Kikuchi, Y. and Senju, Atsushi and Tojo, Y. and Osanai, H. and Hasegawa, T. (2009) Faces do not capture special attention in children with autism spectrum disorder: a change blindness study. Child Development 80 (5), pp. 1421-1433. ISSN 0009-3920.

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Journal Article

http://eprints.bbk.ac.uk/2563

Version: Accepted (Refereed)

Citation:

Kikuchi, Y.; Senju, A.; Tojo, Y.; Osanai, H.; Hasegawa, T. (2009)
Faces do not capture special attention in children with autism spectrum disorder: a change blindness study
Child Development 80 (5), pp.1421-1433

Child Development, September/October 2009, Volume 80, Number 5, Pages 1421–1433

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Faces Do Not Capture Special Attention in Children with Autism Spectrum Disorder: A Change Blindness Study

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Abstract

Two experiments investigated attention of children with autism spectrum disorder (ASD) to faces and objects. In both experiments, children (7-15 year olds) detected the difference between two visual scenes. Results in Experiment 1 revealed that typically developing children (n = 16) detected the change in faces faster than in objects, whereas children with ASD (n = 16) were equally fast in detecting changes in faces and objects. These results were replicated in Experiment 2 (n = 16 in children with ASD and 22 in typically developing children), which does not require face recognition skill. Results suggest that children with ASD lack an attentional bias toward others' faces, which could contribute to their atypical social orienting.

Faces Do Not Capture Special Attention in Children with Autism Spectrum Disorder: A Change Blindness Study

One of the best studied areas concerning the social brain, at least within the field of cognitive neuroscience, is face processing. The human brain has the cortical and subcortical networks that specialize in face processing, for example, the fusiform face area (FFA), superior temporal sulcus, and amygdala (Haxby, Hoffman, & Gobbini, 2000; Johnson, 2005). A lack of such cortical (and possibly subcortical) expertise for face processing is often reported in individuals with autism spectrum disorder (ASD), who suffer from qualitative impairments in social interactions and communication as well as exhibiting restricted, repetitive, and stereotyped patterns of behavior, interests, and activities. Most of the neuroimaging studies on individuals with ASD have found weaker activation or an absence of activation in the FFA, which is one of the core regions of the cortical network for face processing (Critchley et al., 2000; Hubl et al., 2003; Pierce, Müller, Ambrose, Allen, & Courchesne, 2001; Piggot et al., 2004; Schultz et al., 2000; Wang, Dapretto, Hariri, Sigman, & Bookheimer, 2004).

In typical development, infants are born with a bias to orient toward others' faces (Farroni et al., 2005; Morton & Johnson, 1991). This bias is hypothesized to be subserved by subcortical structures including the amygdala, superior colliculus, and pulvinar, and guides cortical specialization for face processing (Johnson, 2005). Other recent studies that adopted a visual search paradigm also support the claim that the face captures and holds attention in typically developing adults (Langton, Law, Burton, & Schweinberger, 2008; Ro, Friggel, & Lavie, 2007).

Some argue that the developmental origin of atypical face processing in ASD is the result of insufficient facial orienting, which is possibly due to the lack of attentional bias (Schultz, 2005) or motivation (Dawson, Webb, & McPartland, 2005) toward others' faces. The lack of facial orienting is one of the most commonly reported characteristics of autistic children, which is manifested very early in their lives. The presence of "abnormal looking behavior toward others" is one of the diagnostic criteria of autism (American Psychiatric Association, 1994). Observational studies have also reported that from an early stage in their development, children with autism look less at other people's faces. Analyses of home videos of first birthday parties have revealed that infants later diagnosed with autism looked at others less frequently than either infants later diagnosed with general learning difficulties (Osterling, Dawson, & Munson, 2002) or typically developing infants (Osterling & Dawson, 1994; Osterling et al., 2002). Twenty-month-old infants with autism spent less time looking at people's faces and looked more briefly at them than did children with developmental delays or typically developing children (Swettenham et al., 1998). Other retrospective studies such as home video analyses (Mars, Mauk, & Dowrick, 1998) and parental reports (Wimpory, Hobson, Williams, & Nash, 2000) also found that young children with autism looked less at others' faces than did children without autism. However, there are other studies that did not find a reduction in facial orienting in infants or young children with autism (Dawson, Hill, Spencer, Galpert, & Watson, 1990; Joseph & Tager-Flusberg, 1997; Maestro et al., 2005; Sigman, Mundy, Sherman, & Ungerer, 1986; Werner, Dawson, Osterling, & Dinno, 2000). Thus it is unclear whether children with autism fixate less on others' faces.

In addition to these behavioral observations, other studies used eye tracking techniques to examine the fixation behavior of individuals with autism. Some studies used naturalistic, social, and dynamic scenes and reported that compared to typically developed individuals, those with autism fixate less on faces (especially the eyes) and more on body parts and objects (Klin, Jones, Schultz, Volkmar, & Cohen, 2002; Speer, Cook, McMahon, &

Clark, 2007). On the other hand, van der Geest, Kemner, Camfferman, Verbaten, and van Engeland (2002) presented cartoon-like scenes and found that just as in the case of typically developing children, children with autism fixated more on human figures than on other objects. Speer et al. (2007) argue that the reduced fixation on the face, especially the eyes, is limited to the observation of social and dynamic scenes.

The current study adopted the change blindness paradigm (see Simons & Levin, 1997; Simons & Rensink, 2005; Yokosawa & Ohtani, 2003 for reviews) to further explore the mechanism underlying atypical facial orienting in children with ASD. The change blindness paradigm consists of the detection of a change in a part of the stimulus display, which comprises multiple objects. The changes are usually separated by a brief interval or interpolated by a series of gradually changing images. In general, observers are surprisingly poor at detecting changes between two images that are separated by a brief interval involving, for example, a flicker (Rensink, O'Regan, & Clark, 1997), mud splashes (O'Regan, Rensink, & Clark, 1999), or a camera cut in a short motion picture (Levin & Simons, 1997). Shore, Burack, Miller, Joseph and Enns (2006) demonstrated the presence of change blindness in school-age children and found that the efficiency to detect change develops through to the adulthood.

The change blindness paradigm might serve as an ideal tool for testing the mechanism underlying reduced orienting to face in children with autism, for the following reasons. Firstly, the change blindness paradigm is one of the best tools to assess attention. Simons and Rensink (2005) even claimed that '*change detection has also been used to measure the locus of attention, much as eye tracking can measure the locus of fixation*' (Simons & Rensink, 2005, p.17). Previous studies have established that attention is needed to detect change. For example, several studies have compared the detection of the changes that occurred in the object in the region of central interest (i.e. maximal interest of an image) and the detection of changes that occurred in the region of marginal interest, and reported that the detection time was shorter for changes in the region of central interest than for changes in the region of marginal interest (see Rensink, 2002; Simons, 2000 for reviews). Moreover, when verbal cues were presented at the beginning of each trial, observers could easily locate a cued target under flicker conditions, where the change that was presented in the background and was very hard to detect without verbal cues (Rensink et al., 1997). Similarly, Scholl (2000) reported that change detection performance could be improved when attention was drawn to the location of change by delayed onset or by the presentation of color singleton. Secondly, and possibly more importantly, change blindness paradigm can assess not only *what* or *where* observers are attending to, but also what *aspects* of it (Simons & Rensink, 2005), which can be difficult by observational or eye tracking techniques. Previously, a change blindness study was successfully conducted in adults with autism (Fletcher-Watson, Leekam, Turner, & Moxon, 2006), in which adults with autism showed faster change detection for the object of central interest than they did for objects of marginal interest.

Several studies have adopted the change blindness paradigm to test the degree of attention paid to other people's faces. For example, Ro, Russell, and Lavie (2001) used a change blindness paradigm which involved showing participants one face and five different objects (food, clothes, musical instruments, appliances, and plants). They found that changes to upright faces were detected more rapidly and accurately than changes to objects. They suggested that faces in competition for visual attention played a special role in this phenomenon. Although some argue that this advantage with regard to face detection might arise due to the "odd-one-out" effect, which occurs possibly because the participants categorize stimuli as either "face" or "non-face" (Palermo & Rhodes, 2003), other studies suggest that such a strategy for categorization cannot fully explain the advantage with regard to face detection. For example, Humphreys, Hodsoll, and Campbell (2005) presented photographs featuring four females, and found that changes in faces in regions of central interest were detected faster than changes in bodies of central interest, which in turn were detected faster than changes in the background. This study demonstrated that face superiority in the change blindness paradigm is based on the attentional bias toward the face, independent of the rapid categorization of the face as opposed to other object categories. However, there are no studies that use the change blindness paradigm in children with and without autism to examine the degree of attention paid to the face.

We conducted two experiments to test the cognitive mechanism underlying reduced facial orienting of children with ASD by adopting the change blindness paradigm. On the basis of observational and eye-tracking studies, it was reported that children with ASD looked less at other people's faces than did typically developing children. Experiment 1 tested whether or not the change blindness paradigm can replicate observational and eye-tracking studies in demonstrating that children with ASD do not detect changes in faces better than in non-facial objects while they view naturalistic scenes. Experiment 2 tested whether such reduced capacity for the detection of face change is based on the difficulty in recognizing face identity, or reduced baseline attention to the faces. In addition, we also investigated the age-related differences in task performance both in typically developing children and in children with ASD.

Experiment 1

We used a change blindness paradigm similar to that of Humphreys et al. (2005) to test whether children with autism lack attentional bias toward others' faces. The stimuli consisted of pairs of photographic images of naturalistic scenes, which included multiple faces and objects. The photographs in each pair were identical to each other, except that a "change" was introduced in one of them by replacing one of the heads or objects with a new image of the same category (Figure 1). Each pair was presented repeatedly in an alternate order, separated by a brief period during which the screen was blank. The participants were required to detect the change as soon as possible and press a key when they detected it. As in previous studies with typically developed adults (Humphreys et al., 2005; Ro et al., 2001), it was predicted that typically developing children would detect the change in heads faster than they would detect the change in objects. In addition, if children with ASD lack a bias to attend more to faces, they should not detect changes in heads better than changes in objects.

In addition to the changes introduced in the heads and objects, which were presented as being in the area of central interest, we presented changes in the backgrounds of the images. These changes were included to test whether children with ASD atypically allocate attention between the center and periphery of their interest. Fletcher-Watson et al. (2006) reported that adults with autism detected central interest changes faster than marginal interest changes as in the case of adults with typical development. Moreover, adults with ASD detected marginal interest changes even slower than did typically developed adults. Fletcher-Watson et al. (2006)'s findings may be inconsistent with the idea of "weak central coherence" or "attention to detail," that is, the idea that children with autism are better at processing local details (Shah & Frith, 1983; see Happé, 1999 for a review). We examined whether we could replicate Fletcher-Watson et al. (2006), who found superior change detection for elements in the center of interest in children with ASD.

Method

Participants. The participants consisted of 16 children with ASD (14 males and 2 females; 9;5–15;2 years old, average age: 12;8 years, SD: 2;0) and 16 typically developing children (14 males and 2 females; 8;4–15;2 years old, average age: 11;8 years, SD: 2;4). All children were students of, or had graduated from, a primary school for children both with and without autism. All the children with autism were diagnosed by at least one child psychiatrist when they entered the school. In addition, experienced clinical psychologists (YT, KY) confirmed the diagnosis based on parental interviews and clinical observation, according to the DSM-IV criteria (American Psychiatric Association, 1994). The Japanese version of Raven's Coloured Progressive Matrices (RCPM; Raven, 1956; Sugishita & Yamazaki, 1993) was administered to all the children as a measure of visuospatial intelligence (children with ASD—average score: 31.8, SD: 4.8; typically developing children—average score: 32.6, SD: 2.1). Written informed consent was obtained from all the children and their parents. The study was approved by the Research Ethics Committee of the University of Tokyo.

Apparatus. The experiment was conducted on an IBM ThinkPad T42 with a 14.1-inch TFT monitor, using SuperLab software. The participants were seated at a distance of approximately 60 cm from the monitor. The reaction time (RT) was obtained by keyboard responses.

Stimuli. Six colored photographs (13.5° × 18°) of natural scenes were used to create the stimuli. Each photograph included one or two person(s) and several objects. Five raters determined the areas of central interest (i.e. a maximal interest of an image) in the photographs. Areas of central interest were defined as areas that three or more observers mentioned as being areas of central interest, while areas of marginal interest were defined as those that were not mentioned by any of the raters. The areas of central interest always included one or two person(s) and several objects. The photographs were edited using Adobe Photoshop 7.0. For each image, a change was made in a head, an object, or a background. In the head change condition, a head was substituted with another head of the same gender. In the object and background change conditions, alterations included deletion, color change, or substitution of one of the objects in the photographs. The average size of the heads was 2.0° × 1.4°; that of the object, 1.8° × 1.6°; and that of the background, 1.8° × 1.6°. A gray image (13.5° × 18°) was presented between the stimulus photographs. As each naturalistic visual scene differs in many visual features such as colour, luminance, saliency of each person and/or object, it is difficult to control these potentially confounding factors between different naturalistic visual scenes. Thus, following Humphreys et al. (2005), we introduced three changes in the same images and presented each of them so that we could control for the potential confounding due to the difference between each visual scene.

Procedure. The participants were asked to detect the change in each photograph and press the space key as soon as possible. Each trial began with the presentation of a fixation cross at the center of the monitor for 2 s. Following the fixation cross, each pair of images was presented in a flicker paradigm that consisted of the original image, a blank screen, the "changed" image, and another blank screen. The images were presented for 900 ms and were immediately followed by a blank screen that was presented for 100 ms (Figure 1). This sequence was looped until the participants identified the difference between the photographs and pressed the space key. The participants were then required to report the difference, either through a verbal description or by pointing out the spot where the alteration was made. The sequence was also stopped if the participants did not respond for 30 seconds, and it was counted as a timeout error.

Design. Experiment 1 comprised 18 trials (six head change, six object change, and six background change trials). The trials were presented in random order. The experimental design consisted of one between-participants factor (group: children with ASD or typically developing children) and one within-participants factor (change: head, object, or background). The RT for the correct responses and error rates were analyzed.

Results

There was no significant difference in the RCPM scores ($t = -.67, p > .1$), indicating that the visuospatial intelligence of children with ASD and typically developing children do not differ. There was also no significant group difference in their chronological age ($t = -1.29$. $p > .1$).

Figure 2 presents the mean correct RT (i.e. RTs for correct responses) for each change condition across participants. The error rates for incorrect responses and timeouts are shown in Table 1.

Reaction time. Figure 2 shows the correct RTs for the head, object, and background change conditions for each group. There was a significant main effect of group (F (1, 30) = 4.25, $p < .05$, $\eta_p^2 = .12$). The main effect of change was also significant (F (2, 60) = 29.5, $p < .01$, $\eta_p^2 = .66$), because changes to heads were detected faster than changes to objects ($t = 2.69$, $p < .01$, $d = .75$), which were faster than changes to background ($t = 4.89$, $p < .01$, $d = 1.06$). The interaction between group and change was not significant (F (2, 60) = .66, $p > .1$). The interaction did not reach significance even when we excluded the background change condition and focused on the difference between face change and object change condition (F (1, 30) = 1.60, $p > .1$).

We also conducted exploratory analyses to compare the performance in head change and object change for each group, due to its theoretical importance. The simple effect analyses revealed that children with ASD took longer to detect head change than did typically developing children (F (1, 90) = 4.72, $p < .05$, $\eta_p^2 = .05$). By contrast, with regard to the detection of object and background changes, the two groups did not differ (object: F (1, 90) = .487, $p > .1$; background: F (1, 90) = 1.09, $p > .1$).

In addition, typically developing children detected head change faster than they detected object change ($t = 2.68$, $p < .01$, $d = 1.39$). However, this superior performance with regard to the detection of head change was not found in children with ASD ($t = 1.13$, $p > .1$).

Additional analysis was also conducted to compare face change trials including one person with face change trials including two persons, as two faces should compete for attention and affect the results. However, the difference was not significant (one person trial: 6.0s, two persons trial: 6.5s in children with ASD; one person trial: 3.7s, two persons trial: 4.4s in typically developing children; F (1, 30) = 1.70, $p > .1$).

Note that for both groups, participants' age did not correlate with any of the RTs for head, object or background change (all $r < -.36$, $p > .1$).

Error rate. The distribution of the error rates for incorrect responses and timeouts in this experiment made the use of parametric tests inappropriate. Therefore, nonparametric tests were used to examine these data. Bonferroni corrections were adopted for all the multiple comparisons.

In the head change condition, children with ASD made more incorrect responses than typically developing children (Mann-Whitney U test; $Z = -2.48$, $p < .05$). In contrast, the number of incorrect responses did not differ between groups in either object change ($Z = -1.79$, $p > .05$) or background change ($Z = -.1.15$, $p > .1$) conditions. The number of timeouts did not differ between groups in any conditions (all $Z < -1.76$, $p > .05$).

Typically developing children made more timeouts in background change condition than in head change ($Z = -3.44$, $p < .01$, Wilcoxon test) and in object change ($Z = -3.27$, $p < .01$, Wilcoxon test) conditions ($\chi^2 = 21.4$, $p < .01$, Friedman test). Incorrect responses, in contrast, did not differ between change conditions ($\chi^2 = 1.00$, $p > .1$). In children with ASD, neither incorrect responses nor timeouts differed between change conditions (all $\chi^2 < 5.12$, $p > .05$, Friedman test).

Discussion

In Experiment 1, typically developing children detected central interest changes (e.g., head and object changes) faster than marginal interest changes (e.g., background change). Moreover, they detected head change faster than object change, which suggests that the advantage with regard to the detecting of heads also exists in typically developing children. These results for typically developing children are consistent with those for typically developed adults (Humphreys et al., 2005; Ro et al., 2001).

Similar to typically developing children, children with ASD also detected central interest change faster than marginal interest change. The result replicated Fletcher-Watson et al. (2006) and suggested that children with ASD paid attention to the area of central interest in the photographs, just as in the case of typically developing children.

On the other hand, children with ASD were slower and made more errors in the detection of head change than typically developing children. This result is consistent with previous studies of behavioral observation, in that children with autism paid less attention to other people's faces (Hobson & Lee, 1998; Mars et al., 1998; Osterling & Dawson, 1994; Osterling et al., 2002; Swettenham et al., 1998). In addition, there was neither an advantage nor disadvantage of head detection over object detection in children with ASD, which is in contrast to the case of typically developing children. Since children with ASD showed preferential change detection for central interest change over marginal interest change, it is unlikely that the lack of face superiority is due to equally distributed attention in children with ASD, which could stem from their superior local processing. However, note that these negative results should be treated with caution, because we did not find significant interaction between the group and the category of the stimulus.

Surprisingly, unlike Shore et al. (2006), who reported that performance in the change detection task became faster and more accurate from 6 years of age to young adulthood, we did not find age-related differences in task performance. Although this negative result needs to be treated with caution due to the small sample size, it might be due to the task demands (i.e. open-ended verbal responses) was not optimal for children (Shore et al., 2006).

There are at least three possibilities as to why children with ASD fail to show superior detection of head changes. The first possibility is that it is due to the lack of attentional bias toward others' faces. The second possibility is that children with ASD do not encode individual faces as effectively as do typically developing children. Previous studies have reported that individuals with ASD have difficulty with face recognition (Klin et al., 1999) and their FFA is less efficient for face processing (Critchley et al., 2000; Hubl et al., 2003; Pierce et al., 2001; Piggot et al., 2004; Schultz et al., 2000; Wang et al., 2004). The third possibility is that the head changes introduced in this experiment were too complex to allow children with ASD to manifest their capacity for face advantage. In this experiment, detection of head change requires a subordinate distinction of homogenous class of visual object (i.e. face), whereas the detection of object change can be achieved by using more salient features (i.e. deletion or colour change).

In Experiment 2, we further examined whether the lack of superior head change detection would be replicated in children with ASD when they do not have to encode individual faces to pass the task, by introducing 'location change' condition. The location change condition included the displacement of a head or an object, which allow children to detect change without recognizing an individual face or object. It also controls for task complexity, which can also affect the performance of children with ASD.

Experiment 2

In Experiment 1, head detection by children with ASD was not better than object detection, which differs from typically developing children. Although these findings are consistent with the argument that individuals with ASD lack an attentional bias toward others' faces, it is also possible that the results of Experiment 1 are due to the difficulty that children with ASD find in encoding individuals' faces (e.g., Grelotti, Gauthier, & Schultz, 2002; Klin et al., 1999; Schultz, 2005). To control the effect of face encoding in children with ASD, the location change condition was introduced. In the location change condition, changes were introduced by spatially displacing a head or an object rather than replacing it. It enabled children to detect changes without encoding the identity of each face or object. If the results of Experiment 1 were due to the face encoding process, we predict that children with ASD will display a performance that is equivalent to that of typically developing children when they detect changes in the location of the heads. In contrast, if their lack of advantage with regard to head detection is due to the lack of attentional bias toward the faces, no advantage with regard to head detection should be replicated in location change conditions.

Methods

Participants. The participants were 16 children with ASD (14 males and 2 females; 7;7–15;1 years old, average age: 12;1 years, SD: 2;7) and 22 typically developing children (12 males and 10 females; 7;4–14;11 years old, average age: 11;2 years, SD: 2;5). As in Experiment 1, all children were students of, or had graduated from, a primary school for children both with and without autism. All the children with autism were diagnosed by at least one child psychiatrist when they entered the school. In addition, experienced clinical psychologists (YT, KY) confirmed the diagnosis based on parental interviews and clinical observation, according to the DSM-IV criteria (American Psychiatric Association, 1994). The picture completion subtest from the Japanese version of the Wechsler Intelligence Scale for Children (WISC–III; Wechsler, 1992; Japanese WISC–III Publication Committee, 1998) was administered to all the children as a measure of attention to visual detail, which is directly related to the current task (children with ASD—average score: 8.9, SD: 2.8; typically developing children—average score: 9.9, SD: 2.7). Written informed consent was obtained from all the children and their parents. The participants partially overlapped with those participated in Experiment 1 (4 children with ASD and 2 typically developing children participated in both experiments), and Experiment 2 was conducted one year after Experiment 1.

Stimuli. Four original colored displays (12° × 18°) were produced to create the changing stimuli. Each display included two heads (Matsumoto & Ekman, 1988) and six objects (two food items, two items of clothing, and two appliances) in a random spatial arrangement. The average size of the stimuli was 2.5° × 2°. There were two types of change conditions: location change and identity change. In the location change condition, one stimulus in the original display was displaced by 1° vertically or horizontally. In the identity change condition, one stimulus in the original display was replaced with another one within the same category (i.e., heads, vegetables, skirts, etc.). The numbered displays, in which each stimulus was numbered, were prepared to confirm the participants' answers.

Procedure. Similar to Experiment 1, the sequence was looped until the participants identified the difference between the displays and pressed the space key. The stimulus display was then replaced with another display which presented numbers in the same spatial location as that in which each object was presented. The participants were then asked to press the number key corresponding to the changed stimulus. An example of this sequence is shown in Figure 3. The sequence was stopped if the participants did not respond for 20 seconds, which was counted as a timeout error. The timeout was reduced from 30 seconds in Experiment 1 to 20 seconds in Experiment 2 based on pilot results with adult volunteers.

Design. Experiment 2 comprised 32 trials (location change: four heads, 12 objects; identity change: four heads, 12 objects). The trials were presented in random order. The experimental design consisted of one between-participants factor of group (children with

ASD or typically developing children) and two within-participants factors of change (location change or identity change) and of stimulus (head or object). The RT for the correct response and the error rates were analyzed.

Results

There was no significant difference in the scores on the picture completion subtest of the Japanese version of the WISC-III ($t = 1.11, p > .1$), indicating that the nonverbal intelligence of the two groups was not different. There was also no significant group difference in the chronological age ($t = –1.04. p > .1$).

Figure 4 shows the mean correct RT for each change condition across the participants. The error rates for incorrect responses and timeouts are shown in Table 2.

Reaction time. There was a significant main effect of group (F (1, 36) = 6.28, $p < .05$, $\eta_p^2 = .15$). This main effect of group suggests that children with ASD respond slower than do typically developing children. The group × stimulus interaction was significant (F (1, 36) = 7.63, $p < .01$, $\eta_p^2 = .17$). Simple effect analyses revealed that typically developing children detected head changes faster than did children with ASD (F (1, 72) = 12.14, $p < .001$, $\eta_p^2 = .14$). In contrast, the RTs did not differ between groups in the object detection condition (F (1, 72) = .97, $p > .1$). Moreover, typically developing children detected head changes significantly faster than object changes (F (1, 36) = 7.25, $p < .05$, $\eta_p^2 = .17$), but there was no significant effect of stimulus among children with ASD (F (1, 36) = 1.47, $p > .1$). No other main effects or interactions, including the main effect or the interactions with the type of change (i.e., location change or identity change), were significant (all $F < 2.67$, all $p > .1$).

In typically developing children, the RTs of the object change detection were faster with increased participant age in both the location and the identity change condition (location change: $r = -.63, p < .01$; identity change: $r = -.46, p < .05$). In contrast, participant age did not affect the speed of head change detection (both $r < -.39, p > .05$). In children with ASD, the RTs in the location change condition decreased with increased participant age in the head change condition ($r = -.52, p < .05$), but not in the object change condition ($r = -.42, p > .1$). In the identity change condition, the RTs of the object detection decreased with increased participant age ($r = -.57, p < .05$), but not in the head change condition ($r = -.41, p > .1$).

Error rate. The distribution of the error rates for incorrect responses and timeouts in this experiment made the use of parametric tests inappropriate. Therefore, nonparametric tests were used to examine these data.

In the location change condition, group difference was not significant in any type of errors (incorrect response or timeouts) or in any stimuli (head or object) (all $Z < -1.76$, $p > .05$, Mann-Whitney U test). In the identity change condition, children with ASD made more errors than typically developing children in object change condition (incorrect responses: $Z = -2.53, p < .05$, timeouts: $Z = -2.09, p < .05$), but not in head change condition (incorrect responses: $Z = -.229, p > .1$, timeouts: $Z = -.000, p > .1$).

In typically developing children, stimulus type did not affect incorrect responses or timeouts in any task (location change or identity change) (all $Z < -1.41$, $p > .1$, Wilcoxon Test). Children with ASD made more incorrect responses for object change than for head change in the identity change condition ($Z = -2.04$, $p < .05$), and made more timeouts for object change than for head change in the location change condition ($Z = -2.12, p < .05$).

Discussion

In Experiment 2, we replicated the lack of superior head change detection in children with ASD, even in the location change condition. In the location change condition, the participants did not have to encode face identity to detect the change. Thus the current results refute the idea that the results of Experiment 1 can be fully explained by the fact that children with ASD experience difficulty in face recognition. These results suggest that the lack of superior head change detection in children with ASD results from the lack of attentional bias toward the face.

As in Experiment 1, typically developing children detected head change faster than they detected object change in both identity change and location change conditions. This result suggests that superior head change detection in typically developing children does not depend on their better face recognition skill. Similarly, Ro et al. (2007) suggest that attentional bias toward the face does not require configural face processing. In their study, attentional capture by facial stimuli was present even when faces were presented upside down. Ro et al. (2007) argued that the mere perception of "faceness" is sufficient to elicit attentional bias toward faces.

In typically developing children, we replicated Shore et al. (2006) in that the latency for object change detection decreases as participants' age increases. However, we did not find the same age-related changes in head change detection, regardless of the type of the change introduced (i.e. identity change or location change). This may suggest that attention to faces is less affected by development during school years. In children with ASD, the results were more complex. In the identity change condition, object change detection was more affected by age than in the head change condition, as in typically developing children. In the location change condition, in contrast, it was head change detection which was more affected by age than object change detection. Although the small sample size made it difficult to interpret the data, these results might suggest that different aspects of faces develop at different rates during the development of children with ASD. Further studies will be beneficial to assess the development of the attention to faces in ASD in more detail.

In this experiment, the error rate results need to be treated with caution, mainly because of the potential problem in the procedure. In the current paradigm, children need to remember the exact spatial locations of the particular object and match them to the location of the numbers in the subsequent displays. Thus, it is possible that the task was more demanding for the spatial memory of the children, especially when the items were close to each other. Further studies will be required to examine the error rates with a less memory-demanding paradigm.

General Discussion

The current results demonstrate that children with ASD lack an attentional bias toward others' heads. In both experiments, typically developing children were faster to detect changes that occurred in a head than in a non-face object, which replicated the findings of previous studies (Humphreys et al., 2005; Ro et al., 2001). On the other hand, children with ASD did not show such a bias, and were equally good at detecting a change in an object and in a head. It cannot be attributed to other general impairments such as difficulty in disengagement, or to their assets such as superior local processing or better attention to detail, for the following reasons. First, although children with ASD were slower to detect head changes than typically developing children, their performance did not differ from that of typically developing children when they detected a change in an object. Second, in Experiment 1, children with ASD were better and faster at detecting changes in objects of central interest than at detecting changes in objects of marginal interest, just as in the case of typically developing children. This suggests that children with ASD as well as typically developing children allocate attention to objects of central interest. In addition, it is unlikely that the current results are solely due to the difficulty in encoding individuals' faces in children with ASD: in the location change condition of Experiment 2, where participants could detect the change without encoding the identity of each face, children with ASD still lacked superior detection of head changes. These results are consistent with those of previous studies involving behavioral observations that report reduced orienting to face in children with ASD (Hobson & Lee, 1998; Mars et al., 1998; Osterling & Dawson, 1994; Osterling et al., 2002; Swettenham et al., 1998), and suggest that children with ASD lack an attentional bias toward others' faces.

Lack of attentional bias towards faces could contribute to the atypical development of cortical expertise for processing facial information. It reduces exposure to the face as well as to opportunities for face-to-face communication, which would result in impeding the developmental specialization of the cortical areas for the processing of social stimuli (Johnson et al., 2005). In addition, reduced attention toward the faces would not only interfere with the development but also the functioning of the social brain. Previous studies have revealed that attention to faces modulates the activation of the FFA when typically developing individuals observe facial stimuli (Bird, Catmur, Silani, Frith, & Frith, 2006; Vuilleumier, Armony, Driver, & Dolan, 2001; Wojciulik, Kanwisher, & Driver, 1998). Even in individuals with ASD, some evidence suggests that attention to faces can modulate their cortical responses to others' faces. For example, Hadjikhani et al. (2004) and Hadjikhani, Joseph, Snyder, & Tager-Flusberg (2007) reported that the FFA of individuals with ASD is activated when they are instructed to fixate on the center of facial stimuli, by the addition of a fixation point on top of the facial stimuli. Similarly, Dalton et al. (2005) reported that in individuals with ASD, the amount of fixation on the eyes of the facial stimuli correlates to the activation of the FFA as well as the amygdala. These studies suggested that the atypical fixation pattern on the face exhibited by individuals with ASD has a strong relation to their atypical cortical processing of others' faces. Thus, the lack of attentional bias toward others' faces, as demonstrated in the current study, can have a profound effect on both the development and the functioning of the social brain network in individuals with ASD.

Since the current studies do not have any neurophysiological measurements, it is very difficult to discuss the neural substrates responsible for the lack of attentional bias toward others' faces in individuals with ASD. However, it is possible that atypical amygdala functioning in individuals with ASD relates to atypical facial orienting. Lesions in the amygdala are known to cause atypical fixation on the face, especially reduced fixation on others' eyes (Adolphs et al., 2005; Spezio, Huang, Castelli, & Adolphs, 2007). Johnson (2005) hypothesized that the amygdala, along with other subcortical structures such as the pulvinar and superior colliculus, control facial orienting from an early stage in human ontogeny. In addition, atypical structure (Aylward et al., 1999; Kemper & Bauman, 1998; Sparks et al., 2002), development (Howard et al., 2000; Schumann et al., 2004), and functions (Baron-Cohen et al., 1999; Critchley et al., 2000; Dalton et al., 2005; Pierce et al., 2001) of the amygdala are reported in individuals with ASD. As mentioned above, Dalton et al. (2005) even found that individual differences in face and eye fixation correlate to the level of amygdala activation in individuals with ASD. It is also possible that atypical amygdala development may have affected orienting to the eyes (Adolphs et al., 2005; Spezio et al., 2007) or impaired them to attach the emotional salience to others' faces (Dawson et al., 2005), which then interfered with the typical development of superior face detection. Further neuroimaging studies will be beneficial to examine the function of the amygdala as well as other cortical and subcortical structures in the atypical facial attention in individuals with ASD.

Interestingly, in typically developing children, face change detection was less affected by the age than object change detection. Moreover, we could not replicate such differences in age-related changes between head detection and object detection in children with ASD. Although the small sample size has made it difficult to interpret these data, it may suggest that attention to faces and attention to objects may develop at different rates within the age range tested in the current study, which is also atypical in children with ASD. Further studies will be beneficial with larger population to establish the typical and atypical developmental pathway of the attention to faces and objects, both in typically developing children and children with ASD. Moreover, one of the major limitations of the current study is that we only tested children older than 7 years, which makes it difficult to discuss the early development of facial orienting in individuals with ASD. In retrospective studies, atypical facial orienting in individuals with ASD is reported from their first year of life (Osterling & Dawson, 1994; Osterling et al., 2002; Swettenham et al., 1998). Thus, to fully understand its typical and atypical developmental pathway, it will be necessary to examine the attention toward others' faces in younger children, or ideally infants, with ASD.

In addition, although it is unlikely, it is still possible that the small number of trials used in the current study may have weakened sensitivity of the current study and failed to find a subtle capacity for face detection in children with ASD. Further studies, ideally with adult participants who can tolerate longer experimental sessions than children, would be beneficial to examine facial attention in ASD with more rigorous measurements.

To summarize, this study examined whether children with and without ASD attend to faces more rapidly than they do to objects. The results for typically developing children replicated previous findings for adults (Humphreys et al., 2005; Ro et al., 2001) and demonstrated that faces are detected faster than objects. Children with ASD, in contrast, did not show such a bias and were able to detect faces and objects equally quickly. These results suggest that children with ASD lack an attentional bias toward others' faces, which might hamper the typical development of face expertise.

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Author Note

We would like to acknowledge all the children, their parents, and the teachers of Musashino Higashi Gakuen. I thank Yura Kunihira and Hironori Akechi and the other staff for their assistance in data collection and all the members of Hasegawa Lab for their support and the helpful discussions. We also thank all the models of the photographs in Experiment 1. This study was supported by the Japan Society for the Promotion of Science (JSPS), 21st Century COE Program J05, “Center for Evolutionary Cognitive Sciences at the University of Tokyo,” and JSPS KAKENHI (16330192). AS was also supported by the ESRC Research Fellowship (RES-063-27-0207).

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Table 1

Mean rates and standard errors (M±SE) of incorrect responses and timeouts (%) in Experiment 1

	Type of change		
	head	object	background
Children with ASD			
incorrect responses	12.5±4.2	6.25±3.4	9.38±5.0
timeouts	4.17±1.9	8.33±2.6	20.8±5.8
Typically Developing Children			
incorrect responses	1.04±1.0	-	1.04±1.0
timeouts	2.08±2.1	11.5±3.3	33.3±3.7

Table 2

Mean rates and standard errors (M±SE) of incorrect responses and timeouts (%) in Experiment 2

	Type of change			
	Location Change		Identity Change	
	head	object	head	object
Children with ASD				
incorrect responses	3.13±2.1	4.69±1.5	1.56±1.6	9.38±2.9
timeouts	-	3.13±1.3	-	2.08±1.2
Typically Developing Children				
incorrect responses	1.14±1.1	3.03±1.4	1.14±1.1	1.89±.94
timeouts	-	.76±.52	-	-

Figure Captions

Figure 1. An example of the sequence in Experiment 1. This figure depicts the head change condition. The head of the person to the left was replaced by another head.

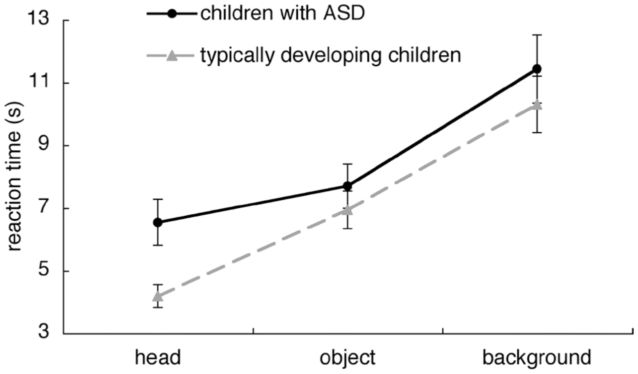

Figure 2. Mean correct RT with standard errors in Experiment 1. The straight black line and broken gray line represent the RTs of children with ASD and those of typically developing children, respectively.

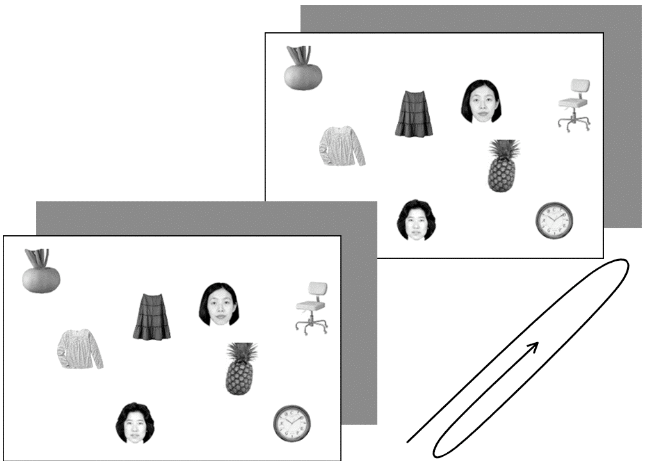

Figure 3. An example of the sequence in Experiment 2. This figure depicts the location change condition. The head at the bottom was presented as moving to the left and right.

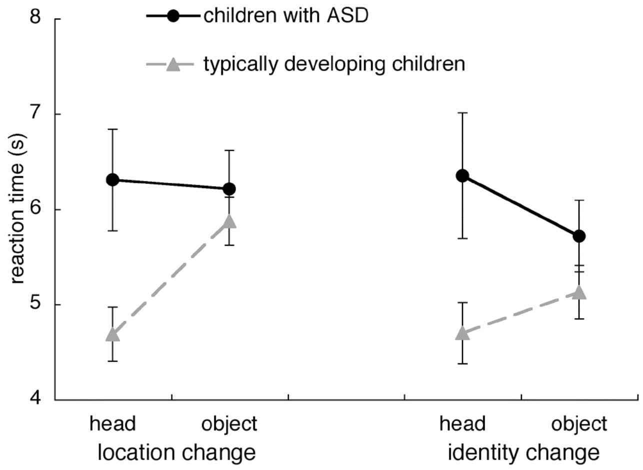

Figure 4. Mean correct RT with standard errors in Experiment 2. The straight black line and broken gray line represent the RTs of children with ASD and those of typically developing children, respectively.