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Gaze and arrow cueing of attention reveals individual differences along the autism spectrum as a function of target context

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Observing averted gaze results in a reflexive shift of attention to the gazed-at location. In two experiments, participants scoring high and low on the Autism-Spectrum Quotient questionnaire (AQ; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001) observed arrow and gaze cues to investigate cueing effect magnitude as a function of the context in which peripheral targets could appear. While identical cueing effects were found with gaze and arrow cues, the more striking results concerned target stimuli. In Experiment 1, targets could appear on a peripheral face, or on scrambled face parts. Overall, greater cueing effects were found when the target appeared on a face. However, this face bias was only observed in participants with low AQ scores, whereas high AQ scorers oriented more to scrambled features. Experiment 2 found equal cueing to targets appearing on tools, as compared with tool parts. However, individual differences were again observed, where low AQ scorers showed larger cueing towards tools, while high scorers oriented more to scrambled parts, as in Experiment 1. These results support the idea that low AQ individuals orient strongly to objects attended by others. However, since the same results were found for arrow cues, this effect may generalize to all central cues to attention. High AQ scorers possessing many more autistic-like traits tended to orient more to scrambled shapes, perhaps reflecting a bias for orienting to local details.

The tendency to orient to the locus of another's attention is clearly of great benefit to an individual. As well as using other conspecifics orienting behaviour to alert the individual to important objects or events in the environment, the ability to accurately encode another's direction of attention may allow at least a coarse representation of the mental state of the observed individual to be constructed by the observer. That is, gaze following may reflect early representations of other minds, leading to the development of a full 'Theory of Mind' (Baron-Cohen, 1995; but see Moore & Corkum, 1994). Gaze following has been found to emerge in infants as young as 3 months old (Hood, Willen, & Driver, 1998; Scaife & Bruner, 1975). Recent studies in adults have shown that

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observing averted gaze results in a reflexive shift of covert attention (Driver *et al.*, 1999; Friesen & Kingstone, 1998; Hietanen, 1999; Langton & Bruce, 1999).

Typically, studies investigating attention shifts following averted eye gaze have presented a face in the centre of the screen, which looks to the left or right. A target then appears on the screen, to the left or right of the face. Manual reaction time to detect, localize or identify the target is shorter when the eyes look at the target location, even when the cue is non-predictive. This paradigm is very effective at measuring the attentional effects of gaze-following. Interestingly, non-predictive arrow stimuli seem to have very similar effects on behaviour (Eimer, 1997; Hommel, Pratt, Colzato, & Godijn, 2001; Ristic, Friesen, & Kingstone, 2002; Shepherd, Findlay, & Hockey, 1986; Tipples, 2002). However, gaze-cues are robust cues to attention, even when participants are told that targets will probably appear at the opposite side of space to the cue, whereas top-down control can be utilized more easily when other directional stimuli are anti-predictive (Downing, Dodds, & Bray, 2004; Friesen, Ristic, & Kingstone, 2004).

One intriguing difference between developmental studies on Joint Attention (where 'two individuals are attending to the same object, based on one individual using the attention cues of the second individual'; Emery, 2000, p. 588), and those using averted gaze as a cue to attention, is that in gaze-cueing paradigms, no object is present until target presentation. In development, infants are able to orient to the correct object of another's attention after around 12 months, before which time, the first object along the line of sight tends to capture attention (Butterworth, 1991). Objects are also important in joint attention episodes when one considers evidence that suggests that language development is correlated with the development of joint attention (Baldwin, 1995). A weak joint attention system, which fails to consistently orient to the correct object, may impede the pairing of a visual object to its name, and hence slow vocabulary acquisition.

The importance of objects to orienting behaviour is also clear from the visuospatial attention literature. For example, the attentional processes of excitation and inhibition have been found to spread across an object's surface (Egly, Driver, & Rafal, 1994; Jordan & Tipper, 1999; Reppa & Leek, 2003). Thus, these studies showed that cueing one part of an object resulted in larger attentional cueing (facilitation or inhibition) to targets appearing in different parts of the same object than to equidistant targets that were part of different objects. Other studies have shown that the inhibition that can be activated via a sudden onset peripheral cue (i.e. inhibition of return; Posner & Cohen, 1984) is larger if attention was oriented to an object rather than to an area of space filled with random patterns with no apparent global form (Jordan & Tipper, 1998). If objects are the unit of attentional selection, then gaze-cueing should also evoke object-based cueing effects, such that greater cueing should be observed towards objects, as compared to towards displays that contain comparable density and complexity of visual information, yet constitute no coherent visual object (Jordan & Tipper, 1998).

We felt that the object category to be presented at target location may be important when considering the context of social interactions that surround gaze-cueing effects. If the objects upon which targets could appear were also themselves faces (Experiment 1), then participants would be observing a highly complex visual scene (see Fig. 1, top panel), in which three potentially mentalistic agents (participant, cue face and cued face) are involved in a mutual attention-sharing episode. If observing this scene strongly activates a social orienting mechanism, then gaze-evoked attention shifts should be much larger than towards displays of scrambled face parts. If the observation of a social interaction is critical, then a central cue other than eye-gaze would not evoke such a difference in cueing. Although arrows are stimuli that are designed to communicate
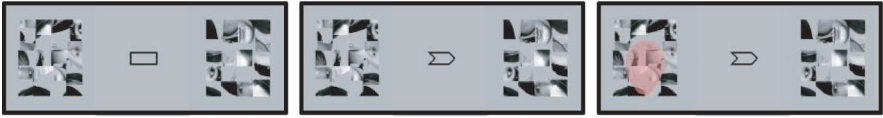
a) Eye-gaze cue, target appearing on a face

b) Arrow cue, target appearing on a face
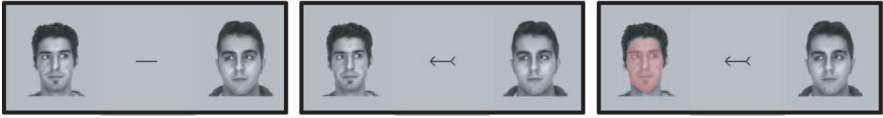
c) Eye-gaze cue, target appearing on scrambled face parts

d) Arrow cue, target appearing on scrambled face parts

1504 ms   376 ms   until response

Time

Figure 1. Illustration of the time-course of conditions in Experiment 1. The displays were preceded by the presentation of a fixation cross in the centre of the screen, for 658 ms. Panels (a) and (b) illustrate valid trials, since the target appears at the cued locations. Panels (c) and (d) are examples of invalid trials. *Note.* Figure 1 is available in colour in the online article and from the author.

direction, they are nevertheless devoid of the socio-biological importance of a gaze-cue. Therefore, if social interactions drive orienting to social stimuli, then greater cueing to faces will only be observed when a face produces a gaze-cue. If object-based attention acts regardless of the cue, then greater orienting to faces (as compared with scrambled face parts) will be observed when a gaze or an arrow produces a cue.

A further concern of this study was the possibility that different individuals might have different orienting biases, related to their overall cognitive processing style. That is, some individuals will be strongly biased to orienting towards social stimuli, while others will not show this bias. Such orienting biases are evident in the autism and sex differences literature. For example, compared to normally developing children, infants with autism spend little time orienting to people (Swettenham *et al.*, 1998). Instead, non-social objects are attended longer by infants with autism. Poor social skills and communication are central to the impairments presented by people with autism. Indeed, while normal children understand that gaze behaviour of others allows one to infer the intentions and desires of mentalistic agents, children with autism seem to utilize gaze on a more superficial level (Baron-Cohen, Campbell, Karmiloff-Smith, Grant, & Walker, 1995). Furthermore, children with autism often have poor joint attention skills (Charman, 2003; Charman *et al.*, 1997). Overall, the poor theory of mind skills in people with autism (e.g. Baron-Cohen, 1989) has led Baron-Cohen (2002) to suggest that people with autism have a general profile of poor *empathizing* skills.

The other significant aspect to the cognitive profile of people with autism-spectrum disorders is the observation that many people with autism have good attention to details, islets of ability and obsessions. A wider reaching theoretical framework that is able to explain both triadic (e.g. impaired social, language and imagination skills) and non-triadic symptoms of autism (e.g. attention to details) is needed to fully explain the syndrome (Frith & Happé, 1994). Weak *central coherence* in perception and processing style has been posited as a deficit in processing global form, with a preserved or superior ability to process local features (Frith, 1989; Frith & Happé, 1994; Happé, 1999). Indeed, people with autism have been shown to have a perceptual bias toward the processing of local details of visual stimuli (Mottron, Belleville, & Menard, 1999; Mottron, Burack, Iarocci, Belleville, & Enns, 2003), superior conjunctive visual search (O'Riordan, Plaisted, Driver, & Baron-Cohen, 2001), and more fluent perceptual processing (Brian, Tipper, Weaver, & Bryson, 2003).

As an alternative to weak central coherence, Baron-Cohen (2002) suggests that a bias towards the processing of local features reflects the stronger tendency to *systemize*, to attempt to understand and build systems. Indeed, children with autism are better at understanding mechanical events than normally developing controls (Baron-Cohen, Leslie, & Frith, 1986), and are more likely to have fathers or grandfathers who have been engineers, perhaps reflecting the genetic basis underlying such traits (Baron-Cohen, Wheelwright, Stott, Bolton, & Goodyear, 1997). Hence, people with autism have a cognitive style that is associated with good systemizing, but poor empathizing skills. However, the more direct relevance this theory has to this study is its relationship to diversity in cognitive style in the normal population. Indeed, empathizing and systemizing are predicted to vary within the normal population, and the majority of evidence for this comes from sex differences in empathizing and systemizing abilities. The extreme male brain theory of autism (Baron-Cohen, 2000, 2002, 2003) suggests that exceptional systemizing and very poor empathizing skills are the hallmarks of the extreme male brain, and of autism. Indeed, the vast majority of people with autism-spectrum disorders are male (Rutter, 1978). Poor systemizing, but good empathizing skills describe the cognitive style associated with the extreme female brain. While the gender of the brain describes only cognitive style and is not necessarily fixed to the biological sex of the person, normal sex differences in infancy and adulthood reflect the idea that empathizing and systemizing vary within the normal population.

Sex differences are apparent from very early in life, since female neonates spend more time looking at a human face than at a mobile, while male neonates show the opposite preference (Connellan, Baron-Cohen, Wheelwright, Batki, & Ahluwalia, 2000). Furthermore, more eye contact is made by female infants than by male infants at 12 months old (Lutchmaya, Baron-Cohen, & Raggatt, 2002). Later in life, these biases are equally striking. Many studies have shown gender differences on a wide range of cognitive skills (see Geary, 1998, for review). Males outperform females in spatial tasks, such as the water-level test (Robert & Ohlmann, 1994), mental rotation (Geary, Gilger, & Elliott-Miller, 1992) and line-angle judgment (Collaer & Nelson, 2002), reflecting superior processing of physical systems in males. Females have been found to perform better in episodic memory tasks involving face recognition (Yonker, Eriksson, Nilsson, & Herlitz, 2003). Also, males are more vulnerable to prosopagnosia, a disorder where familiar faces cannot be recognized following brain damage (Mazzucchi & Biber, 1983). Hall (1978) found that males were less sensitive to visual and auditory non-verbal cues to emotion as compared with females. Furthermore, in a standard gaze-cueing paradigm based on that of Driver *et al.* (1999), males showed weaker attentional effects of

non-predictive eye-gaze cues, as compared to females (Bayliss, di Pellegrino, & Tipper, in press). Interestingly, this sex difference was the same for arrow cues.

These sex differences in sensitivity to and processing fluency of, social and physical stimuli support the extreme male brain hypothesis of autism. The idea that the male population in general have more autistic-like traits than females is borne out by scores on the Autism-Spectrum Quotient (AQ), developed by Baron-Cohen *et al.* (2001), on which males score higher than females. The AQ assesses social, communication and imagination skills, attention to details and attention switching. If people have different levels of autistic-like traits, then a number of predictions might be made about the present study. If social cueing occurs when a face cues another face through averted eye-gaze, then the cueing effect might be expected to be larger in participants who have few autistic traits. When a scrambled display is cued, this pattern might be expected to be absent, or even reversed, since the scrambled displays have the local details of an object, yet form no global pattern, perhaps favouring the orienting biases of people with many autistic traits. Hence, the AQ was given to participants in order to evaluate any possible differences between people scoring high and low scores on the questionnaire.

A further possibility is also explored in this study. Experiment 1 investigates orienting towards social stimuli (faces), compared to scrambled displays. Any differences in orienting magnitudes towards the two types of stimuli could be inferred as being due to the fact that faces are sociobiological stimuli, and scrambled objects are not. Conversely, object coherence could determine cueing magnitude regardless of object category. In order to evaluate these opposing hypotheses, Experiment 2 used an identical procedure, but with whole tools, compared with scrambled tool parts, as the target object context. If object category is important in the modulation of cueing magnitude, then different results would be predicted for Experiment 2, as compared with Experiment 1. Any differences between participants with high and low AQ scores in Experiments 1 and 2 would be especially interesting, since while we predict that low AQ participants would be cued very strongly towards faces by an eye-gaze cue, one might predict that high AQ participants would be strongly cued by an arrow towards tools. However, if object coherence alone determines cueing magnitude, then identical results will be obtained in the two experiments. Nevertheless, how AQ score might modulate cueing magnitude across these two procedures is a somewhat open question.

EXPERIMENT I

Method

Participants
Twenty-five naïve participants (mean age = 20.3 years; 5 males) took part for payment or course credit. They were recruited from the University of Wales, Bangor student population and the School of Psychology participant panel. All participants had normal or corrected-to-normal vision.

Apparatus
The stimulus set consisted of three male and three female faces, which could either have the pupils in the centre, in the left or in the right of the eyes. These faces were used as the gaze-cues and the target placeholders on some trials. The faces were divided into several parts which were rotated and reorganized randomly to create six scrambled face

objects, upon which targets could appear during half the trials. The dimensions of the faces varied from 10×9 cm to 13×13.5 cm. Pupil size was approximately 0.8×0.8 cm. Six differently designed arrows were also created. Arrows varied between 4.8×2 cm and 7×3 cm. The area that the target covered was matched to the size of the visible regions of skin of the six faces, measuring from 6×9 cm to 8×11 cm. Targets were presented as red patches over the faces, or over the scrambled face parts (see Fig. 1). In this way, the targets would be perceived as changes to the stimuli, rather than as new objects appearing on the scene. Such semi-transparent patches have been used before in cueing paradigms (Tipper, Grison, & Kessler, 2003). Red patches were used as target stimuli since they could be perceived as representing a biologically plausible state (i.e. blushing), which can occur during social interactions.

Design

The within-subject factor, Cue Type, was whether the cue was an arrow or a face with averted gaze. Target Object Type was whether the central arrow or face was flanked by faces or scrambled face parts. Finally, Validity was included, where direction of the cue (left or right) was congruent with target location in valid trials, and incongruent on invalid trials. Other facets to the design were not included in the analyses, but are noted below. In gaze-face trials, the flanking faces were always of the opposite gender to the cueing face.[1] Because of the inclusion of this, it was necessary to balance this manipulation by arbitrarily splitting the scrambled faces into two groups – a set of three that could only appear when the centre face was male and another three that could appear when the central face was female. A similar arbitrary process was applied to the arrows, by also treating the six arrows as two sets of three.

The autism spectrum quotient

The 50-item questionnaire is a self-rated scale, assessing normal participants' social skills, communication skills, imagination ability, attention switching (these four traits are generally poor in people with Autism-Spectrum disorders) and attention to details abilities (this trait is often exceptional in people with Autism-Spectrum disorders). Participants responded to 10 statements regarding each of the five assessed traits, reporting whether they 'strongly agree', 'slightly agree', 'slightly disagree' or 'strongly disagree' with each statement. The higher the score on the AQ, the greater number of autistic traits the subject possessed.

Procedure

Participants were instructed to respond to the presentation of a target by hitting the spacebar as soon as they detected the onset of the red patch. They were also informed that the direction of the central cue did not predict target location, and that they should ignore it, while maintaining central fixation throughout each trial. On each trial, a fixation cross was presented on a blank screen for 658 ms. This was followed by the

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[1] *Experiments investigating the effect of sex of participant and gender of face on cueing magnitude were being conducted concurrently with this investigation (see Bayliss* et al.*, in press). For this reason, this design feature was included as an additional manipulation. However, Bayliss* et al. *found no differential cueing effects for male and female faces. For this reason, and for concerns regarding statistical power, this design feature was not analysed. Hence, the focus of this study is target context and individual differences.*

presentation of the central cue (either an arrow or a gazing face) in its neutral position (eyes central, or arrows without arrow heads). Simultaneously, two pictures would appear to the left and right of the centre. These pictures would either be faces looking towards the centre, or two areas of scrambled face parts. The faces were looking towards the centre so that at cue onset, the cue and cued faces would be looking at each other. In this way, the impression of observing an unfolding social interaction was felt to be even more salient to participants. For this reason, gaze towards the centre was preferred to the alternatives: no eye gaze in peripheral faces would have given an unnatural feel to the scene, and a straight-ahead gaze might have resulted in additional attentional capture towards the peripheral faces, compared with the scrambled displays. This display would remain for 1,504 ms before the central cue appeared. This cue was achieved by the movement of the eyes, or the appearance of arrow-heads.[2] The target would then appear on one of the peripheral objects, after 376 ms (see Fig. 1). This display remained until response, or until 2,491 ms had elapsed. A blank screen was then presented for 1,269 ms after each trial. Participants completed a practice block of 15 trials, followed by four blocks of 84 trials. One seventh of trials were catch trials, where no target was presented, leaving 288 trials for analysis. The stimulus set for each trial was selected randomly. At the end of the experiment, all but one participant completed the AQ questionnaire (Baron-Cohen *et al.*, 2001).

Results

Reaction time data

In total, there were few errors (0.4% of trials). A further 5.3% of trials were removed as Reaction Time (RT) outliers (where RT was shorter than 150 ms, longer than 1,000 ms, and was more than 2 *SD* above or below the participant's cell mean). The remaining data points contributed to means for each participant in each condition, which were submitted to repeated measures ANOVA, with Validity (valid or invalid), Cue Type (arrow or eyes) and Target Object Type (face or scrambled face parts) as factors (see Fig. 2).

The main effect of Validity was highly significant, $F(1, 24) = 31.1$, $p < .001$, with RTs to valid targets being quicker than to invalid targets (318 vs. 331 ms). The Cue Type by Target Object Type interaction reached significance, $F(1, 24) = 4.91$, $p = .036$, because when the cue was an arrow, RTs were faster when targets appeared on a face (321 ms) than when targets appeared on scrambled face parts (327 ms). When gaze was the cue, this trend was not apparent, with RTs of 325 and 324 ms to targets on faces and scrambled face parts, respectively. As this interaction is unrelated to hypotheses, and did not involve Validity, it will not be considered further. The non-significant main effect of Target Object Type, $F(1, 24) = 1.99$, $p = .17$, shows that, independently of cueing effects, RTs to targets appearing on either target type were equivalent, demonstrating that targets appearing on both the coherent and scrambled displays were equally

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[2] *Most studies use eye-gaze cues in which the pupils do not move, but appear in their averted gaze position. In this particular study, it was felt that direct gaze at the start of the trial, followed by a realistic shifting of gaze position, would provide additional ecological validity. The impact of pupil motion on gaze-cueing is negligible (Hietanen & Leppanen, 2003). While the pupils move, the arrow-head does not. This difference was again due to the attempt to present cues to attention in an ecologically valid way (Kingstone, Smilek, Ristic, Friesen, & Eastwood, 2003). Hence, moving eyes, compared to the more standard onset-arrow cue, was used in order to detect any possible differences in the basic cueing effects of either cue.*
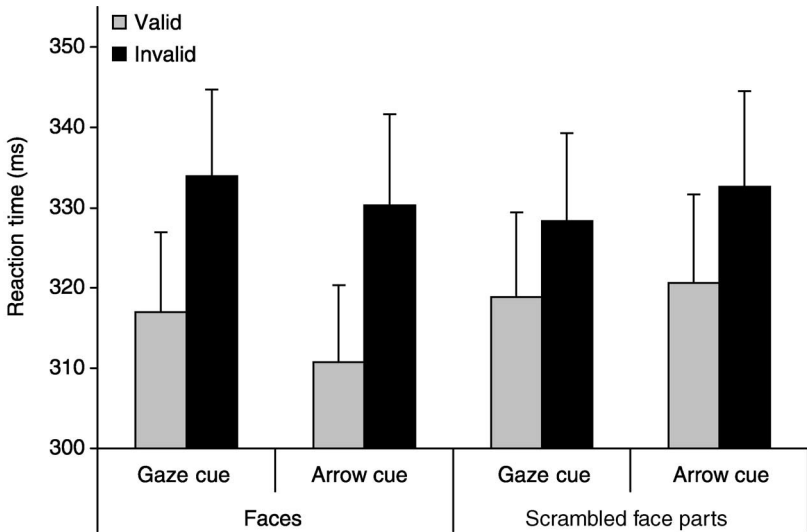
Figure 2. Graph of mean RTs (ms) for each condition in Experiment 1.

discriminable. This suggests that extracting the target from the background is equally demanding in both conditions. The effect that was of direct interest to the hypothesis was the three-way Cue Type by Target Object Type by Validity, which did not approach significance, $F(1, 24) < 1$. However, the Target Object Type by Validity interaction was significant, $F(1, 24) = 5.45, p = .028$. This was due to a greater effect of Validity (i.e. more cueing) in trials where targets appeared on faces (314 vs. 332 ms; 18 ms cueing), than when scrambled face parts were presented as target placeholders (320 vs. 330 ms; 10 ms cueing). These two results suggest that cueing magnitude was only modulated by Target Object Type. However, Cue Type had no reliable influence on cueing magnitude, since the Cue type by Validity interaction did not approach significance, $F(1, 24) < 1$ (see Fig. 2).

Analysis of AQ score

Analysis of the AQ scores in this sample revealed a mean of 15.5 ($SD = 5.9$) out of 50 ($N = 24$; one questionnaire was not completed). Given that most (19 out of 24) of our respondents were female, this mean score is very similar to that found in the original study, when testing normal females ($M = 15.4, N = 98$; Baron-Cohen *et al.*, 2001, p. 8). It was hypothesized that those who scored highly on this questionnaire may display less attentional cueing towards social stimuli (i.e. targets appearing on a face) than those with low scores on the AQ. Based on the distributions of scores reported by Baron-Cohen *et al.* (2001), the cut-off scores were chosen to allow approximately 40% of our sample into either group. Those participants who scored 18 or more were included in the high group ($M = 21.9, SD = 3.1, N = 9$). Participants with a score of 13 or lower were included in the low group ($M = 10.4, SD = 2.4, N = 11$). These groups' scores differed significantly, $t(18) = 9.49, p < .001$. Four participants with intermediary scores (one with 16, and three with 15) were excluded from either group.

   Statistical analysis, similar to that described above, was performed on the remaining 20 participants' data, with AQ group as an additional between-subjects factor. Again, Validity reached significance, $F(1, 18) = 24.1, p < .001$, with faster RTs to validly cued targets (308 vs. 321 ms). In this analysis, the pattern of results of larger cueing to targets

presented on a face than to targets presented on a display of scrambled face parts was not found. That is, the Target Object Type by Validity interaction did not approach significance, $F(1, 18) = 1.14, p = .30$, with 15 ms cueing to targets on a face, and 12 ms to targets on a display of scrambled face parts.

However, there was a significant Target Object Type by Validity by AQ group interaction, $F(1, 18) = 6.20, p = .023$ (see Fig. 3 and Table 1). This interaction was due to greater cueing to targets presented on a face in the low AQ group, but greater cueing to targets presented on the scrambled face parts in the high AQ group. Contrasts showed that the low AQ participants were cued to both faces, $F(1, 10) = 20.7$, $p < .001$, and to scrambled face parts, $F(1, 10) = 10.3, p = .009$. The high AQ group also showed significant cueing towards faces, $F(1, 8) = 6.56, p = .034$, and towards scrambled face parts, $F(1, 8) = 5.70, p = .044$. Note that again, there were no interactions with Cue Type, indicating that the observed individual differences were due to target object properties, not to cue properties.

Discussion

This experiment aimed to evaluate whether the magnitude of orienting to the direction of observed gaze direction could be modulated by the context in which the target could appear. It was found that cueing to targets appearing on faces was larger than cueing to the same targets appearing on scrambled face parts. This effect was found for both gaze cues and arrow cues, suggesting that cue properties had little effect on cueing magnitude. This was contrary to our hypothesis that proposed that any modulation of cueing towards faces or non-faces would only be evident when the cue was averted gaze, produced by a face. The results therefore suggest that observing a social interaction between cue and target, when both are faces, does not result in more cueing than observing an arrow pointing to a face. These data therefore again demonstrate the strikingly similar behavioural effects of non-predictive gaze and arrow-cues on attention, which have been observed before (Bayliss *et al.*, in press; Ristic *et al.*, 2002; Tipples, 2002). Importantly, there was no main effect of Target Object Type, demonstrating that presenting targets on coherent objects versus scrambled object parts results in very similar raw performance. Unpublished pilot data demonstrated that comparing RTs to targets appearing on objects versus in empty space resulted in a large RT advantage for
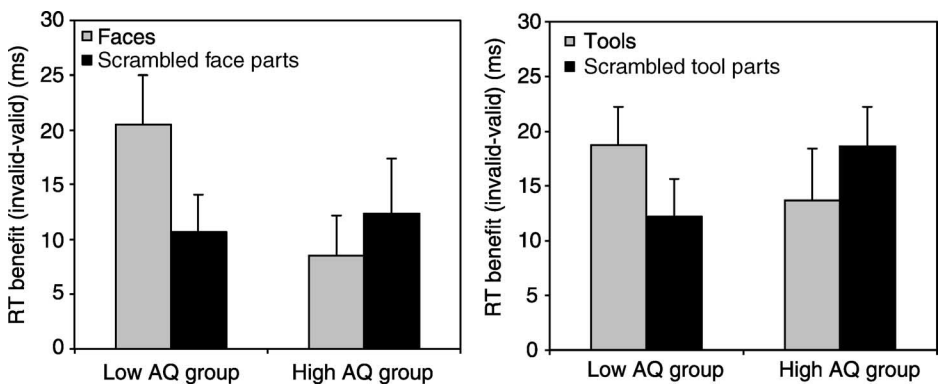

Figure 3. Graph illustrating cueing effect sizes for each AQ group, for either target object type, in Experiments 1 and 2.

Table 1. Mean reaction times (ms) for each AQ group in Experiments 1 and 2, across all conditions. Standard errors in parenthesis (ms)

			Coherent objects		Scrambled objects	
			Gaze cue	Arrow cue	Gaze cue	Arrow cue
Experiment 1 (faces)	Low AQ (N = 11)	Valid	315 (10.1)	307 (8.6)	315 (10.5)	318 (10.9)
		Invalid	333 (12.3)	329 (10.4)	326 (11.1)	329 (14.6)
	High AQ (N = 9)	Valid	303 (17.3)	296 (15.3)	303 (18.2)	298 (15.8)
		Invalid	312 (16.2)	305 (15.5)	310 (17.3)	314 (15.9)
Experiment 2 (tools)	Low AQ (N = 13)	Valid	305 (11.1)	310 (13.1)	312 (12.9)	315 (13.1)
		Invalid	326 (13.6)	326 (13.6)	323 (14.2)	329 (15.0)
	High AQ (N = 9)	Valid	350 (22.3)	352 (22.0)	347 (24.3)	349 (22.6)
		Invalid	364 (21.0)	365 (23.7)	367 (23.2)	367 (24.5)

targets appearing on objects, and hence we decided that a stimulus set which controlled for this should be used in the present study. Scrambled objects were deemed appropriate because detection of the target should be as demanding in both coherent and scrambled conditions, and they also allowed us to investigate the influence of observing local features forming no coherent object in terms of a systemizing account of individual differences.

The response patterns of participants scoring high on the AQ (Baron-Cohen *et al.*, 2001) were very different from those with low scores. Participants reporting few autism-like traits (low AQ) displayed an exaggerated cueing pattern compared with that described above: twice as much cueing towards targets appearing on faces, than to targets appearing on scrambled face parts. High scorers (reporting more autistic-like traits) showed the opposite trend, with slightly greater cueing to targets appearing on scrambled face parts. Again, these group differences were the same with gaze and arrow cues.

This suggests that greater cueing towards faces from a central cue only occurs in people whose cognitive style is biased to the processing of social information. This finding mirrors that of Swettenham *et al.* (1998), who showed that children with autism made fewer attention shifts towards people than normally developing children did. Similarly, Connellan *et al.* (2000) showed that female neonates attended a face for longer, compared with a mobile decorated with scrambled face parts, while male neonates showed the opposite trend. The similarity between these findings and those of Experiment 1 is clear – processing style is highly influential in determining the depth to which social information is processed.

In summary, it appears that when socially relevant stimuli such as faces are objects towards which attention can be oriented, differences between high and low scorers on the AQ can be detected. However, to be confident that the individual differences reflect differences in orienting to social stimuli such as faces, a further test is required. Hence, in replacing the face target holders with tools, Experiment 2 allowed us to examine whether object coherence or social relevance is the important factor in determining the magnitude of attentional shifts away from a central, non-predictive cue.

The procedure for Experiment 2 was identical to that of Experiment 1, except that the objects that would act as target placeholders were power tools, not faces, and the scrambled displays were now made up of tool parts. Tools were considered an appropriate contrast to the faces used in Experiment 1 for several reasons. Firstly, tools

are non-social objects. Thus, if the results from Experiment 1 were due to the use of social stimuli, rather than an effect of presenting a coherent object of any category, then one would predict no repeat of the Validity by Target Object Type interaction that was found in Experiment 1. Secondly, while faces as an object category seem to selectively activate occipito-temporal regions in the ventral visual stream, such as the fusiform face area (FFA) and superior temporal sulcus (STS) (Allison, Puce, & McCarthy, 2000; Hoffman & Haxby, 2000), the observation of tools tends to reveal patterns of activation in the dorsal visual stream, such as the parietal lobe (Chao & Martin, 2000). Thirdly, tools are similar to faces in that they are complex objects made up of several different parts, yet have very different processing demands, and hence may reveal different individual differences from those of Experiment 1. Indeed, one may predict that participants with high AQ scores may now be cued more to tools than low AQ scorers, since Baron-Cohen (2003) suggests that people further along the autism spectrum have superior systemizing abilities, and hence are drawn to physical systems such as mechanical objects (Baron-Cohen *et al.*, 1986; Baron-Cohen *et al.*, 1997).

EXPERIMENT 2

Method

Participants
Twenty-five naïve participants (mean age = 23.7 years; 5 males) took part for payment. They were recruited from the student population of the University of Wales, Bangor. All participants had normal or corrected-to-normal vision.

Apparatus
Instead of faces, six pictures of tools were used (a multi-tool, a vacuum cleaner, a drill, two planers and a circular saw). Sections of each tool were cut and rotated to create scrambled images of tool parts. Targets were presented as red, transparent patches on the main body of the tools, and the shape of these patches were used as the shape on the scrambled tool parts displays (see Fig. 4).

Design and procedure
The design and procedure were identical to that of Experiment 1, with the exception that the levels of the Target Object Type variable were now tools or scrambled tool parts.

Results

Reaction time data
In total, there were few errors (0.2% of trials). A further 4.0% of trials were removed as RT outliers (where RT was shorter than 150 ms, longer than 1,000 ms, and was more than 2 *SD* above or below the participant's cell mean). The remaining data contributed to means for each participant in each condition, which were submitted to repeated measures ANOVA, with Validity (valid or invalid), Cue Type (arrow or eyes) and Target Object Type (tool or scrambled tool parts) as factors (see Fig. 5).

a) Eye-gaze cue, target appearing on a tool

b) Arrow cue, target appearing on a tool

c) Eye-gaze cue, target appearing on scrambled tool parts

d) Arrow cue, target appearing on scrambled tool parts

1504 ms   376 ms   until response

Time

Figure 4. Illustration of the time-course of conditions in Experiment 2. The displays were preceded by the presentation of a fixation cross in the centre of the screen, for 658 ms. Panels (a) and (b) illustrate invalid trials, since the target appears at the un-cued locations. Panels (c) and (d) are examples of valid trials. *Note.* Figure 4 is available in colour in the online article and from the author.

Figure 5. Graph of mean RTs for each condition, for Experiment 2.

The only main effect to reach significance was Validity, $F(1, 24) = 76.4, p < .001$, with faster RTs to valid targets (324 vs. 339 ms). No other main effects or interactions approached significance (all F-ratios < 1.9), including the Target Object Type by Validity interaction, which was central to the hypothesis, $F(1, 24) < 1$, with the validity effect being the same whether the target appeared on a tool (323 vs. 339 ms; 16 ms cueing) or on a scrambled display of tool parts (324 vs. 339 ms; 15 ms cueing).

Analysis of AQ score

The 25 participants scored an average of 14.8 ($SD = 5.8$) on the AQ questionnaire. Thirteen participants scored 13 or less, and were assigned to the low AQ group ($M = 10.3, SD = 2.3$), and the nine scoring 18 or more were assigned to the high AQ group ($M = 21.2, SD = 3.9$). The two groups' scores were significantly different, $t(20) = 8.29, p < .001$. Two participants scoring 15 and one scoring 14 were not included in either group. These 22 participants' data were reanalysed as in Experiment 1, with AQ group as an additional between-groups factor. ANOVA revealed a significant effect of Validity, $F(1, 20) = 60.8, p < .001$. The only other interaction to reach significance, just as in Experiment 1, was the Target Object Type by Validity by AQ group interaction, $F(1, 20) = 4.72, p = .042$. Again, this was due to the low AQ group showing greater cueing to coherent objects (tools; 19 ms cueing) than to scrambled tool parts (13 ms cueing), while the high AQ group showed the opposite pattern, being cued more to scrambled tool parts (19 ms cueing) than to tools (14 ms cueing, see Fig. 3). Contrasts again showed significant cueing effects in the low AQ group towards tools, $F(1, 12) = 29.4, p < .001$, and towards scrambled tool parts, $F(1, 12) = 12.4, p = .004$. The high AQ group were also cued towards tools, $F(1, 8) = 30.0, p < .001$, and to scrambled tool parts, $F(1, 8) = 31.5, p < .001$.

Discussion

The purpose of this experiment was to contextualize the results observed in Experiment 1, where non-informative arrow and gaze cues produced greater attentional effects when targets appeared on faces, as compared to scrambled face parts. This second experiment showed that the magnitude of cueing was not modulated by whether the targets appeared on a different object category, that is, tools, as compared to scrambled tool parts. This suggests that cueing is only modulated when the target appears on a social/biological stimulus such as a face. However, the results of the AQ, suggest an alternative interpretation may be appropriate.

Experiment 1 showed that only low AQ scorers (i.e. those who rated themselves as possessing few autism-like traits) contributed to the effect of greater cueing towards faces than to scrambled face parts. High AQ scorers (possessing more autism-like traits), showed instead a trend for greater cueing towards the scrambled displays. While Experiment 2 demonstrated no overall difference in cueing towards tools, compared to scrambled displays, this too was shown to be a product of two different orienting biases in either AQ group (see Fig. 3). Low scorers again were cued to the coherent objects (tools) more than to the scrambled displays, though this difference was smaller than in Experiment 1. The high AQ group again showed the opposite trend, with more cueing to the scrambled displays than to the coherent object.

These results show that cueing towards tools is not greater in high AQ participants, as might be predicted if one considers that good folk physics (Baron-Cohen, 2000) and

superior systemizing skills (Baron-Cohen, 2002) are associated with people with high AQ scores, hence sharing more traits with people with autism-spectrum disorders. The fact that very similar results were found in Experiments 1 and 2 suggests that participants with high AQ scores readily orient towards scrambled displays, irrespective of object category. The following analysis investigated whether any differences in group performance were present between participants in Experiments 1 and 2.

Combined analysis of the effect of AQ group in Experiments 1 and 2

In order to evaluate the high and low AQ groups orienting effects over both experiments, the data from high AQ and low AQ scorers were analysed in a combined ANOVA. As before, Validity, Cue Type and Target Object Type were within-subjects factors. The levels of Target Object Type factor were Coherent Object (i.e. a face or a tool), or Scrambled Object (i.e. scrambled face or tool parts). Between-subjects factors were AQ group and Experiment.

Validity was highly significant, $F(1, 38) = 77.5$, $p < .001$. The Cue Type by Experiment interaction approached significance, $F(1, 38) = 3.95$, $p = .054$, due to faster RTs when the cue was an arrow in Experiment 1 (312 vs. 314 ms), but faster RTs when the cue was averted gaze in Experiment 2 (336 vs. 339 ms). This interaction did not involve Validity, and was not involved in predictions, so it is not considered further. The overall Target Object Type by Validity interaction did not reach significance, $F(1, 38) = 1.44$, $p = .24$. However, the critical three-way interaction of Target Object Type by Validity by AQ group was highly significant, $F(1, 38) = 9.69$, $p = .004$. The low AQ group showed more cueing towards targets appearing on coherent objects (20 ms) than on scrambled objects (11 ms), while the high AQ group showed the opposite pattern of more cueing towards targets appearing on scrambled objects (15 ms) than on coherent objects (12 ms). No other effects approached significance. Follow-up ANOVAs showed that there was a Target Object Type by Validity interaction in the low AQ group, $F(1, 22) = 8.30$, $p = .009$, whereas there was a trend in the opposite direction in the high AQ group, $F(1, 16) = 2.75$, $p = .117$ (see Fig. 3 and Table 1). This analysis demonstrates that the modulation of cueing by Target Object Type and AQ group was consistent across Experiments 1 and 2.

GENERAL DISCUSSION

This study investigated the effect of manipulating target object context on the magnitude of attentional cueing via the observation of non-informative directional arrows or eye-gaze. Consistent cueing effects were found in all conditions, replicating several studies, with non-predictive gaze cues (e.g. Driver *et al.*, 1999; Friesen & Kingstone, 1998), and non-predictive arrow cues (Eimer, 1997; Hommel *et al.*, 2001; Ristic *et al.*, 2002; Shepherd *et al.*, 1986; Tipples, 2002).

The manipulation of target object context (i.e. whether the target appeared as part of a coherent visual object, or a meaningless scrambled display) was made, in part, as an attempt to reveal differences between eyes and arrows as cues to attention. It was predicted that since in naturalistic situations eye-gaze allows the sharing of experience in shared or joint attention, the presence of objects in the display would allow the stronger activation of joint attention mechanisms. Such mechanisms were not predicted to be so strongly active when observing an arrow. However, arrows and eyes had identical effects on cueing magnitude in this paradigm. It is interesting that gaze and

arrow cues had such similar effects on attention. The similarities between gaze and arrow cueing in the normal population are indeed striking. The two cues produced the same magnitude of effect (Tipples, 2002), across a similar time-course, both effects appear by age 3–5 years (Ristic *et al.*, 2002), both reveal a gender difference such that normal females are more strongly cued by gaze and arrow cues than males are (Bayliss *et al.*, 2004). While symbolic cueing appears to rely on separate neural substrates from gaze cueing (Kingstone, Friesen, & Gazzaniga, 2000; Kingstone, Tipper, Ristic, & Ngan, 2004; Ristic *et al.*, 2002; Vuilleumier, 2002), it is only when cues are anti-predictive that behavioural differences have been found so far. That is, when the participant is aware that the target will usually appear at the location opposite to the cued location, top-down strategic control of attention is unable to suppress the effect of eye-gaze cues, but can override the automatic cueing effect of symbolic cues (Downing *et al.*, 2004; Friesen *et al.*, 2004). Interestingly, Pellicano and Rhodes (2003) have recently demonstrated that conflicting arrows disrupt normal children's ability to infer mental states such as desire and intention from eye-gaze cues. That is, when an arrow points to a different object to that which is looked at by a cartoon character, the character is often thought to want the object indicated by the arrow, not the eye-gaze. This suggests that similarities between eye and arrow cues exist both for high- and low-level functions that these cues have. The origin of any differences between the encoding and function of eyes and arrows is clearly of importance to further research in this area.

Greater cueing towards faces, compared with scrambled displays, was found (Experiment 1). While this result overall did not generalize to tools (Experiment 2), this null effect was due to opposing patterns of cueing magnitude in high AQ and low AQ participants. In both experiments, the high AQ participants showed greater cueing towards scrambled displays than to coherent visual objects. Although this trend failed to reach significance, it was in stark contrast to the pattern showed by low AQ participants. Low AQ participants showed more cueing towards coherent objects than to scrambled displays, with this trend being more exaggerated in Experiment 1 (faces).

Firstly, the low scorers on the AQ will be considered. These participants rate themselves as having relatively good social, communication, imagination and attention switching skills, but relatively poor attention to details. These participants displayed greater cueing towards coherent visual objects than to scrambled displays. This effect was numerically larger when the coherent visual object was a face (Experiment 1) than a tool (Experiment 2), as might be expected in a group biased towards social interactions. The overall pattern that low-AQ participants were cued more to real objects than to meaningless objects has implications for other research. For example, Jordan and Tipper (1998) showed a similar result in a peripheral cueing study, however they did not examine the critical variable of individual differences. Therefore the general claim that objects have much more behavioural relevance than incoherent random patterns, might not be true for all individuals.

The high-AQ participants, on the other hand, show very different patterns of cueing. In both experiments, there was no evidence for greater cueing towards the coherent objects, but trends for greater cueing towards scrambled object parts. The results from Experiment 1 were predicted, since high-AQ participants rated themselves as having poorer social skills, their orienting bias may be comparable to that of male infants (Connellan *et al.*, 2000; Lutchmaya & Baron-Cohen, 2002; Lutchmaya *et al.*, 2002), where females oriented preferentially to social stimuli, but males oriented more to non-social scrambled, or mechanical displays.

In contrast, the idea that males have a bias towards processing mechanical stimuli, led to the prediction that orienting to tools, in Experiment 2, would be larger than scrambled displays in high-AQ participants. Instead, the same trend for greater orienting to the scrambled displays was found. This result led us to consider that the scrambled displays were not necessarily 'meaningless' displays, but rather were displays containing high levels of detail that is appealing to the systematizing cognitive style of high-AQ individuals. As noted before, high-AQ participants tend to have good attention to details (Baron-Cohen, Richler, Bisarya, Gurunathan, & Wheelwright, 2003; Baron-Cohen *et al.*, 2001). This bias for attending to details is similar to the local bias in object processing in participants with diagnoses of autism-spectrum disorders (Mottron *et al.*, 1999, 2003). Hence, tools, as a complex object perhaps contained less complexity for a system biased to the processing of objects in terms of local details than a scrambled display with no obvious global grouping pattern.

Clearly, the two AQ groups displayed very different cueing patterns in this study. However, whether the two groups are displaying differences between object-based and non-object (i.e. location) based attentional orienting remains an open issue. Note that the random feature displays possessed a symmetrical global shape (i.e. rectangle). Therefore it is possible that this stimulus was also encoded as an object in early figure-ground processing. Therefore one interpretation could be that our data do not reflect contrasts between object- and location-based representations (e.g. Jordan & Tipper, 1998); but rather they only reflect contrasts between coherent meaningful objects with incoherent meaningless objects. We gratefully acknowledge an anonymous reviewer for this insight, and further studies that match low level figure-ground properties but vary coherence of the features that are important for object identification, will be necessary to resolve this issue.

With regard to our sample of mainly female undergraduates (40 of the 50 participants), it is likely that the sample was skewed towards the non-autistic end of the normal distribution of the autism spectrum (Baron-Cohen, 2002, 2003; Baron-Cohen *et al.*, 2001). Since much of the evidence for individual differences in social and spatial cognition comes from the sex-difference literature (Bayliss *et al.*, in press; Connellan *et al.*, 2000; Geary, 1998; Geary *et al.*, 1992; Hall, 1978; Lutchmaya & Baron-Cohen, 2002; Lutchmaya *et al.*, 2002), the use of a predominantly female sample may be problematic. However, Baron-Cohen (2002, 2003) suggests that while sex differences exist, and perhaps contribute to the variation of autism traits in the normal population, a normal distribution of traits exists in either gender. Indeed, scores on the AQ are distributed normally in both male and female populations (see Baron-Cohen *et al.*, 2001). It is therefore felt that these experiments effectively compare normal non-autistic participants whose scores fall on either side of the population mean. By randomly recruiting participants of either sex, we sampled a gender ratio similar to that of many psychology experiments, since many psychology studies are conducted on psychology students, who are predominantly female. In this way, this study demonstrates that in a given random sample, individual differences exist in a standard cognitive psychology paradigm (cueing of spatial attention), with the same sampling method as used by researchers not investigating individual differences. It is highly likely that equal numbers of males and females would have revealed even stronger group differences, since more males would have increased the numbers of high-AQ participants. However, the differences might have then been indistinguishable from a general sex difference. Instead, taking the approach of testing the AQ of each participant allowed us to test the idea that autistic traits truly vary in the normal population, somewhat independently of gender.

Inevitably, therefore, this study is more descriptive of low-AQ participants' behaviour. However, according to Baron-Cohen's *et al.* (2001) study, social science students score lower than average on the AQ. This therefore implies that many research samples (in studies where individual differences are not investigated) might be skewed in this way.

In conclusion, these experiments demonstrate that the use of central non-predictive cues can produce object-based attentional effects. However, orienting to coherent visual objects was only larger in participants rating themselves as having few autistic traits. This finding highlights the importance of considering such individual differences in attentional cueing studies. This design, which differed from many symbolic cueing studies by manipulating the object on which targets may appear, adds flexibility to central cueing paradigms in terms of ecological validity. It is notable that gaze cues were not observed to be more effective than arrow cues in low-AQ compared with high-AQ participants, illustrating the similar effects of arrows and eye-gaze on attention in these two groups. Rather, these experiments have revealed for the first time that it is the nature of the objects towards which attention is oriented that is more likely to reveal the effects of different information processing styles.

Acknowledgements

References

Allison, T., Puce, A., & McCarthy, G. (2000). Social perception from visual cues: Role of the STS region. *Trends in Cognitive Sciences*, *4*(7), 267–278.

Baldwin, D. A. (1995). Understanding the link between joint attention and language. In C. Moore & P. J. Dunham (Eds.), *Joint attention: Its origins and role in development* (pp. 131–158). Hillsdale, NJ: Lawrence Erlbaum Associates.

Baron-Cohen, S. (1989). The autistic child's theory of mind: A case of specific developmental delay. *Journal of Child Psychology and Psychiatry*, *30*(2), 285–297.

Baron-Cohen, S. (1995). *Mindblindness: An essay on autism and theory of mind*. Cambridge, MA: MIT Press.

Baron-Cohen, S. (2000). The cognitive neuroscience of autism: Evolutionary approaches. In M. S. Gazzaniga (Ed.), *The new cognitive neurosciences* (pp. 1249–1257). Cambridge, MA: MIT Press.

Baron-Cohen, S. (2002). The extreme male brain theory of autism. *Trends in Cognitive Sciences*, *6*(6), 248–254.

Baron-Cohen, S. (2003). *The essential difference: Men, women and the extreme male brain*. London: Penguin Books.

Baron-Cohen, S., Campbell, R., Karmilloff-Smith, R., Grant, J., & Walker, J. (1995). Are children with autism blind to the mentalistic significance of the eyes? *British Journal of Developmental Psychology, 13*, 379–398.

Baron-Cohen, S., Leslie, A. M., & Frith, U. (1986). Mechanical, behavioural and intentional understanding of picture stories in autistic children. *British Journal of Developmental Psychology, 4*, 113–125.

Baron-Cohen, S., Richler, J., Bisarya, D., Gurunathan, N., & Wheelwright, S. (2003). The Systemising Quotient (SQ): An investigation of adults with Asperger Syndrome or high-functioning autism, and normal sex differences. *Philosophical Transactions of the Royal Society, London, B, 358*(1430), 361–374.

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The Autism-Spectrum Quotient (AQ): Evidence from Asperger syndrome/high functioning autism, males and females, scientists and mathematicians. *Journal of Autism and Developmental Disorders, 31*(1), 5–17.

Baron-Cohen, S., Wheelwright, S., Stott, C., Bolton, P., & Goodyear, I. (1997). Is there a link between engineering and autism? *Autism*, *1*(1), 101–109.

Bayliss, A. P., di Pellegrino, G., & Tipper, S. P (in press). Sex differences in eye-gaze and symbolic cueing of attention. *Quarterly Journal of Experimental Psychology: A*.

Brian, J. A., Tipper, S. P., Weaver, B., & Bryson, S. E. (2003). Inhibitory mechanisms in autism spectrum disorders: Typical selective inhibition of location versus facilitated perceptual processing. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *44*(4), 552–560.

Butterworth, G. (1991). The ontogeny and phylogeny of joint visual attention. In A. Whiten (Ed.), *Natural theories of mind: Evolution, development and simulation of everyday mind-reading*. Oxford: Basil Blackwell.

Chao, L. L., & Martin, A. (2000). Representation of manipulation of man-made objects in the dorsal stream. *NeuroImage, 12*, 478–484.

Charman, T. (2003). Why is joint attention a pivotal skill in autism? *Philosophical Transactions of the Royal Society, London, B*, *358*, 315–324.

Charman, T., Swettenham, J., Baron-Cohen, S., Cox, A., Baird, G., & Drew, A. (1997). Infants with autism: An investigation of empathy, pretend play, joint attention, and imitation. *Developmental Psychology, 33*(5), 781–789.

Collaer, M. L., & Nelson, J. D. (2002). Large visuospatial sex differences in line judgement: Possible role of attentional factors. *Brain and Cognition*, *49*, 1–2.

Connellan, J., Baron-Cohen, S., Wheelwright, S., Batki, A., & Ahluwalia, J. (2000). Sex differences in human neonatal social perception. *Infant Behavior and Development*, *23*, 113–118.

Downing, P., Dodds, C. M., & Bray, D. (2004). Why does the gaze of others direct visual attention? *Visual Cognition*, *11*(1), 71–79.

Driver, J., Davis, G., Ricciardelli, P., Kidd, P., Maxwell, E., & Baron-Cohen, S. (1999). Gaze perception triggers reflexive visuospatial orienting. *Visual Cognition*, *6*(5), 509–540.

Egly, R., Driver, J., & Rafal, R. D. (1994). Shifting visual attention between objects and locations: Evidence from normal and parietal lesion subjects. *Journal of Experimental Psychology: General, 123*(2), 161–177.

Eimer, M. (1997). Uninformative symbolic cues may bias visual-spatial attention: Behavioural and electrophysiological evidence. *Biological Psychiatry*, *46*, 67–71.

Emery, N. J. (2000). The eyes have it: The neuroethnology, function and evolution of social gaze. *Neuroscience and Biobehavioural Reviews*, *24*, 581–604.

Friesen, C. K., & Kingstone, A. (1998). The eyes have it! Reflexive orienting is triggered by nonpredictive gaze. *Psychonomic Bulletin and Review, 5*(3), 490–495.

Friesen, C. K., Ristic, J., & Kingstone, A. (2004). Attentional effects of counterpredictive gaze and arrow cues. *Journal of Experimental Psychology: Human Perception and Performance*, *30*(2), 319–329.

Frith, U. (1989). *Autism: Explaining the enigma*. Cambridge, MA: Blackwell.

Frith, U., & Happé, F. (1994). Autism: Beyond theory of mind. *Cognition*, *50*, 115–132.

Geary, D. C. (1998). *Male, female: The evolution of human sex differences*. Washington, DC: American Psychological Association.

Geary, D. C., Gilger, J. W., & Elliott-Miller, B. (1992). Gender differences in three-dimensional mental rotation: A replication. *Journal of Genetic Psychology, 153*(1), 115–117.

Hall, J. A. (1978). Gender effects in decoding nonverbal cues. *Psychological Bulletin*, *85*, 845–857.

Happé, F. (1999). Autism: Cognitive deficit or cognitive style? *Trends in Cognitive Sciences*, *3*(6), 216–222.

Hietanen, J. K. (1999). Does your gaze direction and head orientation shift my visual attention? *NeuroReport*, *10*(16), 3443–3447.

Hietanen, J. K., & Leppanen, J. M. (2003). Does facial expression affect attention orienting by gaze direction cues? *Journal of Experimental Psychology: Human Perception and Performance*, *29*(6), 1228–1243.

Hoffman, E. A., & Haxby, J. V. (2000). Distinct representations of eye gaze and identity in the distributed human neural system for face perception. *Nature Neuroscience*, *3*(1), 80–84.

Hommel, B., Pratt, J., Colzato, L., & Godijn, R. (2001). Symbolic control of visual attention. *Psychological Science*, *12*(5), 360–365.

Hood, B. M., Willen, J. D., & Driver, J. (1998). Adult's eyes trigger shifts of visual attention in human infants. *Psychological Science*, *9*(2), 131–134.

Jordan, H., & Tipper, S. P. (1998). Object-based inhibition of return in static displays. *Psychonomic Bulletin and Review*, *5*(3), 504–509.

Jordan, H., & Tipper, S. P. (1999). Spread of inhibition across an object's surface. *British Journal of Psychology, 90*(4), 495–507.

Kingstone, A., Friesen, C. K., & Gazzaniga, M. S. (2000). Reflexive joint attention depends on lateralized cortical connections. *Psychological Science, 11*(2), 159–166.

Kingstone, A., Smilek, D., Ristic, J., Friesen, C. K., & Eastwood, J. D. (2003). Attention, researchers! it is time to take a look at the Real World. *Current Directions in Psychological Science*, *12*(5), 176–180.

Kingstone, A., Tipper, C., Ristic, J., & Ngan, E. (2004). The eyes have it!: An fMRI investigation. *Brain and Cognition*, *55*, 269–271

Langton, S. R. H., & Bruce, V. (1999). Reflexive visual orienting in response to the social attention of others. *Visual Cognition*, *6*(5), 541–567.

Lutchmaya, S., & Baron-Cohen, S. (2002). Human sex differences in social and non-social looking preferences, at 12 months of age. *Infant Behavior and Development*, *25*(3), 319–325.

Lutchmaya, S., Baron-Cohen, S., & Raggatt, P. (2002). Foetal testosterone and eye contact in 12-month-old human infants. *Infant Behavior and Development*, *25*(3), 327–335.

Mazzucchi, A., & Biber, C. (1983). Is prosopagnosia more frequent in males than females? *Cortex*, *19*, 509–516.

Moore, C., & Corkum, V. (1994). Social understanding at the end of the first year of life. *Developmental Review, 14*, 349–372.

Mottron, L., Belleville, S., & Menard, E. (1999). Local bias in autistic subjects as evidenced by graphic tasks: Perceptual hierarchization or working memory deficit? *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *40*(5), 743–755.

Mottron, L., Burack, J. A., Iarocci, G., Belleville, S., & Enns, J. T. (2003). Locally oriented perception with intact global processing among adolescents with high-functioning autism: Evidence from multiple paradigms. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *44*(6), 904–913.

O'Riordan, M. A., Plaisted, K. C., Driver, J., & Baron-Cohen, S. (2001). Superior visual search in autism. *Journal of Experimental Psychology: Human Perception and Performance*, *27*(3), 719–730.

Pellicano, E., & Rhodes, G. (2003). The role of eye-gaze in understanding other minds. *British Journal of Developmental Psychology, 21*, 33–43.

Posner, M. I., & Cohen, Y. (1984). Components of visual orienting. In H. Bouma (Ed.), *Attention and performance X*. Hove: Lawrence Erlbaum Associates.

Reppa, I., & Leek, E. C. (2003). The modulation of inhibition of return by object-internal structure: Implications for theories of object-based attentional selection. *Psychonomic Bulletin and Review, 10*(2), 493–502.

Ristic, J., Friesen, C. K., & Kingstone, A. (2002). Are eyes special? It depends on how you look at it. *Psychonomic Bulletin and Review, 9*(3), 507–513.

Robert, M., & Ohlmann, T. (1994). Water-level representation by men and women as a function of rod-and-frame test proficiency and visual postural information. *Perception*, *23*, 1321–1333.

Rutter, M. (1978). Diagnosis and definition. In M. Rutter & E. Schopler (Eds.), *Autism: A reappraisal of concepts and treatment* (pp. 1–26). New York: Plenum Press.

Scaife, M., & Bruner, J. S. (1975). The capacity for joint visual attention in the infant. *Nature, 253*(5489), 265–266.

Shepherd, M., Findlay, J. M., & Hockey, R. J. (1986). The relationship between eye movements and spatial attention. *Quarterly Journal of Experimental Psychology, 38A*, 475–491.

Swettenham, J., Baron-Cohen, S., Charman, T., Cox, A., Baird, G., Drew, A., Rees, L., &Wheelwright, S. (1998). The frequency and distribution of spontaneous attention shifts between social and nonsocial stimuli in Autistic, typically developing and nonautistic developmentally delayed infants. *Journal of Child Psychology and Psychiatry, 39*(5), 747–753.

Tipper, S. P., Grison, S., & Kessler, K. (2003). Long-term inhibition of return of attention. *Psychological Science, 14*(1), 19–25.

Tipples, J. (2002). Eye gaze is not unique: Automatic orienting in response to uninformative arrows. *Psychonomic Bulletin and Review, 9*(2), 314–318.

Vuilleumier, P. (2002). Perceived gaze direction in faces and spatial attention: A study in patients with parietal damage and unilateral neglect. *Neuropsychologia, 40*(7), 1013–1026.

Yonker, J. E., Eriksson, E., Nilsson, L.-G., & Herlitz, A. (2003). Sex differences in episodic memory: Minimal influence of estradiol. *Brain and Cognition, 52*, 231–238.