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Altered perspective-dependent brain activation while viewing hands and associated imitation difficulties in individuals with autism spectrum disorder

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ABSTRACT

Background: Individuals with autism spectrum disorder (ASD) appear to have a unique awareness of their own body, which may be associated with difficulties of gestural interaction. In typically developing (TD) individuals, the perception of body parts is processed in various brain regions. For instance, activation of the lateral occipito-temporal cortex (LOTC) is known to depend on perspective (i.e., first- or third-person perspective) and identity (i.e., own vs. another person's body). In the present study, we examined how perspective and identity affect brain activation in individuals with ASD, and how perspective- and identity-dependent brain activation is associated with gestural imitation abilities.

Methods: Eighteen young adults with ASD and 18 TD individuals participated in an fMRI study in which the participants observed their own or another person's hands from the first- and third-person perspectives. We examined whether the brain activation associated with perspective and identity was altered in individuals with ASD. Furthermore, we identified the brain regions the activity of which correlated with gestural imitation difficulties in individuals with ASD.

Results: In the TD group, the left LOTC was more strongly activated by viewing a hand from the third-person perspective compared with the first-person perspective. This perspective effect in the left LOTC was significantly attenuated in the ASD group. We also observed significant group differences in the perspective effect in the medial prefrontal cortex (mPFC). Correlation analysis revealed that the perspective effect in the inferior parietal lobule (IPL) and cerebellum was associated with the gestural imitation ability in individuals with ASD.

Conclusions: Our study suggests that atypical visual self-body recognition in individuals with ASD is associated with an altered perspective effect in the LOTC and mPFC, which are thought to be involved in the physical and core selves, respectively. Furthermore, the gestural imitation difficulty in individuals with ASD might be associated with the altered activation in the IPL and cerebellum, but not in the LOTC. These findings shed light on common and divergent neural mechanisms underlying atypical visual self-body awareness and gestural interaction in ASD.

Abbreviations: ACC, anterior cingulate cortex; AQ, autism spectrum quotient; ASD, autism spectrum disorder; CMS, cortical midline structure; DISCO, diagnostic Interview for Social and communication Disorders; EBA, extrastriate body area; FISQ, full-scale intelligence quotient; IOG, inferior occipital gyrus; IPL, inferior parietal lobule; IQ, intelligence quotient; LOTC, lateral occipito-temporal cortex; MFG, middle frontal gyrus; MNS, mirror neuron system; MOG, middle occipital gyrus; mPFC, medial prefrontal cortex; SRS, social responsiveness scale; TD, typically developing; ULS, upper limb sensitive

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1. Introduction

Autism spectrum disorder (ASD) is a range of neurodevelopmental conditions characterized by difficulties in social communication and interaction, as well as restricted, repetitive behaviors, interests, or activities (American Psychiatric Association, 2013). The difficulties in social communication and interaction encompass both verbal and nonverbal behaviors. With respect to the nonverbal behaviors, individuals with ASD experience difficulties recognizing another person's action (Cossu et al., 2012) and interacting with another person using their bodies (e.g., reciprocal imitation [Gergely, 2001; Nadel, 2002; Williams et al., 2004]).

In addition to social-communicative difficulties, individuals with ASD have been reported to present with atypical self-recognition abilities (Lombardo and Baron-Cohen, 2011; Uddin, 2011). The self includes the physical self (i.e., the external features, such as those of the body) and the psychological self (i.e., the internal features, such as the individual traits). Although several researchers have proposed that atypicality is limited to the psychological self (Lombardo and Baron-Cohen, 2011; Uddin, 2011), recent behavioral studies have reported that individuals with ASD have unique awareness of their bodies, a component of the physical self that has a more primitive function than social interaction (Asada et al., 2017; Cascio et al., 2012; Kern et al., 2006; Paton et al., 2012). For instance, estimation of own body size is less accurate in individuals with ASD than in typically developing (TD) individuals (Asada et al., 2017). The physical self is thought to contribute to social development (Neisser, 1988; Sugiura, 2013). Therefore, altered self-body recognition might be the cause of atypical bodily interaction in ASD individuals. If this is the case, which neural mechanism is associated with atypical self-body recognition in ASD? In the present study, we focused our investigation on visual processing for self-body recognition in ASD.

Previous neuroimaging studies of TD individuals have found that perception of the physical self involves a distributed network of brain regions including the lateral occipito-temporal cortex (LOTC), superior temporal sulcus (STS), inferior parietal lobule (IPL), and inferior frontal gyrus (IFG) (Sugiura, 2013; Uddin et al., 2007; Uddin, 2011). While multi-sensory inputs can drive this network (e.g., proprioception), a detailed network for visual processing has been proposed: visual features of a body are initially processed in the LOTC and then sent to other nodes (Gazzola and Keysers, 2009; Taylor et al., 2007). The LOTC contains a region (the extrastriate body area [EBA]) that is more strongly activated by viewing body parts relative to viewing other objects such as scenes or tools (Downing et al., 2001). Moreover, adjacent to the EBA, there is a region more strongly activated by the upper limbs relative to other body parts such as the trunk and lower limbs (Bracci et al., 2010; Orlov et al., 2010; Peelen and Caramazza, 2010). The LOTC is also thought to process several visual features associated with self-body recognition. Specifically, LOTC activation is modulated by perspective (i.e., first- vs. third-person perspective) and identity (i.e., own body vs. the body of another person) (Chan et al., 2004; Myers and Sowden, 2008; Saxe et al., 2006). These findings suggest that the LOTC is involved in the categorization of body parts (e.g., hand or foot) and differentiation of the owner of these body parts (i.e., own hand vs. another person's hand). These findings suggest that LOTC dysfunction is a possible neural mechanism underlying the atypical awareness of the visual self-body in individuals with ASD.

In previous fMRI studies, we have found that, although TD and ASD adults show similar LOTC selective responses to body parts (Okamoto et al., 2014, 2017), the EBAs of adults with ASD show atypical responses when observing another person's action contingent on self-action (Okamoto et al., 2014). These findings indicate that lower-level LOTC functions such as object categorization may be intact in adults with ASD, whereas higher-order functions such as detecting social contingency are perturbed. Therefore, we expected that the processing of perspective and identity of bodies in this area, more complex than simple categorization, might also be dysfunctional in adults with ASD. However, to the best of our knowledge, no study to date has examined how perspective and identity of bodies affect LOTC activation in individuals with ASD.

In the present study, we used fMRI to examine brain activation during an experimental task in which young male adults with ASD and TD individuals observed their own or another person's hands from the first- and third-person perspectives. To evaluate LOTC activation, we initially depicted the upper-limb-sensitive (ULS) region within the LOTC and then examined the sensitivity of this region to hand viewing with different perspectives and identities. We predicted that the effects of perspective and identity on hand perception were different between young adults with and without ASD. We further explored if brain activation was associated with difficulties in bodily interaction in individuals with ASD, which allowed us to examine the nature of heterogeneity among ASD participants. In particular, as some individuals with ASD show a unique imitation error due to a failure to adopt another person's perspective (i.e., reversal error) (Ohta, 1987; Williams et al., 2004), atypical perspective-dependent brain activation might be associated with the severity of imitation difficulties in individuals with ASD. Although the perspective of observed action can affect the activation of brain regions beyond the LOTC (Jackson et al., 2006), it is not clear if such activation is associated with the imitation difficulties in individuals with ASD. To examine this possibility, we evaluated the imitation ability in ASD participants and depicted the brain regions the activity of which was correlated with it.

2. Materials and methods

2.1. Participants

Eighteen young male adults with ASD (age, mean ± standard deviation [SD]: 28.2 ± 6.9 years) and 18 young male TD adults (age: 24.8 ± 5.0 years) participated in the study (Table 1). ASD participants were recruited from the outpatient department of the University of Fukui Hospital and diagnosed by a psychiatrist (H.K) based on the DSM-5 diagnostic criteria (American Psychiatric Association, 2013). To establish a DSM-5 diagnosis, H.K. applied the Diagnostic Interview for Social and Communication Disorders (DISCO) (Wing et al., 2002), which collects information about various developmental and behavioral features including social functioning and communication (Wing et al., 2002). TD individuals were recruited from the local community. Participants of both groups were excluded if they had a history of major

Table 1
Demographic data.

		TD group	ASD group	p-Values
Number		18	18	
Age		24.8 ± 5.0	28.2 ± 6.9	0.102
IQ	FSIQ	113.7 ± 8.6	109.2 ± 12.6	0.214
	vIQ	116.2 ± 12.6	112.9 ± 16.2	0.506
	pIQ	107.6 ± 7.5	104.8 ± 12.0	0.413
SRS		58.3 ± 26.5	110.7 ± 26.8	< 0.001
AQ	Total	17.7 ± 3.6	34.9 ± 5.0	< 0.001
	Social	3.0 ± 2.2	8.4 ± 1.5	< 0.001
	Attention switching	4.8 ± 1.6	7.5 ± 1.8	< 0.001
	Attention to detail	4.2 ± 2.4	5.4 ± 2.4	0.176
	Communication	2.1 ± 1.6	7.6 ± 1.8	< 0.001
	Imagination	3.6 ± 1.4	5.7 ± 2.4	0.004

TD: Typically developing, ASD: Autism spectrum disorder, Number: Number of participants, IQ: Intellectual quotient assessed by the Wechsler Adult Intelligence Scale, Third Edition (Wechsler, 1997), FSIQ: Full scale IQ, pIQ: Performance IQ, vIQ: Verbal IQ, SRS: Social responsive scale score (Constantino and Todd, 2005), AQ: Autism Spectrum Quotient (Baron-Cohen et al., 2001). Age and IQ, SRS, and AQ scores are shown as mean ± SD. The p values indicate the results of independent-samples *t*-tests that compared the ASD and TD groups.