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Electrophysiological evidence for selective impairment of optic flow perception in autism spectrum disorder

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ABSTRACT

People with autism spectrum disorder (ASD) often show inferior global motion performance with superior performance in detail form perception, suggesting dysfunction of the dorsal visual stream. To elucidate the neural basis of impaired global motion perception in ASD, we measured psychophysical threshold and visual event-related potentials (ERPs) with a 128-channel system in 12 ASD and 12 healthy control adults. Radial optic flow (OF) and horizontal motion (HO) were used as the visual stimuli. The former was related to the ventro-dorsal stream formed by the inferior parietal lobule, while the latter was conveyed from the dorso-dorsal stream formed by the superior parietal lobule. No significant group differences were observed in the motion thresholds for both OF and HO. N170 and P200 were elicited as major components of ERPs in both groups. However, the latencies of both components for OF but not HO were significantly prolonged in ASD compared with the control group. Our ERP results suggest that ASD has a selective impairment for OF processing even though the psychophysical thresholds are preserved. Therefore, we provide the first electrophysiological evidence for altered function of the higher-level dorsal visual stream in ASD, specifically the ventro-dorsal stream closely related to OF perception.

1. Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental disorder characterized by social interaction and communication impairments, as well as restricted and repetitive behaviors and interests (Frith & Happé, 2005; Kamio et al., in press). Individuals with ASD show superior performance in processing fine details (Happé & Frith, 2006; Happé, 1996; Jolliffe & Baron-Cohen, 1997), while even those with high IQ are poor at processing global structure and motion perception (Bertone, Mottron, Jelenic, & Faubert, 2003; Milne et al., 2002; Spencer et al., 2000). This unusual cognitive style of reduced global bias coupled with enhanced local bias may be related to abnormal integration of perceptual information and may affect cognitive operations. Thus, low-level perception is considered to contribute to higher-level impairments of social

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cognition in ASD (Dakin & Frith, 2005; Mottron & Burack, 2001). Consequently, to elucidate the neural basis of impaired social interaction and communication in ASD, it is important to investigate visual motion perceptual function.

Fine-form perception is mainly processed in the parvocellular (P) pathway. In contrast, global motion is processed in the magnocellular (M) pathway on a basis of parallel visual information processing (Livingstone & Hubel, 1988; Tobimatsu & Celesia, 2006). After the primary visual cortex (V1), the M pathway projects to the dorsal stream that includes V1–3, V3a, V5/MT, MST, V6, and the posterior parietal lobule. Recently, the dorsal stream has been divided into two functional streams in primates: the dorso-dorsal (d-d) and ventro-dorsal (v-d) streams (Rizzolatti & Matelli, 2003). The former consists of V6 and the superior parietal lobule (SPL), whereas the latter is formed by V5/MT and the inferior parietal lobule (IPL). Given this background, we hypothesized that the atypical visual findings seen in ASD might derive from abnormalities at higher-level processing in the M pathway.

It is well known that the higher-level dorsal pathway including V5/MT integrates local motion signals from V1 into global motion (Snowden, Treue, Erickson, & Andersen, 1991). Therefore, coherent motion stimuli have been widely used to investigate global motion processing in psychophysical, electrophysiological, and neuroimaging studies (Morrone et al., 2000; Newsome & Paré, 1988; Niedeggen & Wist, 1999). There are several types of global motion including radial optic flow (OF) and horizontal motion (HO). Radial OF is the visual motion seen during observer self-movement and is known to be important for daily life because it provides cues about the heading direction and the three-dimensional structure of the visual environment (Gibson, 1950; Warren & Hannon, 1988). Using functional magnetic resonance imaging (fMRI), we recently reported that OF is mainly processed in the v-d (IPL) stream, while HO is mostly related to the d-d (SPL) stream in healthy humans (Yamasaki & Tobimatsu, in press). Thus, the use of both stimuli can reveal the function of two distinct higher-level dorsal pathways in ASD in detail.

Many psychophysical studies have been conducted to investigate motion perception in ASD. Motion coherence thresholds for HO (Milne et al., 2002; Spencer et al., 2000), OF (Del Viva, Igliozzi, Tancredi, & Brizzolara, 2006; Tsermentseli, O'Brien, & Spencer, 2008), and plaid motion (Vandenbroucke, Steven Scholte, van Engeland, Lamme, & Kemner, 2008) were measured to evaluate the function of the dorsal stream. Conversely, several studies evaluated the function of the lower and higher levels of the dorsal streams separately. One study examined motion sensitivity to the lower level of first-order (luminance-defined) and higher level of second-order (texture-defined) motion (Bertone et al., 2003). Other studies assessed dorsal stream functioning at both lower (sensitivity to flicker contrast) and higher (sensitivity to coherent HO) levels (Pellicano & Gibson, 2008; Pellicano, Gibson, Maybery, Durkin, & Badcock, 2005). However, it is still controversial whether impaired motion perception exists, and if it exists, it remains unclear how the M (or dorsal) pathway is functionally impaired in ASD.

Visual event-related potentials (ERPs) can detect abnormalities not only in patients with visual complaints but also in patients with no visual symptoms on examination (Tobimatsu & Celesia, 2006). Therefore, ERPs are considered to be useful for resolving the psychophysical controversy about motion perception (function of the dorsal pathway) in ASD; however, to date, there have been no such ERP studies on ASD. Therefore, in the present study, the psychophysical threshold of coherent motion (OF and HO) and ERP responses to these stimuli were measured to evaluate the function of the two distinct higher-level dorsal pathways in ASD.

2. Methods

2.1. Experiment 1: psychophysical threshold measurements

2.1.1. Subjects

Twelve ASD adults (nine males and three females, aged 20–39 years) and 12 control adults with similar chronological age and sex ratios (nine males and three females, aged 20–39 years) participated in this experiment. The ASD patients comprised six patients with Asperger's syndrome and six patients with pervasive developmental disorder not otherwise specified (PDD-NOS). These patients were diagnosed by a research team, including an experienced child psychiatrist (Y.K.), according to DSM-IV criteria (American Psychiatric Association, 1994) based on clinical interviews with patients and/or parents using semi-structured interviews that were validated for the Japanese PDD population (Pervasive Developmental Disorders Autism Society Japan Rating Scale; Kamio et al., 2006). Diagnostic agreement among the team was obtained for all subjects. Control subjects were recruited from the college student and faculty population and were confirmed as having no developmental problems by interviews.

Intellectual function of the ASD patients was evaluated using WAIS-R. ASD participants with full-scale IQ scores below 70 were not included in the study. All subjects exhibited normal or corrected-to-normal visual acuity (>1.0), evaluated using the Landolt's ring (Landolt, 1905). Autism-Spectrum Quotient (AQ) (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001; Wakabayashi, Baron-Cohen, Wheelwright, & Tojo, 2006) was also examined.

Informed consent was obtained after the nature of the experiment had been fully explained. The experimental procedures were approved by the ethics committee of the Graduate School of Medical Sciences, Kyushu University.

2.1.2. Visual stimuli

The visual stimuli were generated by the software Presentation (Neurobehavioral Systems, Inc., San Francisco, CA, USA), which was run on a personal computer and displayed on a gamma-corrected color monitor with a frame rate of 60 Hz