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Face Recognition Deficits in Autism Spectrum Disorder are Present in both Central and Peripheral Vision

Les déficits de reconnaissance faciale dans le trouble du spectre de l'autisme sont présents à la fois dans la vision centrale et périphérique

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Abstract

This pilot study aimed to examine whether individuals with autism spectrum disorder (ASD) have face recognition deficits in either their central or peripheral vision or both of these. Ten individuals with ASD and 10 individuals with typical development (TD) were asked to observe a picture of a face with expression that was presented in either the central or peripheral visual field for 160 ms and then to distinguish whether the face was presenting a "happy" or "angry" expression, by pressing the corresponding one of the two labelled buttons. Using an eye tracker, each participant's vision was confirmed during each trial. Subsequently, upon the performance of the next task series, the stimuli were substituted with numerals (0–9) and their names (zero–nine). Results showed that, in the face recognition task, individuals with ASD demonstrated significantly longer reaction time to stimuli in both their central and peripheral vision compared to individuals with TD. In addition, individuals with ASD gave significantly fewer correct answers for stimuli in their peripheral vision. In the numeral recognition task, no difference was found between the two groups.

Résumé

Cette étude pilote visait à déterminer si les personnes ayant un trouble du spectre de l'autisme (TSA) ont des déficits de reconnaissance faciale dans leur vision centrale, périphérique ou autant centrale que périphérique. Dix personnes ayant un TSA et 10 personnes ayant un développement typique (DT) ont été invitées à observer l'image d'un visage avec une expression, présentée dans leur champ visuel central ou périphérique pendant 160 ms. Les participants devaient ensuite distinguer si le visage présentait une expression « joyeuse » ou « colérique » en appuyant sur l'un de deux boutons. La vision de chaque participant a été confirmée au cours de chaque essai au moyen d'un traqueur oculaire. Dans une série de tâches subséquente, les stimuli ont été remplacés par des chiffres (0-9) et leurs noms (zéro-neuf). Les résultats indiquent que dans la tâche de reconnaissance faciale, les personnes ayant un TSA démontrent un temps de réaction significativement plus long aux stimuli dans leur vision centrale et périphérique par rapport aux personnes ayant un DT. De plus, les personnes ayant un TSA ont donné significativement moins de réponses correctes pour les stimuli présentés de façon périphérique. Aucune différence n'a été trouvée entre les deux groupes dans la tâche de reconnaissance numérique.

Mots clés : trouble du spectre de l'autisme, reconnaissance faciale, vision centrale, vision périphérique

Introduction

Autism spectrum disorder (ASD) is a developmental disorder in which patients experience persistent deficits in social communication and interactions and demonstrate repetitive patterns of behavior, interests, and activities (American Psychiatric Association, 2013). With respect to deficits in social communication and interactions, many previous studies have reported facial recognition difficulties in individuals with ASD (Ashwin et al., 2005; Boraston et al., 2007; Dalton et al., 2005; Pelphrey et al., 2002; Riby et al., 2009; Tang et al., 2015). Many previous studies have also reported difficulties faced by individuals with ASD regarding various aspects of facial expression processing (Ashwin et al., 2006; Gross, 2008; Humphreys et al., 2007; Mazefsky & Oswald, 2007; Wright et al., 2008). Some of these previous studies have suggested specific difficulties with particular emotional expressions, such as fear (Pelphrey et al., 2002), sadness (Boraston et al., 2007), or negative expressions (Ashwin et al., 2006; Humphreys et al., 2007). It has commonly been reported that individuals with ASD are less sensitive to the eye-region of the face (Boraston et al., 2008; Dalton et al., 2005; Pelphrey et al., 2002) and selectively pay attention to the mouth region (Joseph & Tanaka, 2003). In the context of the eye-region displacement test, Rutherford et al. (2007a) divided participants with ASD into two sub-groups, and found that those who performed in a typical fashion fell into an average range of verbal intelligent quotient (VIQ), but those who experienced more difficulty with the eye-region task had a VIQ below average. On the contrary, the object processing abilities of individual with ASD are generally reported to be equivalent to those of individuals with TD (Boucher & Lewis, 1992; Celani et al., 1999; Dawson et al., 2002).

In terms of the field of view, Plaisted et al. (1999) used the Navon task (Navon, 1977) and found no global advantage in individuals with ASD in the divided attention task, but the same performance as controls in the selective attention task. Rondan & Deruelle (2007) used another variation of the Navon type task to examine configurational versus local matches in schematic face and non-face stimuli. Individuals with ASD, who had shown equivalent performance to the controls in the original Navon task, favoured the local shape match over the configuration match far more than the controls. Following on from this, Rondan & Deruelle (2007) suggested that configurational processing, rather than global processing, is impaired in ASD. Rutherford et al. (2007b) assessed the attention span of individuals with ASD using the "Useful Field of View (UFOV)". The UFOV comprises a central letter-identification task (focused-central) and a peripheral task (focused-peripheral). The performance of individuals with ASD in the peripheral task was not very affected by the simultaneous presence of the central task; however, the control group was significantly affected.

As described above, individuals with ASD are generally considered to have difficulties in the recognition of faces and facial expressions despite having little difficulty with recognizing objects. On the other hand, in terms of field of view in ASD, several different research findings have been presented. These included a disadvantage in global view, a disadvantage in configurational view, and an advantage in peripheral view. If individuals with ASD have effective visual processing of objects in their peripheral vision, the question remains whether they do as well with facial stimuli. In fact, it remains uncertain whether individuals with ASD have difficulty with face recognition in both their central and peripheral vision or in only one of these.

The present paper is a pilot study that aimed to elucidate the ability of individuals with ASD to recognize others' faces and numerals in both their central and peripheral vision, based on their number of correct answers and reaction time.

Methods

Participants

Ten adults with ASD (six males and four females; 19–22 years old) who visited the university laboratory for periodic consultations participated in this study. In addition, 10 adult students with TD (six males and four females; 18–21 years old) were recruited from the university via a public advertisement using leaflets. Of the 10 adults with ASD, three were diagnosed with Asperger's syndrome, two with autism, two with pervasive developmental disorder, two with ASD, and one with high-functioning autism; these diagnoses were made by psychiatrists with expertise in developmental disorders according to the Diagnostic and Statistical Manual of Mental Disorders (DSM)-IV Text Revision (American Psychiatric Association, 2000) or DSM-5 (American Psychiatric Association, 2013). To confirm their clinical manifestations, the parents of all participants with ASD were asked to complete the Japanese version of the Social Communication Questionnaire (SCQ) (Rutter et al., 2013; mean, *M*: 23.0; standard deviation, *SD:* 5.5; range: 15–32; cutoff value: 15). To confirm that all participants with ASD had sufficient verbal comprehension ability, thus ruling out any external effects on their task performance, the Japanese version of the Picture Vocabulary Test-Revised (PVT-R) (Ueno et al., 2008) was administered. All participants with ASD exhibited a Picture Vocabulary Age (PVA) of > 12 years and 3 months, which is the maximum age measured by PVT-R. Further, to confirm that the intelligence of all participants with ASD was in the normal range, the Japanese version of the Kohs block design test (Owaki,1959) was administered. The results of the Kohs test revealed that the mean IQ was 117 (*SD*: 9.6; range: 102–124). All participants had normal or corrected-to-normal vision.

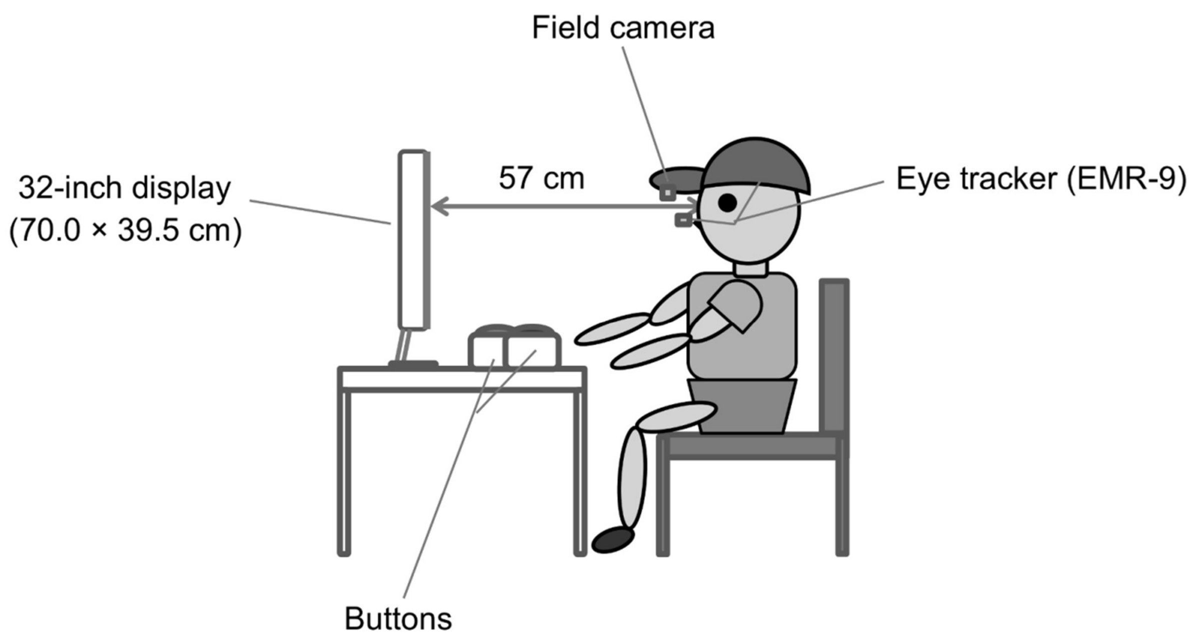
Apparatus

To ascertain whether the participants used their central or peripheral vision when presented with stimuli, participants' eye movements were recorded using an eye tracker (EMR-9; nac Image Technology, Inc., Tokyo, Japan) with a sampling frequency of 60 Hz, detecting infrared reflections from the cornea. The EMR-9 comprised an eye camera head unit, which was attached to the head of each participant, and a controller (Figure 1). A pupil camera and a field camera were installed in the eye camera head unit. Using the controller, the visual axis marker from the pupil camera was superimposed on a picture from the field camera. The head unit field camera had a 92° angle-of-view, which produced a wide image without skewness.

Each participant put on the eye camera head unit and was seated in front of a 32-inch display at a viewing distance of 57 cm (this viewing distance was in accordance with Rutherford et al., 2007b). The display was connected to the static image presentation system (Multi Trigger System MTSO400V Ver2.40; Medical Try System, Inc., Tokyo, Japan). Two buttons, connected to the presentation system, were placed on the table in front of the participants to allow them to perform the experimental tasks described below.

Figure 1

Schema of the Experimental Apparatus



Note: The eye tracker system (EMR-9) with the 32-inch display was connected to the static image presentation system (Multi Trigger System) as shown.

Experimental Condition

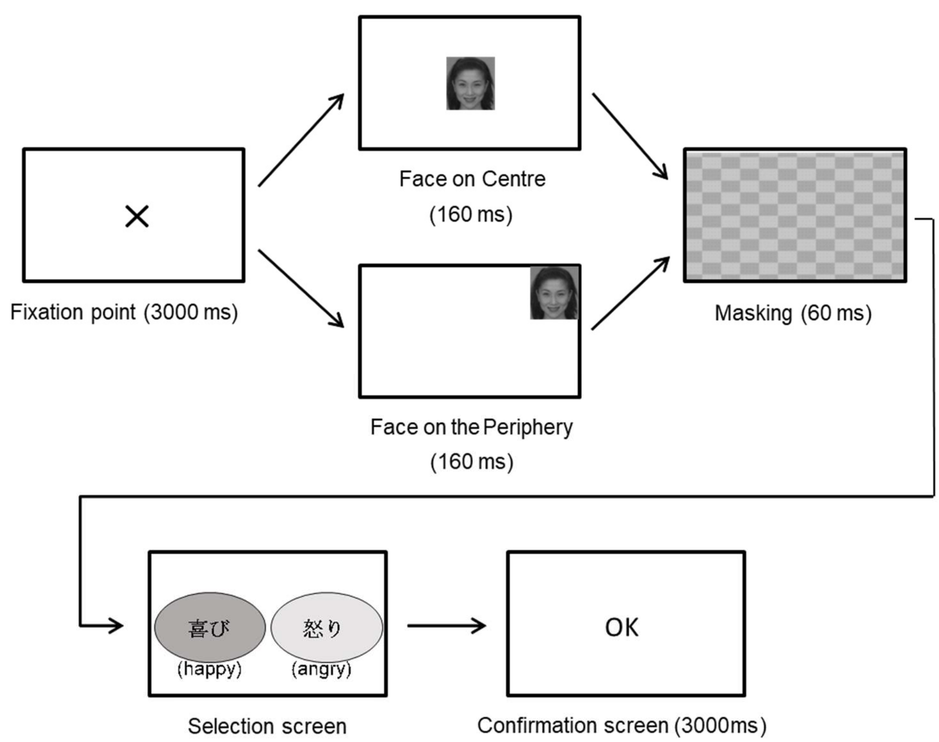
A fixation point (×) appeared on the centre of the screen for 3000 ms. When this point disappeared, a stimulus was presented on the screen for 160 ms at the position of the fixation point (central vision condition) or in the peripheral visual field. That is, a stimulus was placed outside the retinal eccentricity of 18 degrees (according to Gupta et al., 2010) on one of the eight radial positions selected at random (peripheral vision condition).

Experimental Tasks and Procedures

The stimuli shown to the participants after the disappearance of the fixation point (×) comprised faces of five different models with happy or angry expressions taken from the ATR face database (ATR-promotions, Inc., Kyoto, Japan). The stimuli were 9 degrees high and 7 degrees wide (an eye was approximately 0.5 degrees high and 1.2 degrees wide, and a mouth was approximately 0.6 degrees high and 1.7 degrees wide) at a visual angle viewed at 57 cm from the display, and they were presented in random order. The participants were asked to distinguish between "happy" and "angry" by pressing one of two buttons (labelled accordingly) just after the stimulus disappeared. Afterwards, "OK" was displayed on the screen for confirmation. Each participant performed 10 tasks in the central vision condition, followed by 10 more tasks in the peripheral vision condition (Figure 2).

Figure 2

The Procedure of Presenting the Facial Expression Recognition Task in the Central and Peripheral Visual Fields



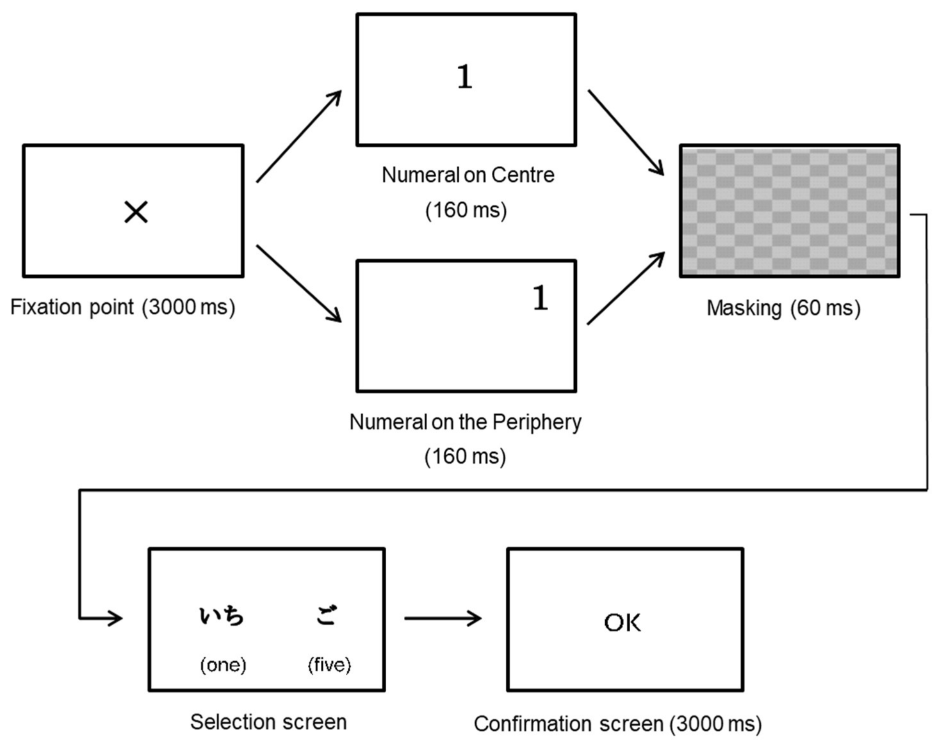
Note: The facial image in this figure is an ATR facial expression database. Permission to publish was provided by ATR-Promotions Corpus Division, Japan.

Using the visual axis markers of the eye tracker EMR-9, it was confirmed that participants continued to focus on the fixation point and did not take their eyes off it during the 160 ms in which a stimulus was presented during each task. Additionally, even in the peripheral vision condition, the visual axis markers did not move to any stimulus presented during the 160 ms.

The participants then performed the remaining tasks in the same manner but with numerical stimuli (0–9). These numerical stimuli were presented in the same size as the facial stimuli. During presentation of this set of stimuli, two sets of Japanese letters (*hiragana*), which showed the participants how to read the numerals, were presented on the selection screen (Figure 3).

Figure 3

The Procedure of Presenting the Numeral Recognition Task in the Central and Peripheral Visual Fields



Analysis

BellCurve for Excel 3.20 (Social Survey Research Information Co., Ltd., Tokyo, Japan) was used to perform statistical analyses. First, the number of correct answers made by the participants in each task series was calculated using the Steel-Dwass test for multiple comparisons. Next, the participants' button-pressing reaction time while selecting an answer was measured, and the median reaction time of each series of 10 tasks for each participant in each combination of factors was analyzed using three-way ANOVA as follows: Group (ASD, TD) × Stimulus condition (Face, Numeral) × Vision condition (Central, Peripheral). Thereafter, multiple comparisons using Bonferroni correction were carried out.

Ethical Approval

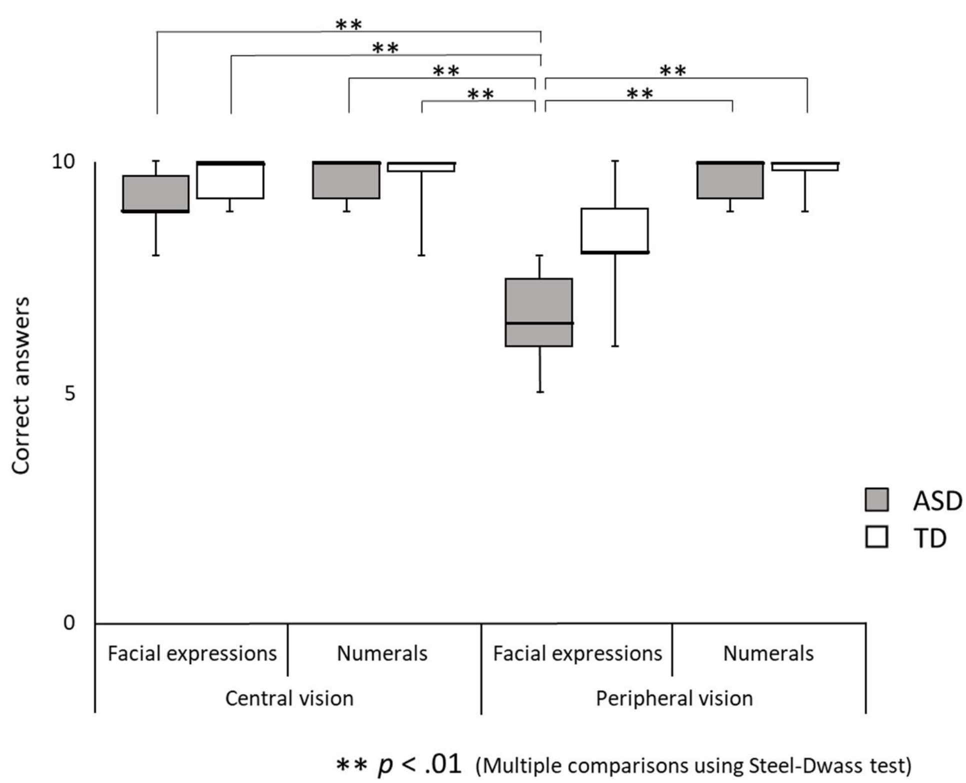
This study was conducted with the approval of the Ethics Committee of Yamagata Prefectural University of Health Sciences to which authors were affiliated, in accordance with the principles of the Declaration of Helsinki as revised in 2000. All participants expressed their willingness to participate in the study. Written informed consent was obtained from all participants as well as from the guardians of the participants with ASD.

Results

The median number of correct answers is shown in Figure 4. The mean reaction time for facial stimuli and numerals for the central and peripheral vision of participants with ASD and with TD is shown in Figure 5.

Figure 4

Median (Quartile, Range) Number of Correct Answers for Facial Expressions and Numerals in the Central and Peripheral Vision in Each Group



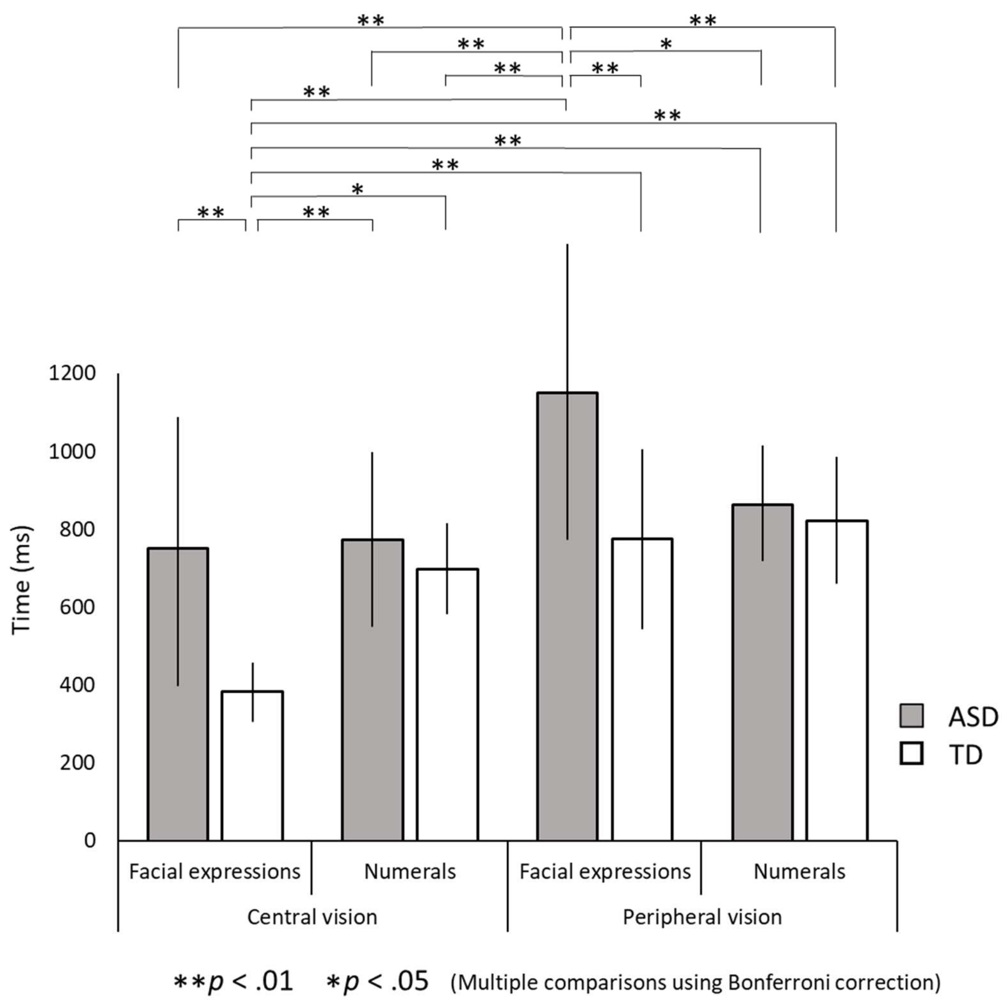
1. Correct Answers

The median numbers and ranges of correct answers in each combination of factors were as follows: 9 (8–10) in ASD-central-facial; 10 (9–10) in ASD-central-numeral; 6.5 (5–8) in ASD-peripheral-facial; 10 (9–10) in ASD-peripheral-numeral; 10 (9–10) in TD-central-facial; 10 (8–10) in TD-central-numeral; 8 (6–10) in TD-peripheral-facial; and 10 (9–10) in TD-peripheral-numeral.

The Steel-Dwass test for multiple comparisons revealed that the number of correct answers in the ASD-peripheral-facial combination was significantly smaller compared with the six other combinations of factors (t = 3.75–3.93, p < .01).

Figure 5

Mean (±SD) Reaction Time for Facial Expressions and Numerals in the Central and Peripheral Vision in Each Group



2. Reaction Time

The mean reaction time and standard deviation in each combination of factors was as follows: 752 (354) ms in ASD-central-facial; 772 (224) ms in ASD-central-numeral; 1150 (379) ms in ASD-peripheral-facial; 862 (149) ms in ASD-peripheral-numeral; 383 (77) ms in TD-central-facial; 697 (108) ms in TD-central-numeral; 775 (228) ms in TD-peripheral-facial; and 822 (161) in TD-peripheral-numeral.

The results of three-way ANOVA revealed significant main effects of the Group condition (F (1, 18) = 6.28, $p < .05$, $\eta^2 = .13$)) and Vision condition (F (1, 18) = 48.55, $p < .01$, $\eta^2 = .18$)), as well as significant interactions between the Group and Stimulus condition (F (1, 18) = 14.72, $p < .01$, $\eta^2 = .19$)), and between the Vision and Stimulus condition (F (1, 18) = 33.10, $p < .01$, $\eta^2 = .16$)).

Regarding these interactions, the simple effect of Group was significant in facial stimuli (F (1, 26) = 15.34, $p < .01$, $\eta^2 = .19$)), but not in numerical stimuli. In other words, there was a difference in reaction time between the ASD group and the TD group with only facial stimuli. Also, the simple effect of Vision condition was significant in both facial stimuli (F (1,32) = 81.07, $p < .01$, $\eta^2 = .22$)) and numerical stimuli (F (1,32) = 6.01, $p < .05$, $\eta^2 = .02$)). In other words, there were differences in reaction time between central vision and peripheral vision in both facial stimuli and numerical stimuli.

Multiple comparisons using Bonferroni correction were carried out for the interactions and the simple effects described above. This test revealed that the mean reaction time in the TD-central-facial combination was significantly shorter than in the other combinations of factors (t = 3.72–9.09, p < .01–.05). On the other hand, the mean reaction time in the ASD-peripheral-facial combination was significantly longer than in the other combinations of factors (t = 3.41–9.09, p < .01–.05).

Discussion

The results revealed that individuals with TD had an advantage in the face recognition task using central vision compared to those with ASD, as demonstrated by their reaction time. However, there was no difference in reaction time between individuals with ASD and with TD in the numeral recognition task using central vision.

These findings partly support previous studies that reported facial recognition difficulties in individuals with ASD (e.g., Pelphrey et al., 2002 ; Ashwin et al., 2005) as well as studies that reported the object processing abilities of individuals with ASD to be equivalent to those of individuals with TD (e.g., Celani et al., 1999; Dawson et al., 2002). However, these studies did not necessarily consider the vision field.

In addition, the results revealed that individuals with ASD had a serious disadvantage in the face recognition task using peripheral vision, as demonstrated by the small number of correct answers and long reaction time in this group. However, no difference was found in the number of correct answers and the reaction time in the numeral recognition task using peripheral vision between individuals with ASD and TD. Previous studies have reported the performance of individuals with ASD in the peripheral letter-identification task to be better than that of individuals with TD (Rutherford et al., 2007b). The results of our study did not corroborate these findings, but they were able to demonstrate that the letter recognition of individuals with ASD using peripheral vision was not worse than that of individuals with TD. However, the results of this study suggest that individuals with ASD have difficulty in face recognition using peripheral vision; of note, there are few studies of face recognition using peripheral vision.

In summary, individuals with ASD have a disadvantage in facial recognition compared to individuals with TD when using either central or peripheral vision. The reason for these findings can be linked to the following neurological findings. It has previously been reported that there is a rapid, non-conscious, automatic process of face perception prior to a conscious process for discriminating between emotional facial expressions (Palermo & Rhodes, 2007). It is believed that the amygdala is involved in this automatic process (Adolphs et al., 1998; Breiter et al., 1996; Carr et al., 2003; Whalen et al., 1998). Also, it has been revealed that the left amygdala and left cerebellar region do not get activated in individuals with ASD when implicitly processing emotional facial expressions (Critchley et al., 2000). However, other reasons may also exist, including spatial frequency (Kéïta et al., 2014) of facial stimuli or facial structure perception (Rutherford et al., 2007a), among others. Further research should be conducted in these areas.

Implications

In daily life, it is necessary to capture people's faces quickly and accurately, as facial expressions are used to determine the feasibility of positive relationships with people (Fujita, 2007). Further, facial expressions are used as cues to indicate the location where a target will appear and may facilitate the detection and orientation of attention to others' faces (Fox et al., 2000; Langton et al., 2008; Vuilleumier & Schwartz, 2001).

When we assess daily social situations, we may not only examine another person's face in the central vision, but also grasp other individuals' faces using peripheral vision. This is followed by selective recognition of each person's facial expression using central vision. The difficulty that individuals with ASD experience in assessing social situations may be influenced by their significant inaccuracy in peripheral vision and significant delay in perceiving the expression in others' faces in both central and peripheral vision compared to individuals with TD. Accordingly, such individuals may benefit from others giving them sufficient time to precisely recognize others' facial expressions using central vision and also verbal explanations of others' present emotions or feelings.

Limitations of the Study

The number of participants in the current study is not yet large, and it may be necessary to continue the study by recruiting more participants in the future. In addition, the faces used as stimuli in this study were photos from only five models whose expressions displayed were only two: "happy" and "angry", and the stimuli used as controls were only numerals. In the future, it will be necessary to use various facial stimuli and characters considering spatial frequency and stimulus structure to reevaluate the results of this study.

Conflicts of Interest

The authors declare that the study was conducted in the absence of any commercial or financial

relationships that could be construed as a potential conflict of interest.

Key Messages from this Article

People with Disabilities. When looking at objects, you have excellent central and peripheral vision. When looking at others' facial expressions, there may be inefficiencies in your peripheral vision. In this case, please try to consciously use your central vision.

Professionals. Giving people with ASD enough time to accurately recognize others' facial expressions using their central vision and verbally describing others' current emotions and feelings may be important as a support strategy.

Policymakers. In terms of employment support and education for people with ASD, please consider that their central vision and peripheral vision when looking at objects are excellent.

Messages clés de cet article

Personne ayant une incapacité : Lorsque vous regardez des objets, vous avez une excellente vision centrale et périphérique. Lorsque vous regardez les expressions faciales des autres, il peut y avoir des inefficacités dans votre vision périphérique. Dans ce cas, essayez d'utiliser consciemment votre vision centrale.

Professionnels : Donner assez de temps aux personne ayant un TSA pour reconnaitre avec précision les expressions faciales des autres en utilisant leur vision centrale et en décrivant verbalement les émotions et sentiments des autres pourrait être important comme stratégie de soutien.

Décideurs : En terme de soutien à l'emploi et l'éducation pour les personnes ayant un TSA, considérez que leur vision centrale et périphérique sont excellentes lorsqu'ils regardent des objets.

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