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Neural correlates of emotion processing during observed self-face recognition in individuals with autism spectrum disorders

Tomoyo Morita[a,b], Hirotaka Kosaka[c,d,e], Daisuke N. Saito[c,e], Takeshi Fujii[c,e,f], Makoto Ishitobi[d,g], Toshio Munesue[h], Keisuke Inohara[d,i], Hidehiko Okazawa[c,e], Ryusuke Kakigi[a], Norihiro Sadato[e,j,k,*]

[a] *Department of Integrative Physiology, National Institute for Physiological Sciences, Okazaki, Aichi 444-8585, Japan*
[b] *Graduate School of Engineering, Osaka University, Suita, Osaka 565-0871, Japan*
[c] *Research Center for Child Mental Development, University of Fukui, Eiheiji, Fukui 910-1193, Japan*
[d] *Department of Neuropsychiatry, Faculty of Medical Sciences, University of Fukui, Eiheiji, Fukui 910-1193, Japan*
[e] *Biomedical Imaging Research Center, University of Fukui, Eiheiji, Fukui 910-1193, Japan*
[f] *Department of Psychiatry, National Center of Neurology and Psychiatry Hospital, Kodaira, Tokyo 187-8551, Japan*
[g] *Department of Child and Adolescent Mental Health, National Institute of Mental Health, National Center of Neurology and Psychiatry, Kodaira, Tokyo 187-8553, Japan*
[h] *Research Center for Child Mental Development, Kanazawa University, Kanazawa, Ishikawa 920-8641, Japan*
[i] *The University of Electro-Communications Graduate School of Informatics and Engineering Department of Informatics, Chofu, Tokyo 182-8585, Japan*
[j] *Department of Cerebral Research, National Institute for Physiological Sciences, Okazaki, Aichi 444-8585, Japan*
[k] *Department of Physiological Sciences, The Graduate University for Advanced Studies (Sokendai), Okazaki, Aichi 444-8585, Japan*

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ABSTRACT

When exposed to self-face images, individuals often experience embarrassment, which is enhanced by being observed. This self-evaluative emotion is related to activity in the right anterior insula and the functional connectivity between the anterior cingulate and prefrontal cortices. Coupling between cognitive evaluation of self-face images and emotional response to them (cognitive–emotional coupling) is weaker in individuals with autism spectrum disorder (ASD), in parallel with reduced activity of the right insula. To determine whether self-evaluative emotions of individuals with ASD are less strongly impacted by observation, we conducted functional MRI in 14 adult men with ASD and 18 age-matched control men while the participants viewed self-face images. Increased embarrassment upon observation was positively correlated with increased activity in the right anterior insula in the control group, but not in the ASD group. In addition, awareness of being observed enhanced cognitive–emotional coupling in the controls but not in the ASD group. The coupling was correlated with the functional connectivity between the anterior cingulate and medial prefrontal cortices. These results suggest that the reduced impact of observation on embarrassment induced by self-face images in individuals with ASD is related to impairment in the right anterior insula, which is involved in creating

* Correspondence author at: Division of Cerebral Integration, Department of Cerebral Research, National Institute for Physiological Sciences, Myodaiji, Okazaki, Aichi 444-8585 Japan.
E-mail addresses: morita@ams.eng.osaka-u.ac.jp (T. Morita), hirotaka@u-fukui.ac.jp (H. Kosaka), sdaisuke@u-fukui.ac.jp (D.N. Saito), tfujii@ncnp.go.jp (T. Fujii), mak1977019@yahoo.co.jp (M. Ishitobi), munesue@med.kanazawa-u.ac.jp (T. Munesue), kei.inohara@gmail.com (K. Inohara),

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subjective feelings, and the anterior cingulate cortex, which acts as a hub for integrating information from others during self-face evaluation.

1. Introduction

In human society, the ability to interact with others in a socially appropriate manner is essential. In addition to basic emotions, such as happiness, fear, and anger, humans experience higher-order self-conscious emotions (e.g., coyness, shyness, pride, embarrassment, shame, and guilt). Unlike basic emotions, self-conscious emotions tend to arise through relationships with others and serve important interpersonal functions (Miller & Leary, 1992; Tangney, 1999; Lewis, 2000). For instance, when individuals are exposed to self-images via mirrors, photographs, or videos, they sometimes experience early forms of self-conscious emotions (e.g., coyness or shyness). This type of emotion emerges at around 18–24 months of age, and only after self-recognition appears (Lewis, Sullivan, Stanger, & Weiss, 1989). Furthermore, when individuals are exposed to visual self-images that deviate substantially from the individual's ideals or standards, they can experience more complex negative self-conscious emotions (e.g., embarrassment) (Duval & Wicklund, 1972; Carver & Scheier, 1981; Carver & Scheier, 1998). Such negative emotions emerge at around 3–4 years of age, when the child has internalized rules or standards for self-evaluation. Therefore, this class of self-conscious emotions are called "self-evaluative emotions", and they can be viewed as part of an alarm system that detects deviations of behaviors and attitudes relative to social standards. This system could play an important role in guiding appropriate social conduct.

Previously, we demonstrated that the anterior insula (AI) and the anterior cingulate cortex (ACC) are involved in the experience of embarrassment (Morita et al., 2008; Morita et al., 2012). These areas were more active when participants viewed self-face images, including those that would be expected to elicit feelings of embarrassment, than when they viewed images of others' faces. These brain regions are co-activated when subjects experience a range of basic emotions, including disgust and fear, as well as social emotions including romantic love, injustice, and social exclusion (Blood & Zatorre, 2001; Eisenberger, Lieberman, & Williams, 2003; Wicker et al., 2003; Bartels & Zeki, 2004; Takahashi et al., 2008; Onoda et al., 2010; Moor et al., 2012). In addition, these regions are also co-activated in response to salient stimuli or events that do not necessarily elicit a specific emotional feeling (Craig, 2002). Therefore, the ACC and AI are thought to be components of a "salience network" that functions to identify the most relevant among several internal and extra-personal stimuli in order to guide appropriate behavior. In this framework, the AI serves as an integral hub in mediating dynamic interactions between other large-scale brain networks: the central executive and default mode networks (Seeley et al., 2007; Menon & Uddin, 2010).

Recently, we also obtained evidence that social situations in which participants are observed by others modulate activation patterns in the AI and ACC in distinct manners (Morita et al., 2014). In that study, we showed that individuals view self-face images while being observed by others, they experience a stronger feeling of embarrassment than when viewing the same images in the absence of an observer. Individual increases in the subjective feeling of embarrassment are positively correlated with individual increases in self-related activity (self vs. others) in the right AI, but not in the caudal part of the ACC. According to the Craig's model of integration across the insula cortex, diverse information, including homeostatic, environmental, hedonic, motivational, social, and cognitive activity, is integrated in a posterior-to-anterior direction to produce subjective experiences representing the sentient self at a particular moment in time (Craig, 2009). Considering this view together, it is suggested that the right AI plays a crucial role in creating the subjective experience of embarrassment.

On the other hand, we also found that being observed increased functional connectivity between the caudal ACC and medial prefrontal cortex (MPFC) when viewing self-face images. The MPFC is consistently activated by self-reflective processing, in which participants are required to think about their own mental or inner states (e.g., emotions or personality traits) (Northoff et al., 2006; Murray, Schaer, & Debbané, 2012). In addition, the MPFC is also activated by tasks that require participants to infer others' mental states or take a third-person perspective (i.e., mentalizing) (D'Argembeau et al., 2007; Gallagher & Frith, 2003; Frith and Frith, 2006). Several recent studies suggested that the MPFC was involved in inference of the more complex mental states of others. For example, the MPFC is recruited when thinking about how another person would appraise us (Ochsner et al., 2005; Amodio & Frith, 2006; D'Argembeau et al., 2007; Frith & Frith, 2008; Izuma, Saito, & Sadato, 2008,Izuma, Saito, & Sadato, 2010a; Sugiura, Sassa, & Jeong, 2012). All these evidence considered, in our previous study, we proposed that being observed during self-face recognition would increase accessing information about the self that is reflected in the eyes or minds of others. This would lead to an increase in functional connectivity between the caudal ACC and MPFC. That is, unlike the functional role of the AI, the caudal ACC seems to serve as a hub, integrating information about the reflective self that is used for self-evaluative processing.

Autism spectrum disorder (ASD) is characterized by persistent deficits in social communication and social interaction across multiple contexts, in conjunction with restricted, repetitive patterns of behavior, interests, or activities (Diagnostic and Statistical Manual of Mental Disorders, DSM-5, American Psychiatric Association, 2013). A great deal of research has demonstrated that individuals with ASD exhibit deficits in face perception (eye gaze or facial expression) at both the behavioral and neural levels (Dalton et al., 2005; Dawson, Webb, & McPartland, 2005; Pierce, Müller, Ambrose, Allen, &