Neural Basis of Self-Reflection on Self-Face Image in Patients with Social Anxiety Disorder

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Abstract

Background: Patients with social anxiety disorder (SAD) have heightened self-reflection. In the self-focused cognition, they ruminate negative self-image or evaluation both by themselves and others. It leads to self-conscious emotions, such as embarrassment. Previous functional magnetic resonance imaging (fMRI) studies with healthy subjects revealed that anterior rostral medial prefrontal cortex (arMPFC) plays a key role in self-reflection. However, neural basis of self-reflection in patients with SAD has not been studied in detail. This study aimed to investigate the neural basis of self-reflection in patients with SAD using self-face images. We hypothesized that patients with SAD would show excessive embarrassment and it would cause aberrant neural hyperactivity in arMPFC as compared to controls (CTL).

Methods: Thirteen outpatients with SAD and 17 CTLs enrolled in this study. fMRI was acquired while participants reported the degree of their embarrassment by the visually presented their self-face image and images of others’ with and without an observer.

Results: The SAD group reported significantly greater embarrassment for self-face images than the CTL regardless of observation. The SAD group showed enhanced self-related activation in the left arMPFC as compared with the CTL. Furthermore, positive correlation between the self-related activity and Liebowitz Social Anxiety Scale was observed only in the arMPFC.

Conclusion: We suggest that the arMPFC takes charge of their elevated-level of self-reflection in patients with SAD, and the level of the neural activity was correlated to the severity of the symptom.
Key Words: social anxiety disorder (SAD)/social phobia, functional magnetic resonance imaging (fMRI), anxiety disorders, cognition, self-reflection

[Introduction]

Social anxiety disorder (SAD) is characterized by excessive fear and avoidance of social situations (Diagnostic and Statistical Manual-V (DSM-5), (American Psychiatric Association, 2013)). Previous studies revealed that patients with SAD have heightened self-reflection (Smith & Sarason, 1975; Clark & Wells, 1995; Philippi & Koenigs, 2014) which is defined as the inward attention to personal thoughts, memories, feelings, and actions (Philippi & Koenigs, 2014). According to Clark and Wells model (Clark & Wells, 1995), patients with SAD tend to ruminate negative self-image or evaluation both by themselves and others. It leads to negative self-conscious emotions, such as embarrassment. Thus, it is no exaggeration to say that self-reflection is a central feature of SAD.

Some previous functional magnetic resonance imaging (fMRI) studies with healthy subjects (Moran et al., 2006; Murray et al., 2012) and injured brains (Eslinger & Damasio, 1985) or frontotemporal dementia (FTD) (Eslinger et al., 2005) revealed that anterior rostral medial prefrontal cortex (arMPFC) plays a key role in self-reflection. In the neural level of self-reflection, self-knowledge processing has a major function (Mitchell et al., 2005; D’Argembeau, 2013). arMPFC is involved in processing self-knowledge, such as traits, values, mental state and physical appearance (Devue & Bredart, 2011; D’Argembeau, 2013). Furthermore, the amount of arMPFC activity is modulated by the degree of self-reflection (D’Argembeau et al., 2005), the amount of self-relevance (Philippi & Koenigs, 2014), and the importance of self-related information (D’Argembeau et al., 2012). These findings suggest that arMPFC has a role in self-reflection in healthy people. However, little is known the role of arMPFC in the pathophysiology of SAD.

Most of the fMRI studies of SAD have focused on the limbic hyperactivity with facial expressions (Etkin & Wager, 2007; Hattingh et al., 2012). Only a few investigated the role of MPFC using self-referential tasks. Blair et al. examined the information-processing bias of SAD using self-referential criticism (Blair et al., 2008), unintentional transgressions (Blair et al., 2010), and self-referential comments made by one’s self or others’ viewpoints (Blair et al., 2011). In their first study, patients with SAD showed dorsal regions of MPFC hyperactivity for negative self-criticism. They suggested that the negative self-referential criticism might enhance the metalizing and mediate the post-event processing or retrospective rumination. In the second study (Blair et al., 2010), arMPFC of patients with SAD responded to unintentional transgression whereas that of the controls responded to intentional transgressions. They concluded that it might be associated with the information processing bias of patients with SAD. Their further study (Blair et al., 2011) revealed that patients with SAD showed enhanced neural activity in arMPFC and dorsal and lateral PFC for self-referential comments. Although this study is in line with the self-reflection, there is no established consensus about the neural mechanism of self-reflection in SAD.

The purpose of the present study was to
explore the neural basis of the SAD, focusing on the dysfunctional self-reflection. To induce self-reflection, we used the self-face images. Self-face image has been used as a task of self-knowledge (Sugiura et al., 2005; Devue & Bredart, 2011). According to the previous fMRI studies of Morita et al. (Morita et al., 2008), even healthy people feel embarrassed when they view their own face due to the difference between the actual image and their internal ideal image of their own face. Self-face image induces people to think about an imaginary observer in their mind and to be concerned about how they would be judged.

Besides, when there is an observer who sees the same image, his/her embarrassment is enhanced because the subjects’ concern about the judgement from the observer is also enhanced. If patients with SAD see their self-face images, we expect that the embarrassment will be more prominent than normal control because seeing their self-face images would enhance the above mentioned self-reflective processing. Furthermore, embarrassment may be more enhanced in SAD group by the presence of observer. In summary, we hypothesized that patients with SAD would show excessive embarrassment toward self-face image and it would cause aberrant neural hyperactivity in arMPFC.

[Methods]

1. Subjects

Thirteen outpatients with SAD (5 males and 8 females; age range 20–56 years; mean ± standard deviation [SD] 36.2 ± 11.8 years), and 17 CTL subjects (5 males and 12 females; age range 21–53 years; mean ± SD 33.3 ± 9.7 years) matched in age, gender, and Intelligence Quotient (IQ) were enrolled. Patients with SAD were recruited from the Nagoya City University Hospital. All patients fulfilled the criteria for generalized subtype of SAD as the primary disorder in accordance with the Structured Clinical Interview for DSM-IV (SCID). The CTLs were recruited from the general population. They did not have concurrent and past Axis I disorders. All subjects were Japanese and right handed. Participants were excluded if they had a history of major medical or neurological illness, significant head trauma, or a lifetime history of alcohol or drug dependence. Although some patients had concurrent Axis I comorbidities (Table 1), SAD was their primary disorder and those comorbid symptoms were under control to the extent that they could endure the fMRI scanning. The SAD subjects were free of psychotropic medications on the day of the scanning (Eleven patients took antidepressant, 7 patients took antianxiety agents, 4 patients took hypnotics and 3 patients took antipsychotic agents). This study was approved by the Institutional Review Board and the Ethics Committee of the Nagoya City University Graduate School of Medical Sciences and National Institute for Physiological Sciences and was conducted in accordance with the Helsinki Declaration. Written informed consent was obtained from each subject before enrollment.

2. Psychiatric Assessment

All the participants were assessed by the Liebowitz Social Anxiety Scale (LSAS) (Liebowitz, 1987; Asakura et al., 2002), Brief Version of the Fear of Negative Evaluation Scale (BFNE) (Leary, 1983), Hamilton Rating Scale for Depression (HRSD) (Hamilton, 1960; Furuwaka et al., 2007), Japanese version of National Adult Reading Test (JART) (Matsuoka et al.,
2006), and Self Consciousness Scale (SCS) (Fenigstein et al., 1975; Sugawara, 1984). All of the rater-assessed psychiatric assessments were performed by a board-certificated psychiatrist (A.K.).

3. **fMRI task**

We followed the method reported by Morita et al. (Morita et al., 2016). The experiment was scheduled for two days. On the first day, we conducted psychiatric assessments and video interviews. Twenty-one black and white face-images of each participant, ranging from attractive to unattractive, were selected from the video by an experimenter according to the criteria used in our previous study (Morita et al., 2016) and were used as SELF stimuli. Twenty-one face-images of gender-matched unfamiliar individuals were used as OTHER stimuli. fMRI scanning was acquired a few weeks after the first day. The participants were introduced to their partner (“observer”), who was a sex-matched volunteer (there were 2 actors and 2 actresses) and unfamiliar to each participant. The participants were informed that the observer would sit in the booth and view the face-images that the participants would see in the MRI scanner, and that the observer would score the photogenicity of the face-images in half of the runs (Observed condition; OB condition). They were also informed that, under a Non-observed (NOB) condition, the participants would see the face-images without sharing with the observer.

In the fMRI experiment, each participant completed four runs, each of which lasted for
6 min 2.5 sec. Two runs were for the OB condition, and the other two were for the NOB condition. The order of conditions was counterbalanced across participants to avoid order effects (Figure 1). In each run, 21 SELF images, 21 OTHER images, and 7 “null events” (no stimulus, white cross on black screen) were shown in a pseudorandom order. After a face stimulus was shown for 3 sec, a visual analogue scale appeared for 4.5 sec. The images were rated from “None at all” (not embarrassed) to “Strong” (most embarrassed). The participants scored their embarrassment using a two-button response box. The scale was subsequently divided into 100 equal intervals for analysis. The experimental design was based on a rapid event-related paradigm. More detail of this experimental design is described in the previous studies (Morita et al., 2008; Morita et al., 2016).

After fMRI scanning, the participants answered the photogenicity of the same face stimuli by visual analogue scale. The visual analogue scale was categorized from “Good” to “Bad” and divided into 100 equal intervals.

4. MRI Image Acquisitions

The functional MRI images were acquired using T2*-weighted, gradient echo, echo-planar imaging (EPI) sequences with a 3-T MR imager (Magnetom Skyra, Siemens Medical Solutions, Erlangen, Germany), and a 32-channel array coil. There were four MRI runs and each run consisted of 148 volumes. Each volume included 39 slices with a thickness of 3 mm and a 0.5 mm gap to cover the whole brain. The time interval between every two successive acquisitions of the same slice (TR) was 2,500 ms, with an echo time (TE) of 30 ms and a flip angle (FA) of 80°. The field of view (FOV) was 192 × 192 mm, and the matrix size was 64 × 64, giving voxel dimensions of 3 × 3 mm. A board-certified neuroradiologist reviewed all the scans and found no major abnormalities in any of the subjects.

5. Behavioral Data Analysis

Behavioral data was analyzed using SPSS version 19.0J software (SPSS Japan, Tokyo, Japan). The embarrassment scores measured during the MRI scanning were compared based on three-way analysis of variance (ANOVA), with face
type (SELF, OTHER) × observation (NOB, OB) × group (CTL, SAD), on the average ratings. The photogenicity was also compared by two-way ANOVA in the same way. Other psychiatric measurements or demographic data were analysed with unpaired t-tests for continuous variables and $\chi^2$-square tests for categorical variables. Results were considered statistically significant at $p < 0.05$.

6. Imaging Data Analysis

All images were preprocessed and analyzed using Statistical Parametric Mapping 8 (SPM8; www.fil.ion.ucl.ac.uk/spm/). We excluded the first 5 volumes of each session because of unsteady magnetization. In individual pre-processing, all the images were realigned using the last image as a reference. Then, we used slice-timing correction to adjust the differences in slice-acquisition times so that the slices were acquired at the same time as the reference slice, namely the middle slice. EPI template image was used for anatomical normalization. The normalized fMRI data was filtered using a Gaussian kernel with a full width at half maximum of 8 mm in the x, y, and z axes. After preprocessing, the individual task-related activation was evaluated with general linear model. In the single-subject analyses, the design matrix contained two task-related regressors (the SELF and OTHER conditions), one for parametric modulation (the embarrassment ratings for each condition), and the other for motor response and one constant term. The presentation of each face stimulus was embedded in a series of delta functions. More detail of the fMRI analyses is provided in the previous articles (Morita et al., 2008; Morita et al., 2014; Morita et al., 2016). In the second level analyses, a random effect model was used (Holmes & Friston, 1998). First, we conducted a one-sample t-test using the SELF-OTHER contrast images of the above described individual analyses to detect the self-related activity of each group. Second, we conducted the two-sample t-tests with the SELF-OTHER contrast images to examine brain regions that showed group difference in self-related activity. Third, we also applied correlation analyses in the whole brain with LSAS, BFNE, and SCS. Statistical significance was set to $p < 0.05$, corrected for multiple comparisons for the entire brain at cluster level with a height threshold of $p < 0.001$. We identified the name of active brain regions by using Anatomy toolbox implemented in SPM8 (Eickhoff et al., 2005).

[Results]

1. Demographic and Behavioral Data

Demographic and diagnostic characteristics of the participants were summarized in Table 1. The patients with SAD had severe symptoms as compared to the CTLs. There were no statistically significant group differences in gender, age mean, IQ, HRSD scores and Private SCS scores.

Figure 2 shows the range of embarrassment scores measured during the MRI scanning. A three-way ANOVA, with face type (SELF, OTHER) × observation (OB, NOB) × group (CTL, SAD), revealed a significant main effect of face type ($F(1, 28) = 199.15, p < 0.001$), group ($F(1, 28) = 12.15, p < 0.01$), and observation ($F(1, 28) = 8.17, p < 0.01$). Significant group x face type interaction ($F(1, 28) = 5.12, p < 0.05$) and face type x observation interaction ($F(1, 28) = 4.25, p < 0.05$) were also observed. Post-hoc tests revealed that the SAD group reported greater embarrassment for self-images as compared with the CTLs ($p < 0.01$), while there was no group difference in the
embarrassment ratings for face images of others and observation enhanced the embarrassment significantly for self-face ($p < 0.01$), but not for other-face. Preplanned paired $t$-tests were performed separately for each group and each face type showed that being observed significantly increased the extent of embarrassment provoked by self-face in the CTL group ($t(17) = 2.86, p < 0.05$), but not in the SAD group ($t(13) = 1.11, p = 0.28$). Considering this result as ceiling effect in SAD group, we focused on the group difference in behavioral and brain responses to self-face, collapsing across conditions of observation. Figure 3 summarizes the

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**Figure 2** Result of Embarrassment Scores of Both Groups with Three-Way Analysis of Variance (ANOVA)

*Note.* The embarrassment elicited by self-face images was significantly higher in the SAD group than the CTL group. There was no significant observation effect in the SAD group. Error bars indicate standard deviation.

Abbreviations: OB; observed condition, NOB; non-observed condition, CTL group; control group, SAD group; social anxiety disorder group

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**Figure 3** Result of Embarrassment Scores of Both Groups with Two-Way ANOVA

*Note.* The embarrassment for self-face images was significantly higher in the SAD group than the CTL group. Error bars indicate standard deviation.

Abbreviations: CTL group; control group, SAD group; social anxiety disorder group

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**Figure 4** Result of Photogenicity Ratings of Both Groups with Two-Way ANOVA

*Note.* The photogenicity score for self-face was significantly lower in the SAD group than the CTL group. Error bars indicate standard deviation.

Abbreviations: CTL group; control group, SAD group; social anxiety disorder group
average embarrassment ratings for each face in each group.

Figure 4 shows the average photogenicity ratings measured outside the MRI scanner. A two-way ANOVA, with face type (SELF, OTHER) × group (CTL, SAD), revealed a significant main effect of face type ($F(1, 28) = 83.67, p < 0.001$). A significant group × face type interaction was also observed ($F(1, 28) = 5.64, p < 0.05$). Post-hoc tests revealed that the SAD group reported
lower photogenicity ratings for self-images as compared with the CTL group (p<0.05), while there was no group difference in the photogenicity ratings for other images.

2. fMRI results

First, we identified the brain regions showing self-related activity (SELF vs. OTHER) in each group. The CTLs showed significant self-related activation in the bilateral insular cortex, medial frontal gyrus including anterior cingulate cortex, inferior frontal gyrus, and inferior/middle occipital gyrus (Figure 5 top, Table 2). In contrast, the SAD group showed bilateral insular cortex, anterior cingulate cortex, and right inferior frontal gyrus (Figure 5 middle, Table 3). We found that the SAD group showed greater self-related activation in the medial frontal gyrus (x = −10, y = 58, z = 20) as compared with the CTLs, which well corresponds to the arMPFC known to play a key role in self-reflection (Figure 5 bottom, Table 4). We confirmed

| Table 2 | Significantly more activated voxels in the control group in the contrast of SELF minus OTHERS condition |
|---------|-------------------------------------------------------------------------------------------------------|
| Structure                  | MNI Coordinates | t      | p          | Cluster size (Voxels) |
| Left insular cortex        | −32 18 6       | 6.18   | <0.001    | 1054                  |
| Left inferior frontal gyrus| −32 20 −6    | 5.18   |           |                       |
| Left middle occipital gyrus| −36 −84 −4   | 4.37   | 0.009     | 266                   |
| Right insular cortex       | 32 18 2      | 6.10   | <0.001    | 1172                  |
| Right inferior frontal gyrus| 42 10 30    | 6.78   | <0.001    | 579                   |
| Right precentral gyrus     | 52 12 40    | 4.99   |           |                       |
| Right inferior occipital gyrus| 30 −86 −4 | 5.65   | <0.001    | 460                   |
| Right medial frontal gyrus | 4 12 52   | 5.59   | <0.001    | 496                   |
| Right anterior cingulate cortex| 6 16 26 | 4.20   |           |                       |

| Table 3 | Significantly more activated voxels in the social anxiety group in the contrast of SELF minus OTHERS condition |
|---------|-------------------------------------------------------------------------------------------------------|
| Structure                  | MNI Coordinates | t      | p          | Cluster size (Voxels) |
| Left insular cortex        | −28 16 −6      | 6.01   | <0.001    | 1027                  |
| Left anterior cingulate cortex| −10 32 28  | 4.24   | 0.003     | 326                   |
| Right inferior frontal gyrus| 44 34 6     | 4.86   | 0.043     | 181                   |
| Right insular cortex       | 34 12 −4     | 4.41   | 0.046     | 177                   |

| Table 4 | Significantly more activated voxels in the social anxiety group than control group in the contrast of SELF minus OTHERS condition |
|---------|-------------------------------------------------------------------------------------------------------|
| Structure                  | MNI Coordinates | t      | p          | Cluster size (Voxels) |
| Left medial frontal gyrus  | −10 58 20     | 4.44   | 0.031     | 197                   |
| Right postcentral gyrus    | 22 −42 70    | 6.20   | <0.001    | 454                   |
that the arMPFC activity for the self-face was substantially increased as compared to that for others’ faces in the SAD group, while it was decreased as compared to that for others’ faces in the CTLs (Figure 6).

Then, we searched for the brain regions where the self-related activity was positively correlated with the LSAS score in the whole brain. As a result, we found significant clusters only in the bilateral arMPFC (Figure 7, Table 5). The self-related activation of the peak in each hemisphere was also significantly correlated with BFNE (left: $r = 0.62, p < 0.001$; right: $r = 0.63, p < 0.001$), and public SCS scores (left: $r = 0.37, p < 0.05$; right: $r = 0.57, p < 0.001$). These arMPFC were almost the same with the brain regions showing the significant group difference in the self-related activity.
Discussion

1. Behavioral level

In this study, we investigated emotional and neural responses to self-face images in patients with SAD, especially when they were being observed by others. We found that patients with SAD experienced stronger embarrassment for self-face as compared with the CTLs. In addition, we found a significant group difference in the observation effect on the embarrassment. Embarrassment for self-face was enhanced by observation by others in the CTLs, but not in the patients with SAD. The lack of observation effect might have resulted from ceiling effect: since the strength of embarrassment was already so high even without observation, it could not be further enhanced by observation. Regardless of the presence/absence of the ceiling effect, we can emphasize that patients with SAD experienced excessive embarrassment for self-face even without observation.

It is widely accepted that discrepancy between the actual self-image and a standard or ideal image leads to reduction in self-esteem and to negative affect (Buss, 1980; Carver, 1998). Consistent with this view, a previous study showed that healthy individuals feel strong embarrassment when they view their own face-images which they evaluate as “bad” (Morita et al., 2008). In the present study, such close relationship between negative evaluation and embarrassment was also observed in both groups.

According to previous clinical studies, patient with SAD showed heightened self-reflection (Clark & Wells, 1995; Philippi & Koenigs, 2014). They had a tendency to strictly direct their attention inwardly to themselves. In particular, they engaged in self-reflected thoughts concerning negative self-appraisal and expectation for negative appraisal from others (Smith & Sarason, 1975). A lot of studies have shown that patients with SAD appraise their own performance more negatively than ratings made by others (Alden & Wallace, 1995; Meltings & Alden, 2000; Abbott & Rapee, 2004). Consistent with these findings, in this study, photogenicity ratings for their self-face were lower in the SAD group (Figure 4). When we prepared the face stimuli, each face image was rated by an experimenter according to attractiveness and the scores of SELF images matched across participants. These indicate that individuals with SAD had more negative self-evaluation than CTLs, even though there was no group difference in objective photogenicity.

Considering the close relationship between negative evaluation and embarrassment, negative self-evaluation in patients with SAD may cause excessive embarrassment when they view their self-face.

According to previous psychological studies, patients with SAD tend to have negative self-image and to see oneself from observers’ perspective (Hackmann & Clark, 1998; Wells & Papageorgiou, 1999; Spurr & Stopa, 2003). When considering the self-reflected in others,

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| Table 5 | Significantly more activated voxels as a result of correlation analysis with LSAS |
|---------|---------------------------------------------------------------|
| Structure | MNI Coordinates | t | p | Cluster size (Voxels) |
|----------|-----------------|---|---|----------------------|
| Left medial frontal gyrus | -10 | 58 | 20 | 4.12 | 0.015 | 235 |
| Right middle frontal gyrus | 22 | 54 | 26 | 4.68 | 0.021 | 215 |

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patients with SAD reinforce the negative self-image. In other words, their self-evaluation is strongly influenced by the expectation for negative evaluation by others. This “evaluation by others” is not necessarily an actual evaluation but merely their imagination. As a result of expectation for negative evaluation by others even in the absence of an observer, their self-esteem is lowered and they feel more embarrassed.

2. Neural level

According to the behavioral result, we focused on the group difference of self-face effect in neural activity. Although brain regions showing self-related activity (by SELF-OTHER contrast) in each of CTLs and SAD are almost consistent with the previous studies (Morita et al., 2008, 2014). However, the SAD group showed stronger self-related activity in the left arMPFC as compared with CTLs. We could not identify the arMPFC in brain regions which showed significant self-related activity in the SAD group, as shown in figure 5 (middle). However, at more lenient threshold of $p<0.001$ uncorrected, we observed significant self-related activation in the arMPFC. Therefore, it is likely that the arMPFC activity for the self-face was increased as compared to that for others’ faces in the SAD group, while it was not the case in the CTLs. Furthermore, we found that the self-related activity in the bilateral arMPFC was positively correlated with LSAS scores.

arMPFC is located in the rostral portion of the medial prefrontal cortex and is represented by the Brodmann area 10. Recently, it is revealed that it works as a part of default mode network (Shulman et al., 1997; Philippi & Koenigs, 2014) which plays a major role in self-reflection. Several studies showed that self-report assessments of self-reflection are associated with default mode network activity (Philippi & Koenigs, 2014). Moreover, Amodio et al. (Amodio & Frith, 2006) summarized the role of arMPFC. According to this, there are three major roles: (1) Self-knowledge (e.g., evaluation of self-related traits or monitoring of one’s own emotional state), (2) Person perception, and (3) Mentalization (e.g., predicting the behaviour of others). Among the three roles, the neural mechanism of self-knowledge processing was well established using personality trait judgment tasks (Johnson et al., 2002; Kelley et al., 2002; Zysset et al., 2002; Schmitz et al., 2004) or self-image tasks (Sugiura et al., 2005). The results are recognized as the neural representation of self-reflection. Thus, arMPFC is an area that contributes to the self-reflection including self-knowledge processing.

In our study, we used self-face images and asked the subjects to report their embarrassment. This self-trait and emotion evaluation process is a kind of the self-knowledge processing included in the self-reflection (Amodio & Frith, 2006). During this self-knowledge processes including the evaluation of self-related trait or monitoring of participants’ own emotional state, patients with SAD might recognize their self-face as important self-knowledge information and ruminate negative self-reflection as compared with the CTLs. Positive correlation between the LSAS scores and the self-related activity in the arMPFC suggests that the pathology of SAD is in the dysfunctional self-reflection which causes the prediction of negative responses of others which in turn induces anxiety. Besides, not only LSAS but also the result of correlation analyses of BFNE and SCS in the whole brain detected the arMPFC although it was not statistically significant.
These results also support the relationship among low self-evaluation, self-reflected thought and excessive embarrassment for their self-images as well as in the behavior results.

Primarily, we speculate that our result can be explained by the self-knowledge processing, however, self-reflection may be used to infer the mental state of others (Mitchell et al., 2005). Although, expecting the mental state of others is so-called “mentalization”, Mitchell et al (Mitchell et al., 2005) suggested that self-reflection was used to infer this. They also mentioned about the false consensus effect. This means that people tend to believe that their own opinions represent other people’s opinion (Ross et al., 1977; Nickerson, 1999). This is truly applied to the pathology of SAD (Clark & Wells, 1995). Thus, we speculate that our result may contain elements of mentalization.

3. Limitations

The present study had several limitations. First, some of the patients had comorbid psychiatric disorders. However, their HRSD scores were at a low level and there was no statistically significant group difference. Second, psychotropic medications were allowed except the day of the scanning. This might have had an effect on outcome. Third, observation effect was mostly replicated in the behavior result and anterior cingulate cortex, however, there was a small discrepancy in self-related activity of the right anterior insula. It might have been caused due to the difference in the participants’ characteristics: their ages being higher than those in the previous studies (Morita et al., 2014). Consciousness for observation by others is excessive in adolescents and tends to decrease with the age (Horii, 2002). Because this study was conducted at small sample size, we could not correct the results according to age, gender, and depression level. Our result should be confirmed at lager sample.

Despite the several limitations, this is the first study that has found out about the neural basis of embarrassment and self-reflection in patients with SAD. In the future study it might be interesting that we can compare the activity of arMPFC before and after treatment.

[Conclusion]

We suggest that the arMPFC takes charge of the elevated-level of self-reflection in patients with SAD, and the level of the neural activity is correlated with the severity of the symptom.

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