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Does the perception of moving eyes trigger reflexive visual orienting in autism?

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Does movement of the eyes in one or another direction function as an automatic attentional cue to a location of interest? Two experiments explored the directional movement of the eyes in a full face for speed of detection of an aftercoming location target in young people with autism and in control participants. Our aim was to investigate whether a low-level perceptual impairment underlies the delay in gaze following characteristic of autism. The participants' task was to detect a target appearing on the left or right of the screen either 100 ms or 800 ms after a face cue appeared with eyes averting to the left or right. Despite instructions to ignore eye-movement in the face cue, people with autism and control adolescents were quicker to detect targets that had been preceded by an eye movement cue *congruent* with target location compared with targets preceded by an *incongruent* eye movement cue. The attention shifts are thought to be reflexive because the cue was to be ignored, and because the effect was found even when cue–target duration was short (100 ms). Because (experiment two) the effect persisted even when the face was inverted, it would seem that the direction of movement of eyes can provide a powerful (involuntary) cue to a location.

Keywords: autism; visual orienting; joint attention; perception; face processing

1. INTRODUCTION

The ability to follow another person's direction of gaze arises in infancy and marks an important breakthrough in the development of social communication (Butterworth & Jarrett 1991; Corkum & Moore 1995; Emery 2000). Although infants are sensitive to whether others are making direct eye contact with them (mutual gaze) from birth (Bakti *et al.* 2000; Farroni *et al.* 2002), and respond to eye contact with smiles and teasing facial expressions during the first few months (Aitken & Trevarthen 1997), it is not until at least four months of age that they can perceive the movement in another's gaze shift as a directional cue, facilitating saccadic reaction time to targets appearing in the visual field (Hood *et al.* 1998; Farroni *et al.* 2000). By nine months, infants can use another's head turn to search for an object at a particular location even when that object is not present (Corkum & Moore 1998), and by 18 months they can use eye movements alone as cues to follow direction of gaze (Butterworth & Jarrett 1991). The gaze direction of another person can be important not only because it may reveal an interesting location or object in the environment, but also because it reveals what another person is attending to. Gaze following can therefore allow the infant to establish triadic joint attention with others, whereby the child becomes aware that both itself and the other person are attending to the same object (Butterworth & Jarrett 1991). The developing child's gaze-following behaviour and engagement in triadic joint attention is commonly thought to be important for language and social development (Baron-Cohen 1995).

There is now considerable evidence that children with autism are impaired in the processing of gaze. Lack of gaze following is apparent in autism at 18 months of age, one of the earliest detectable symptoms (Baron-Cohen *et al.* 1996; Baird *et al.* 2000), and an insensitivity to direction of gaze is reflected in impairments in joint attention: the ability to coordinate attention between people and objects (Curcio 1978; Loveland & Landry 1986; Baron-Cohen 1989; Mundy *et al.* 1994; Lord 1995; Leekam *et al.* 1997). Although some children with autism eventually develop the ability to follow gaze (particularly if they have an IQ of 70 or above), the onset of this ability is still severely delayed relative to children of equivalent mental age (Leekam *et al.* 1998, 2000).

Two main views have emerged regarding the origins of the joint attention impairment in autism. One is that the origin of the impairment is *affective*. According to this view children with autism have difficulty engaging in joint attention either as a result of a deficit in intersubjective relatedness (see Hobson 1993), or because of a deficit in social-emotional approach (see Mundy 1995). The other view is that the impairment is *cognitive*. The origin of the impairment, according to this view, is in understanding and representing the psychological relationship between oneself, another person and an object: that oneself and another person are 'attending' to the same object (Baron-Cohen 1995).

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More recently, a third view has emerged, that children with autism may have a low-level *attentional* or *perceptual* impairment affecting their ability to make a response to another's head or eye movements. It is this theory that has informed the studies reported here. Leekam & Moore (2001) point out that even if children with autism have difficulty understanding another person's focus of attention or experience, it is still surprising that they do not at least use gaze as an instrumental cue to the location of an object or event in the environment. For example, Povinelli & Eddy (1997) have shown that chimpanzees can use gaze direction as a cue to the location of an object, even though they do not initiate joint attention acts like pointing and showing (Tomasello *et al.* 1993) and are unlikely to be representing another's attention or sharing affective experience when following gaze. Leekam and colleagues therefore tested the ability to execute shifts of overt attention in young children with autism by measuring head turn responses to mechanical objects or the viewed head turn of the experimenter. They found that low-functioning children with autism were able to overtly disengage attention and turn to look from a centrally viewed object towards an object appearing in peripheral vision (Leekam *et al.* 2000). In such a task, attention can be automatically captured by the target appearing in the periphery. It was therefore argued that exogenous orienting and the ability to disengage from a central stimulus may be intact. Exogenous orienting refers to a reflexive system driven by the physical characteristics of the information in the visual field (Posner 1980) and is characteristic of attention in the early months of normal development (Atkinson *et al.* 1992). However, the same children with autism had difficulty overtly shifting attention from a face to search for an object not present in the visual field (Leekam *et al.* 1998). This task, they argued, involved interpreting the meaning of the cue as a predictor of location (particularly as the target was absent). The results therefore indicated an impairment in endogenous orienting. Endogenous orienting is considered to be goal directed and under voluntary control, involving cognitive interpretation of stimuli and the formation of expectation from predictive cues (Jonides 1981; Lauwereyns 1998), and it seems to develop later in the first year of life (Gilmore & Johnson 1995).

Evidence from the attentional literature on autism, using non-social stimuli and testing adolescents or adults has also indicated an attentional impairment in autism, but the pattern of intact exogenous orienting and impaired endogenous orienting is less clear. In these non-social tasks measures are typically of covert orienting (rather than overt head turns) and involve verbal instruction and key presses in response to the detection of targets on a computer display. Although the disadvantage of these studies is that they can only be used with older adolescents or adults who understand the instructions, the advantage is that they do not rely on overt head turns or looking behaviour as measures. This may be important because it is possible to orient attention even without making a head turn or eye movement. In addition they can identify subtle differences in the efficiency of attentional orienting by measuring reaction time and accuracy under highly controlled conditions. With respect to exogenous orienting the results are mixed, some studies suggesting an impairment and others suggesting intact orienting response to visual or auditory stimuli (Courchesne *et al.* 1985, 1994; Rincover & Ducharme 1987; Burack & Iarocci 1995; Townsend *et al.* 1996; Wainwright & Bryson 1996). Studies of endogenous orienting, for example where a central arrow cue indicates the location of an oncoming target, have also suggested that individuals with autism have difficulty shifting attention efficiently to a peripheral target (Casey *et al.* 1993; Wainwright-Sharp & Bryson 1993). However, it remains unclear whether this is because of a difficulty in disengaging attention from a central cue, or in forming an expectation from the 'symbolic' central arrow cue (Burack *et al.* 1997).

The attentional literature using non-social stimuli indicates impairments in attentional orienting in autism, but how might this relate to attentional orienting in response to faces? Recent work using adaptations of traditional cueing tasks indicate that head and face cues may elicit a reflexive orienting response in an adult viewer: a result not traditionally found in response to non-social cues (Friesen & Kingstone 1998; Driver *et al.* 1999; Hietanen 1999; Langton & Bruce 1999; Vuilleumier 2002). In other words a directional face cue is a special sort of stimulus which is hard to ignore, rapidly and reflexively effecting a shift of attention in a viewer in the direction of seen gaze. Whether this is because of an innate mechanism or whether the automatic cueing effects are acquired through experience (overlearning) remains controversial (Vecera & Johnson 1995). In either case it is important to know whether gaze direction cues reflexive orienting in children with autism. If gaze direction has a special reflexive orienting effect in typically developing children, but not children with autism, then this would indicate a failure to develop a specialized reflexive response in children with autism.

The experiments reported here therefore examine whether perceived gaze direction can elicit reflexive shifts of spatial attention in children with autism. Our questions were as follows: is the special mechanism present in normal adults, eliciting reflexive shifts of attention in response to perceived gaze direction, present in normally developing children? Is this mechanism working to the same extent in children with autism?

The cueing tasks that have demonstrated these reflexive orienting effects in normal adults (Friesen & Kingstone 1998; Driver *et al.* 1999; Hietanen 1999; Langton & Bruce 1999; Vuilleumier 2002) typically involve detecting a target stimulus that appears either to the left or right of the screen shortly after the appearance of a centrally placed directional face cue. In some cases the cue used has been a directional head profile and in others it has been averted eyes within a full face. On each trial the gaze direction of the cue is either congruent with target location (validly predicting location) or incongruent (invalid). The consistent finding has been that even when the gaze cue is *not predictive* overall (i.e. only valid on 50% of trials), and participants are told to ignore it, attention is still recruited to the location congruent with gaze direction, indicating that the allocation of attention is *reflexive*. The viewer is unable to ignore the gaze direction cue. Therefore targets appearing at locations congruent with gaze direction are responded to more quickly than incongruently cued targets.

Table 1. Mean (and s.d.) chronological age and Raven's progessive matrices scores for the group of children with autism and typically developing children.

group	age (years:months)	Raven's matrices scores
autism ($n = 15$)		
mean	10:2	37.6
(s.d.)	(0:9)	(10.3)
control ($n = 15$)		
mean	10:2	37.7
(s.d.)	(0:9)	(10.4)

2. EXPERIMENT ONE

In the first experiment, we examined the influence of the to-be-ignored eye movement cue on the speeded detection of an aftercoming target. The full face cue appeared in the centre of the screen and the eyes moved to the left or right. After a delay of either 100 ms or 800 ms a target stimulus appeared to the left or right of the screen. The use of variable delay meant that it was not possible to predict when the target would appear. If the viewer cannot resist shifting attention in direction of gaze this would be reflected in faster detection of validly cued target compared with an invalidly cued target. This would indicate a reflexive attention shift. If spatial cueing effects were found even after a short duration delay of 100 ms, allowing little time to prepare a voluntary attention shift, this would be even stronger evidence that the cue triggers reflexive shifts of attention. The dependent variable was speed of response to detect the target.

We predicted that the perceived direction of eye movement would reflexively trigger attention shifts in the typically developing children but our predictions were open with respect to children with autism.

(a) *Methods*

(i) *Participants*

Fifteen high-functioning children with autism and 15 typically developing children took part in the study. The children with autism had all been diagnosed using the ADI-R (Lord *et al.* 1994) and all met established criteria for autism, as specified in DSM-IV (American Psychiatric Association 1994). Each child with autism was individually matched to a typically developing child according to chronological age and raw score on the Raven's progressive matrices (a non-verbal IQ test). Participants were aged between 8 years, eight months and 11 years, two months. Table 1 shows the mean chronological age and Raven's matrices raw score for the two groups of children. Independent sample *t*-tests revealed that there were no significant group differences in either chronological age ($t = -0.57$, $p = 0.96$), or Raven's matrices ($t = -0.18$, $p = 0.99$)

(ii) *Materials*

Digital grey-scale photographs of a male face were used as the cues. The face was 70 mm in height presented on a lap-top computer monitor. Five images of a face were used. In all the images the head was facing forwards. In the first image the eyes were central (looking forward); and in the four remaining images the eyes were averted increasingly to the left. Mirror images of these five photographs were also used, with eyes therefore averted to the right. The 'eyes forward' image followed by rapid presentation of the four images with eyes increasingly averted laterally created the impression of eyes moving (looking) to one side. There was also a fixation cross (0.5 cm × 0.5 cm) and a target asterisk (0.5 cm × 0.5 cm). The display was viewed 60 cm away from a 15 inch monitor.

(iii) *Procedure*

Participants were asked to press the space bar on the keyboard, as quickly as they could, when they detected a target asterisk on the screen. The asterisk would appear on each trial to the right or left of a centrally placed face cue. Participants were told that on each trial the face would appear and the eyes would look either to the left or to the right. It was emphasized that the face would provide no information about where the asterisk would appear, but that they should keep looking at the face throughout each trial. Participants then received 10 practice trials, and the experimenter checked carefully that the child had understood the task.

The sequence of events for each trial was as follows: a central cross appeared as a fixation point for either 1000 ms or 2000 ms. The random duration of the fixation point was intended to stop participants from anticipating the cue onset. The face then appeared on the screen, with eyes forward, for 500 ms. The eyes 'looked' to the left or right (56 ms total, each brief display lasting 14 ms), and then following a delay between cue and target of either 100 ms or 800 ms an asterisk appeared on either the left or right of the screen. Both cue and target remained on the screen until the participant made a response. Each response was followed by an inter-trial interval of 1000 ms, and then the fixation point appeared again marking the onset of a new trial. Figure 1*a*,*b* illustrates the sequence of events for an example trial.

The experiment consisted of four blocks of 64 trials. The direction of eye gaze provided a valid cue to the location of the target on 50% of the trials. The direction of gaze (left or right), location of target asterisk (left or right), and the length of SOA (100 ms or 800 ms) were randomly generated but equi-probable in appearance. Anticipatory responses (less than 100 ms before target appearance) and responses that were too long (more than 1500 ms) were followed by a warning method and excluded from the analysis. These error trials were replaced with repeat trials.

(b) *Results*

We aimed to examine whether the gaze cue produced a *validity effect*: i.e. when the target appeared in a position indicated by the gaze cue (valid) its processing should be relatively more efficient (e.g. faster detection) than when it was not. The median reaction times were derived for each participant for each condition (valid/invalid; 100 ms/800 ms SOA). Figure 2 shows the mean median reaction times for each group. The validity effect at each SOA can be seen by the difference in reaction time to valid versus invalidly cued targets.

The data were analysed using ANOVA with one between-subjects factor of group (autism, typically developing) and two within-subjects factors of cue validity (valid, invalid) and SOA (100 ms, 800 ms).

ANOVA revealed a main effect of validity ($F_{(1,28)} = 13.41$, $p < 0.01$) indicating that participants in both groups were faster to respond to valid versus invalidly cued targets. Both groups were affected by the eye gaze cue. There was also a main effect of SOA ($F_{(1,28)} = 26.26$,

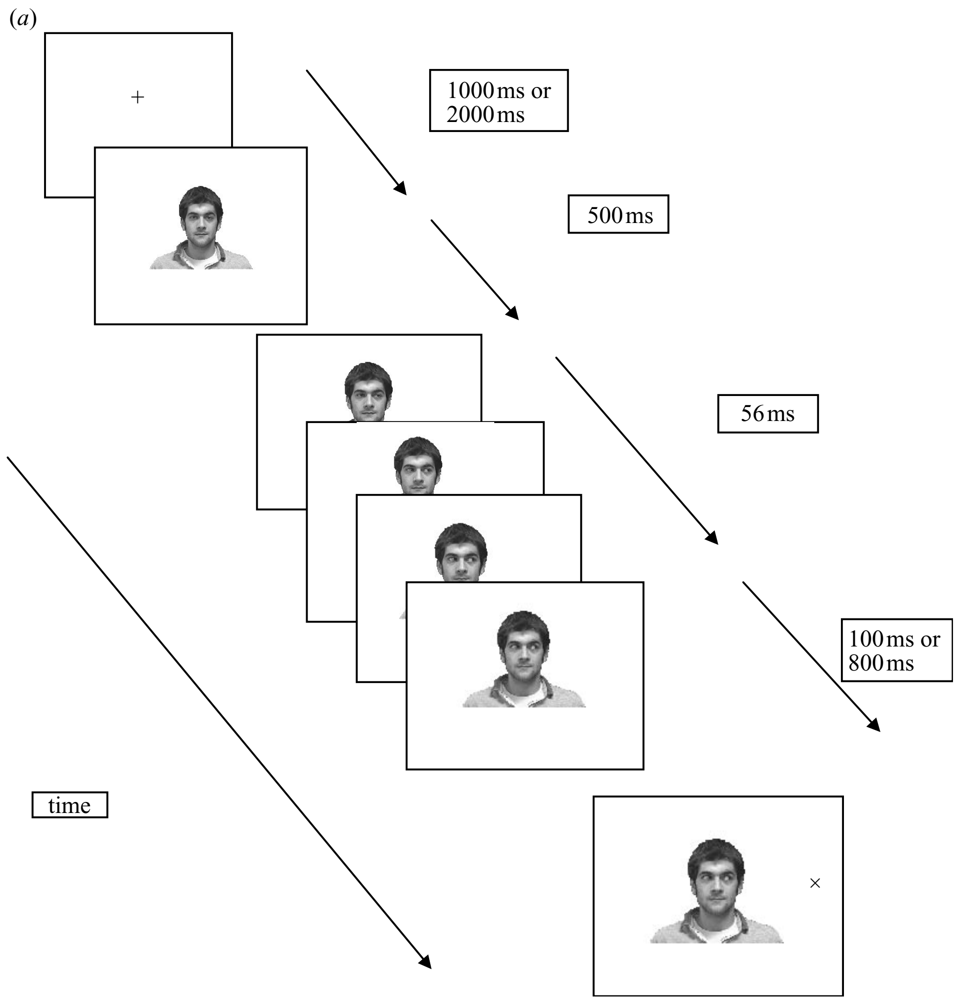

Figure 1. Frame by frame sequence of events presented on the computer: (*a*) upright face, valid trials; and (*b*) upright face, invalid trials.

$p < 0.01$) indicating that participants were faster overall to respond to targets appearing 800 ms after the cue onset compared with targets appearing at 100 ms SOA. In addition, there was a group by SOA interaction ($F_{(1,28)} = 4.98$, $p < 0.05$); *post hoc* analysis using Tukey's HSD revealed that typically developing children made faster responses at 800 ms SOA than children with autism ($p < 0.05$). There was no group difference at 100 ms SOA.

(c) *Discussion*

In this experiment perceived direction of gaze triggered reflexive orienting in both the typically developing children and the children with autism. It is likely that the orienting effects were reflexive for two reasons. First, the effects were found even though the perceived direction of eye gaze was random with the respect to the location of the target and the participants were aware that the direction of eye gaze should be ignored. Second, the effects were found even when the delay between the eyes moving and the onset of the target was short (100 ms SOA) allowing little time for a voluntary cognitive strategy to be recruited. Typically, reflexive orienting effects are found with a short duration between cue and target (Posner 1980). These data provide powerful evidence for the existence of a specialized mechanism, present in both typically developing and autistic children, which results in a reflexive orienting response to perceived direction of gaze. No evidence was found here supporting the hypothesis that the delay in the development of gaze is due to a perceptual or attentional impairment.

We also found a small but significant interaction between group and SOA, so that when the cue–target delay is 800 ms, the children with autism tended to respond more slowly, regardless of whether the cue was valid or invalid. Despite the instruction to ignore the cue, and the randomness of validity, participants may still follow gaze direction voluntarily at 800 ms SOA because the longer delay allows for the recruitment of voluntary attention. One possibility is that for longer duration cue–target intervals, voluntary orienting mechanisms could be recruited on at least some trials. If this were the case then the generally slower responses of the autistic children at 800 ms SOA might reflect impairments in voluntarily orienting attention (Wainwright-Sharp & Bryson 1993; Wainwright & Bryson 1996). However, a simpler explanation for the slower responses to longer SOAs might be that children with autism are slower to prepare and initiate any response to an imperative cue, independent of the context of attentional shifts or social gaze processing.

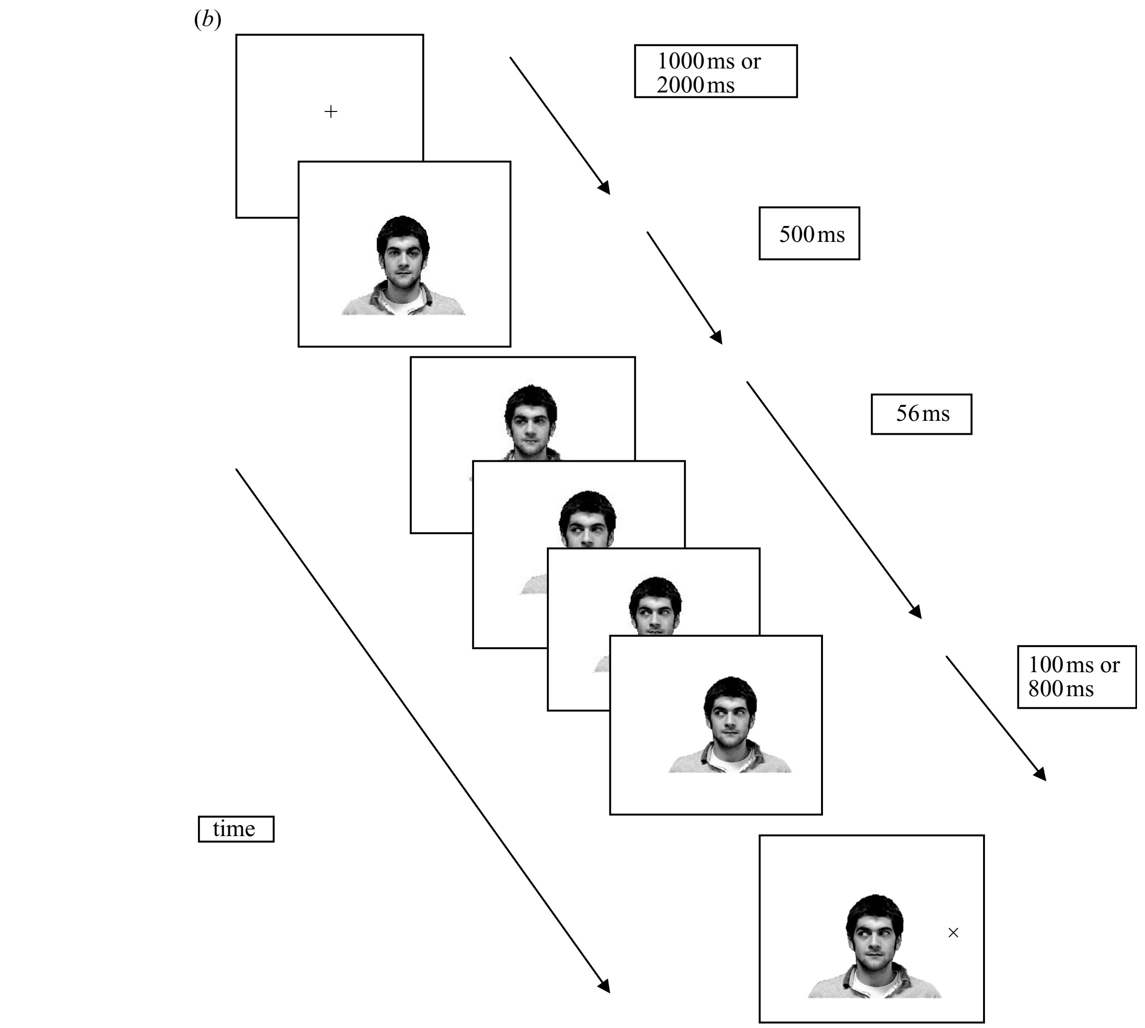

Figure 1. (*Continued.*)

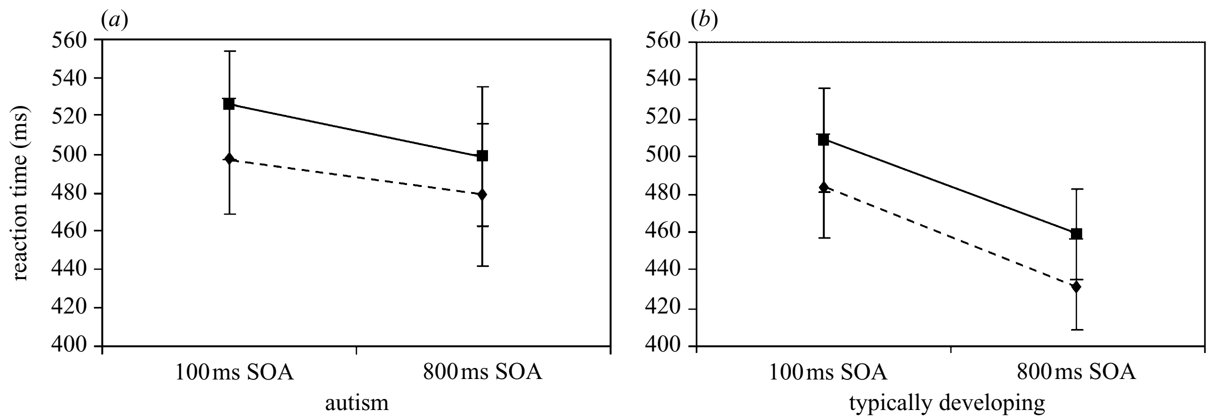

Figure 2. Mean median reaction times for validly (diamonds) and invalidly (squares) cued targets in (*a*) children with autism and (*b*) typically developing children. Upright face (error bar, 1 s.e.m.).

3. EXPERIMENT TWO

The reflexive orienting effect found in experiment one indicates that perception and attentional orienting are intact in high-functioning adolescents with autism at least for responses to eye direction in a face. However, despite the similarity in orienting responses of the two groups, it is still possible that they were perceiving the face stimuli differently (see Grelotti *et al.* (2002) for a review of face perception in autism). Research on general perceptual processing in autism has revealed a preference for processing individual features rather than global properties (Frith 1989). One possibility is that the children with autism are perceiving two moving features, while the typically developing children are perceiving eyes moving in the context of the configuration of the whole face. If this were the case then we might expect the two groups to respond differently when the face is inverted. For example, when

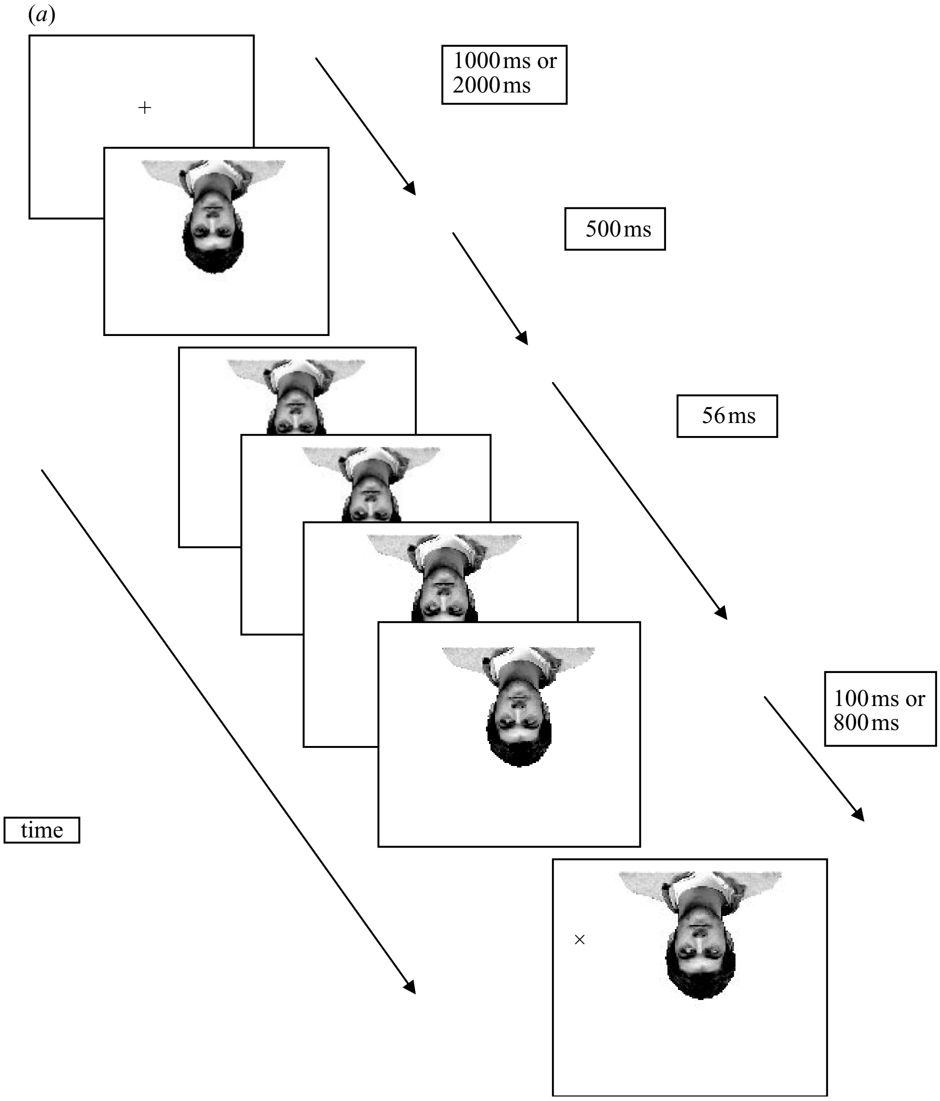

Figure 3. Frame by frame sequence of events presented on the computer: (*a*) inverted face, valid trials; and (*b*) inverted face, invalid trials.

the face cue is inverted, accuracy judgements of gaze direction are disrupted (Campbell *et al.* 1990) and the reflexive orienting effect is reduced in normal adults (Langton & Bruce 1999).

Our second experiment used an inverted face stimulus with moving eyes. Our prediction was that the children with autism would continue to be cued by the direction of eye movement even within an inverted face, as people with autism are relatively insensitive to face configuration (Langdell 1978; Volkmar *et al.* 1989; Davies *et al.* 1994). However, in normally developing children, the upright face may be an important determinant of sensitivity to gaze, so that inverting the face abolishes the validity effect.

(a) *Methods*

The participants who took part in experiment one also took part in experiment two (see table 1 for details). The second experiment differed from the first only in that an inverted version of the face cue with moving eyes was used as a cue (see figure 3*a*,*b*). In all other respects the procedures were the same.

(b) *Results*

The median reaction times for each participant were derived for each condition (valid/invalid; 100 ms/800 ms SOA) for the inverted face stimuli. Figure 4 shows the mean median reaction times for each group. The validity effect at each SOA can be seen by the difference in reaction time to valid versus invalidly cued targets.

The data were analysed using ANOVA with one between-subjects factor of group (autism, typically developing) and two within-subjects factors of cue validity (valid, invalid) and SOA (100 ms, 800 ms).

ANOVA revealed a main effect of validity ($F_{(1,28)} = 27.67$, $p < 0.01$) indicating that participants in both groups were faster to respond to valid versus invalidly cued targets. Both groups were affected by the inverted eye gaze cue. There was also a main effect of SOA ($F_{(1,28)} = 30.07$, $p < 0.01$) indicating that participants were faster overall to respond to targets appearing 800 ms after the cue onset compared with targets appearing at 100 ms SOA. There were no significant interactions and no main effect of group.

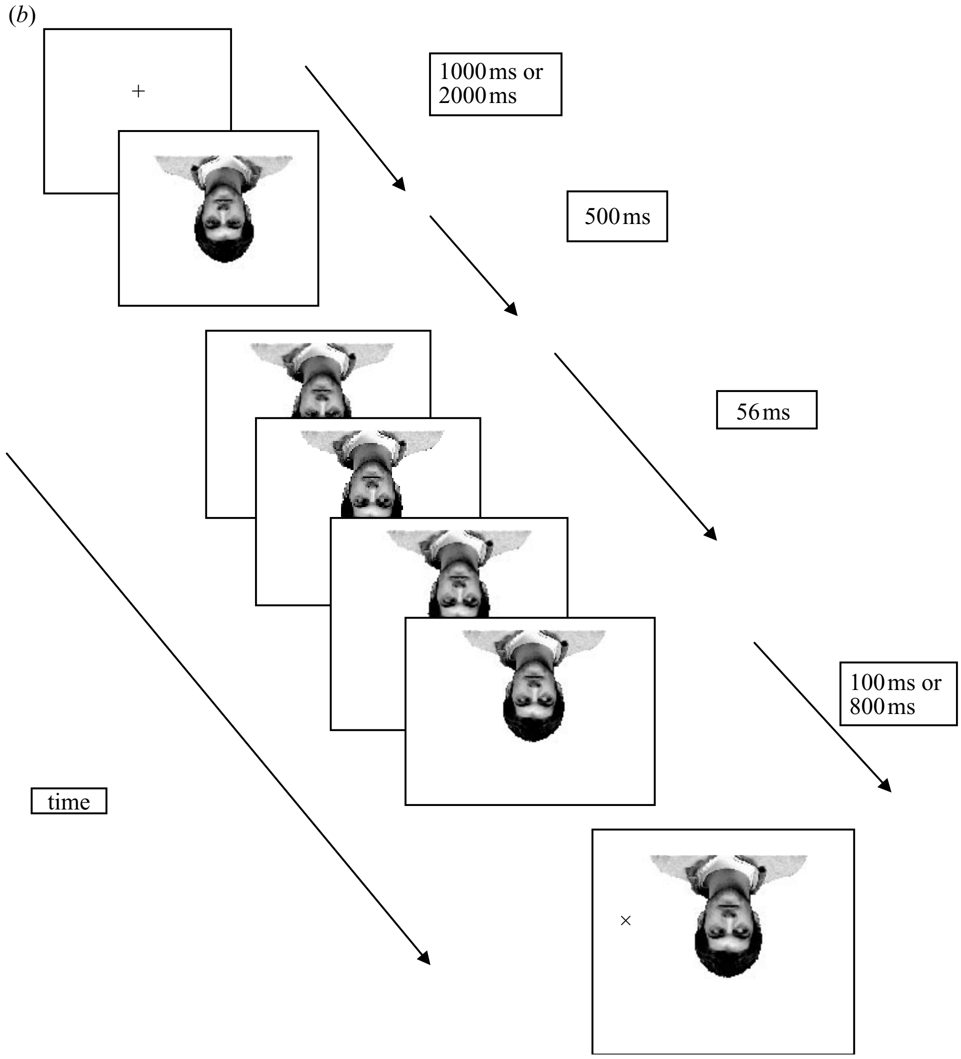

Figure 3. (*Continued.*)

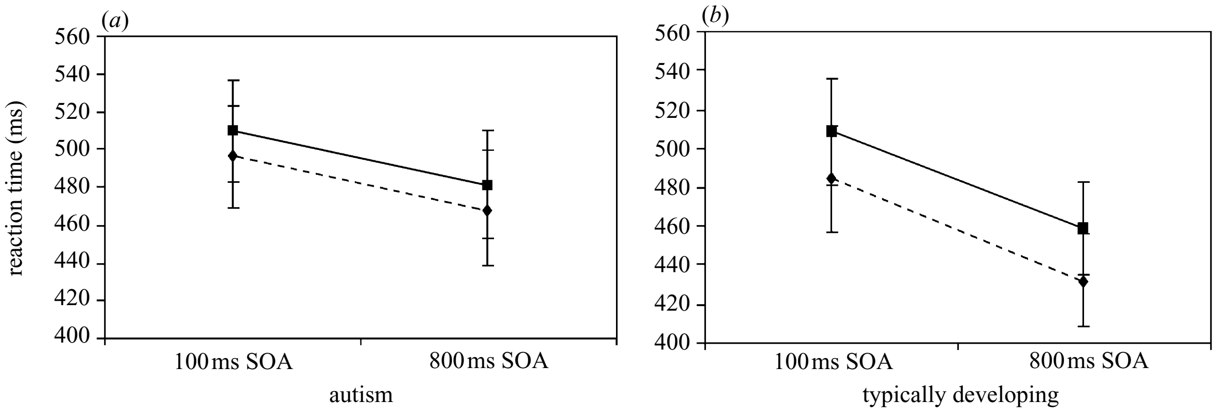

Figure 4. Mean median reaction times for validly (diamonds) and invalidly (squares) cued targets in (*a*) children with autism and (*b*) typically developing children. Inverted face (error bar, 1 s.e.m.).

(c) *Discussion*

The results of experiment two revealed that both the typically developing children and the children with autism were unable to resist the eye movement cue, even in an inverted face. Both groups were faster to detect targets appearing on the side of the screen towards which the eyes moved, compared with the opposite side. This was despite the fact that the direction of movement was random with respect to the location of the target, and participants had been told to ignore the cue. Moreover, this validity effect was found in both groups when there was a short cue–target delay of 100 ms as well as a longer cue–target delay of 800 ms. The result indicates that the moving eyes trigger rapid reflexive shifts of visual attention.

We had hypothesized that inverting the face might eliminate the reflexive cueing effect of the moving eyes in typically developing children but not the children with autism. This prediction was made because the face appears to lose configural information when inverted, disrupting face processing in typically developing children but not autistic children (Langdell 1978; Volkmar *et al.* 1989; Davies *et al.* 1994). In addition, Langton & Bruce (1999) have reported that inverting the face cue significantly reduces the strength of the reflexive cueing effect in adult viewers. Looking at experiment two compared with experiment one, both groups maintained reflexive cueing effects with the inverted cue, and showed an equally strong validity effect (faster responses to valid rather than invalid trials). Although it was somewhat surprising that the face inversion did not suppress reflexive gaze effects (particularly in the control group), this may have been because the stimuli were repeatedly displayed. Face inversion experiments do not normally involve such a large number of presentations. Alternatively, the perception of eye movements independent of face configuration may be producing the reflexive orienting effects in both groups. It would be interesting, for example, to test whether eyes alone (i.e. not in a face) trigger reflexive orienting.

4. GENERAL DISCUSSION

In two experiments this study showed that children with autism, when matched to a group of typically developing children, show an equal sensitivity to the disruptive effect of a gaze cue. Neither group were able to ignore an incongruent cue, reflexively orienting in the direction of seen gaze. The reflexive response would seem to be insensitive to facial configuration because the effects are similar in both experiments one and two. We were surprised that there were so few group differences in our findings. One interpretation of this could be that our tasks and analyses were relatively insensitive to any possible group differences. However, the mean reaction times with similar standard deviations in the two groups seemed to us to indicate that our tasks were sensitive to any group differences should these be present. The one small group difference that we did find was in experiment one: children with autism were slower than typically developing children to respond in general to cues presented at 800 ms SOA. The simplest explanation for this result would be that children with autism are slower to prepare and initiate any response to an imperative cue, independent of the context of gaze processing or attention shifting.

Children with autism are impaired in a range of joint attention behaviours (Curcio 1978; Loveland & Landry 1986; Landry & Loveland 1988; Baron-Cohen 1989; Mundy *et al.* 1994; Lord 1995; Charman *et al.* 1997; Leekam *et al.* 1997, 2000). One of the earliest recognizable symptoms is an absence of gaze following (Baron-Cohen *et al.* 1996; Baird *et al.* 2000). Direction of gaze is an important social signal (Argyle & Cook 1976; Kleinke 1986), indicating the location of objects or events that others are attending to. A delay in the development of gaze following could be expected to impair the development of subsequent social communication skills, including theory of mind (Baron-Cohen 1995). Recent work with autistic individuals has suggested an attentional impairment which may underlie the joint attention impairment (Courchesne *et al.* 1985; Rincover & Ducharme 1987; Casey *et al.* 1993; Wainwright-Sharp & Bryson 1993; Burack & Iarocci 1995; Wainwright & Bryson 1996; Leekam *et al.* 1998, 2000). The study reported here looked specifically at attentional orienting in response to gaze direction cues to establish whether an attentional impairment might be the origin of the gaze-following impairment. Recent work in the literature about adult attention has shown that gaze direction cues may differ from non-social directional cues, such as arrows, in that they trigger reflexive orienting responses in the viewer (Friesen & Kingstone 1998; Driver *et al.* 1999; Hietanen 1999; Langton & Bruce 1999; Vuilleumier 2002). We therefore decided to test whether moving eyes in a full face would trigger reflexive shifts of attention in the children with autism and typically developing children.

Our initial hypotheses were open with respect to autism, although given autistic children's behavioural delay in gaze following (Leekam *et al.* 1998), we suspected they may have shown reduced sensitivity to gaze direction in a face. However, we found strong evidence that moving eyes did trigger reflexive shifts of attention not only in typically developing children, but also in a group of children with autism.

If eye direction reflexively orients attention in children with autism, why have previous observational studies shown a lack of gaze following (Leekam *et al.* 1997, 2000)? First, previous studies have tested autistic children who are at an earlier stage of development (either in terms of chronological age or mental age). In other words, a developmental delay evident in early behaviour has been overcome in these older, high-functioning participants. Second, Leekam *et al.* measured overt attentional orienting (the child's own head turns) which may function independently of covert orienting measured in our tasks here. One interpretation is that the origin of the gaze-following deficit in general, is not related to a low-level perceptual or attentional deficit. Instead, the origin is either cognitive (e.g. Baron-Cohen 1995) or affective (Hobson 1993; Mundy 1995). However, our results do not rule out the possiblity that children with autism are *delayed* in the onset of a reflexive orienting response. It would be possible to test this by doing the same experiments with younger children.

The notion that the reflexive response may take longer to develop in people with autism would be consistent with the idea that it is acquired through overlearning. Lambert & Sumich (1996) have demonstrated using arbitrary pairings between word categories and side of a subsequent target, that learned associations between cue events and the subsequent position of targets can produce a reliable orienting response in normal adults, even when participants are unaware of contingency between cue and target. In the case of gaze direction, the repeated pairing of another person's direction of gaze and the location of interesting objects or events through extensive social experience may have resulted in association being so overlearned that it becomes reflexive. Given the evidence that early in development young children with autism look less at people (Swettenham *et al.* 1998) then we might expect them to only have enough exposure to acquire a reflexive response later in development. According to this view the reflexive response to gaze direction develops as a consequence of exposure to the association of seen gaze direction and objects. Children must first be following gaze before the reflexive response develops. The relationship between the development of overt gaze following and reflexive orienting could be tested in future experiments. A plausible *developmental* scenario could be that in all children an 'innate' or at least early sensitivity to direction of gaze (proto-reflexive orienting) operates to allow young infants to shift attention in response to gaze cues without further inferential work. Indeed, this function may well be specific only to humans and some primate species (Emery 2000). However, the further development of this skill to sustain joint attention abilities involving the reading of intention in others (Baron-Cohen 1995) will depend on further developmental factors, some of which may be anomalous in people with autism. Thus, it may be possible for the young child with autism to follow the gaze of another to some extent and be 'captured' by the direction of gaze of another, although s/he may not be able to make further use of this skill.

Although the results suggest that moving eyes reflexively orient attention in the direction of seen gaze we cannot be sure from these experiments whether such effects are only found for moving *social* stimuli. The inclusion of a non-social but moving cue, matched for stimulus complexity, would be useful as a control condition in future experiments. It is also possible that other social cues including whole face orientation may produce different effects to eyes. For example, recent experiments indicate that a face profile may fail to produce a reflexive orienting response in children with autism (Swettenham *et al.* 2003).

Do our results mean that perception and attention in general are intact in autism? This still seems unlikely given the number of studies demonstrating perceptual and attentional impairments in autism (e.g. Courchesne *et al.* 1985; Rincover & Ducharme 1987; Casey *et al.* 1993; Wainwright-Sharp & Bryson 1993; Burack & Iarocci 1995; Wainwright & Bryson 1996). Our findings only apply to responses to eye direction, and given that gaze direction seems to elicit powerful effects not traditionally found in laboratory cueing tasks it would be unwise to generalize to other attentional studies. Our findings of no difference between the groups in the magnitude of the validity effect indicates that some exogenous orienting mechanisms, at least, may be intact in autism.

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GLOSSARY

IQ: intelligence quotient
HSD: Tukey's Honestly Significant Difference test
SOA: stimulus onset asynchrony