Neuroscience Research 87 (2014) 66–76

Contents lists available at ScienceDirect

Neuroscience Research

journal homepage: www.elsevier.com/locate/neures

Attenuation of the contingency detection effect in the extrastriate body area in autism spectrum disorder

Yuko Okamoto[a,b,c], Ryo Kitada[a,b], Hiroki C. Tanabe[a,d], Masamichi J. Hayashi[a,b,e,f], Takanori Kochiyama[g], Toshio Munesue[h], Makoto Ishitobi[i,j], Daisuke N. Saito[k,l,m], Hisakazu T. Yanaka[c,k,l], Masao Omori[n], Yuji Wada[i,m], Hidehiko Okazawa[k,l,m], Akihiro T. Sasaki[a,b,o,p], Tomoyo Morita[q,r], Shoji Itakura[s,t], Hirotaka Kosaka[i,k,m], Norihiro Sadato[a,b,k,*]

[a] Division of Cerebral Integration, Department of Cerebral Research, National Institute for Physiological Sciences, Japan
[b] Department of Physiological Sciences, The Graduate University for Advanced Studies (Sokendai), Japan
[c] Department of Education, Faculty of Regional Sciences, Tottori University, Japan
[d] Department of Social and Human Environment, Graduate School of Environmental Studies, Nagoya University, Japan
[e] Institute of Biomedicine, Physiology, University of Helsinki, Finland
[f] Brain Research Unit, O.V. Lounasmaa Laboratory, Aalto University School of Science, Finland
[g] Advanced Telecommunications Research Institute International, Brain Activity Imaging Center, Kyoto, Japan
[h] Research Center for Child Mental Development, Kanazawa University, Japan
[i] Department of Neuropsychiatry, Faculty of Medical Sciences, University of Fukui, Japan
[j] Department of Child and Adolescent Mental Health, National Institute of Mental Health, National Center of Neurology and Psychiatry, Japan
[k] Biomedical Imaging Research Center, University of Fukui, Japan
[l] Research and Education Program for Life Science, University of Fukui, Japan
[m] Research Center for Child Mental Development, University of Fukui, Japan
[n] Faculty of Nursing and Social Welfare Sciences, Fukui Prefectural University, Japan
[o] Department of Physiology, Osaka City University Graduate School of Medicine, Japan
[p] Pathophysiological and Health Science Team, RIKEN Center for Life Science Technologies, Japan
[q] Division of Sensori-Motor Integration, Department of Integrative Physiology, National Institute for Physiological Sciences, Japan
[r] Department of Adaptive Machine System, Graduate School of Engineering, Osaka University, Japan
[s] Department of Psychology, Graduate School of Letters, Kyoto University, Japan
[t] Advanced Telecommunications Research Institute International, Intelligent Robotics and Communication Laboratories, Japan

ARTICLE INFO

Article history:
Received 17 February 2014
Received in revised form 11 June 2014
Accepted 26 June 2014
Available online 24 July 2014

Keywords:
Being imitated
Autism spectrum disorders
Extrastriate body area

ABSTRACT

Detection of the contingency between one's own behavior and consequent social events is important for normal social development, and impaired contingency detection may be a cause of autism spectrum disorder (ASD). To depict the neural underpinnings of this contingency effect, 19 adults with ASD and 22 control participants underwent functional MRI while imitating another's actions and their actions being imitated by the other. As the extrastriate body area (EBA) receives efference copies of one's own movements, we predicted that the EBA would show an atypical response during contingency detection in ASD. We manipulated two factors: the congruency of the executed and observed actions, and the order of action execution and observation. Both groups showed the congruency effect in the bilateral EBA during imitation. When action preceded observation, the left EBA of the control group showed the congruency effect, representing the response to being imitated, indicating contingency detection. The ASD group showed a reduced contingency effect in the left EBA. These results indicate that the function of the EBA in the contingency detection is altered in ASD.

1. Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental disorder characterized by difficulties in social communication and social interaction, and restricted, repetitive patterns of behavior,

* Corresponding author at: Division of Cerebral Integration, National Institute for Physiological Sciences, Okazaki 444-8585, Japan. Tel.: +81 564 55 7841; fax: +81 564 55 7843.
E-mail address: sadato@nips.ac.jp (N. Sadato).

http://dx.doi.org/10.1016/j.neures.2014.06.012
0168-0102/

interests or activities (DSM-5; American Psychiatric Association, 2013). The impairments in social communication and social interaction include both verbal and nonverbal behaviors. One of the impaired nonverbal behaviors is body gesture. Individuals with ASD have a fundamental impairment in gestural interaction in terms of social cause–effect representation ("I smile, therefore another person smiles"; i.e., social contingency detection, Gergely, 2001; Nadel, 2002), which is a basic element of the development of social communication skills (Mundy and Sigman, 1989). When being imitated, typically-developing children frequently changed their actions and looked at the person they were interacting with. However, most children with ASD did not display these behaviors (Nadel, 2002).

In order to account theoretically for the deficit in social contingency detection in ASD, Gergely and Watson (1999) postulated the presence of a "contingency detection module (CDM)", which functions to establish the primary representation of the bodily self as well as the later orientation toward reactive social objects. This module is innately set to preferentially explore perfect response-contingent stimulation. Around 3 months of age, the CDM is "switched" toward a preference for less-than-perfect contingent actions of others, such as reciprocal imitation (Bahrick and Watson, 1985; Gergely and Watson, 1999). In contrast, children with ASD fail to switch their preference from perfect to less-than-perfect contingency. As a result, children with ASD become less sensitive to less-than-perfect contingency situations, such as being imitated, and spend more time in repetitive motor activity in order to seek out self-related perfect contingency (Gergely, 2001). Although this hypothesis might explain the pathological origin of ASD, the neural underpinnings of the CDM are not yet understood.

Previous neuroimaging studies suggest that the occipito-temporal region is related to the detection of the congruency between one's own and another person's actions when imitating and being imitated (Decety et al., 2002; Chaminade et al., 2005). Within the occipito-temporal region, one candidate region is the extrastriate body area (EBA), which is selectively activated when viewing the human body (Downing et al., 2001) and the movements of one's own body (Astafiev et al., 2004; Orlov et al., 2010). Previous neuroimaging studies have reported that the bilateral lateral occipito-temporal region around the EBA shows a "congruency effect": it is strongly activated when one's own and another's actions were congruent (i.e., imitating and being imitated) compared to when they were different (Decety et al., 2002; Chaminade et al., 2005). These findings suggest that the EBA may be the "comparator" of the efference copy/proprioceptive information of one's own actions and the visual information received about another's actions.

If the EBA is the neural substrate of the CDM, we can predict that activity in the EBA during contingency detection between one's own actions and the resulting actions of others should be reduced in ASD. However, to our knowledge, no previous neuroimaging study has examined the effect of ASD on the neural network underlying contingency detection. In the present study, we examined brain activation of adults with ASD when they imitated hand actions and when their hand actions were imitated. Based on a previous study on being imitated (Decety et al., 2002), we manipulated the two factors: (1) the congruency between observed and executed actions (congruent/incongruent) and (2) the order of executed and observed actions (the participants executed the action BEFORE/AFTER observing the action of another person). In this task design, we were particularly interested in whether adults with ASD have abnormal congruency effect in being imitated (BEFORE conditions). If EBA corresponds to CDM, the EBA in adults with ASD should show reduced activity in BEFORE conditions.

2. Materials and methods

2.1. Participants

Nineteen adults with ASD and twenty-two typically-developing adults participated in the present study. The protocol was approved by the ethics committee of the University of Fukui (Japan), and the study was conducted in accordance with the Declaration of Helsinki. Participants were excluded if they had a history of major medical or neurological illness including epilepsy, significant head trauma, or a lifetime history of alcohol or drug dependence. Written informed consent was obtained from each participant after a complete explanation of the study. Handedness was assessed by the Edinburgh Handedness Inventory (Oldfield, 1971). All participants' intelligence quotient (IQ) scores were obtained using the Wechsler Adult Intelligence Scale-III (WAIS-III) (Wechsler, 1997). We also measured the autism-spectrum quotient (AQ) total score (Baron-Cohen et al., 2001), which has been validated in a clinical sample (Woodbury-Smith et al., 2005).

2.1.1. High-functioning ASD group

Eighteen males and one female (mean ± standard deviation [SD] age = 24.8 ± 4.4 years) were recruited at the Department of Neuropsychiatry of the University of Fukui Hospital (Japan) and the Department of Psychiatry and Neurobiology of Kanazawa University Hospital (Japan) (Table 1). Two psychiatrists (6th and 16th authors) diagnosed the participants as ASD based on the DSM-5 classifications (American Psychiatric Association, 2013) and standardized criteria using the Diagnostic Interview for Social and Communication Disorders (DISCO) (Wing et al., 2002). These two authors were trained in the diagnosis of ASD under T. Uchiyama and are qualified to use the DISCO Japanese edition (2007). The DISCO has good psychometric properties (Nygren et al., 2009), and it contains items on early development and activities of daily life, giving the interviewer some idea of the level of functioning in several different areas, not only social functioning and communication (Wing et al., 2002). Eight of 19 patients took medications including antipsychotics (four patients), antidepressants (four patients), anxiolytics (four patients) and hypnotics (three patients) at MRI examination day. Four of 19 patients with ASD have comorbidity with obsessive compulsive disorder (two patients), anxiety disorder (one patient) and atopic dermatitis (one patient).

2.1.2. Control group

Twenty-two age-matched typically-developing volunteers (20 males and 2 females) were recruited from the local community for the CTL group (mean ± SD age = 24.2 ± 3.7 years; Table 1). They were screened to exclude individuals who had a first-degree relative with an axis I disorder based on DSM-5 criteria. The full-scale IQ (FSIQ) scores of all participants were greater than 75, and the mean FSIQ scores of each group were over 100. Although there was a significant difference in FSIQ scores between the ASD and CTL groups ($t(39) = 2.6$, $p < .05$, two-sample t-test), there was no significant difference in verbal IQ scores between the two groups ($t(39) = 1.6$, $p > .1$, two-sample t-test). In contrast, the AQ total scores and sub-scores were significantly higher in the ASD group than in the CTL group (both $p < .01$, two-sample t-test; Table 1).

2.2. MRI parameters

All functional volumes were acquired using T2*-weighted gradient-echo echo-planar imaging (EPI) sequences with a 3 Tesla MR imager (Sigma Horizon; GE Medical Systems, Milwaukee, Wisconsin). A volume consisted of 37 oblique slices, each 3.0 mm in thickness, with a 15% gap, in order to cover the entire cerebral and cerebellar cortices. The axial slices were acquired sequentially in