Local Processing Bias in Attention and Enhanced Local Processing in Perception in Children With Autism Spectrum Disorder

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This study examines whether local processing in children with autism spectrum disorder (ASD) is related to both attention and perception. Thirteen children with ASD and 20 normative controls completed a selective attention task involving Navon stimuli, in the active attention task and a priming task involving facial stimuli with spatial frequency (SF) filtering as primes in the unconscious perception task. In the selective attention task, children with ASD showed slower responses to both global and local conditions, and fewer correct responses for the global condition than the controls. Results suggest that children with ASD exhibit biased processing towards local information. In the priming task, controls responded faster and more accurate in the low-SF primed stimuli condition compared to the high-SF one, but children with ASD did not show response differences between low- and high-SF conditions. Thus, children with ASD exhibit enhanced local processing in perception. As regards to both attention and perception, children with ASD showed local processing advantage compared with controls.

Key Words: autism spectrum disorder, global processing, local processing, attention, perception

Introduction

During visual information processing, it has been said that humans first attend to the whole of the object (Kimchi, 1992). Therefore, individuals respond more slowly to the small letters that make up a large letter as hierarchical stimulus, due to the interference of the large letter (Navon, 1977). However, autism spectrum disorder (ASD) has been found to be associated with a weaker global but stronger local processing advantage, compared to individuals with typical development (Frith, 1989; Happé, 1994; Mottron & Belleville, 1993). For example, in the block design task and the Embedded Figures Test, individuals with, compared to those without, ASD have been found to respond faster, indicating an advantage in processing local details rather than global elements (Jolliffe & Baron-Cohen, 1997; Shah & Frith, 1983, 1993).

The mechanism of the local processing advantage in individuals with ASD has been explained using two theories. One theory is weak central coherence, which predicts that improved local processing is associated with weak global processing in individuals with ASD (Happé & Frith, 2006). The other theory is enhanced perceptual functioning, which predicts that the advantage in local processing in people with ASD is a result of enhanced local processing, rather than weak global processing, compared to individuals with typical development (Mottron, Dawson, Soulières, Hubert, & Burack, 2006).

Navon stimuli that comprise a large letter made up of small letters have been used to test the potential of local processing bias among individuals with ASD. Results indicated that individuals with ASD can engage in global processing and attend to global elements when instructed to do so, but tend to use local processing in the absence of instructions. For example, Plaisted, Swettenham, and Rees (1999) used Navon stimuli in a divided attention task that required children with and without ASD to attend to both a large letter and small letters, and a selective attention task that required children with and without ASD to attend to either large letter or small let-

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Children with ASD showed slower responses to the large letter in the divided attention task, indicating an interference effect of the small letters. On the other hand, in the selective attention task, children with ASD who were instructed to pay attention to the large letter were as able as children without ASD were to attend to this without interference from small letters. Rinehart, Bradshaw, Moss, Brereton, and Tonge (2000) observed a similar interference effect for a number-based Navon stimulus task. Koldewyn, Jiang, Weigelt, and Kanwisher (2013) demonstrated that children with ASD showed a reduced preference to report global information of a stimulus when given a choice, although they are unimpaired to process global information when instructed to do so. Most recently, Guy, Mottron, Berthiaume, and Bertone (2016) found that effect of local-to-global interference emerges in childhood and persist throughout adolescence in individuals with ASD. Moreover, a meta-analysis of visuo-spatial skills showed that individuals with ASD show a small local advantage, and individuals with typical development show stronger global advantage in both the selective and divided attention task (Muth, Hönekopp, & Falter, 2014). Taken together, previous research results show that visual information processing in individuals with ASD do not have a deficit in global processing but, rather, show a tendency toward local processing compared to individuals with typical development. The essential mechanism behind the local processing advantage in individuals with ASD has been suggested to be due to a weak ability to broaden the spread of attention from the local level to the global level (Mann & Walker, 2003), or difficulty in switching attention from the local to the global level (Katagiri, Kasai, Kamio, & Murohashi, 2013).

Individuals with ASD may differ from those with typical development in terms of early-stage visual information processing. Prior research has suggested that individuals with ASD exhibit low scores for Gestalt perception (Brosnan, Scott, Fox, & Pye, 2004), which is negatively correlated with an advantage in local processing for hierarchical tasks, like Navon stimuli (Bölte, Holtmann, Poustka, Scheurich, & Schmidt, 2007). Happé (1996) found that individuals with ASD failed to succumb to most illusions, except Muller-Lyer illusions. In contrast, Ropar and Mitchell (1999, 2001) found that individuals with and without ASD were equally likely to succumb to illusions, and that individuals with ASD failed to succumb to Muller-Lyer illusions. Thus, additional research is needed to clarify how perception processing functions in individuals with ASD.

In the above studies, the global/local information stimuli were collocated, similar to the format of Navon stimuli. However, Navon stimuli are not appropriate for use in this context because one cannot discriminate global information by using only local information, as is the case for Gestalt stimuli. Therefore, face stimuli are suitable for the above investigation purposes. Individuals with ASD have been said to display weak face recognition compared to individuals with typical development (Deruelle, Rondan, Gepner, & Tardif, 2004; Jemel, Mottron, & Dawson, 2006; Sasson, 2006). Langdell (1978) found that individuals with ASD did not show the face inversion effect, that is, difficulty in discriminating inverted from upright faces (Yin, 1969), and proposed that this was due to a reliance on facial features without global processing. However, face inversion is an indirect way of manipulating the relative location of the facial features (Valentine, 1991); thus, spatial frequency (SF) filtering has been used as a more direct method of manipulating information that can be encoded from a face. High spatial frequency (HSF) involves extracting low-frequency content from an original image so that the contrast of facial features is highly salient. In contrast, low spatial frequency (LSF) involves extracting high-frequency content from an original image where facial features are unclear and the image become blurred. HSF relates to local processing and LSF to global processing in face perception because images are processed by analyzing spatial and frequency dimensions (Goffaux, Hault, Michel, Vuong, & Rossion, 2005; Shulman & Wilson, 1987).

During face perception in the context of SF, children with typical development preferentially discriminated a LSF face that was easily identifiable as a whole image, whereas children with ASD preferentially discriminated a HSF face (Deruelle et al., 2004). However, Deruelle, Rondan, Salle-Collemiche, Bastard-Rosset, and Da Fonséca (2008) asked participants to perform a facial identity matching task using a hybrid stimulus with superpositioning of HSF and LSF filtered stimuli, and indicated that while controls exhibited a LSF facial identity advantage, individuals with ASD revealed no SF bias. Further, individu-
als with ASD and controls discriminated face identity better in LSF than in HSF conditions. In fact, individuals with ASD may discriminate facial identity by means of global processing as did the controls in Deruelle et al. (2008). Deruelle et al. (2004) examined the factor of attention in the form of the local processing advantage in individuals with ASD, by using a matched task with SF filtering stimuli to assess face perception. Individuals with ASD may discriminate facial identity by means of global processing, as did the controls in Deruelle et al. (2008). Therefore, to investigate perception processing in individuals with ASD, there is a need to set tasks to measure unconscious processing that exclude the factor of attention.

The purpose of this study was to determine whether individuals with ASD exhibit the local processing advantage in relation to attention and/or perception. We developed a selective attention task with Navon stimuli, using numbers in the active attention task and a priming task with facial pictures in which SF filtering was the prime stimulus in the unconscious perception task. This yielded two hypotheses. First, if there is the local processing advantage in attention, then correct responses will be fewer for global processing and reaction times will be slower because Stroop interference occurs for both global and local processing in the selective attention task. Second, in contrast, if the local processing advantage is exhibited in relation to perception, but also occurs at a comparable level with global processing, there will be no difference in correct responses and reaction times between HSF and LSF filtered face primes in the priming task. However, if individuals with ASD exhibit the global processing advantage in line with the controls without local processing advantage in relation to perception, then correct responses will be increased and reaction times will be faster for LSF filtered face primes in the priming task.

Method

Participants

Thirteen individuals with ASD (M_{age}=9.6 years, SD=1.1, range=7.10–11.4; 11 male, 2 female) and 20 individuals without ASD (controls; M_{age}=9.6 years, SD=1.1, range=7.8–11.4; 11 male, 9 female) participated in this study. It was analyzed regardless of sex because both group did not significantly differ in sex (p>.10 for correct responses and reaction time in each task). All participants had normal or corrected-to-normal visual acuity. Participants in the ASD group, all of whom had received individualized instructions after their parents had had consultations with the authors, were recruited based on educational consultations with the university. The controls were recruited from local elementary schools and agreed to participate in the present study.

All participants in the ASD group had received a diagnosis of a pervasive developmental disorder (i.e., autism or Asperger's disorder) by experienced clinicians using standard criteria, according to the DSM-IV (American Psychiatric Association, 1994). Two members of the ASD group had received a diagnosis of attention deficit hyperactivity disorder. The intellectual function of the ASD group was assessed to confirm that their Full scale IQ or IQ scores were above 85, using the Japanese version of the Wechsler Intelligence Scale for Children, third edition (WISC-III) or the Tanaka–Binet Intelligence Test, fifth edition (M_{IQ}=107.9, SD=11.55, range=89–126). Although controls did not complete an intelligence test, their homeroom teacher reported that they had exhibited no learning difficulties in each primary school grade.

Informed consent was obtained from both parents and participants before testing began. The study was approved by the Ethics Committee of the Graduate School of Comprehensive Human Sciences, University of Tsukuba.

Apparatus and Stimuli

We generated a selective attention task with number-based Navon stimuli, and a facial perception priming task using SuperLab 4.0 software (Cedrus Corporation, US). These were displayed on a 12.1-in. notebook computer monitor (Panasonic, Let’s Note).

Selective attention task with Navon stimuli. The task, which was adopted from Rinehart et al. (2000), was to identify either the small (local condition) or large (global condition) number for the large number composed of small numbers. There were three stimulus configurations: congruent, neutral, and incongruent. Congruent and incongruent configurations were identical in local and global conditions. For the congruent configuration, the large number was the same as the small numbers (e.g., a large “1” made up of smaller “1”’s). For the incongruent configuration, the large number differed from the small numbers (e.g.,
a large “1” made up of smaller “2”s). For the neutral configuration, the large number was irrelevant to the local response condition (e.g., a large “3” or “4” made up of smaller “1”s) and the small number was irrelevant to the global response condition (e.g., a large “1” made up of smaller “3”s or “4”s). Participants sat 450 mm away from the computer monitor, so that the visual angle of the large number was 5.1° × 1.4°–3.1° and that of the small number was 0.2° × 0.1°–0.2°.

The large number that composed of smaller numbers (presented in black font) was presented at the center of a computer screen (white background) after a fixation point was presented for 1,500 ms (Fig. 1). Participants pressed a keyboard button as quickly and accurately as possible when small numbers were “1” or “2” for the local condition and the large number was “1” or “2” for the global condition. Each stimulus appeared on the screen until a response had been made. Participants performed six practice trials, followed by one block of the local condition and the global condition. There were 18 trials in one block, so that each of the configurations had six trials. Stimuli were presented in random order and the chance level was 50%. Reaction times from the onset of the target stimulus to button press, and errors, were recorded.

**Facial perception priming task.** Four different black-and-white facial pictures of Japanese celebrities (two males and two females) were used as primes (filtered SF processing; Deruelle et al., 2008) and targets (original facial pictures). All images were presented at a size of 250×250 pixels. The high-pass filtered faces only contained spatial frequencies above six cycles/degree of visual angle. The low-pass filtered faces only contained spatial frequencies below two cycles/degree of visual angle. Stimuli were created using Scion Image 1.62 software (Scion Corporation, USA). Primes and targets stimuli were presented with the same orientation (upright or inverted). The person of prime and target stimuli set comprised two conditions of congruent (same person) and incongruent (different person). Participants sat 670 mm away from the computer monitor; at this distance, the visual angle was 5.1° × 5.1°.

A fixation point was presented at the center of a computer screen on a white background for 1,500 ms, and then the prime was presented for 250 ms after a 100-ms blank interval. Following a second blank interval, the target was presented until a response had been made (Fig. 2). The stimulus onset asynchrony (SOA) set comprised two conditions of 300 ms and
700 ms. The participants pressed one of four keyboard buttons as quickly and accurately as possible to select the identity of the face, and performed 16 practice trials followed by two blocks (total=128 trials). There were 64 trials in one block so that each of the configurations had eight trials. Stimuli were shown in random order and the chance level was 25%. When participants did not know the actors, they were instructed about their identity beforehand. Reaction times from the onset of the target stimuli to button press, and errors, were recorded.

**Procedure**

The selective attention task was completed before the priming task. The presentation order of local and global conditions was counterbalanced across participants in the selective attention task. Participants were tested individually in a quiet room in the university or in the elementary school classroom. Each complete task took approximately 40 min to administer and participants were given a break in between tasks.

**Statistical Analyses**

In the selective attention task, a mixed design analysis of variance (ANOVA) was conducted, with the between-subjects factor of groups (ASD, control) and the within-subject factor of configuration type (congruent, neutral, incongruent) in local and global conditions, respectively. In the priming task, a mixed design ANOVA was conducted, with the between-subjects factor of groups (ASD, control) and the within-subject factors of SOA (300 ms, 700 ms), orientation (upright, inverted), SF (HSF, LSF), and configuration type (congruent, incongruent).

Rates of correct response and reaction time (RT) served as dependent variables in the selective attention and priming tasks. In the ANOVA, rates of correct responses were converted to an angular transformation, and RTs were converted to a logarithmic transformation. Analyses were conducted using SPSS for Windows, Version 22.0.

**Results**

Means and standard deviations of reaction times (RTs) were calculated for each participant. Those greater than or equal to 3 SD above or below the mean RTs were considered outliers, whereas those under the 100-ms duration were only considered outliers. Outliers were excluded from the analyses (selective attention task: 0.59%; priming task: 1.70%); however, error responses were included.

**The Selective Attention Task with Navon Stimuli**

Analysis of correct responses for local (Fig. 3a) and global (Fig. 3b) conditions indicated that there were significant main effects of configuration type (local condition: $F(2, 62)=12.99$, $p<.001$; global condition: $F(2, 62)=7.34$, $p<.01$). Post hoc Bonferroni comparisons confirmed that significantly fewer correct responses were made for the incongruent stimuli compared to the congruent and neutral stimuli in both local (congruent–incongruent: $MSe=.07$, $p<.001$; neutral–incongruent: $MSe=.09$, $p<.01$) and global (congruent–incongruent: $MSe=.08$, $p<.01$; neutral-incongruent: $MSe=.08$, $p<.05$) conditions. Furthermore, analysis of correct responses for the global condition indicated that there was a significant main effect of group, with the ASD group making fewer correct responses than the control group did, $F(1, 31)=4.63$, $p<.05$, but no main effect of group for the local condition, $F(1, 31)=0.21$, $p=.654$. Furthermore, no interaction of configuration type and group for both conditions (local condition: $F(2, 62)=0.59$, $p=.555$; global condition: $F(2, 62)=0.15$, $p=.859$).

Analysis of RTs for the local condition (Fig. 4a) indicated that there were significant main effects of configuration type, $F(2, 62)=8.26$, $p<.01$, and group, $F(1, 31)=5.04$, $p<.05$, but no interaction of configuration type and group, $F(2, 62)=0.98$, $p=.380$. Post hoc Bonferroni comparisons confirmed that both groups were slower to respond to the neutral and incongruent stimuli compared to the congruent stimuli (congruent–neutral: $MSe=.01$, $p<.01$; congruent–incongruent: $MSe=.01$, $p<.01$) and that the ASD group was slower to respond than the control group across all conditions.

Analysis of RTs for the global condition (Fig. 4b) indicated that there were significant main effects of configuration type, $F(2, 62)=8.75$, $p<.001$, and significant interaction, $F(2, 62)=3.76$, $p<.05$. Analysis of simple main effects revealed that configuration type influenced RTs in the ASD group, $F(2, 30)=7.53$, $p<.01$. Post hoc Bonferroni comparisons confirmed that children with ASD were slower to respond to the neutral and incongruent stimuli compared to the congruent stimuli (congruent–neutral: $MSe=.02$,
One participant of the ASD group had poor accuracy (i.e., 59.58% correct responses) for LSF congruent stimuli in the facial perception priming task, and was excluded from analyses because of extremely low correct responses compared to the other participants. Therefore, the sample comprised 12 individuals with ASD ($M_{age}=9.8$ years, $SD=1.1$, range=7.10–11.4; 10 male, 2 female) and 20 individuals without ASD in the facial perception priming task.

Analysis of correct responses (Fig. 5) revealed significant interactions among group, orientation, SF, and configuration type, $F(1, 30)=10.20$, $p<.01$. Analysis of simple interaction effects about each group revealed no significant difference across conditions in the ASD group; however, in the control group, a significant simple interaction was observed among orientation, SF, and configuration type, $F(1, 19)=8.51$, $p<.01$. The SF of the congruent stimuli for upright faces influenced correct responses, $F(1, 19)=6.47$, $p<.05$. There were fewer correct responses for HSF than LSF congruent stimuli for upright faces. Analysis of simple-simple main effects revealed that the orientation of LSF congruent stimuli influenced correct responses, $F(1, 19)=4.95$, $p<.05$, with LSF congruent stimuli for inverted faces resulting in fewer correct responses than LSF congruent stimuli for upright faces.

In the control group, analysis of simple-simple main effects revealed that the LSF configuration type for upright faces influenced correct responses, $F(1, 19)=13.06$, $p<.01$, with LSF incongruent stimuli for upright faces resulting in fewer correct responses than congruent stimuli, but no
Local Processing Bias in Attention

significant differences in configuration type for LSF inverted faces. Moreover, there were no significant differences in configuration type for HSF stimuli, regardless of orientation. Additionally, analysis of simple main effects revealed that the group of LSF incongruent stimuli for upright faces influenced correct responses, $F(1, 30)=8.66, p<.01$, with the control group making fewer correct responses than the ASD group of LSF incongruent stimuli for upright faces. These results showed that the control group observed a face inversion effect. There were no other significant main effects (group:
For the selective attention task, the ASD group was slower to respond in both local and global conditions. These results show that there was interference from local information when responding to the large number and also interference from global information when responding to the small number, as was the case for the controls. Our results for the selective attention task with Navon stimuli are consistent with previous findings that individuals with ASD show interference from both local and global information when the direction of attention (global or local) is dictated beforehand (Plaisted et al., 1999; Rinehart et al., 2000). However, ASD group had fewer correct responses of all configuration type for the global condition than the control group. This finding is the result of focusing on local information and reflects the ASD individuals’s exhibition of bias towards processing local information in attention.

In the priming task, both ASD and control groups showed a priming effect. However, while the control group showed faster and more accurate responses in LSF conditions than in HSF, the ASD group did not show significant differences in LSF and HSF conditions in terms of correct responses and RTs. Thus, in terms of perception, individuals with ASD performed global and local processing equally well, whereas controls showed superior performance for global processing, and these results are consistent with the finding of Deruelle et al. (2008) that facial identity was discriminated by advantage of LSF. The results suggest that individuals with ASD performed local processing at a comparable level with global processing and exhibited the local processing advantage compared to individuals with typical development.
because the ASD group did not show differences between SF conditions. Therefore, individuals with ASD exhibit enhanced local processing in perception.

Taken together, the results of this study in relation to perception suggest that the local processing advantage may be explained by the enhanced perceptual functioning hypothesis (Mottron et al., 2006), as distinct from the deficit of global processing in visual information processing that results in enhanced local processing in individuals with ASD. The study of visual evoked potentials to use SF stimuli suggest that children with ASD show atypical processing of HSF rather than LSF (Boeschoten, Kenemans, van Engeland, & Kemner, 2007), enhanced neural activity to HSF information (Vlamings, Jonkman, van Daalen, van der Gaag, & Kemner, 2010), and supported the result of this study that the individuals with ASD exhibit the local processing advantage. By contrast, in relation to attention, they exhibited not enhanced local processing but a bias towards processing local information. It has been reported that individuals with ASD experience difficulty in switching attention from the local to the global level, as opposed to the reverse direction (Katagiri et al., 2013), indicating that they find it hard to inhibit local information (Plaisted et al., 1999). Therefore, the local processing advantage of individuals with ASD exhibit enhanced local processing in perception, and a bias towards processing local information because of difficulty to inhibit local information in attention.

In the priming task, although the control group made more correct responses and were faster to respond to upright, compared to inverted, faces for LSF conditions and showed the face inversion effect (Yin, 1969), the ASD group did not show such effect. Moreover, the ASD group was slower to respond than the control group. This indicates that individuals with and without ASD performed different processes to differentiate between faces, which is consistent with previous research findings (Langdell, 1978). Individuals with ASD were slower to respond regardless of the test conditions presented, suggesting that they are slower at facial recognition. Additionally, neural responses to faces of individuals with ASD appear to differ. Individuals with typical development under a year old show different event related potentials (ERPs) to different emotion expressions (Nelson & De Haan, 1996). However, individuals with ASD do not appear to have different ERPs responses between familiar and unfamiliar faces (Dawson, Carver, Meltzoff, Panagiotides, McPartland, & Webb, 2002), or between faces and objects (Webb, Dawson, Bernier, & Panagiotides, 2006). Moreover, Scherf, Luna, Minshew, and Behrmann (2010) found that individuals with ASD not only exhibited weak activation in the fusiform face area compared to controls but also activated face stimuli processing in the right fusiform gyrus, which activate to processing of objects in controls. The finding in this study that individuals with ASD performed global and local processing equally during face perception and that they did not display the face inversion effect, confirmed they process faces in the same way they do objects, and is supported by the neuroimaging study.

The use of face stimuli in the priming task may also be subject to potential motivation effects in facial recognition in the individuals with ASD, because neural activation to faces may be linked to emotion related motivation or familiarity (Pierce & Redcay, 2008). Individuals with typical development may show both an advantage in facial recognition and their motivation to recognize the celebrity faces used as stimuli in light of variance in motivation to visual processing in individuals with ASD (Behrmann, Thomas, & Humphreys, 2006; Dakin & Frith, 2005). Grelotti, Klin, Gauthier, Skudlarski, Cohen, Gore, Volkmar, and Schultz (2005) found an ASD subject activated amygdala and fusiform face area (FFA) when viewing highly favoured Digimon cartoon characters, but not when viewing typical familiar or unfamiliar face stimuli. Thus, use of naturalistic facial stimuli (respective parental faces) may have arguably removed some motivation or recognition bias between the groups. As the wider ASD literature concerning FFA activation and facial stimuli does show highly conflicting results and further evidence may be needed (Simmons, Robertson, Mckay, Toal, McAleer, & Pollick, 2009), a further option to remove some stimuli bias may involve naturalistic or meaningful objects respective to each individual, in light of evidence that motivation and attention may affect FFA activation in individuals with ASD.

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Local Processing Bias in Attention

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