EYE GAZE TRIGGERS VISUOSPATIAL ATTENTIONAL SHIFT IN INDIVIDUALS WITH AUTISM

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We examined whether eye gaze triggers reflexive attentional shift in autism. First, autistic individuals who were lacking both joint attention behaviors and theory-of-mind abilities were examined. Targets were randomly presented to either the left or right side of a gazing face. Autistic subjects localized the targets faster when targets were congruent with than against gaze directions. The occurrence of this gaze-triggered attentional shift was further examined using different stimulus onset asynchronies (SOAs) in autistic individuals and non-autistic controls. Autistic subjects similar to non-autistic controls responded faster when the targets were congruent with than against gaze directions for short SOA conditions. These results suggest that autistic individuals, even those lacking joint attention behaviors, respond reflexively to another person's gaze directions.

Key words: autism, gaze, visuospatial attention, joint attention

Autism is a pervasive developmental disorder, clinically defined as impaired development in social interaction and communication and a restricted repertoire of activity and interests (American Psychiatric Association, 2000). Since the middle 1980s, many researchers have tried to identify the fundamental deficits which underlie various characteristic behaviors in autism. Baron-Cohen et al. considered a lack of theory-of-mind as the primary cognitive deficit in autism (Baron-Cohen, Leslie, & Frith, 1985; Baron-Cohen, 1989b). Mundy and Sigman reported that autistic children lack joint attention behaviors, which are expected to develop prior to theory-of-mind, and insisted that deficits in joint attention behaviors should be considered as the primary deficit in

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autism (Mundy, Sigman, Ungerer, & Sherman, 1986; Sigman, Mundy, Sherman, & Ungerer, 1986). Many reports have described the defective joint attention behaviors in autism, such as impairments in gaze-following (Leekam, Hunnisett, & Moore, 1998), protodeclarative pointing (Baron-Cohen, 1989a) and showing (Baron-Cohen, 1995). It is useful for the early detection of autism to examine whether such joint attention behaviors are impaired or not (Baron-Cohen, Cox, Baird, Swettenham, Nightingale, Morgan, Drew, & Charman, 1996).

Monitoring another person's gaze is considered to be a highly social behavior, because it has an adaptive value for gaining social information and enables us to infer another person's current focus of attention. Thus, Baron-Cohen regarded it as a precursor of theory-of-mind abilities (Baron-Cohen, 1995). Some recent studies, however, have raised doubts about this idea. A behavioral investigation on nonhuman primates showed that even young chimpanzees spontaneously attend to and follow the visual gaze of others, even though they may not appreciate the underlying mentalistic significance of these behaviors (Povinelli & Eddy, 1996). Psychological studies in humans using the cuing paradigm also reported a rapid and automatic component of joint attention behaviors (Friesen & Kingstone, 1998; Driver, Davis, Ricciardelli, Kidd, Maxwell, & Baron-Cohen, 1999; Langton & Bruce, 1999). In these experiments, subjects were required to detect, localize, or identify targets that appeared randomly congruent with or against the gaze direction of the picture of a face. Although they were instructed to ignore the directions of the gaze cues, subjects responded to the targets faster when the targets appeared congruent with the gaze direction. These findings suggest that eye gaze triggers a reflexive shift of attention in normal healthy adults (Friesen & Kingstone, 1998; Driver et al., 1999; Langton & Bruce, 1999).

Although there are consistent reports of deficits in interpersonal joint attention behaviors in autism (Baron-Cohen, 1989a; Baron-Cohen, 1995; Leekam et al., 1998), no studies have examined whether another person's gaze direction triggers a reflexive shift of attention in individuals with autism. If the problem specific to children with autism is that they cannot represent that self and other are attending to the same object, this does not necessarily predict that these children will have difficulty in orienting their attention to another person's gaze directions by using a nonrepresentational strategy (Leekam et al., 1998). In the present study, we addressed this issue through two experiments using the cuing paradigm described in a previous study (Driver et al., 1999). In Experiment 1, we examined gaze-triggered reflexive attentional shift in adults with autism who were lacking joint attention behaviors in interpersonal situations and with deficits in theory-of-mind. In Experiment 2, we examined this attentional shift in detail by fine-grained manipulation of the stimulus onset asynchronies (SOAs) in autistic subjects and non-autistic controls, who were matched for age and performance IQ.

EXPERIMENT 1

Method

Subjects: Subjects were three male adults (A, B, C) with autistic disorder, as diagnosed by the criteria of DSM-IV-TR (American Psychiatric Association, 2000). All subjects were right-handed, and the age of each subject was A: 20 years, B: 31 years, and C: 31 years. Their scores on the Wechsler Adult Intelligence Scales-Revised (WAIS-R) were A: Total IQ 58 (Verbal IQ 68, Performance IQ 59), B: Total IQ 66 (Verbal IQ 72, Performance IQ 64), and C: Total IQ 55 (Verbal IQ 72, Performance IQ 40). They had failed first-order (Baron-Cohen, Leslie, & Frith, 1985) and second-order (Baron-Cohen, 1989b) false belief tasks, indicating that they lacked theory-of-mind abilities. They were also reported by their parents to be lacking joint attention behaviors in interpersonal situations. When the experimenter called the name of each subject or talked to him repeatedly, it was possible to make eye-contact. Then the experimenter suddenly averted his gaze and turned his head to look at another object several times, but no subjects followed the gaze direction of the experimenter, which confirmed the lack of gaze-following behavior described in parent interviews and seen in direct observations.

All subjects were concentrated and mentally stable during the testing. They were able to understand the instructions and test procedures. Before testing, written informed consent was obtained from the subjects and their parents after the procedure and the purpose of this study had been fully explained. The study protocol was approved by the Ethical Review Board of Department of Psychiatry, Kyoto University Hospital.

Apparatus: Stimuli were presented on a 19-inch flat-type CRT monitor (Sony GDM-F400). The refresh rate of the monitor was set to 100 Hz and the resolution was 1024×768 pixels. The presentation of stimuli was controlled by an NEC personal computer with SuperLab Pro for Windows ver. 2.0 (Cedrus) software. Reaction times (RTs) and accuracy measures were based on responses through the Cedrus RB-400 Response Box.

Stimuli: The central fixation cross subtended 0.4°. A full-face photograph of a gazing-left female face was taken by a digital camera (Fuji Fine Pix 4900z) and this was used as the gazing-left cue. The gazing-right cue was produced by a mirror reflection of the eye-regions alone using Adobe Photoshop 6.0 software (Adobe Systems). This was to ensure that no asymmetric properties of the face (wisp of hair, etc.), other than the direction of gaze, could be responsible for any differences in the lateral orientation produced by the two cues. A photograph with the eyes occluded by uniform gray regions was also produced using the same software. The photographs subtended 8.5°×6.5°. The target circle, subtending 0.8°, was presented on the left or right side, 5.0° from the center of the monitor.

Procedure: The experiments were conducted in a dark, quiet room. Subjects were tested individually. They were seated 57.3 cm from the monitor and instructed to look at the monitor in front of them.

A schematic representation of each trial is shown in Fig. 1. SOAs of 300 and 700 ms were adopted. The start of a trial was signaled by a warning sound and a central fixation cross was presented. Subjects were instructed to look at the fixation cross. After 675 ms, the photograph with eyes occluded was presented. After 900 ms, a photograph depicting gaze was randomly presented. After the SOA (300/700 ms), the target was randomly presented on one side, regardless of gaze direction, and it remained on the screen until the response was made. Subjects were instructed to indicate whether targets appeared on the left or right side of the face by pressing the left key with the left index finger for the target on the left or by pressing the right key with the right index finger for the targets on the right. The hand used for pressing the response box should have had no effect on median RTs because all conditions consisted of the same number of trials with targets on the left and right sides. RTs were recorded in milliseconds and timed from target onset.

The presentations of the cues and targets were divided into valid (i.e., the gaze direction was towards the target; the pairs of cue-target directions were left-left or right-right) and invalid (i.e., the gaze direction was away from the target; the pairs of cue-target directions were left-right or right-left) conditions. Test trials consisted of 40 trials for each SOA, including the same number of four types of trials (left-left, right-right, left-right, right-left). The orders of the test trials were randomized in each patient. There were long breaks (up to a few minutes) between sessions with different SOAs, and short breaks (30 seconds) between blocks of twenty trials. Before starting a new session, ten practice trials were conducted.

Before the start of test trials, the subjects were informed that it was important to fixate their eyes on the central fixation cross while it was presented and that the gaze direction was not predictive of the location of
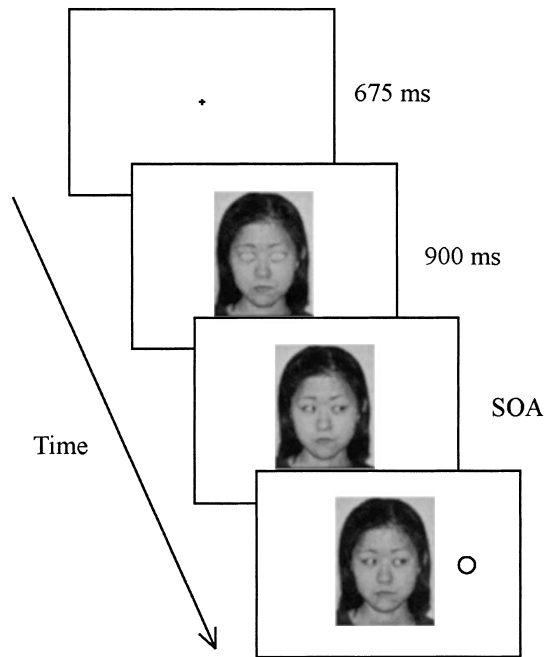
Fig. 1. Schematic depiction of a typical sequence of events within one trial from Experiment 1, with successive events running from top-left to bottom-right in the figure. Each trial began with a central fixation cross and warning sound. Then, 675 ms later, the photograph of the face appeared with its eyes occluded. After a further 900 ms, the deviated gaze of the face was revealed. Finally, after a variable delay depending on cue-target SOA (300/700 ms), the target circle randomly appeared on one side regardless of gaze direction. The trial, illustrated in this figure, is an example of valid trials, because the target appeared congruent with gaze direction.

the targets. They were also instructed to locate the targets as quickly and accurately as possible.

Data analysis: All data were analyzed with SPSS ver. 10.0J software (SPSS Japan Inc.). The mean RT of correct responses (all responses were correct in these experiments) was calculated for each subject, rejecting any data under each condition that were beyond the mean ± *SD*. By collapsing the effect of SOAs, Wilcoxon's rank test (one-tailed) was used to examine the effect of conditions (valid vs. invalid). Values were considered significant at $p<.05$.

Results

The mean RTs for different SOAs are shown in Fig. 2. The RTs were shorter in the valid than invalid conditions ($z=1.78$, $p<.05$).

EXPERIMENT 2

Method

Subjects: Subjects were four children with autistic disorder (DSM-IV-TR) and five non-autistic children with mental retardation. The subjects were recruited from two high schools for children with learning disabilities. The profiles of the subjects in both groups are shown in Table 1. The autistic and non-autistic subjects were matched for chronological age and performance IQ. Autistic subjects had a lower
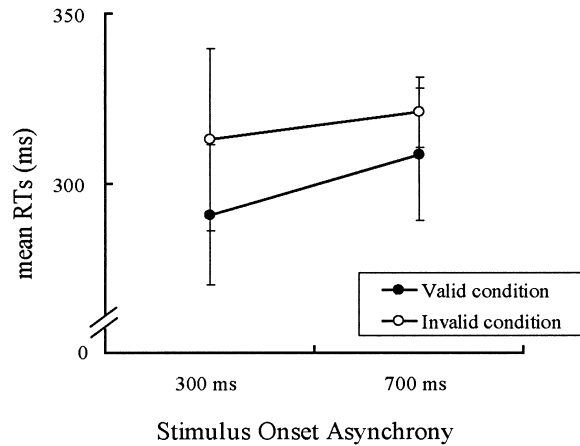
Fig. 2. The mean RTs for correct responses for each SOA (300/700 ms) in Experiment 1. Error bars show the standard errors.

Table 1. Profiles of Subjects in Autistic and Non-autistic Groups (Mean ± *SD*)

	N (M, F)	Age	Total IQ	Verbal IQ	Performance IQ
Autistic group	4 (3, 1)	16.5 ± 0.5	54.8 ± 6.7	53.3 ± 8.1	67.3 ± 3.9
Non-autistic group	5 (5, 0)	16.7 ± 0.7	65.8 ± 4.3	66.0 ± 6.0	72.6 ± 6.5

verbal IQ and total IQ than the non-autistic subjects. All subjects were right-handed. They were able to understand the instructions for the tasks and responded adequately as they were instructed. All subjects were concentrated and mentally stable during the testing. Before testing, written informed consent was obtained from the subjects and their parents after the procedure and the purpose of this study had been fully explained.

Procedure: The stimuli, apparatus and procedure were the same as those of Experiment 1, except for the SOAs. In this experiment, SOAs of 100, 300, 500, 700, 900 and 1100 ms were used. The orders of the sessions of different SOAs were randomized in each subject. There were long breaks (up to a few minutes) between sessions with different SOAs, and short breaks (30 seconds) between blocks of twenty trials. Before starting a new session, ten practice trials were conducted.

Data analysis: The mean RT of correct responses (all responses were correct), rejecting any data under each condition that were beyond the mean ± 2*SD*, was calculated. Wilcoxon's rank test (one-tailed) was used to examine the effect of conditions (valid vs. invalid) for each SOA (100/300/500/700/900/1100 ms). Values were considered significant at *p*<.05.

Results

The mean RTs for different SOAs are shown in Fig. 3. In the non-autistic group (Fig. 3a), RTs were shorter in the valid than invalid conditions for SOAs of 100, 300, and 700 ms (all *p*s<.05). Cuing effects were not significant for the other SOAs. In the autistic group (Fig. 3b), RTs were shorter in the valid than invalid conditions for SOAs of 100, 300, and 500 ms (all *p*s<.05). Cuing effects were not found for longer SOAs.

(a) non-autistic group
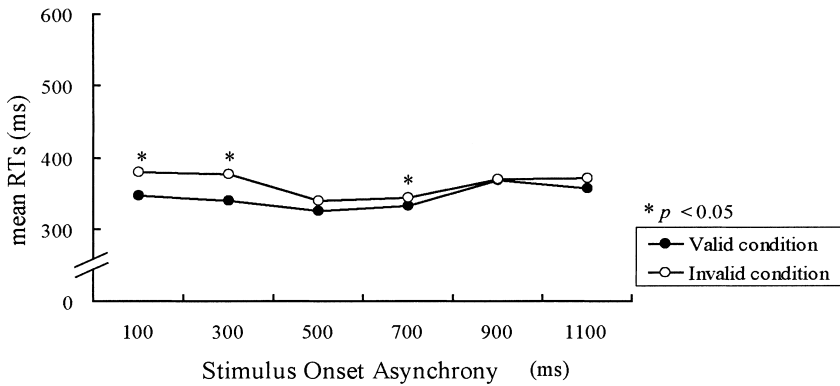
(b) autistic group
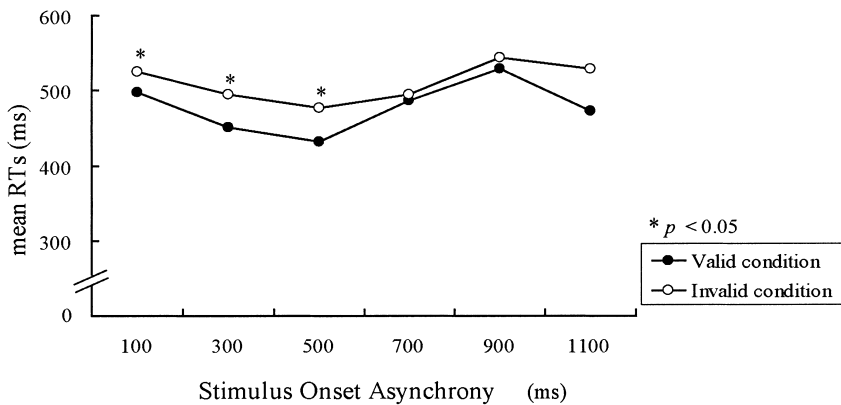
Fig. 3. The mean RTs for correct responses for each SOA (100/300/500/700/900/1100 ms) in Experiment 2: (a) non-autistic group; and (b) autistic group.

DISCUSSION

The present study examined whether eye gaze triggers shifts of visuospatial attention in individuals with autism. In Experiment 1, we examined adults with autism who showed deficits in gaze-following behaviors and theory-of-mind abilities. The gaze cues were not predictive of the locations of the targets, and the subjects were instructed to locate the targets as quickly as possible. RTs were shorter following the presentation of the valid gaze cues.   This finding suggests that the task-irrelevant gaze cues triggered an appropriate, reflexive attentional shift in autistic subjects. In Experiment 2, we further examined gaze-triggered attentional shifts using different SOAs in autistic subjects and age- and ability-matched non-autistic controls. Although the eye gaze triggered a shift in the observer's visuospatial attention for short SOAs in both autistic and non-autistic subjects, this cuing effect vanished for long SOAs. These results are consistent with those

of previous studies using the gaze cuing paradigm in normal healthy adults (Friesen & Kingstone, 1998; Driver et al., 1999; Langton & Bruce, 1999). Taken together, our results indicate that a reflexive attentional shift triggered by the very short presentation of gaze directions occurs in individuals with autism as well as those without autism. To our knowledge, this study is the first to report intact reflexive gaze processing in autism.

Some recent studies suggested that the engagement in joint attention does not necessarily require the representation of another person's mental state (Povinelli & Eddy, 1996). The current results suggest that individuals with autism, even those lacking theory-of-mind abilities, orient their visuospatial attention reflexively to another person's gaze direction. This suggests that the reflexive component of joint attention behavior can occur without a representational strategy.

It has been reported that human infants first follow another's gaze at their early stage of development (ranging from 6 to 18 months, with the variety probably due to the differences in experimental methodology and definitions for gaze) (Emery, 2000). Human infants follow their mother's gaze before 12 months old; they begin to follow their mother's gaze towards the peculiar objects in their visual fields at around 12 months old, and they can shift their attention to objects outside of their visual fields (Butterworth, 1991). These results suggest that the gaze following behavior can be observed at very young ages and then it develops into a broader range of joint attention behavior. A recent experiment reported that 2-year-old children with autism as well as typically developing controls can saccade their eyes to perceived gaze directions (Chawarska, Klin, & Volkmar, 2003). This result suggests that the young children with autism can direct their attention reflexively to another's gaze just as observed in our studies. It means that the autistic individuals are equipped with, at least, part of the intact neural mechanisms for the early and basic gaze processing, i.e. the rapid, automatic, nonrepresentational shift of attention triggered by gazing.

Previous studies have identified neural systems dedicated to gaze processing (Emery, 2000). Single-cell recording (Perrett, Smith, Potter, Mistlin, Head, Milner, & Jeeves, 1985) and lesion studies (Campbell, Heywood, Cowey, Regard, & Landis, 1990; Heywood & Cowey, 1992) in macaque monkeys have revealed that specific cells in the anterior part of the superior temporal sulcus (STS) are responsive to specific gaze directions and devoted to their discrimination. A recent functional imaging study in humans reported that the perception of another individual's averted gaze automatically activated the posterior STS (Hoffman & Haxby, 2000). An event-related potential study reported that the perception of another's averted gaze increased and speeded up early visual activity of the posterior temporal areas (Schuller & Rossion, 2001). We suggest that such automatic and rapid gaze processing in the STS is intact in individuals with autism. Consistently, a recent imaging study demonstrated that a gaze processing task elicited temporal cortex activity including the superior temporal gyrus in autistic individuals as well as normal subjects (Baron-Cohen, Ring, Wheelwright, Bullmore, Brammer, Simmons, & Williams, 1999).

The present study has shown that individuals with autism, even those who are lacking joint attention behaviors in interpersonal situations, orient their attention

reflexively to another person's gaze direction. It is necessary to clarify what causes the dissociation between gaze-triggered reflexive shift of attention and joint attention behaviors in interpersonal situations in individuals with autism. First, if individuals with autism, as Baron-Cohen et al. suggested, have difficulties in representing another person's mental state (Baron-Cohen, 1995), they should not represent why the other person is attending to the object even though they orient their attention in that direction. In other words, they should not understand the meaning of the other person's eye-gaze in context of what the other person would like to do next or thinks. The representational process does not facilitate their joint attention behaviors, and their response to another person's gaze direction remains at the reflexive level. If this hypothesis is correct, there is a possibility to facilitate joint attention behaviors by teaching the significance of gaze direction. In fact, when more cues (pointing, language) were added or when feedback from targets was given, gaze-following abilities were reported to improve (Leekam et al., 1998). Another possibility is that individuals with autism may have disabilities in extracting socially important cues from a large amount of social and nonsocial cues. In the current study, we presented a single social cue that belongs to only one category in a single modality. If other social and nonsocial cues could be controlled in real-life situations, individuals with autism may more easily respond to another person's eye gaze.

The present study examined whether eye gaze triggers reflexive shifts of attention in individuals with autism. Target localization tasks using the gaze cuing paradigm were conducted. In Experiment 1, three male adults with autism, who were lacking both joint attention behaviors in interpersonal situations and theory-of-mind abilities, were found to localize the targets faster when the targets were presented congruent with rather than against the nonpredictive gaze directions. In Experiment 2, individuals with autism and non-autistic individuals, who were matched for age and performance IQ, were examined using the same localization tasks with SOAs of 100, 300, 500, 700, 900 or 1100 ms. Individuals with autism localized the targets faster when the targets were presented congruent with gaze directions, at short SOAs. The pattern of responses to eye gaze were similar in autistic and non-autistic groups across various SOAs. These results suggest that individuals with autism, even those lacking joint attention behaviors in interpersonal situations, respond reflexively to another person's gaze direction, like non-autistic individuals.

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