NeuroImage

www.elsevier.com/locate/ynimg
NeuroImage 23 (2004) 967–974

Brain activation associated with evaluative processes of guilt and embarrassment: an fMRI study

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Received 21 January 2004; revised 5 June 2004; accepted 19 July 2004
Available online 6 October 2004

We aimed to investigate the neural substrates associated with evaluative process of moral emotions. Using functional magnetic resonance imaging (fMRI), we examined the similarities and differences between evaluative process of guilt and that of embarrassment at the neural basis level. Study of the neural basis of judgments of moral emotions might contribute to a better understanding of the amoral behavior observed in neurological and psychiatric disorders. Nineteen healthy volunteers were studied. The participants read sentences carrying neutral, guilty, or embarrassing contents during the scans. Both guilt and embarrassment conditions commonly activated the medial prefrontal cortex (MPFC), left posterior superior temporal sulcus (STS), and visual cortex. Compared to guilt condition, embarrassment condition produced greater activation in the right temporal cortex (anterior), bilateral hippocampus, and visual cortex. Most of these regions have been implicated in the neural substrate of social cognition or Theory of Mind (ToM). Our results support the idea that both are self-conscious emotions, which are social emotions requiring the ability to represent the mental states of others. At the same time, our functional fMRI data are in favor of the notion that evaluative process of embarrassment might be a more complex process than that of guilt.

Keywords: Guilt; Embarrassment; Social cognition; Theory of Mind; Medial prefrontal cortex; Superior temporal sulcus

Introduction

Although there have been numerous neuroimaging studies on primary emotions (fear, disgust, happiness, and sadness) that have led to a better understanding of the neuroanatomical correlates of emotions (Phan et al., 2002), only a few studies on complex social emotions such as guilt, shame, and embarrassment have been reported. These social emotions have been viewed as moral emotions because they occur in response to moral violation and promote moral behavior, interpersonal etiquette, and personal hygiene (Eisenberg, 2000; Haidt, 2003). At the same time, these emotions inhibit transgression of social standards and motivate reparative action such as apology, confession, and atonement.

Impairment of possessing the mental states of these moral emotions could lead to amoral, inappropriate behaviors observed in neurological and psychiatric disorders such as brain injuries (Anderson et al., 1999; Beer et al., 2003), frontotemporal dementia (Miller et al., 2003; Snowden et al., 2002), autism (Capps et al., 1992; Frith, 2001; Hillier and Allinson, 2002), and antisocial personality (Brower and Price, 2001; Moll et al., 2003). Studying the neural substrates of judgments of moral emotions should add to the understanding of the neural basis of amoral behaviors observed in neurological and psychiatric disorders.

From a psychological point of view, guilt, shame, embarrassment, and pride are categorized into the same emotion family, "self-conscious emotions". "Self-conscious emotions" are emotions founded in social relationship and arise from concerns about others' opinions of self or the behavior of self (Eisenberg, 2000; Haidt, 2003; Tangney and Dearing, 2002). Negative evaluation of self or the behavior of self is fundamental to guilt, shame, and embarrassment, while positive evaluation of self leads to pride. In other words, one needs the ability to represent the mental states of others (intention/emotion), that is, Theory of Mind (ToM), to recognize self-conscious emotions. The recognition of negative self-conscious emotions involves understanding of the violation of social norms and the negative evaluation of self, both important aspects of ToM. Children with autism demonstrating impaired ToM showed impaired recognition of self-conscious emotions (Heerey et al., 2003). In line with this notion, a recent functional magnetic resonance imaging (fMRI) study demonstrated activation in the medial prefrontal cortex (MPFC), temporal regions, and orbito-

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Available online on ScienceDirect (www.sciencedirect.com.)

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doi:10.1016/j.neuroimage.2004.07.054

frontal cortex (OFC) during the emotional judgments of embarrassment (Berthoz et al., 2002). These areas have been implicated in ToM, social cognition, and moral judgment (Adolphs, 2001; Allison et al., 2000; Frith, 2001; Frith and Frith, 1999; Greene and Haidt, 2002; Greene et al., 2001; Moll et al., 2003; Pinkham et al., 2003). However, a previous positron emission tomography (PET) study using a guilt-related script reported a slightly different activation pattern in anterior paralimbic regions during the experience of guilt (Shin et al., 2000). In the former fMRI study, an emotional judgment task was used. Participants read various kinds of stories depicting embarrassing situations and were instructed to imagine what the story protagonist (participant himself or a third person in the story) would feel. In the latter PET study, an emotion induction method was used. Participants listened to audio-taped personal events involving the most guilt they had actually experienced. They recalled and imagined the event as if they were actually participating in it again. These two studies differed in the emotional tasks and measurement methods, making it difficult to compare the results directly. To our knowledge, no neuroimaging study has as yet investigated the different types of self-conscious emotions and compared the neural activation patterns directly in one session.

Although the distinctions among guilt, shame, and embarrassment are not clear-cut, psychologists have challenged this issue. Although embarrassment has traditionally been considered to be a variant of shame (Lewis, 1993), recent psychological data support the notion that embarrassment is an emotion distinct from other self-conscious emotions (Keltner and Buswell, 1997). Embarrassment has higher affinity to violation of social conventions, while guilt and shame have higher affinity to violation of a moral norm (Eisenberg, 2000; Haidt, 2003; Tangney et al., 1996). In this sense, among the negative self-conscious emotions, distinction between guilt and embarrassment is considered to be relatively clear-cut. Therefore, we focused on these two emotions.

We used block-design fMRI to measure regional activation associated with judgments of guilt and embarrassment during an emotional judgment task presenting short sentences. Emotion processing is composed of evaluative, experiential, and expressive components. We did not intend to induce emotional states because we thought it would be difficult to induce emotional states of guilt or embarrassment by merely having the subjects read short sentences. Moreover, it would be difficult to control the situation so as not to induce emotions other than guilt and embarrassment (e.g., anger, shame, sadness) as reported in the previous induction study (Shin et al., 2000). We aimed to elucidate the similarities and differences between the evaluative process of guilt and that of embarrassment at the neural basis level by measuring neural activation during judgments of both emotions in a session using fMRI.

We hypothesized that both emotional conditions would commonly activate the components of the neural substrates (MPFC, superior temporal sulcus (STS)) that have been implicated in social cognition (Adolphs, 2001; Allison et al., 2000) or ToM (Frith, 2001; Frith and Frith, 1999), and at the same time, would show differences in the extent of activation of the components.

Method

Participants

Nineteen healthy right-handed Japanese subjects (10 men, mean age 30.8 years, SD = 6.2; nine women, mean age 25.1 years, SD = 3.2) were recruited from the surrounding community. Their mean educational achievement level was 16.2 years (SD = 2.1). They did not meet criteria for any psychiatric disorder. None of the controls were taking alcohol or medication at the time, nor did they have a history of psychiatric disorder, significant physical illness, head injury, neurological disorder, or alcohol or drug dependence. All subjects underwent an MRI to rule out cerebral anatomic abnormalities. After complete explanation of the study, written informed consent was obtained from all subjects, and the study was approved by the Ethics Committee.

Materials

Because our experimental design was a block design, we aimed to control readability, the number of words, and luminance across blocks using short sentences. In addition, we expected participants to make emotional judgments repeatedly in a block. For this reason, we used short sentences instead of other forms, for example, stories. Three types of short sentences were provided (neutral, guilt, and embarrassment). Each sentence was written in Japanese and in the first person, past tense. Each sentence was expected to carry guilt, embarrassment, or no prominent emotional content. To validate our expected results, other healthy volunteers (10 men and 10 women, mean age 28.6 years, SD = 3.7) than the subjects participating in this fMRI study were screened. They read each sentence and rated the described situations according to how guilty or embarrassing they seemed using a 6-point analog scale (1 = none, 6 = extremely intense). As we predicted, the mean ratings of guilt and embarrassment for neutral sentences were 1.0 (SD = 0.1) and 1.0 (SD = 0.1), for guilt-related sentences 4.4 (SD = 0.4) and 1.6 (SD = 0.4), and for embarrassing sentences 1.5 (SD = 0.3) and 3.5 (SD = 0.5), respectively. Examples of the sentences are shown in Table 1. The sentences were projected via a computer and a telephoto lens onto a screen mounted on a head coil. The subjects were instructed to read the sentences silently and were told that they would rate the described situations according to how guilty or embarrassing they seemed. After reading each sentence, the subjects were instructed to press a selection button with the right index finger, indicating that they had read and understood it. The experimental design consisted of six blocks for each of the three conditions (neutral, guilt, and embarrassment) interleaved with 20-s rest periods. The order of presentation for the three conditions was fixed in the neutral–guilt–embarrassment sequence (Fig. 1). During the rest condition,

Table 1
Examples of sentences

Neutral	I used a cellular phone in the park.
	I used a computer on the internet.
	I change into pajamas at night.
	I washed my clothes.
	I had dinner at the restaurant.
Guilt	I used a cellular phone in the hospital.
	I sent a computer virus by e-mail.
	I shoplifted a dress from the store.
	I betrayed my friend.
	I left the restaurant without paying.
Embarrassment	I was not dressed properly for the occasion.
	I mistook a stranger for my friend.
	I noticed that the zipper of my pants was open.
	I soiled my underwear.
	I did not know the right behavior at the restaurant.

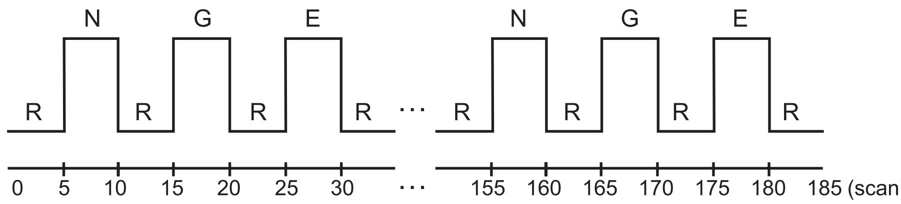

Fig. 1. Block design paradigm in the fMRI study. R = rest, N = neutral, G = guilt, E = embarrassment.

participants viewed a crosshair pattern projected to the center of the screen. In each 20-s block, five different sentences of the same emotional class were presented for 4 s each. After the scan, subjects rated the described situations according to how guilty or embarrassing they seemed using a 6-point analog scale.

Image acquisition

Images were acquired with a 1.5-T Signa system (General Electric, Milwaukee, WI). Functional images of 185 volumes were acquired with T2*-weighted gradient echo planar imaging sequences sensitive to the blood oxygenation level dependent (BOLD) contrast. Each volume consisted of 40 transaxial contiguous slices with a slice thickness of 3 mm to cover almost the whole brain (flip angle, 90°; TE, 50 ms; TR, 4 s; matrix, 64 × 64; field of view, 24 × 24 cm). High-resolution, T1-weighted anatomic images were acquired for anatomic comparison (124 contiguous axial slices, 3D Spoiled-Grass sequence (SPGR), slice thickness 1.5 mm, TE, 9 ms; TR, 22 ms; flip angle, 30°; matrix, 256 × 192; field of view, 25 × 25 cm).

Analysis of functional imaging data

Data analysis was performed with statistical parametric mapping software package (SPM99) (Wellcome Department of Cognitive Neurology, London, UK) running with MATLAB (Mathworks, Natick, MA). All volumes were realigned to the first volume of each session to correct for subject motion and were spatially normalized to the standard space defined by the Montreal Neurological Institute (MNI) template. After normalization, all scans had a resolution of $2 \times 2 \times 2$ mm^3. Functional images were spatially smoothed with a 3D isotropic Gaussian kernel (full width at half maximum of 8 mm). Low frequency noise was removed by applying a high-pass filter (cutoff period = 240 s) to the fMRI time series at each voxel. A temporal smoothing function was applied to the fMRI time series to enhance the temporal signal-to-noise ratio. Significant hemodynamic changes for each condition were examined using the general linear model with boxcar functions convoluted with a hemodynamic response function. Statistical parametric maps for each contrast of the t statistic were calculated on a voxel-by-voxel basis. The t values were then transformed to unit normal distribution, resulting in Z scores.

To assess the specific condition effect, we used the contrasts of guilt minus neutral (G − N) and embarrassment minus neutral (E − N). A random effects model, which estimates the error variance for each condition across subjects, was implemented for group analysis. This procedure provides a better generalization for the population from which data are obtained. The contrast images were obtained from single-subject analysis and were entered into the group analysis. A one-sample t test was applied to determine group activation for each effect. Significant clusters of activation were determined using the conjoint expected probability distribution of the height and extent of Z scores with the height ($Z > 3.09$; $P <$

Table 2
Brain activation in guilt condition and embarrassment condition relative to neutral condition

Brain region	Coordinates			BA	Z score	Voxels
	x	y	z			
Guilt minus neutral						
L visual cortex (cuneus, LG)	−6	−95	12	17,18,19	4.55	1114
R visual cortex (LG)	2	−85	6	17,18	5.41	
L MPFC (MFG, SFG)	−16	49	9	6,8,9,10	4.7	1175
R MPFC (MFG)	4	57	16	9,10	3.62	
L posterior STS (MTG)	−44	−61	20	39	4.4	210
Embarrassment minus neutral						
L visual cortex (cuneus, LG, FG)	−2	−89	4	17,18,19	4.91	4343
R visual cortex (cuneus, LG)	20	−70	0	17,18	5.52	
L MPFC (MFG, SFG)	−8	50	25	6,8,9,10	4.44	840
R MPFC (MFG, SFG)	2	59	17	9,10	3.75	
L posterior STS (MTG, STG)	−42	−59	18	39	4.24	185
L middle temporal cortex (MTG)	−51	−31	−7	21	4.56	132
L anterior temporal cortex (MTG)	−53	1	−24	21	4.3	50
R anterior temporal cortex (MTG, FG)	48	−7	−27	20	3.69	44
L OFC (IFG)	−44	31	−7	47	3.68	36
L hippocampus	−34	−18	−18		3.85	23

Coordinates and Z score refer to the peak of each brain region. BA = Brodmann area; L = left; R = right; LG = lingual gyrus; FG = fusiform gyrus; MFG = medial frontal gyrus; SFG = superior frontal gyrus; MTG = middle temporal gyrus; STG = superior temporal gyrus; IFG = inferior frontal gyrus; MPFC = medial prefrontal cortex; STS = superior temporal sulcus; OFC = orbitofrontal cortex.

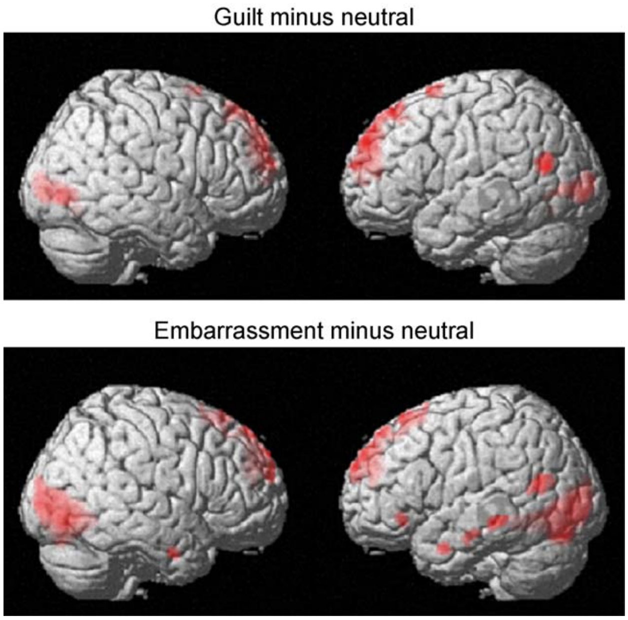

Fig. 2. Images showing brain activation in guilt and embarrassment conditions relative to neutral condition. Guilt minus neutral (top). Activated regions were in the MPFC, posterior STS, and visual cortex. Embarrassment minus neutral (bottom). In addition to activations in the MPFC, left posterior STS, and visual cortex, more widespread activations were shown in the left OFC, left temporal cortex (anterior and middle), and right temporal cortex (anterior). Note that both emotional conditions commonly activated the MPFC, left posterior STS, and visual cortex. Significant differences were recognized at a height threshold ($Z > 3.09$; $P < 0.001$, uncorrected) and extent threshold (15 voxels).

0.001, uncorrected) and extent threshold (15 voxels). We used a relatively large extent threshold to sufficiently minimize the risk of type 1 errors due to the relatively low height threshold. To assess common areas activated by the guilt and embarrassment conditions, we created a mask from the G − N contrast in the random effect analysis (threshold at $P < 0.001$, uncorrected). This mask was applied inclusively to the E − N contrast.

To ensure relative differences between activity associated with guilt and embarrassment, random effect analyses of guilt minus embarrassment contrast (G − E) and embarrassment minus guilt contrast (E − G) were conducted. Because one of the aims of this study was to investigate differences between guilt and embarrassment at the neural basis level, we reported the differences at a lower threshold (height threshold at $P < 0.005$, uncorrected, and extent threshold of 15 voxels).

We conducted additional analysis to demonstrate a more direct link between regional brain activity with subjective emotional judgments. Using the mean of ratings of guilt and embarrassment for each subject as the covariate, regression analyses with the contrast (G − N and E − N) and the covariate were done at the second level (height threshold at $P < 0.001$, uncorrected, and extent threshold of 15 voxels). Using the effect sizes, representing the percent signal change, of the contrasts (E − N and G − N) at the peak coordinates uncovered by regression analyses, we plotted fMRI signal changes and ratings of guilt and embarrassment. Coordinates of activation were converted from MNI coordinates to the Talairach and Tournoux (1988) coordinates using the mni2tal algorithm (M. Brett, Cambridge, MA).

Results

Self-rating

The neutral sentences were judged as carrying neither guilty nor embarrassing contents. The mean ratings of guilt and embarrassment for neutral sentences were, respectively, 1.0 (SD = 0.0) and 1.0 (SD = 0.0), for guilt-related sentences 4.1 (SD = 0.7) and 1.6 (SD = 0.7), and for embarrassing sentences 1.5 (SD = 0.4) and 3.7 (SD = 0.6). The mean ratings of guilt were significantly greater for guilt-related sentences than for embarrassing sentences ($t = 10.6$, $df = 36$, $P < 0.001$). The mean ratings of embarrassment were significantly greater for embarrassing sentences than for guilt-related sentences ($t = 12.4$, $df = 36$, $P < 0.001$).

fMRI result

Guilt condition relative to neutral condition (G − N) produced greater activations in the MPFC, left posterior STS, and visual cortex. Embarrassment condition relative to neutral condition (E − N) produced greater activations in the MPFC, left posterior STS, left temporal cortex (anterior and middle), left orbitofrontal cortex (OFC), right temporal cortex (anterior), left hippocampus, and visual cortex (Table 2 and Fig. 2). In other words, both conditions commonly activated the MPFC, left posterior STS, and visual cortex (Table 3), but the embarrassment condition produced more widespread activations in the left temporal cortex (anterior and middle), right temporal cortex (anterior), left OFC, and left hippocampus.

Embarrassment condition relative to guilt condition (E − G) produced greater activation in the right temporal cortex (anterior), bilateral hippocampus, and visual cortex. In contrast, guilt condition relative to embarrassment condition (G − E) produced greater activation in the MPFC (Table 4 and Fig. 3).

Regression analyses revealed positive linear correlations between self-rating of guilt and the degree of activation in the

Table 3
Brain regions commonly activated by guilt and embarrassment conditions

Brain region	Coordinates			BA	*Z* score	Voxels
	x	*y*	*z*			
L visual cortex (LG)	−12	−77	6	17,18,19	4.37	1021
R visual cortex (LG)	2	−85	6	17,18	5.41	
L MPFC (MFG, SFG)	−10	36	52	8,9,10	4.35	429
R MPFC (MFG)	4	57	16	10	3.62	
L posterior STS (MTG)	−44	−61	20	39	4.4	101

A mask from the G − N contrast by random effect analysis (threshold at $P < 0.001$, uncorrected) was applied inclusively to the E − N contrast (height threshold at $P < 0.001$, uncorrected, and extent threshold of 15 voxels). See Table 2 legend.

Table 4
Comparisons between regional brain activities associated with guilt and embarrassment

Brain region	Coordinates			BA	*Z* score	Voxels
	x	*y*	*z*			
Embarrassment minus guilt						
R visual cortex (cuneus, LG, FG)	12	−83	8	17,18,19	3.28	393
R visual cortex (IOG)	38	−68	−5	19	3.59	49
L visual cortex (LG)	−10	−62	−2	18,19	3.48	140
L visual cortex (LG)	−8	−80	1	19	2.86	77
R anterior temporal cortex (MTG)	42	−3	−27	21	2.96	25
R hippocampus	32	−18	−13		2.91	32
L hippocampus	−20	−14	−9		3.21	49
Guilt minus embarrassment						
L MPFC (MFG)	−16	49	14	10	3.39	24

Random effect analyses of G − E and E − G contrast were conducted. See Table 2 legend.

MPFC (medial frontal gyrus, $x = -8$, $y = 55$, $z = 3$; $Z = 4.26$; 31 voxels), posterior STS (middle temporal gyrus, $x = -58$, $y = -56$, $z = 10$; $Z = 4.23$; 81 voxels), and visual cortex (lingual gyrus, $x = -14$, $y = -58$, $z = 3$; $Z = 3.82$; 24 voxels). There were positive linear correlations between self-rating of embarrassment and the degree of activation in the posterior STS (middle temporal gyrus, $x = -46$, $y = -57$, $z = 23$; $Z = 3.88$; 37 voxels) and visual cortex (lingual gyrus, $x = -16$, $y = -49$, $z = -4$; $Z = 3.48$; 20 voxels) (Figs. 4 and 5).

Discussion

We investigated the neural response associated with evaluative processes of self-conscious moral emotions. Recent neuroimaging studies have reported the neural substrate of moral judgment (Greene et al., 2001; Moll et al., 2002a,b). However, few reports are available on specific moral or social emotions (Berthoz et al., 2002; Shin et al., 2000). This study showed similarities and differences during evaluative processes of two moral emotions, guilt and embarrassment, at the neural basis level by measurements of neural responses in the same session.

As we predicted, both guilt and embarrassment conditions relative to neutral condition commonly produced greater activity in the components of neural substrates of social cognition or ToM, the MPFC, left posterior STS, along with the visual cortex. Several neuroimaging studies in healthy subjects using different variants of the ToM paradigm have consistently reported activation in the MPFC, predominantly on the left side (Fletcher et al., 1995; Gallagher et al., 2000; Goel et al., 1995). Additionally, autism, which is considered to have impairments in ToM, showed reduced activation in the MPFC (Baron-Cohen et al., 1999; Castelli et al., 2002; Happe et al., 1996). The MPFC has been suggested to play an important role in monitoring one's own mental state as well as that of others (Castelli et al., 2000; Frith, 2001). Recent studies reported that the MPFC was also recruited in moral judgment (Greene et al., 2001; Heekeren et al., 2003).

Activations in the posterior STS have also been consistently reported in social cognition or ToM tasks (Calder et al., 2002; Castelli et al., 2000; Gallagher et al., 2000; Winston et al., 2002) and in moral judgment tasks (Greene et al., 2001; Heekeren et al., 2003), while the area identical to the posterior STS was variously described as the temporoparietal junction or angular gyrus. Originally, STS was known to be activated by biological motions such as movement of eyes, mouth, hands, and body, but it has been suggested to have a more general function in social cognition (Adolphs, 2001; Allison et al., 2000), detection of intention (Gallagher et al., 2000), evaluation of trustworthiness of faces (Winston et al., 2002), detection of the behavior of agents and analysis of goal, and outcome of the behavior (Frith, 2001; Frith and Frith, 1999).

Common activations in the MPFC and posterior STS support the notion that both guilt and embarrassment are self-conscious

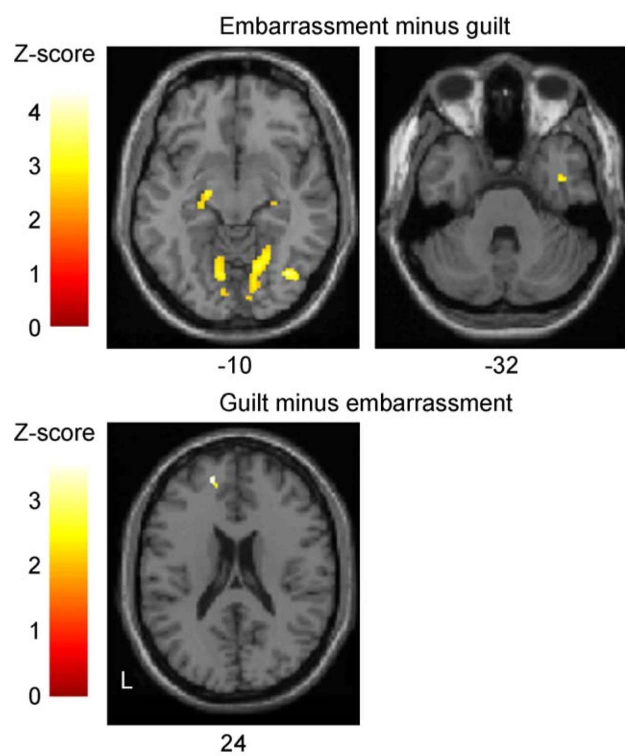

Fig. 3. Comparison of guilt and embarrassment conditions with height threshold ($P < 0.005$) and extent threshold (15 voxels). Embarrassment minus guilt (top). Compared to guilt, greater activation was shown in the right temporal cortex (anterior), bilateral hippocampus, and visual cortex. Guilt minus embarrassment (bottom). Compared to embarrassment, greater activation was shown in the MPFC. The bar shows the range of the Z score. Within the image, L indicates left. Numbers in the bottom row indicate the z coordinates of the Montreal Neurological Institute brain.

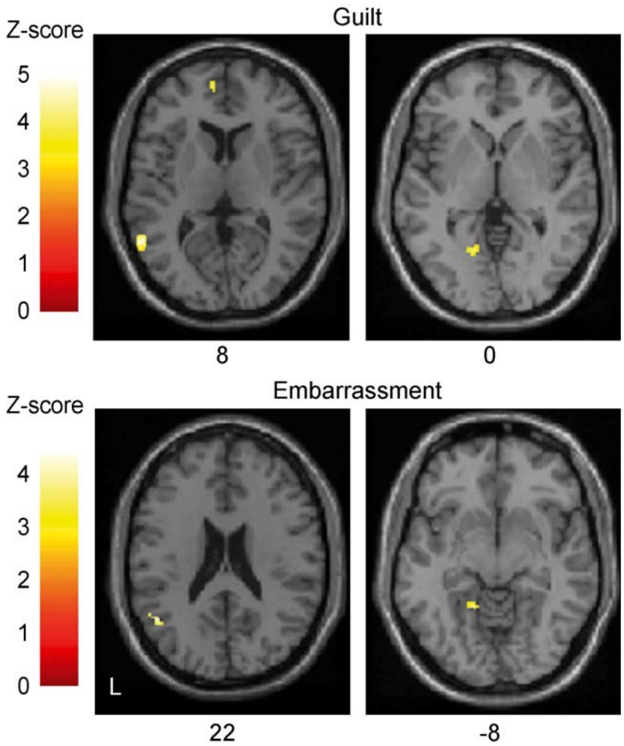

Fig. 4. Correlation between brain activation and the self-ratings of guilt and embarrassment with height threshold ($P < 0.005$) and extent threshold (15 voxels). There were positive linear correlations between self-rating of guilt and the degree of activation in the posterior STS and visual cortex (top). There were positive linear correlations between self-rating of embarrassment and the degree of activation in the posterior STS and visual cortex (bottom). The bar shows the range of the Z score. Within the image, L indicates left. Numbers in the bottom row indicate the z coordinates of the Montreal Neurological Institute brain.

emotions that can arise from concerns about others' evaluation of one's own behavior (Eisenberg, 2000; Haidt, 2003; Tangney and Dearing, 2002). In other words, one needs the ability to take the perspective of others and to represent their mental state, that is, ToM, to understand the sense of guilt or embarrassment.

In spite of our attempt to control the linguistic features of the visual stimuli, increased activations were found in the visual cortex in response to the emotional conditions relative to the neutral condition. Enhanced visual cortex activations by emotionally salient visual stimuli have been extensively reported (Phan et al., 2002; Takahashi et al., 2004). Emotionally salient stimuli or attention demanding stimuli have been suggested as modulating sensory processing in the visual cortex. Early visual cortex receives prominent feedback projection from limbic structures such as amygdala (Emery and Amaral, 2000), and such pathway could act to enhance visual processing (Morris et al., 1998; Vuilleumier et al., 2001).

Interestingly, compared to the G − N contrast, the E − N contrast demonstrated more widespread activations in the left temporal cortex (anterior and middle), right temporal cortex (anterior), left OFC, and left hippocampus. Direct comparison between guilt and embarrassment conditions showed that the E − G contrast demonstrated significantly greater activation in the right anterior temporal cortex, bilateral hippocampus, and visual cortex. All these regions are also considered as the brain area related to social or moral cognition (Adolphs, 2001; Casebeer, 2003; Greene and Haidt, 2002; Moll et al., 2003). We did not expect the greater activation in the hippocampus in the embarrassment condition. The hippocampus is suggested to engage in retrieving behaviorally relevant memories (Strange et al., 1999). In moral judgment, the hippocampus might facilitate conscious recollection of memories that allow past events to affect current decisions (Casebeer, 2003).

Embarrassment has a higher affinity to the violation of social conventions (choices of clothing, etiquette and hygiene, etc.) that depend on societies or cultures, while guilt has a higher affinity to the violation of moral norms (issues of harm, right and justice, etc.) that are universal among human beings (Eisenberg, 2000; Haidt, 2003; Tangney et al., 1996). Moreover, embarrassment is uniquely a public emotion that depends on a real or imagined presence of others among one's self-conscious emotions. If people do experience embarrassment in private, it is a situation of vividly imagining what others might think of them (Miller, 1996; Tangney et al., 1996). Guilt does not necessarily depend on personal acquaintances. Guilt could be elicited not only by concerns with others' evaluation of self but also by private conscience (Haidt, 2003; Tangney and Dearing, 2002; Tangney et al., 1996). In light of these points, embarrassment could be regarded as a more social and public emotion that depends on personal interactions. Regression analyses showed that subjective ratings of guilt and embarrassment correlated with the degree of activation in the posterior STS, visual cortex, and MPFC, brain areas commonly activated by both emotional conditions. In other words, emotional intensity did not appear to account for the more widespread activation observed in embarrassment condition. Considering the regression analyses results, our interpretation was that the additional activations found in embarrassment condition might reflect more complex processes that detect and understand the complex social information of embarrassment.

This study has some limitations. First, a moral emotion could be accompanied by another emotion. For instance, guilt and shame could co-occur in some situations (Eisenberg, 2000). In moral transgression, people may feel guilty for violating a social norm and at the same time might feel shameful about one's own shortcomings. For this reason, we carefully chose the situations, although we understand that it is not feasible to extract "pure" emotion. Second, as mentioned above, embarrassment depends on society and culture. The social background of participants, such as gender, generation, religion, and education, could be confounding factors. Further studies that can control these factors would be recommended. Finally, we should acknowledge general limitations of a functional imaging study to reveal the neural substrates of social cognition or social emotions. The processing of social information is distributed in space and time, ranging from the perception of socially relevant stimuli to the elicitation of social behavior. Most functional imaging studies focused on the perception and interpretation of socially relevant stimuli. Emotional judgment tasks such as facial expression discrimination task or our task could also be regarded as a task of the perception and interpretation of socially relevant stimuli. It should be noted that emotional states that elicit social or emotional behaviors are not necessarily induced by merely viewing facial expressions or reading sentences. Social cognition is a domain with fuzzy boundaries and vaguely specified components. Processes of social cognition overlap with those of emotions. Although it is difficult to assess specific components of social cognition or emotions by a single modality, at least in this study, we assessed the evaluative processes of moral emotions. To complement fMRI studies, electrophysiological methods that have good temporal resolution

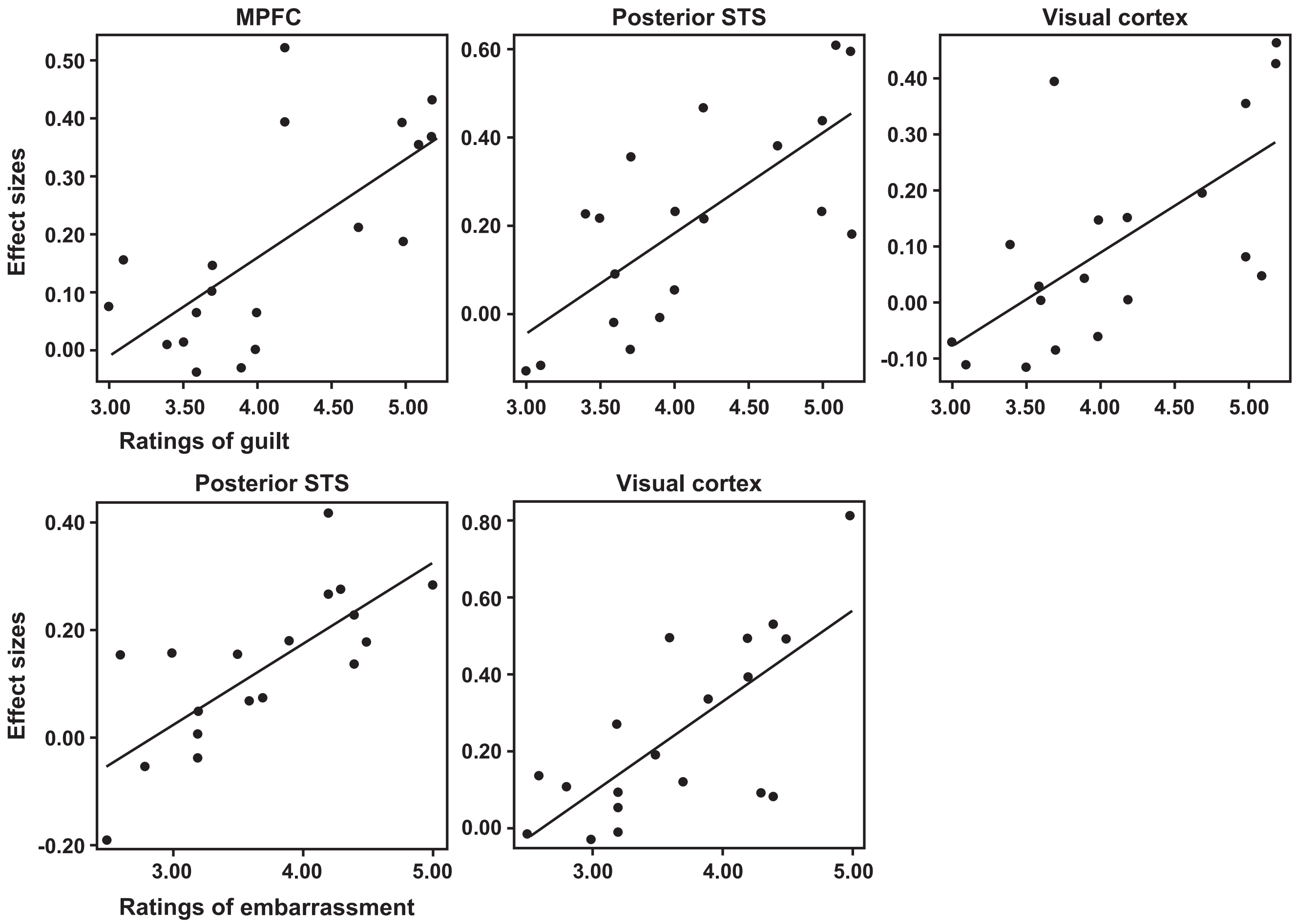

Fig. 5. Plots and regression lines of correlations between self-ratings and degree of activation in the brain regions. There were correlations between self-rating of guilt and degree of activation in the MPFC ($x = -8$, $y = 55$, $z = 3$, $r = 0.686$, $P < 0.005$), posterior STS ($x = -58$, $y = -56$, $z = 10$, $r = 0.722$, $P < 0.005$), and visual cortex ($x = -14$, $y = -58$, $z = 3$, $r = 0.653$, $P < 0.005$) (top). There were positive linear correlations between self-rating of embarrassment and degree of activation in the posterior STS ($x = -46$, $y = -57$, $z = 23$, $r = 0.744$, $P < 0.005$) and visual cortex ($x = -16$, $y = -49$, $z = -4$, $r = 0.719$, $P < 0.005$) (bottom).

would be recommended. Moreover, it is difficult to assess real-life human social behavior or to induce complex emotions in an MRI environment. Lesion studies can at least indicate the structures necessary for mediating social behavior (Adolphs, 2003).

Notwithstanding the difficulties in measuring social behavior, recording autonomic responses will be useful for assessing some aspects of social behavior or emotional responses. For instance, monitoring blushing, the hallmark of embarrassment, by recording face temperature or facial blood flow will be useful to distinguish embarrassment from guilt (Gerlach et al., 2003).

In conclusion, we investigated the neural substrates of evaluative processes of specific moral emotions and demonstrated similarities and differences between guilt and embarrassment at the neural basis level. Supporting the concept that both guilt and embarrassment could be regarded as self-conscious emotions, both emotional conditions produced similar activation patterns in the components of neural substrates implicated in social cognition or ToM. Moreover, our fMRI data lead us to conjecture that the evaluative process of embarrassment might be a more complex process than that of guilt. We expect our findings to contribute to a broadening of the knowledge concerning the neural basis of amoral behavior observed in neurological and psychiatric disorders.

Acknowledgments

We thank Professor Toru Nishikawa of the Section of Psychiatry and Behavioral Science, Graduate School of Medicine, Tokyo Medical and Dental University. The staff of the Section of Biofunctional Informatics, Graduate School of Medicine, Tokyo Medical and Dental University, and of Asai Hospital are gratefully acknowledged. This work was supported by a Grant-in-Aid for Scientific Research from the Japanese Ministry of Education, Culture, Sports, Science and Technology (15390348), a research grant for nervous and mental disorders (14B-3), and a Health and Labor Sciences Research Grant for Research on Psychiatric and Neurological Diseases and Mental Health (H15-KOKORO-003) from the Japanese Ministry of Health, Labor and Welfare.

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