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Brief article

Eye contact does not facilitate detection in children with autism

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Abstract

Eye contact is crucial in achieving social communication. Deviant patterns of eye contact behavior are found in individuals with autism, who suffer from severe social and communicative deficits. This study used a visual oddball paradigm to investigate whether children with high functioning autism have difficulty in detecting mutual gaze under experimental conditions. The results revealed that children with autism were no better at detecting direct gaze than at detecting averted gaze, which is unlike normal children. This suggests that whereas typically developing children have the ability to detect direct gaze, children with autism do not. This might result in altered eye-contact behavior, which hampers subsequent development of social and communicative skills.

Keywords: Eye gaze; Direct gaze; Face; Autism; Oddball task

1. Introduction

Eye gaze direction conveys much information about the internal states of social partners. In particular, mutual gaze (eye contact) is an important signal of another's interest and intentions towards the perceiver (Gibson & Pick, 1963); it serves to establish a communicative context (Kleinke, 1986) and functions in the maternal-infant affective

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bond (Robson, 1967). Therefore, it is quite natural that humans are especially adept at processing gaze information, especially mutual gaze. In fact, discrimination between direct and averted gaze is highly accurate (Gibson & Pick, 1963), and direct gaze is detected faster than averted gaze (the stare-in-the-crowd effect; von Grünau & Anston, 1995). Moreover, even newborns show a visual preference for direct gaze over averted or closed eyes (Batki, Baron-Cohen, Wheelwright, Connellan, & Ahluwalia, 2000; Farroni, Csibra, Simion, & Johnson, 2002). These findings suggest that there is an innate, cognitively specialized mechanism for processing mutual gaze.

Impairment in the use of eye contact for non-verbal communication has been argued as a major characteristic of autism (American Psychiatric Association, 1994). Individuals with autism show a deviant pattern of mutual or reciprocal gaze behavior with their caregivers and other people (Buitelaar, 1995; Volkmar & Mayes, 1990). In the current 'theory of mind' hypothesis, these deficits are thought to be strongly related to their deficits in social and communicative development (Baron-Cohen, 1995).

On the other hand, several experimental studies have found an intact attentional mechanism to process eye gaze, especially decoding its direction and reflexively orienting in the corresponding direction (Neely, 2001; Okada et al., 2002; Senju, Tojo, & Hasegawa, 2001; Swettenham, Milne, Plaisted, Campbell, & Coleman, 2000). However, these findings were limited to the processing of averted gaze, and the functioning of direct gaze processing in individuals with autism is still unknown. Considering the critical role of eye contact in social-communicative behavior, and the pervasive difficulties in social development in autism (American Psychiatric Association, 1994), it is possible that individuals with autism are impaired specifically in mutual gaze processing, not in gaze processing in general.

To date, no previous experiments have found deviant direct gaze processing in autism. Although clinical and observational intuition strongly suggest that the salience of direct eye gaze lacks in autism, it has actually only been folklore up to now.

We investigated this mechanism using a visual oddball paradigm (Garcia-Larrea, Lukaszewicz, & Mauguière, 1992). An oddball task involves presenting a series of frequent stimuli, into which rare stimuli are inserted. This study used two kinds of rare stimuli: one using direct gaze and the other using averted gaze. The participants were instructed to respond to one of the two rare stimuli, while ignoring the other. If failure in establishing a normal pattern of eye contact has a perceptual or attentional background, we predicted that children with autism would not show relative superiority in detecting direct gaze over averted gaze, which is usually the case for typically developing children (von Grünau & Anston, 1995).

2. Method

2.1. Participants

Thirteen children with autism (all males; mean age 12:1 years, range 9:10–14:11 years; mean Raven's Colored Progressive Matrices (RCPM) score 31.8, range 27–36) and 15 age-matched typically developing children (13 males and two females; mean age

12:1 years, range 9:5–14:10 years; mean RCPM score 34.2, range 26–36) participated in this study. All of the children were Japanese, and all were students or graduates of a primary school that is attended by both autistic and typically developing children. Verbal informed consent was obtained from each child, his or her parents, and the school director. One child with autism refused to participate in the experiment and was excluded from the study. All of the children with autism met the DSM-IV criteria for autistic disorder (American Psychiatric Association, 1994), and all had been diagnosed with autistic disorder by at least one child psychiatrist when they entered the school. Japanese RCPMs (Raven, 1956; Sugishita & Yamazaki, 1993) were administered to all of the children to estimate their non-verbal cognitive ability, which might affect their performance in the task. All the children had normal or corrected to normal acuity. All the experiments were conducted with the children individually in a quiet room at the National Institute of Special Education, which is near their primary school.

2.2. Apparatus and stimuli

The experiment was run on a PC with a 17-inch color monitor using Neuroscan Stim software. The participants were seated approximately 130 cm from the monitor. The children's reaction time (RT) and accuracy were measured from their button-press responses.

A fixation point consisting of a central cross that subtended 0.5° appeared on the screen and the children were instructed to fixate on it before the experiment started. Color photographs of the laterally averted faces of three female models were cut into ovals (5° wide and 7° high) to produce one frequent and two rare stimuli for each model. Examples of each stimulus type are shown in Fig. 1. The frequent stimuli (Fig. 1, left) were faces glancing downward. The eyes of the rare stimuli were either in direct gaze (Fig. 1, center) or laterally averted (Fig. 1, right). Adobe Photoshop 7.0 software was used to produce

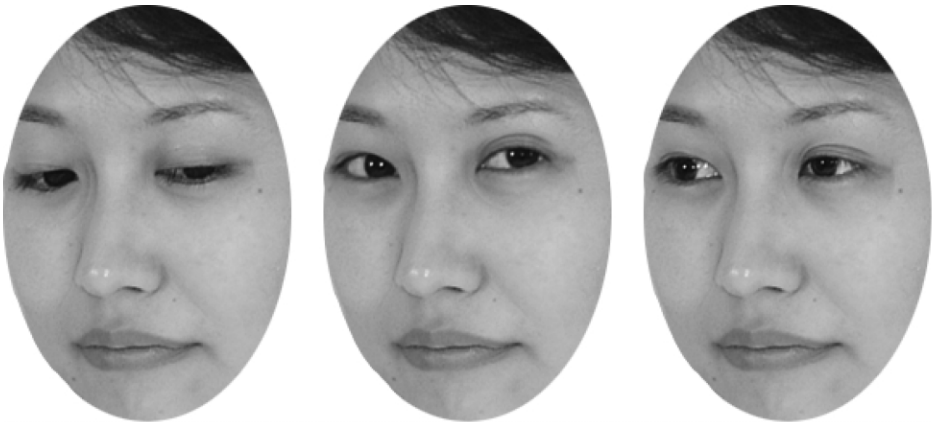

Fig. 1. Examples of frequent and rare stimuli. Left: frequent stimulus. Center: rare stimulus (direct gaze). Right: rare stimulus (averted gaze).

the three stimuli from the same basic image, on which the same person's eyes were superimposed from other photographs according to stimulus type. This resulted in three stimuli that were exactly the same, except for eye direction. In all, nine stimuli (three models × three eye directions) were used in this experiment.

2.3. Design and procedure

On arrival, each child was familiarized with the experimental setting. The experiment used an oddball task with three different stimuli, presented at frequencies of 82% (standard), 9% (target), and 9% (non-target). Each block consisted of a practice sequence, followed by a test sequence. A practice sequence involved the presentation of the series of standards and targets. Before beginning a practice sequence, the experimenter showed the child printed photographs of the standard and target, and the child was instructed to press one button on seeing the standard and another for the target, as soon as they detected the stimulus. The test sequence included non-targets, in addition to standards and targets, and the task was to press the corresponding buttons for the standards and targets, but not to press any buttons for the non-targets. The first target did not appear until at least 14 standard stimuli had been shown. The presentation of subsequent rare stimuli (both targets and non-targets) was pseudorandomized. Each trial started with presentation of the fixation point for 200 ms, followed by presentation of one of the stimuli, which remained on the screen for 500 ms. The intertrial interval (ITI) was 1500 ms. No feedback was given.

The experiment consisted of six blocks. In each block, standards, targets, and non-targets were always photographs of the same model. Faces with direct gaze were used as the target in half of the blocks, and those with gaze-averted faces were the targets in the other blocks. Non-targets were always the other rare stimuli, or the counterpart of targets. The presenting order of blocks was randomized among children. The practice sequence consisted of 29 trials, while the test sequences varied from 112 to 162 trials across blocks, in order to make the end of the block unpredictable for the participants.

3. Results

There was a slight, but significant, group difference in the RCPM scores ($t(26) = 2.30$, $P < 0.05$). Since non-verbal cognitive ability might affect detection accuracy and speed, the RCPM scores were introduced as a covariate in all subsequent analyses of covariance (ANCOVA) to rule out the possible effect of non-verbal cognitive ability.[1,2]

First, the average hit rates, false alarm (FA) rates, and RTs for frequent stimuli were analyzed to examine how accurately and quickly the children detected the frequent stimuli. In addition, based on signal detection theory, d' was calculated to examine the

[1] Since there were no effects of the identity of the stimulus faces, the data were pooled for the subsequent analyses.

[2] Responses faster than 100 ms or slower than 1300 ms were omitted as anticipations or time-outs, respectively. Less than 1% of all trials were thus excluded.

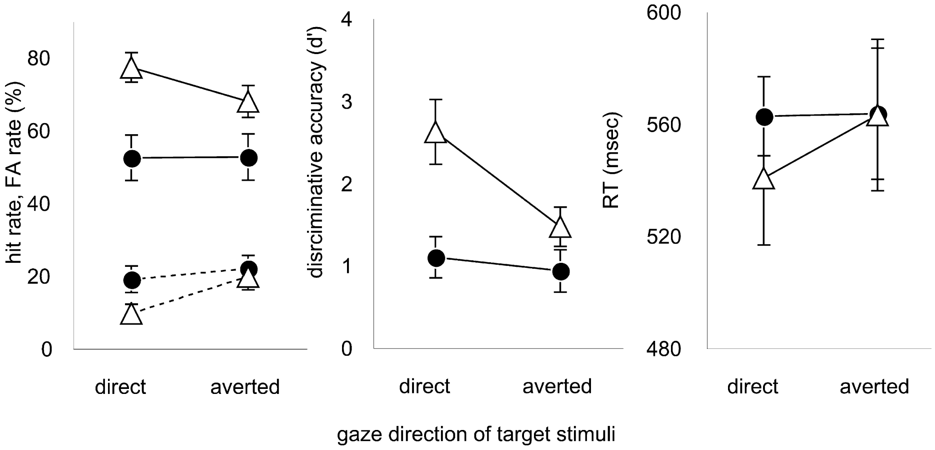

Fig. 2. Mean hit rates (%), discrimination accuracy (d'), and reaction times (ms) for targets. Left: hit rates (continuous lines) and FA rates (dotted lines). Center: d'. Right: reaction times. Circles: children with autism. Triangles: normal children. Error bar: SE.

children's discriminative accuracy between the two types of stimuli, i.e. frequent and rare stimuli. The results suggested that the hit rates were sufficiently high in both groups (91.8% and 96.7% for children with autism and control children, respectively), which indicated that both groups of children were good at discriminating frequent from rare stimuli. One-way ANCOVA revealed that there were no significant group differences in hit rate, FA rate, discriminative accuracy (d'), or RT (all $F < 2.8$, all $P > 0.1$).[3]

Then, the average hit rate, FA rate, discriminative accuracy, and RT for targets (see Fig. 2) were presented in Fig. 2, which were subjected to two-way ANCOVA for group (autism vs. control) and target (direct gaze vs. averted gaze). A significant main effect of group ($F[1, 25] = 7.86$, $P < 0.01$) was found for hit rate, and a main effect of target ($F[1, 26] = 5.06$, $P < 0.05$) was found for FA rate. The main effects of group ($F[1, 25] = 5.88$, $P < 0.05$), target ($F[1, 26] = 9.09$, $P < 0.01$), and their interaction ($F[1, 26] = 5.11$, $P < 0.05$) were significant for discriminative accuracy. For RT, neither the main effects nor their interaction were significant. To examine whether each group of children detected direct gaze with relative ease, the simple main effects of the targets were analyzed. For children with autism, the gaze direction of targets had no effect on their hit rate, FA rate, discriminative accuracy, or RT (all $F < 1$, all $P > 0.1$). By contrast, for control children, the simple main effects of hit rate ($F[1, 26] = 5.27$, $P < 0.05$) and FA rate ($F[1, 26] = 6.10$, $P < 0.05$) were significant, which suggests that direct gaze was more likely to be detected than averted gaze, and it was easier to suppress the false response to averted gaze. Consequently, discriminative accuracy was also significantly higher for direct gaze ($F[1, 26] = 13.91$, $P < 0.01$). Since the simple main effect of RT

[3] The FA rate was 34% for children with autism and 22% for typically developing children. The discriminative accuracy (d') was 2.059 for children with autism and 2.826 for control children. The mean RTs were 324.2 and 330.3 ms for children with autism and control children, respectively.

was not significant ($F[1, 26] = 2.39$, NS), the difference in the hit rate, FA rate and d' cannot be attributed to trade-offs between response accuracy and speed.

Since the performances of the control children differed according to the gaze direction of the targets, group differences for each gaze direction were examined. When the targets were direct gaze faces, there were significant group differences for hit rate ($F[1, 25] = 11.08$, $P < 0.01$) and discriminative accuracy ($F[1, 25] = 12.84$, $P < 0.01$). For gaze-averted targets, the group differences were not significant ($F[1, 25] = 4.16$, NS, for hit rate; $F[1, 25] = 1.59$, NS, for discriminative accuracy).[4] FA rate and RT did not differ significantly in either condition (all $F < 1$, all $P > 0.1$). Therefore, children with autism had more difficulty than control children in detecting faces with direct gaze, but were equally able to detect averted gaze, and this effect cannot have been due to trade-offs involving accuracy or speed.

4. Discussion

First, our results show that typically developing children detect faces with a direct gaze more effectively than faces with an averted gaze, which replicates the findings of von Grünau and Anston (1995) in a visual oddball paradigm. Second, and more importantly, the gaze direction of the stimuli had no effect on the performance of children with autism. Accordingly, typically developing children detected direct gaze better than children with autism, while performance in detecting averted gaze did not differ between the groups. These results suggest that direct gaze has a facilitative effect on the performance of typically developing children for two reasons. First, when non-verbal cognitive abilities were controlled for, the accuracy of discrimination between frequent and rare stimuli did not differ between groups, which suggests an equivalent baseline ability at the required task. Second, recent studies have found that in a typically developing population direct gaze enhances the speed with which faces are discriminated (Macrae, Hood, Milne, Rowe, & Mason, 2002), which is in line with current findings regarding typically developing children. With regard to children with autism, direct gaze had no effect on their performance. This cannot be attributed to problems specific to the oddball paradigm, because their achievement in detecting averted gaze equaled that of typically developing children. Therefore, the children with autism had a problem specific to direct gaze processing, in that they failed to preferentially detect direct gaze. To our knowledge, this is the first report of restricted impairment in mutual gaze detection with intact averted gaze processing. This finding is concordant with clinical and ethological observations, which report failure in establishing the normal course of eye contact behavior, and suggests that the behavioral difficulty of autistic children may have a perceptual or attentional background.[5]

[4] From the apparent look of the data, one might doubt that there is a slight difference between groups for the hit-rate in the averted gaze condition, although not significant. However, even if it might be the case, it may best be explained by the difference in response criterion between groups rather than impairment in averted gaze processing in autism, because no group difference was found in discrimination accuracy (d').

[5] However, whether such a lack of eye contact advantage is specific to autism remains unknown. Further research including individuals with other disorders will be required to fully address this issue.

Direct gaze indicates another's social attention or intention towards oneself, playing a crucial role in social interaction. Recent neuroimaging studies with typically developed adults have found that another's direct gaze modulates brain activity corresponding to the evaluation of facial attraction (Kampe, Frith, Dolan, & Frith, 2001) or facial expression of emotion (Wicker, Perrett, Baron-Cohen, & Decety, 2003). Our results imply that direct gaze may not have such a modulatory function in facial perception in autism. Neural activation of individuals with autism during perception of the face (Pierce, Miller, Ambrose, Allen, & Courchesne, 2001; Schultz et al., 2000) or facial expression (Critchley et al., 2000) differs from that in individuals without autism. It is possible that future research will find such differences in gaze perception, or in the pattern of modulation of facial processing by direct gaze.

Baron-Cohen (1995) argued that individuals with autism have a modular impairment in sharing attention with others, called the shared attention mechanism (SAM), which follows difficulty in acquiring a theory of mind mechanism (TOMM). In addition, Perrett and Emery (1994) claimed that SAM requires the coupling of two independent processes: the mutual attention mechanism (MAM) provides a means of detecting whether others are looking at me, and the direction of attention detector (DAD) calculates another's gaze direction geographically. Previous findings suggest that children with autism have an intact DAD, in that they can recognize the direction of an averted gaze (Baron-Cohen, Campbell, Karmiloff-Smith, Grant, & Walker, 1995; Leekam, Baron-Cohen, Perrett, Milders, & Brown, 1997) or shift reflexive attention in the direction corresponding to averted eye gaze (Neely, 2001; Okada et al., 2002; Senju et al., 2001; Swettenham et al., 2000). In contrast, our study suggests that children with autism have a deviant MAM. In our experimental setting, children without autism were asymmetrically more effective in detecting direct gaze than averted gaze. For children with autism, direct gaze does not seem to be 'special' enough to facilitate performance. This suggests that children with autism have an intact ability to detect gaze direction, but lack a perceptual or attentional tendency to enhance processing in response to another's direct gaze, which seems to be present in the typically developing population and might be a requirement for the development of SAM and TOMM.

What do our findings tell us about the social cognitive deficit present in individuals with autism? Previous findings suggest that failure to understand the significance of another's gaze interferes with social and communicative development. From early in infancy, attention to mutual gaze plays a major role in establishing bonds of affection with caretakers. Moreover, it is quite probable that an appropriate response to another's social attention, or eye contact, is a prerequisite in initiating and responding to functional social interactions, in learning about the social attention of others, and for subsequently understanding the communicative and emotional significance of eye gaze. In autism, deficits in the neural mechanism dedicated to the processing of mutual gaze, or MAM, might hamper this development of social cognition.

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