These three stimuli were produced from the same basic image, on which the same person's eyes were superimposed from other photographs according to stimulus type, using Adobe Photoshop 7.0 software. This resulted in three face types that were exactly the same except for eye direction. The targets in each condition were faces with either direct or averted gaze, with the other two stimuli types serving as distractors.

Design and procedure.   The experiment consisted of five factors: Eye direction of target face (target gaze; direct or averted), facial orientation (upright or inverted), facial direction (left or right),[1] number of presented faces (array size; five or nine items), and presence of the target (present or absent). One of the possible eight combinations of the target condition (target gaze, facial orientation, and facial direction) served as a target in each block (i.e., direct gaze in an upward and left-looking face was a target in one block, averted gaze in an inverted and right-looking face was a target in another block, and so on.), which yielded eight blocks in total. Within each block, distractors were always the same as targets with respect to the facial orientation and facial direction, but had different gaze direction from that of targets. Each block consisted of 32 test trials, preceded by 8 practice trials. Accordingly, each participant went through a total of 320 trials. Within each block, the target was presented in 50% of the test trials, and was absent in the other 50% (i.e., 16 trials each). Each array size also appeared an equal number of times. The presentation order of each trial, as well as the order of the blocks, was randomized across participants.

Participants were instructed to fixate on the central fixation cross before each trial, and to respond as soon as possible by pressing a key on the computer keyboard corresponding to the presence or absence of the target (i.e., to press one key when the target is present, and to press another key when the target is absent), using their preferred hand. Eight practice trials preceded the test trials for each block, in order to familiarize participants with the task and the target stimuli. Each trial started with presentation of the central fixation cross for 500 ms, which was then replaced with the stimulus array. The stimulus array remained on the display until the participant responded. Immediately after the participant's response, feedback was presented on the centre of the screen for 500 ms (''Good job!'' for correct response and ''–'' for incorrect response). The next trial started after a 1000 ms interstimulus interval. Participants were

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[1] We did not have special prediction about the effect of face direction. This factor was subjected into analyses in order to increase the statistical power.

allowed to take a brief rest between experimental blocks, and a 5 min rest was inserted between the fourth and the fifth block.

Results and discussion

The average reaction times (RTs) and the average error rates (Table 1) were subjected to a five-way analysis of variance (ANOVAs), with target gaze (direct or averted), facial orientation (upright or inverted), facial direction (left or right), array size (five or nine items), and presence of the target (present or absent) as independent variables. Trials with RTs of less than 100 ms were regarded as anticipatory responses and disregarded from the analysis. These resulted in the elimination of less than 1% of the trials. In addition, only RTs for correct responses were averaged.

For RTs, the ANOVA yielded significant main effects of array size, $F(1, 7) = 75.69$, $p < .01$, and presence of the target, $F(1, 7) = 50.49$, $p < .01$, and a significant interaction between array size and presence of the target, $F(1, 7) = 30.01$, $p < .01$. These results are in accordance with previous visual search

TABLE 1
Mean reaction times with standard errors and error rates for
Experiment 1*

Gaze direction	Face upright		Face inverted	
	Direct	Averted	Direct	Averted
Target present				
5 items				
M	1214.2	1476.5	1275.3	1354.4
SE	93.8	103.5	97.1	94.7
%E	13.2	13.2	14.6	15.3
9 items				
M	1533.4	1990.5	1701.5	2009.5
SE	114.0	171.2	110.3	192.9
%E	16.0	16.0	16.0	15.3
Target absent				
5 items				
M	1503.2	1793.7	1591.3	1658.2
SE	124.7	145.7	123.7	126.6
%E	2.1	3.5	2.1	5.6
9 items				
M	2247.6	2818.5	2458.0	2576.1
SE	175.2	297.3	199.0	252.5
%E	2.1	0.7	0.0	6.9

*Data for left and right face orientation was pooled, as orientation had no significant effect.

experiments (e.g., Treisman & Souther, 1985; von Grünau & Anston, 1995), indicating that search was dependent on the number of distractors, and that visual search was more exhaustive when the target is not present.

Most importantly, there was a significant main effect of target gaze, $F(1, 7) = 14.13$, $p < .01$, and a significant interaction between target gaze and facial orientation, $F(1, 7) = 8.49$, $p < .05$. Simple effect analyses revealed that the detection of direct gaze was significantly faster than that of averted gaze in the upright face condition, $F(1, 7) = 11.16$, $p < .01$, but that this effect was not significant when the faces were inverted, as we predicted (see also Figure 2). In addition, there was a significant interaction between target gaze and array size, $F(1, 7) = 8.22$, $p < .05$, as indicated by a shallower search slope for the targets with direct gaze than for the gaze-averted targets. No other main effects or interactions approached significance.

For error rates, there was a main effect of the presence of the target, $F(1, 7) = 53.18$, $p < .01$, indicating that participants made more errors by missing presented targets than false positive errors when targets were absent. No other main effects or interactions were significant. However, since such low error rates may suggest the ceiling effect, only the findings regarding RT will be discussed below.

Figure 2. Mean reaction times with standard errors (in ms) as a function of target gaze direction and facial orientation in Experiment 1. The white bars represent RTs for targets with direct gaze and the black bars represent RTs for targets with averted gaze. **$p < .01$.

These results clearly demonstrated that for three-quarter faces, perceived direct gaze was detected faster than averted gaze. This successfully extends the findings of von Grünau and Anston (1995), and suggests that it is the perceived direction of another's gaze, not the relative position of the iris in the eyelid, that facilitates the speed of visual search. In addition, the search slope (detection time per item) was also shallower when the target had a direct gaze relative to an averted gaze, which indicated that direct gaze was detected more efficiently (Wolfe, 2001). Moreover, the superiority of perceived direct gaze was found only for upright faces, and was diminished when faces were presented upside-down. Since face inversion is known to distort configurative facial processing (Valentine, 1988; Yin, 1969), and is thought to interfere with the perception of gaze direction in relation to the facial frame, this result also points to the importance of gaze perception, rather than to other perceptual features specific to current stimuli, in facilitating the detection of faces with direct gaze, as compared to those with averted gaze. However, it is still unclear why such Target gaze × Facial orientation interaction was significant in overall RT but failed to approach significance in search efficiency: Target gaze × Facial orientation × Array size interaction, $F(1, 7) = 0.92$, n.s. Since the data clearly showed the significant effect of gaze direction on search efficiency, it might suggest that gaze direction in an upside-down face could have a smaller effect on search efficiency, but did not affect overall RT. However, evidence is still limited and further research will be required to figure out the search mechanism underlying the facial inversion effect found in this study.

Experiment 2

Experiment 1 replicated the findings of von Grünau and Anston (1995) utilizing ''direct'' but not ''straight'' eye gaze and revealed that perceived direct gaze facilitates the speed of detection in a visual search paradigm. In Experiment 2, we investigated whether this asymmetrical sensitivity to direct gaze, as compared to averted gaze, is also present in children with autism. Because atypical gaze processing in individuals with autism has been reported elsewhere (Baron-Cohen, 1995; Senju et al., 2003), we predicted that perceived direct gaze would not facilitate detection latency in children with autism.

Method

The participants consisted of 17 children with autism (all males; 9:5–14:11 years old, average age: 12:5 years; average RCPM score: 32.18) and 18 typically developing children (1 female and 17 males; 9:5–14:8 years old, average age: 11:10 years; average RCPM score: 33.50). All children were students of, or had graduated from, a primary school for children both with and without autism. All the children with autism were diagnosed by at least one child psychiatrist when they entered the school, according to the DSM-IV criteria (American Psychiatric

Association, 1994). Children were tested with a Japanese version of Raven's Colored Progressive Matrices (RCPM) to assess their levels of nonverbal intelligence (Raven, 1956; Sugishita & Yamazaki, 1993). All children had normal or corrected-to-normal visual acuity.

The stimuli, apparatus, experimental design, and procedure were exactly the same as those of Experiment 1, except that the number of trials was reduced by half (i.e., 160 trials per participant) to decrease the demands on the children. To test whether the use of reduced set of trials might change the results, we calculated the correlation between the first 16 trials of each block and the full 32 trials in each block in Experiment 1. The correlations were fairly high (0.64–0.99, mean: 0.92), which assures that the reduced numbers of trials would yield essentially the same results with the full set of trials. In addition, there was an additional block with 12 practice trials that used unrelated targets and distractors (such as a triangle, a square, and a cross). This additional practice trial block was presented before the gaze visual search in order to familiarize the children with the task requirements. There were three additional children with autism, who either had difficulty in understanding the task requirements or refused to participate in the experiment, and their data were excluded from analysis. Written informed consent was obtained from all the parents of the participants, which was first approved by a local ethical committee.

Results and discussion

Because age or levels of general intelligence might affect the results, the average RTs for the correct response and the average error rates (Table 2) were subjected to six-way analyses of covariance (ANCOVAs), with participant group (autism or typical development), target gaze (direct or averted), facial orientation (upright or inverted), facial direction (left or right), array size (five or nine items), and presence of the target (present or absent) as independent variables, controlling the age and the RCPM score. As before, trials with RTs of less than 100 ms were regarded as anticipatory responses and disregarded from the analysis, which eliminated less than 1% of the trials.

As in Experiment 1, for RTs, the main effects of array size, $F(1, 33) = 266.29$, $p < .01$, and presence of the target, $F(1, 33) = 149.04$, $p < .01$, were significant, as was their interaction, $F(1, 33) = 77.05$, $p < .01$. This replicated previous findings regarding visual search (Treisman & Souther, 1985; von Grünau & Anston, 1995).

For RTs, there was also a significant three-way interaction between participant group, target gaze and facial orientation, $F(1, 33) = 4.51$, $p < .05$ (see also Figure 3). Typically developing children were faster in detecting faces with direct gaze than those with averted gaze when faces were presented in normal orientation, $F(1, 33) = 6.28$, $p < .05$, but their performance for upside-down faces was not affected by gaze direction, $F(1, 33) = 1.49$, n.s. This replicated the

TABLE 2
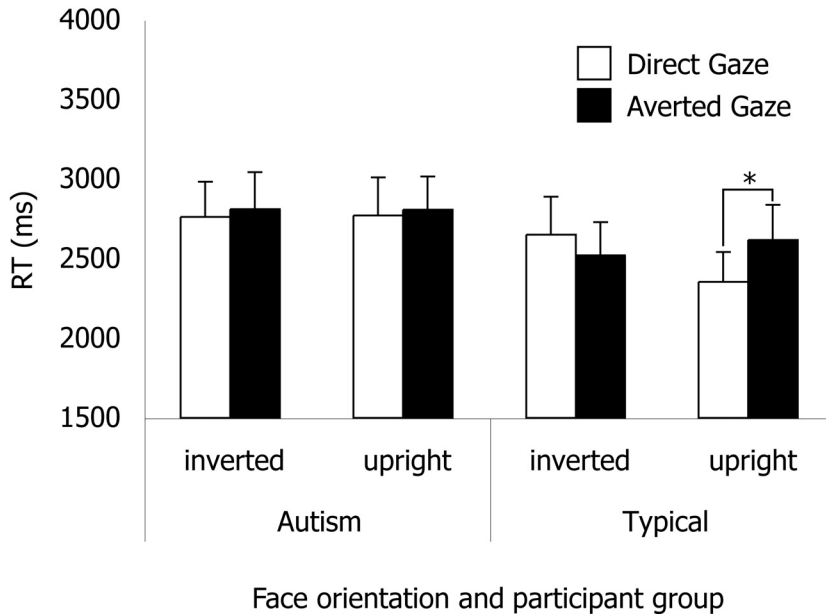Mean reaction times with standard errors and error rates for Experiment 2*.

| | Autism | | | | Typical | | | |
| | Face upright | | Face inverted | | Face upright | | Face inverted | |
Gaze direction	Direct	Averted	Direct	Averted	Direct	Averted	Direct	Averted
Target present								
5 items								
M	2105.7	2179.7	2182.6	2102.1	1801.7	2021.3	2009.6	1849.0
SE	219.4	180.1	157.3	197.7	158.7	178.0	188.0	155.5
%E	13.1	9.8	7.2	7.8	9.9	7.4	17.9	10.5
9 items								
M	2618.8	2897.0	2562.6	2724.3	2254.9	2445.9	2614.1	2426.4
SE	259.7	242.6	213.4	233.2	177.7	163.8	291.9	203.5
%E	17.6	25.5	9.2	12.4	8.0	14.8	13.0	7.4
Target absent								
5 items								
M	2613.5	2528.2	2689.8	2739.7	2216.6	2396.8	2534.9	2447.5
SE	203.0	161.3	238.5	214.5	170.6	237.8	225.5	238.4
%E	11.1	7.2	7.2	5.9	7.4	3.7	9.3	3.7
9 items								
M	3743.0	3619.2	3617.0	3671.1	3144.1	3603.8	3437.0	3361.4
SE	277.0	253.1	269.0	289.9	244.1	298.4	252.2	234.7
%E	5.9	6.5	11.1	7.8	5.6	3.7	5.6	3.7

*Data for left and right face orientation was pooled, as orientation had no significant effect.

findings for adults in Experiment 1. However, in children with autism, gaze direction had no effect on detection speed, regardless of whether they were presented in a normal orientation, $F(1, 33) = 0.12$, n.s., or upside-down, $F(1, 33) = 0.20$, n.s. Note that it is not the presence or absence of the facial inversion effect, since facial orientation made no significant effect both in children with autism, $F(1, 33) = 0.01$, n.s., and in typically developing children, $F(1, 33) = 2.11$, n.s.

For error rates, there was a main effect of presence of the target, $F(1, 33) = 22.63$, $p < .01$, which indicated that children had ''misses'' of the presented target more often than ''false positives'' when the target was absent, similar to the adults in Experiment 1. No other main effects or interactions approached significance. As in Experiment 1, such low error rates may suffer from ceiling effect, so the discussion will be limited to the findings regarding RT.

For typically developing children, the results replicated Experiment 1, in that direct gaze was detected more quickly than averted gaze only when faces were presented upright, which suggests that sensitivity to another's direct gaze is

Figure 3.   Mean reaction times with standard errors (in ms) as a function of participant group, target gaze direction, and facial orientation in Experiment 2. The white bars represent RTs for targets with direct gaze and the black bars represent RTs for targets with averted gaze. *$p < .05$.

present as early as school age.[2] However, this was not the case for children with autism. Gaze direction did not affect the speed of visual search, replicating our previous findings (Senju et al., 2003) in a different experimental paradigm. This is in agreement with clinical findings regarding atypical mutual gaze behaviour, especially the lack of interest in perceived eye contact, in individuals with autism (American Psychiatric Association, 1994; Baron-Cohen, 1995; Osterling (1994; Osterling et al., 2002), which may relate to the lack of a facilitatory effect of perceived direct gaze in their search performance. The present results support the notion that individuals with autism are relatively insensitive to another's direct gaze, unlike those without autism. This insensitivity to perceived eye contact may relate to their impairment in social interaction and communication (Baron-Cohen, 1995). However, there are other possible interpretations of our

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[2] Different from the results in Experiment 1, interaction between gaze direction and array size was not significant. We have come up with no explanation why children failed to show ''search asymmetry'' in this experiment.
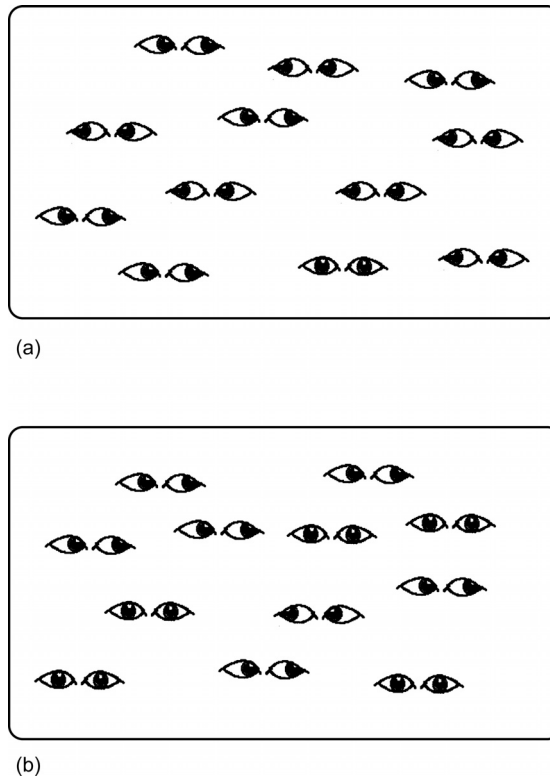
results. One possibility is that individuals with autism do not show a relative superiority in detecting certain stimuli over other stimuli in any visual search, although this seems less plausible, as previous research has found that individuals with autism are quite adept at detecting targets in a difficult visual search (O'Riordian et al., 2001; Plaisted et al., 1998). It is possible that such superior visual search ability masks any differences in search efficiency across stimuli. Another possibility is that individuals with autism may show faster detection of direct gaze in some other conditions, despite the fact that they failed to show a relative sensitivity to direct gaze with our facial stimuli. In Experiment 2, as in Experiment 1, we eliminated possible local cues to define direct gaze, such as the relative position of the iris in the eyelid. Accordingly, viewers were required to grasp the relative direction of the eye gaze with reference to facial direction in order to detect another's direct gaze. Because individuals with autism are known to have difficulties with central coherence (Happé, 1999; Shah & Frith, 1993), or the predominance of holistic information processing over part-based processing (but see also Joseph & Tanaka, 2003), it is possible that such individuals may show a relative superiority in detecting direct gaze when it is defined by local information, such as the relative position of the iris in the eyelid. In addition, it has also been demonstrated that individuals with autism do not rely on the eye region when processing facial information (Joseph & Tanaka, 2003; Langdell, 1978). These possibilities were examined further in Experiment 3.

In Experiment 2, there was no significant interaction between gaze condition and array size, which makes it doubtful that the superiority in detecting direct gaze by typically developing children resulted from ''search asymmetry''. Furthermore, there were no group differences in overall RT or error rate when the effects of age and RCPM scores were controlled. It is possible that the target differed from distractors in a single feature (i.e., the shape of the eye region). Previous research has also shown that individuals with and without autism did not differ in their performance in a simple feature visual search (O'Riordian et al., 2001; Plaisted et al., 1998).

EXPERIMENT 3

The results of Experiment 2 clearly revealed that individuals with autism did not show the ''stare-in-the-crowd'' effect in response to perceived direct gaze. However, because the stimuli used in previous experiments were ''direct'' but not ''straight'' gaze, it is not clear whether individuals with autism really lack sensitivity to another's staring at all. For example, a ''straight gaze'', or gaze with the iris centred in the eyelids, contains additional information, such as symmetrical features. Since individuals with autism are quite adept at estimating another's eye direction (Leekam et al., 1997), it might be the case that children with autism have a relative sensitivity to ''straight gaze'', or to the relative position of the iris in the eyelid. This possibility led us to conduct another

experiment. In this experiment, our aim was to replicate von Grünau and Anston's (1995) study in children with and without autism, where the individuals saw eyes with central, leftward, or rightward gaze. We asked participants to detect one of the gazing targets from among the background distractors, which consisted of the other two types of stimuli (Figure 4). Since these stimuli consisted of only the eye region, it might be relatively easy for children with autism to perceive gaze direction. We predicted that if children with autism lacked sensitivity to another's direct gaze, they would not show faster detection for straight gaze, as compared to averted gaze. On the other hand, if straight gaze was salient for them, children with autism, as well as typically developing children, would detect straight gaze faster than averted gaze.

(a)

(b)

Figure 4. Examples of stimulus displays for Experiment 3. (a) The central-gaze condition with a target (central gaze, appeared to the lower right) present among distractors (rightward and leftward gaze). (b) The rightward-gaze condition with a target (rightward gaze, appeared to the middle right) present among distractors (central and leftward gaze).

Method

Participants.   The participants consisted of 13 children with autism (all males; 9:10–14:11 years old; average age: 12:1 years; average RCPM score: 31.8) and 16 typically developing children (2 females and 14 males; 9:5–14:11 years old; average age: 12:8 years; average RCPM score: 34.2). All of the children were either students of, or had graduated from, a primary school for children both with and without autism. All children with autism had been diagnosed with DSM-IV criteria by at least one child psychiatrist when they entered the school. Written informed consent was obtained from all the parents of the participants before the experiment, which was first approved by a local ethical committee.

Apparatus and stimuli.   The experiment was controlled by the same laptop PC as Experiments 1 and 2, using Cedrus SuperLab Pro software. The participants were seated approximately 67 cm from the monitor. The participants' reaction times (RT) and accuracy were measured from their keyboard responses.

Stimuli consisted of schematic eyes with central (straight) gaze and left-averted or right-averted gaze, which basically followed von Grünau and Anston (1995, Exp. 2). Each pair of eyes subtended 3.5° wide and 1° high (see Figure 4).

Design and procedure.   There were three gaze conditions, in which either central, left-averted, or right-averted gazes were the target stimuli, with the other two stimuli as background distractors. The presenting order of the three gaze conditions was randomized across participants. Each condition was composed of 4 practice trials and 20 test trials. The target was present in half the trials and absent in the other half. In order to reduce the total number of trials, the number of presenting items (array size) was set at 12. The order of presentation was also randomized within each block. Because there was no significant interaction between gaze condition and array size in Experiment 2, we decided to concentrate on investigating the relative speed in detecting each gaze, omitting the investigation regarding search slope.

As in previous experiments, participants were instructed to fixate on the central fixation cross before each trial, and to respond as soon as possible by pressing a key on the computer keyboard corresponding to the presence or absence of the target, using their preferred hand. Participants first completed 12 practice trials, which used unrelated targets and distractors (such as a triangle, a square, and a cross), in order to familiarize themselves with the task require-ments. Then the test trials started. Each trial began with presentation of the central fixation cross for 500 ms, which was then replaced with the stimulus array. The stimulus array was displayed until the participant responded. Immediately following the participant's response, feedback was presented on the

centre of the screen for 500 ms (''O'' for correct response and ''–'' for incorrect response), and then the next trial started after a 1000 ms interstimulus interval. Participants were allowed to take a brief rest between experimental blocks. The experimental design and procedure were similar to those of von Grünau and Anston (1995), except that only one array size (i.e., 12 items) was used in present study. Because our main aim was to investigate the effect of perceived gaze direction, we believed this difference would not affect the main findings.

Results and discussion

As in Experiment 2, age and general intelligence, which might affect performance, were included in the analysis as covariates. The average RTs for correct response and average error rates (Table 3) were subjected to three-way analyses of covariance (ANCOVAs), with participant group (autism or typical development), target gaze (central, leftward, or rightward), and presence of the target (present or absent) as independent variables, controlling the age and RCPM score. Trials with RTs of less than 100 ms were regarded as anticipatory responses and disregarded from analysis, which eliminated less than 1% of the data.
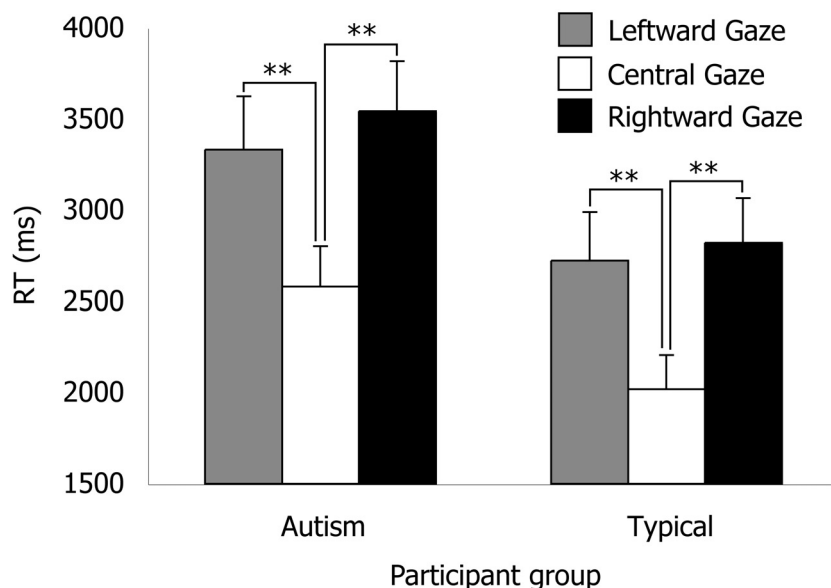
As in previous experiments, a main effect for the presence of the target, $F(1, 27) = 127.94$, $p < .01$, was significant for RTs, which replicated previous basic findings regarding visual search (Treisman & Souther, 1985; von Grünau & Anston, 1995).

For RTs, there was also a significant main effect of target gaze, $F(2, 54) = 37.46$, $p < .01$, and a significant interaction between target gaze and presence of the target, $F(2, 54) = 5.05$, $p < .01$. Further analysis revealed that central gaze was detected significantly faster than leftward- or rightward-looking gaze ($p < .01$; Tukey's HSD test), which did not differ from each other. This replicated

TABLE 3
Mean reaction times with standard errors and error rates for Experiment 3

Gaze direction	Autism			Typical		
	Leftward	Centre	Rightward	Leftward	Centre	Rightward
Target present						
M	2539.7	1908.8	2929.9	2077.4	1570.2	2405.1
SE	226.6	127.0	226.5	202.1	144.4	215.2
%E	18.6	11.5	16.0	16.1	10.4	10.4
Target absent						
M	4126.6	3253.4	4159.4	3369.0	2471.1	3238.6
SE	359.4	314.9	321.0	333.9	227.4	271.4
%E	2.6	3.2	5.1	1.0	2.6	1.0

Figure 5. Mean reaction times with standard errors (in ms) as a function of participant group and target gaze direction in Experiment 3. The grey bars represent RTs for targets with leftward-looking gaze, the white bars represent RTs for targets with direct gaze, and the black bars represent RTs for targets with rightward-looking gaze. **$p < .01$.

von Grünau and Anston's (1995) findings. Most importantly, as is evident in Figure 5, children both with and without autism showed asymmetrically faster detection for central gaze, as compared to leftward or rightward gaze (Group × Target gaze interaction, $F(2, 54) = 0.29$, n.s.

For error rates, as in previous experiments, a main effect of the presence of the target, $F(1, 27) = 46.77$, $p < .01$, was the only significant effect, indicating that participants made more errors by missing presented targets than false positives when targets were absent. No other main effects or interactions were significant.

Our results replicated those of von Grünau and Anston (1995) in that straight gaze was detected faster than averted gaze. The effect of faster detection for straight gaze was present in children both with and without autism, suggesting that the straight gaze used in this experiment is more salient than leftward- or rightward-looking gazes for children with autism, as well as for typically developing children.

These results demonstrate that there is at least one condition where children with autism show a sensitivity to direct gaze, contradicting the prediction that they do not detect direct gaze at all. However, there are at least two possibilities

as to the nature of the crucial factor that made direct gaze more salient than averted gaze for individuals here. One possibility is that, in Experiment 2, the presentation of the whole face interfered with performance in the detection task for children with autism. Individuals here lack the relative predominance of eye region in face recognition that is present in those without autism (Baron-Cohen et al., 1997; Hobson, Ouston, & Lee, 1988; Joseph & Tanaka, 2003; Langdell, 1978). In addition, recent studies with eye-tracking devices have also found reduced visual scanning of the eye region in those with autism (Klin, Jones, Schultz, Volkmar, & Cohen, 2002; Pelphrey et al., 2002). Thus, it is possible that presentation of the whole face masked the relative salience of direct gaze for children with autism. The other possibility is that children with autism use a different aspect of the stimuli, such as the symmetrical feature of straight gaze, in visual search. In our previous study, we found that although children with autism showed reflexive orienting to the direction of another's eye gaze, as do typically developed children, there was no relative superiority of the social cue (i.e., eye gaze) over a nonsocial cue (i.e., arrows), as is present in typically developing children (Senju et al., 2004). It might be the case that individuals with autism process social cues in a nonsocial way. However, further study will be required to determine how individuals with autism process social information.

In addition to the above two possibilities, another factor might affect autistic performance. In Experiment 3, the stimuli were schematic image of eyes, which contrasts with the photographs used in Experiment 2. We believe it unlikely that such differences in stimuli affected current results because von Grünau and Anston (1995) found no difference between the ability to perceive straight gaze in typically developed adults with realistically drawn stimuli and schematic stimuli, and because individuals with autism show atypical gaze processing both with photographs (Klin et al., 2002; Pelphrey et al., 2002; Senju et al., 2003, 2004) and schematic eyes (Baron-Cohen et al., 1995; Coss, 1979). However, recent studies have found that children with autistic spectrum disorder can show better face matching using high-frequency compared with low-frequency information, a result that contrasts with the performance of nonautistic children (Deruelle, Rondan, Gepner, & Tardif, 2004). This indicates that a further study needs to be conducted to investigate whether children with autism were better at using high-frequency information (i.e., edge) in gaze processing as well, and whether this contributed to the differences between Experiments 2 and 3.

GENERAL DISCUSSION

The experiments in this study examined how we perceive and attend to another's direct gaze using a visual search paradigm. We predicted that perceived direct gaze in averted faces would facilitate detection in a typically developing population, but not in individuals with autism. There were two main findings.

First, in visual search, direct gaze was detected faster than averted gaze, which elicited a ''search asymmetry'' in typically developed adults. Because the stimuli in Experiments 1 and 2 included ''direct gaze'' but not ''straight gaze'', these results extend previous findings (the stare-in-the-crowd effect; von Grünau & Anston, 1995) and are the first to reveal that the ''directedness'' of another's eye gaze is sufficient to make direct gaze relatively salient to the perceiver. Moreover, the predominance of direct gaze detection disappeared when facial stimuli were presented upside down, revealing that configurative facial processing is necessary to elicit the relative salience of another's direct gaze.

Second, in Experiment 2, accelerated detection of direct gaze was not found in children with autism. Because of other characteristics specific to visual search (i.e., elongation of RT for larger item size, faster RT for target present condition than for target absent condition), and because individuals with autism are reportedly superior, rather than inferior, to those without autism in visual search paradigms (O'Riordian et al., 2001; Plaisted et al., 1998), this finding cannot be attributed to a general deficit in task performance. In addition, since children with autism were faster to detect ''straight'' gaze than those without autism (see Experiment 3), our results cannot be attributed to a general lack of sensitivity to another's gaze towards oneself. Instead, the absence of a facilitative effect of another's direct gaze for children with autism in Experiment 2 may reflect the absence of lower perceptual cues such as symmetry, or may be masked by the presentation of the entire face, overriding the processing capacity of children with autism and making it difficult to attend to the eye region. In any case, our results clearly demonstrate that ''direct'' but not ''straight'' eye gaze was not salient for individuals with autism, although the exact nature of the difference in the gaze perception of individuals with and without autism needs thorough examination in further studies. Since the interaction between gaze condition and item size was not significant in typically developing children, it is unclear whether the relative ease of detecting direct gaze in typical children can be referred to as a ''search asymmetry''. However, this result might be indicative of large individual variance in task performance, and a more controlled study will be required to further investigate the nature of task performance in typical children.

To perceive direct gaze from the facial stimuli used in Experiments 1 and 2, observers must integrate face direction with eye direction and represent the actual direction of the perceiving face, which is thought to be processed in the STS (Allison, Puce, & McCarthy, 2000; Perrett et al., 1985). Perceived direct gaze in averted faces has also been reported as activating the amygdala (Kawashima et al., 1999), or as increasing the correlation between activities in the fugiform gyrus and the amygdala (George, Driver, & Dolan, 2001). Thus, it is possible that the faster detection of perceived direct gaze in Experiments 1 and 2 reflects the processing of the STS and the amygdala. A lack of sensitivity to perceived direct gaze in individuals with autism might reflect malfunctioning of

the STS and/or the amygdala for face processing in autism. Previous MRI studies have also reported a lack of, or decreased, activation of the STS (Critchley et al., 2000; Pierce, Müller, Ambrose, Allen, & Courchesne, 2001) and the amygdala (Baron-Cohen et al., 1999; Critchley et al., 2000; Pierce et al., 2001) when individuals with autism processed face or eye gaze. However, additional studies are required to reveal the neural correlates of the faster detection of perceived direct gaze, and the lack of such sensitivity in individuals with autism.

Interestingly, neural correlates of gaze direction have been found to interact with other facial attributes such as perceived attractiveness (Kampe, Frith, Dolan, & Frith, 2001), or facial expressions (Wicker, Perrett, Baron-Cohen, & Decety, 2003). In human communication, gaze direction is thought to play a role, in conjunction with other cues, in signalling another's intention or possible reward value. Therefore, it must be productive to examine whether such combinations of social cues affect visual search in individuals with and without autism. Because facial expression, as well as gaze direction, reportedly affects the search latency (Fox et al., 2000; Hansen & Hansen, 1988), the visual search paradigm may be a useful method for investigating human sensitivities to a variety of social cues.

In summary, our findings replicated the previous finding of von Grünau and Anston (1995), i.e., that perceived direct gaze facilitates detection speed. In addition, our findings are the first to demonstrate that the increased detection speed of direct gaze is mediated by configurative facial processing, which may be impaired in individuals with autism. In addition, targets with straight (centre) gaze, which were used in the original study, facilitated detection speed in individuals with autism, as well as in those without autism. These findings suggest that the perception of direct gaze in averted faces is processed differently from straight gaze, at least in individuals with autism. Further studies will be required to examine whether differential gaze processing occurs in the general population.

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