

Cultural influences on neural systems of intergroup emotion perception: An fMRI study

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ABSTRACT

Cultural factors, such as cultural group membership, have been shown to affect neural bases of face and emotion perception. However, little is known about how cultural factors influence neural processing of emotional faces expressed by in-group and out-group members. In this study, we examined cultural influences on neural activation during the intergroup perception of negative emotional faces. We used functional magnetic resonance imaging to compare neural activation during intergroup emotion processing across cultures in three participants groups; two monocultural groups (i.e. Caucasian-Americans and native Japanese) and a bicultural group (i.e. Japanese-Americans). During scanning, the participants completed an emotional match-to-sample task consisting of negative facial expressions of Japanese and Caucasians. Our results show cultural modulation of neural response in the bilateral amygdala as a function of in-group biases and collectivistic values. Additionally, bicultural Japanese-Americans showed enhanced neural responses in the ventral medial prefrontal and posterior cingulate cortices, which had been related to self-related processing, during the perception of negative facial expression of Japanese. Neural activation in the ventral and posterior cingulate cortices reflected individuals' collectivistic tendencies only in the Japanese-American group, possibly due to greater sensitivity to ingroup biases in bicultural individuals. Our results demonstrate the influence of culture on neural responses during the perception of intergroup emotion from faces.

1. Introduction

One of the most important aspects of social interaction is the capacity to know about and be aware of the emotions experienced by oneself and others (Darwin, 1872). The expression of feelings via facial or bodily gestures or vocal tones provides communicative signals that allow for the understanding and appreciation of phenomenological experiences. Perceiving or recognizing the feelings or phenomenological experiences of others serves as an adaptive function, allowing individuals to know whether environmental or ecological pressures, such as dangers or

rewards, are present, as well as about the kinds of behaviors that may be adaptive in a given situation.

It has been shown that cultural group membership affects how emotional expressions are recognized by others; emotions expressed by members of one's own cultural group are recognized with greater accuracy likely due to greater familiarity with members of one's own cultural group, or in-group members, relative to members of another group, or out-group members (Marsh et al., 2003). However, how one recognizes other in- or out-group members could vary across situations. Perceptual cues from the face are important for social inference of

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cultural in-group and out-group members and play a crucial role in interacting with the others (Bandura, 1986). Indeed, individuals generally prefer others with trait attributes similar to their own (Byrne and Griffitt, 1969; Carli et al., 1991; Deutsch et al., 1991; Griffitt, 1966, 1969), and tend to be attracted to, and more satisfied with, interactions involving people similar to themselves (Byrne and Griffitt, 1969; Carli et al., 1991). They also show biases favoring their in-group members and feel more similar to them than to members of out-groups, even when assignment to those groups is random (Bigler et al., 1997; Turner, 1982; Van Bavel et al., 2008).

Racial identity is another cultural factor that may affect recognition of cultural in- or out-group members. Previous studies have shown that perception of group membership based on racial identity affects how people understand and share in the suffering of others (Chiao and Mathur, 2010; Mathur et al., 2012) and is a potent modulator of the neural responses underlying social behavior (Eberhardt, 2005; Ito and Bartholow, 2009; Kubota et al., 2012; Mathur et al., 2012). Mathur et al. (2012) found that African-Americans (AAs) who expressed greater racial identification than Caucasian-Americans (CAs) demonstrated increased neural responsiveness within cortical midline structures to empathic reactions to the pain of members of one's own racial group when they were shown static pictures of suffering people.

Culture is a significant social factor which contributes to the generation and regulation of the psychological and neural architecture of behavioral adaptation (Boyd and Richerson, 1985; Chiao and Blizinsky, 2010; Fincher et al., 2008; Lieberman et al., 2005). Culture affects how people recognize emotions (Elfenbein and Ambady, 2002; Mesquita and Frijda, 1992; Russell, 1991). For instance, cultural psychologists have argued that a fundamental way in which cultural values shape psychological processes is in how people define themselves and their relation to others in their environment (Markus and Kitayama, 1991; Nisbett et al., 2001; Oyserman et al., 2002; Triandis, 1995). In particular, they have identified two primary self-construal styles across cultures, individualism and collectivism; people who endorse individualistic values perceive themselves as stable entities, autonomous from other people and their environment, while people who endorse collectivistic values view themselves as dynamic entities, continually defined by their social context and relationships. (Markus and Kitayama, 1991; Oyserman et al., 2002; Triandis, 1995). As compared to individuals from individualistic culture, members of collectivistic groups may show greater in-group preferences during emotion recognition due to their greater reliance on contextual compared to focal strategies (Masuda et al., 2008) during emotional perception (Stanley et al., 2013). Cultures may vary in what kind of emotion is considered ideal (Tsai, 2007) and how emotions are regulated across cultures (Ekman et al., 1969; Ford and Mauss, 2015; Matsumoto et al., 2008). Ford and Mauss (2015) have shown that individuals from Asian backgrounds (i.e. collectivistic culture) were more likely to report using emotional suppression than individuals from European backgrounds (i.e. individualistic culture). To put it the other way, it might be likely that people from collectivistic culture were less familiar with been exposed to emotional facial expression straightforwardly expressed by others as compared to people from individualistic culture. Cultural factors, such as interracial attitudes, have been also shown to modulate neural responses to a specific racial group (Kubota et al., 2012). Phelps et al. (2000) found that when White American subjects observed faces of unfamiliar Black and White males, the strength amygdala activation to Black-versus-White faces was correlated with two indirect (unconscious) measures of race evaluation, but not with direct (conscious) expression of race attitudes.

Although there are many previous studies examining how culture might affect the way in which people perceive and recognize emotions expressed by others, very little is known about how culture might influence neural processing of emotional faces expressed by in-group and out-group members especially in bicultural individuals. A previous neuroimaging study examined influence of group membership on recognition of facial expression within two different cultural groups (i.e.

native Japanese living in Japan and Caucasian-Americans in the United States) and reported an in-group bias for negative facial expression (i.e. fear) but not for positive facial expression (i.e. happy) in the both participants groups; they showed greater amygdala activation to fear expressed by members of their own cultural group during they made an emotion categorization judgment for faces in static pictures presented on a screen (Chiao et al., 2008). Given that the amygdala has been shown to take an important role in detecting emotionally relevant stimuli (Davis and Whalen, 2001; Phelps, 2006) and in processing of faces (Iidaka et al., 2012; Kubota et al., 2012; Lieberman et al., 2005), it might not be surprising that the amygdala showed enhanced neural responses to negative facial expressions of in-group members irrespective of cultures due to the significance of detecting of communicative signals from in-group members to a greater extent as adaptive function for survival. However, one might wonder which was important factor that would affect recognition of others as in-group members and resulting amygdala responses, familiarity obtained in daily life or a genetic factor (i.e. similarity of physical appearance). That is to say, what neural modulation in the amygdala would be observed in Japanese-American individuals, who are very familiar with Caucasian-Americans' faces while they have a similarity of physical appearance to native Japanese people, when they were shown facial emotional expressions of Caucasians and Japanese?

In the current study, we investigated the influence of culture on amygdala responses to negative emotional faces (i.e. anger and fear) of racial ingroup and outgroup members. We studied neural response to intergroup emotion in three cultural groups, native Japanese (JP) participants living in Japan, a collectivistic culture, and Caucasian-American (CA) and Japanese-American (JA) participants living in the United States, an individualistic culture. We hypothesized that bicultural individuals (JA) would show greater amygdala responses to the negative facial emotion of racial in-group members. Furthermore, we hypothesized that collectivistic tendencies would be related to neural responses of intergroup negative facial expression. During fMRI scanning, participants completed an emotional face and perceptual matching task, viewing stimuli of either Japanese or Caucasian facial expressions of emotion (i.e. either Japanese or Caucasian faces depicting fear or anger) or simple shapes (i.e. ellipses), which served as a control.

2. Materials and methods

2.1. Participants

Fifty-eight healthy right-handed university students with normal or corrected-to-normal vision participated in this study for payment. Participants included 24 JP young adults (11 females, 13 males; mean age = 21.8 ± 4.1 (SD) years, range: 18–32 years) living in Japan, 19 CA (14 females, 5 males; mean age = 23.1 ± 4.0 (SD) years, range: 18–30 years) and 15 JA (6 females, 9 males; mean age = 22.9 ± 3.7 (SD) years, range: 16–31 years) young adults living in the United States (Fig. 1A). All of the JA participants self-reported as a first- or second-generation American-born and raised in the US or moved to the US when they were a small child with Native Japanese parents. Handedness was determined using the Edinburgh Handedness Inventory (Oldfield, 1971). No participant had a history of neurological or psychiatric disorder, or of drug or alcohol abuse. Written informed consent was obtained from each participant prior to the experiment. This study was approved by the Ethics Committees of Northwestern University, Nagoya University and National Institute for Physiological Sciences.

2.2. Stimuli

The stimuli consisted of 24 grayscale photographs of faces and 6 grayscale photographs of shapes. The facial stimuli consisted of 12 CA faces (CFace: three female and three male faces depicting anger, three female and three male faces depicting fear) and 12 Japanese faces

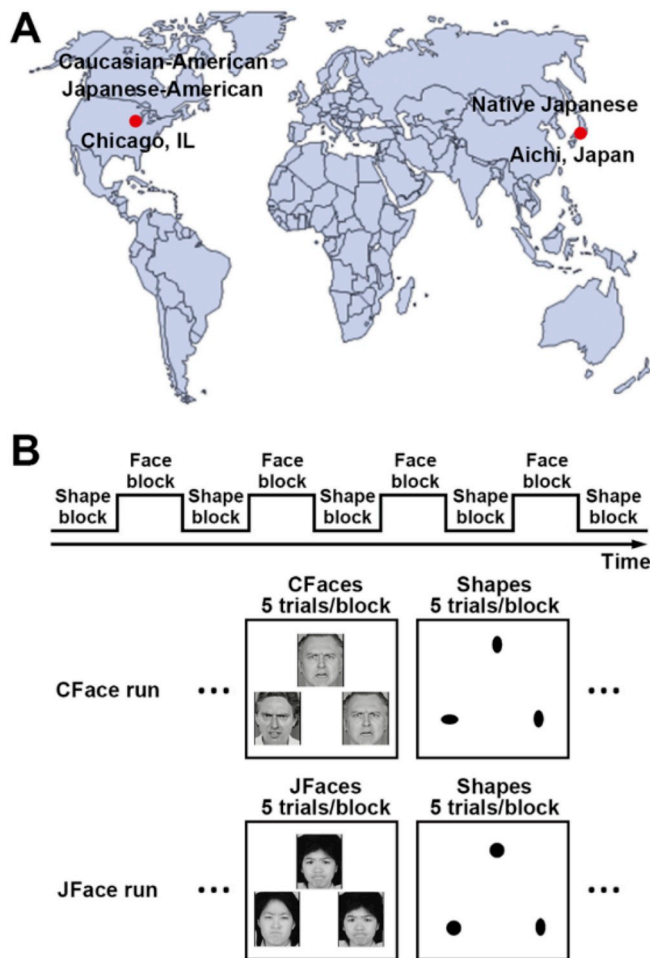


Fig. 1. (A) The geographical locations of the study sites. (B) The schema of the study paradigm consisted of the matching-faces judgment and matching-shapes judgment tasks. During the study paradigm, participants selected the bottom face/shape that was consistent with a top face/shape. The study consisted of two experimental runs with a block design of Caucasian–American faces (CFace) and Japanese faces (JFace).

(JFace: three female and three male faces depicting anger, three female and three male faces depicting fear) (Chiao et al., 2008) (Fig. 1B). Face photographs were derived from the Pictures of Facial Affect (POFA) (Ekman and Friesen, 1976) or the Japanese and Caucasian Facial Expressions of Emotions (JACFEE) (Matsumoto and Ekman, 1988). All the face stimuli were standardized for size and background using Adobe Photoshop. The shape stimuli, which served as controls for relatively lower-level cognitive processes (e.g. choosing the same picture as the target, button response), consisted of photographs of either horizontal or vertical ellipses or circles (Hariri et al., 2002) (Fig. 1B).

2.3. Procedure

There were 2 experimental runs with a block design. Each run consisted of 4 CFace and 5 shape blocks or 4 JFace and 5 shape blocks (Hariri et al., 2002). Each block consisted of six unique trials of that block type. A stimulus was displayed for 4000 ms in each trial, and trials were separated by a fixation cross presented for 2,000 to 6000 ms (average duration of inter-trial interval for each block = 4000 ms). During scanning, the participants completed the matching-faces judgment task and the matching-shape judgment task (Fig. 1B), with the latter serving as a control. In the both judgment tasks, the participants were asked to choose a face/shape (from a pair of faces/shapes at the bottom of the screen) that was the same as the target face/shape at the

top of the screen and respond by pressing a button with their right index or middle finger as quickly and accurately as possible. In the current study, Caucasian and Japanese faces were presented in separate runs rather than within the same run, as our primary purpose was to compare the three participants' groups (i.e. CA, JA and JP groups) for each of CFace and JFace conditions separately. We assigned higher priority to avoid a possible block-by-block effect, which means a possible effect of perception of Caucasian faces in CFace blocks on perception of Japanese faces in JFace blocks and vice versa when Caucasian and Japanese faces were closely presented within the same run, rather than having a shared baseline for CFace and JFace conditions. To avoid possible order effects of runs, the 2 experimental runs were presented in a counterbalanced order across participants. Prior to entering the scanner, participants were shown examples of each type of task and given multiple practice trials to become familiar with all the tasks.

2.4. Definition of collectivism

We defined participants' collectivism based on participants' self-report on the Self-Construal Scale (SCS) survey (Singelis, 1994). They answered twenty four items, which consists of twelve individualistic items (e.g. My personal identity, independent of others, is very important to me.) and twelve collectivistic items (e.g. I often have the feeling that my relationships with others are more important than my own accomplishments.), by using a 7-point Likert scale (from 1 = strongly disagree to 7 = strongly agree). To calculate each participants' level of collectivism, mean agreement for the twelve individualistic (IND) and twelve collectivistic (COL) items were calculated respectively and subtracted the mean of agreement for IND items from that for COL items for each participant, which was defined as the collectivism index [$SCS\ index = (COL_{score} - IND_{score})$] in the current study (Chiao et al., 2009). The larger value of the collectivism index a participant showed, the higher level of collectivism the participant endorsed.

2.5. Functional magnetic resonance imaging (fMRI) measurement

Functional brain images were acquired at two facilities, the Center for Advanced Magnetic Resonance Imaging (CAMRI) facility located at Northwestern Medical Hospital in Chicago, IL, USA, and the National Institute for Physiological Sciences (NIPS) in Okazaki, Japan. Scanning at CAMRI occurred on a 3.0-T Siemens Trio MRI scanner, and scanning at NIPS occurred on a comparable 3.0-T Siemens Allegra MRI scanner. We acquired functional images by using T2*-weighted, gradient-echo, echo-planar imaging sequences [repetition time (TR) = 2000 ms; echo time (TE) = 25 ms; flip angle = 70°; FOV = 20 cm, 64 × 64 matrix; 34 slices; voxel size = 3.0 × 3.0 × 3.0 mm³] at the both scanning sites. High-resolution anatomical T1-weighted images were also acquired for subjects at CAMRI [TR = 2300 ms; TE = 2.91 ms; flip angle = 9°; FOV = 256 mm; 256 × 256 matrix; 176 slices; voxel size = 1.0 × 1.0 × 1.0 mm³] as well as for those at NIPS [TR = 2500 ms; TE = 4.38 ms; flip angle = 8°; FOV = 256 mm; 256 × 256 matrix; 256 slices; voxel size = 0.75 × 0.75 × 1.0 mm³]. All stimuli were presented using the Presentation software (Neurobehavioral Systems, Albany, CA, USA) and projected onto a half-transparent viewing screen located behind the head coil. Subjects viewed the projected stimuli through a mirror attached to the head coil.

2.6. Cross-site scanner comparison

Because we used two scanner facilities (i.e. NIPS and CAMRI) to acquire functional brain images, it is possible that variation in the scanner performance between these two facilities may have led to variations in the neural activation patterns across the two groups. However, several prior neuroimaging studies examined different approaches to measuring and minimizing cross-site variation in the fMRI data collected from multiple fMRI sites (Friedman and Glover, 2006). We accounted for

the possibility of systematic, site-dependent effects in the fMRI sensitivity of the two scanner facilities in two ways (Friedman and Glover, 2006). First, functional neuroimaging data were collected from the two scanner sites using nearly identical vendor instrumentation and imaging parameters, a practice that has previously been shown to result in negligible inter-scanner variability (Friedman and Glover, 2006). Secondly, we conducted an inter-scanner reliability test by scanning a separate cohort of four participants (one female, three males, mean age = 33.8 ± 9.7 (SD) years) at both scanner facilities within 6 months. Participants at both sites were scanned while completing an emotion task (i.e. matching-faces and matching-shapes judgment tasks in the current study), a self-judgment task (Chiao et al., 2009) and a cognitive-inhibition task (i.e. Go/No-Go task) (Pornpattananangkul et al., 2016). Prior scanner variability studies have also included a small sample of participants tested at each site using the same functional task (Friedman and Glover, 2006). We acquired functional images by using T2*-weighted, gradient-echo, echo-planar imaging sequences [repetition time (TR) = 2000 ms; echo time (TE) = 25 ms; flip angle = 70° ; FOV = 20 cm, 64×64 matrix; 34 slices; voxel size = $3.0 \times 3.0 \times 3.0$ mm³] at the both sites. High-resolution anatomical T1-weighted images were also acquired for subjects at CAMRI [TR = 2300 ms; TE = 2.91 ms; flip angle = 9° ; FOV = 256 mm; 256×256 matrix; 176 slices; voxel size = $1.0 \times 1.0 \times 1.0$ mm³] as well as for those at NIPS [TR = 2500 ms; TE = 4.38 ms; flip angle = 8° ; FOV = 256 mm; 256×256 matrix; 256 slices; voxel size = $0.75 \times 0.75 \times 1.0$ mm³].

A cross-site scanner comparison of signal-to-noise ratio (SNR) (Parish et al., 2000) within the bilateral amygdala, the hypothesized regions in the current study, defined as a spherical region of interest (ROI) with an 8-mm radius centered on X = ± 24 , Y = -4 , Z = -23 , was conducted on functional images acquired during the emotion task. The results indicated no significant differences in the SNR [left amygdala: $t(3) = 1.27$, $p = 0.30$; right amygdala: $t(3) = 1.52$, $p = 0.22$] across scanner sites. Furthermore, we conducted a whole brain analysis directly comparing neural responses to negative facial expressions (i.e. a contrast [(CFace – Shape) + (JFace – Shape)]) between the US and Japan sites (see the next section for details of image pre-processing and estimation of activation). There was no significant difference of neural responses in the bilateral amygdala between the two scanner sites even at a liberal threshold (i.e., a height threshold of $p < 0.1$ uncorrected for multiple comparisons and cluster size > 0). Also, the ROI analysis was conducted to test whether neural responses in the bilateral amygdala were significantly different between the two scanner sites, comparing parameter estimates from the left and right amygdala (Automated Anatomical Labeling or AAL) ROIs (Tzourio-Mazoyer et al., 2002) between the US and Japan sites. The result of ROI analysis indicated no significant difference of activation in the bilateral amygdala between the two scanner sites (all $ps > 0.05$, two-sided student's two-sample t -tests) (Supplemental Fig. 1). Hence, variation in scanner-site performance is not a likely explanation for the variability in neural responses in the bilateral amygdala.

2.7. Image pre-processing and estimation of activation

The following pre-processing procedures were performed using the Statistical Parametric Mapping (SPM8) software (Wellcome Department of Imaging Neuroscience, London, UK) implemented in MATLAB R2012a (MathWorks, Sherborn, MA, USA). The first six volumes were discarded due to unsteady magnetization, and all the remaining volumes were spatially realigned to the first volume, and a mean image was created. After a high-resolution image was coregistered onto the mean image, all volumes were normalized to Montreal Neurological Institute (MNI) space using a transformation matrix obtained from the normalization process of the high-resolution image of each individual subject to the MNI template. The normalized images were then spatially smoothed with an 8-mm Gaussian kernel.

After pre-processing, statistical analysis for each individual subject

was conducted using a general linear model (Friston et al., 1995). At the first level, each block was modeled by convolving with a hemodynamic response function. High-pass filters (128 s) were applied to the time-series data and an autoregressive model was used to estimate the temporal autocorrelation. The signals of images were scaled to a grand mean of 100 overall voxels and volumes within each run. In addition, six regressors for head movement parameters obtained in the realignment process were entered in the design matrix. In the subtraction analysis, the two task conditions (i.e., CFace and Shape for the CFace run, and JFace and Shape for the JFace run) were modeled separately, including fixations because stimuli and fixations within the same block could not be mathematically separable in analyses. As the shape condition served as a control, the two contrast images, (CFace – Shape) and (JFace – Shape), were subjected to the group-level analyses.

For the group analysis, first we conducted a conjunction analysis to examine brain regions commonly involved in negative face recognition across the three participants' groups including three contrasts; CA (CFace-Shape + JFace-Shape), JA (CFace-Shape + JFace-Shape) and JP (CFace-Shape + JFace-Shape). Secondly, whole-brain, voxel-wise random-effects analyses were conducted to compare neural responses to Caucasian and Japanese negative faces among the three participants groups (i.e. CA, JA and JP groups); CA > JA, CA > JP, JA > CA, JA > JP, JP > CA and JP > JA for each of two contrasts (i.e. (CFace – Shape) and (JFace – Shape)). According to the results from the cross-site scanner comparison, we excluded the temporal, and occipital regions (the Talairach Daemon TD) Lobar Atlas implemented in WFU Pickatlas (<http://www.ansir.wfubmc.edu>) from the analyses only when directly comparing neural responses between the two scanner sites; we excluded the temporal region only when comparing CA with JP groups, and the occipital region only when comparing JP with CA groups.

For all whole-brain analyses, we tested our hypotheses utilizing a height threshold of $p < 0.001$ uncorrected for multiple comparisons and an extent threshold of $p < 0.05$ FWE-corrected for multiple comparisons in the current study (Slotnick, 2017). All the coordinates were reported in the MNI space. Brodmann areas and brain regions were identified based on the Talairach Atlas (Talairach and Tournoux, 1988) after converting MNI coordinates to Talairach space with a nonlinear transformation (<http://imaging.mrc-cbu.cam.ac.uk/imaging/MniTalairach>).

To examine the neural responses to Caucasian and Japanese negative faces in each of the three participant groups (i.e., CA, JA and JP groups) in more depth, we conducted ROI analyses in the hypothesized brain regions; the bilateral amygdala, which have shown an in-group bias during recognizing negative faces of in-group members in a previous study (Chiao et al., 2008). The parameter estimates of two contrasts of comparisons [i.e., (CFace-Shape) and (JFace-Shape)] were extracted from ROIs of the bilateral amygdala. We used Automated Anatomical Labeling (AAL) ROIs (Tzourio-Mazoyer et al., 2002) as an independently defined amygdala ROIs. The extracted parameter estimates were subjected to one-way ANOVAs, and Post-hoc t -tests with Bonferroni correction for multiple comparisons to examine whether there were significant differences of the neural activities in the left and right amygdala among the participant groups. To further examine how differently the bilateral amygdala would respond to Caucasian and Japanese negative faces in JA groups in terms of comparisons with CA and JP groups, the mean parameter estimates of the bilateral amygdala were curve-fitted with a quadric polynomial function. Curve-fitting with a quadric polynomial function allows us to examine the relationship between a dependent variable and experimental condition when experimental condition changes symmetrically in incremental steps (e.g. Iidaka et al., 2012, in which they reported that amygdala activity showed a quadratic polynomial function with accuracy of familiarity/unfamiliarity for faces).

Furthermore, to examine whether people's collectivistic tendencies might affect neural responses to negative facial expression of in- and out-group members, we explored correlations between individuals' collectivistic tendencies and neural responses to Caucasian and Japanese

negative faces especially within the brain areas with significantly different neural responses among the participants groups.

3. Behavioral results

3.1. Collectivism

The mean (\pm SD) percentages of the collectivism index were -0.24 ± 1.24 , 0.57 ± 0.90 and 0.01 ± 0.69 for the CA, JA and JP groups respectively. A one-way ANOVA revealed a marginally significance in the collectivistic tendency among the three groups [$F(2, 55) = 3.09$, $p = 0.054$]. Post-hoc two-sample *t*-tests with Bonferroni correction revealed that the JA group had marginally higher collectivistic tendency than the CA group ($p = 0.053$). No significant difference was observed between the CA and JP groups, or the JA and JP groups.

3.2. Accuracy and reaction time

The mean (\pm SD) percentages of correct responses and reaction times during the matching-faces and matching-shapes judgement tasks are presented in Tables 1 and 2.

A three-way ANOVA [3 participants' groups (i.e. CA, JA and JP groups) \times 2 task runs (i.e. CFace and JFace runs) \times 2 task conditions (i.e. matching-faces judgment and matching-shapes judgment tasks)] revealed a significant main effect of task conditions on accuracy [$F(1, 55) = 18.41$, $p < 0.01$], indicating that the participants more accurately responded in the matching-face judgment task than the matching-shape judgment task. There was no significance observed in a three-way interaction or other main effects (all $ps > 0.05$). To explore possible significance in detail, the accuracy data were subjected to two-way ANOVAs for each of the three factors (i.e. participants' groups, task runs and task conditions) separately. A two-way ANOVA [task runs \times task conditions] for each participants' group showed a significant main effect of task conditions for all the three participants' groups (all $ps < 0.05$), indicating that the participants more accurately responded in the matching-face judgment task than the matching-shape judgment task irrespective of participants' culture. There was no significance observed in main effects of task runs or two-way interactions (all $ps > 0.05$). A two-way ANOVA [participants' group \times task conditions] for each of task runs showed a significant main effect of task conditions for both of the two task runs (all $ps < 0.05$), indicating that the participants more accurately responded in the matching-face judgment task than the matching-shape judgment task irrespective of task runs. There was no significance observed in main effects of participants' groups or two-way interactions (all $ps > 0.05$). A two-way ANOVA [participants' group \times task runs] for each of task conditions showed no significance in main effects or a two-way interaction irrespective of task conditions (all $ps > 0.05$). Overall, these results indicate that the participants more accurately responded in the matching-face judgment task than the matching-shape judgment task irrespective of participants' culture or task runs.

Table 1
Mean percentages (\pm SD) of correct responses.

	Caucasian Faces (CFace) run		Japanese Faces (JFace) run	
	Emotion	Shape	Emotion	Shape
Caucasian-American (CA)	99.6 \pm 1.3	98.1 \pm 3.2	99.3 \pm 1.6	98.6 \pm 2.0
Japanese-American (JA)	99.7 \pm 1.1	98.2 \pm 2.8	99.2 \pm 1.7	97.8 \pm 3.3
Native Japanese (JP)	99.7 \pm 1.2	98.3 \pm 2.2	98.4 \pm 6.1	97.8 \pm 4.9

Notes: "Emotion" indicates Caucasian and Japanese face tasks of CFace and JFace runs respectively. "Shape" indicates the shape task of each of CFace and JFace runs. CFace and JFace tasks were given in separate runs in the current study, hence the mean percentage of correct response of the shape task was calculated for each experimental run separately.

Table 2
Mean (\pm SD) of reaction times (ms).

	Caucasian Faces (CFace) run		Japanese Faces (JFace) run	
	Emotion	Shape	Emotion	Shape
Caucasian-American (CA)	1094 \pm 253	925 \pm 194	1021 \pm 191	886 \pm 154
Japanese-American (JA)	1030 \pm 229	859 \pm 181	1027 \pm 224	844 \pm 135
Native Japanese (JP)	965 \pm 168	893 \pm 126	986 \pm 199	878 \pm 140

Notes: "Emotion" indicates Caucasian and Japanese face tasks of CFace and JFace runs respectively. "Shape" indicates the shape task of each of CFace and JFace runs. CFace and JFace tasks were given in separate runs in the current study, hence the mean of reaction time of the shape task was calculated for each experimental run separately.

A three-way ANOVA [3 participants' groups (i.e. CA, JA and JP groups) \times 2 task runs (i.e. CFace and JFace runs) \times 2 task conditions (i.e. matching-faces judgment and matching-shapes judgment tasks)] revealed a significant main effect of task conditions on reaction time [$F(1, 55) = 114.95$, $p < 0.01$], indicating that the participants responded faster in the matching-shape judgment task than the matching-face judgment task. Also, there was a significant interaction of participants' groups and task conditions [$F(2, 55) = 4.21$, $p < 0.05$]. There was no significance observed in other main effects or interactions (all $ps > 0.05$). To further explore the interaction in detail, the reaction time data was subjected to two-way ANOVAs and post-hoc *t*-tests for each of the two factors (i.e. participants' group and task conditions). A two-way ANOVA [task conditions \times task runs] for CA group showed a significant main effect of task conditions [$F(1, 18) = 34.77$, $p < 0.01$] and task runs [$F(1, 18) = 5.71$, $p < 0.05$], and a marginal significance of interaction [$F(1, 18) = 3.98$, $p = 0.061$]. The result indicates that CA participants responded faster during the matching-shapes than matching-faces judgment tasks, and also in JFace than CFace runs. A post-hoc *t*-test with Bonferroni corrections further indicated that the mean reaction time were significantly different during the matching-face judgment task ($p < 0.05$), but not during the matching-shape judgment task ($p > 0.05$), comparing CFace and JFace runs. A two-way ANOVA [task conditions \times task runs] for JA group showed a significant main effect of task conditions [$F(1, 23) = 30.78$, $p < 0.01$], indicating that JA participants responded faster during the matching-shapes than matching-faces judgment tasks irrespective of task runs. There was no significance observed in a main effect of task runs or an interaction (all $ps < 0.05$). A two-way ANOVA [task conditions \times task runs] for JP group showed a significant main effect of task conditions [$F(1, 14) = 44.03$, $p < 0.01$], indicating that JP participants responded faster during the matching-shapes than matching-faces judgment tasks irrespective of task runs. There was no significance observed in a main effect of task runs or an interaction (all $ps < 0.05$). A two-way ANOVA [participants' groups \times task runs] for each of task conditions showed no significance in main effects or a two-way interaction irrespective of task conditions (all $ps > 0.05$). Overall, these results indicate that participants responded faster during the matching-shapes than matching-faces judgment tasks irrespective of task runs or participants' culture. Importantly, there was no significant difference of reaction time during the matching-shapes judgment task between CFace and JFace runs, although only CA participants responded faster to Caucasian faces than Japanese faces.

3.3. fMRI results

The bilateral inferior occipital gyri extending to fusiform gyri and cerebellum, the bilateral middle frontal gyri and the right amygdala extending to hippocampus were commonly activated during negative face recognition across the three participant groups (Fig. 2 and Table 3).

There was a significant in-group effect observed in the bilateral amygdala when comparing Native Japanese group with Caucasian-

American group. Native Japanese participants showed larger neural responses in the bilateral amygdala to Japanese faces than Caucasian-American participants did (i.e. JP ($J_{\text{Face-Shapes}}$) > CA ($J_{\text{Face-Shapes}}$)) (Fig. 3 and Table 4), while the Caucasian-American group showed no significant in-group effect on neural responses to Caucasian faces when comparing with Native Japanese group (i.e. CA ($C_{\text{Face-Shapes}}$) > JP ($C_{\text{Face-Shapes}}$)).

Although the results of ROI analyses showed no significant difference of neural responses across the participant groups in the bilateral amygdala (one-way ANOVAs and Post-hoc t-tests, all p s > 0.05, with marginally significant difference in the right amygdala activity to Japanese faces between JP and CA individuals ($p = 0.097$)), neural activity in the bilateral amygdala showed a quadric polynomial curve as a function of participant groups (Fig. 4A and B). This result indicates that activity in the amygdala was highest to negative faces of the same cultural and racial members (i.e. in-group members) and lowest to those of the different cultural and racial group members (i.e. out-group members). Interestingly, Japanese-American participants showed neural responses that were intermediate in height between those of Caucasian-American and Native Japanese participants to both of Caucasian and Japanese faces. Furthermore, to examine whether people's collectivistic tendencies might affect neural responses to negative facial expression of in- and out-group members, we explored correlations between individuals' collectivistic tendencies and neural responses in the bilateral amygdala (Fig. 5). There are significant linear correlations between participants' collectivistic tendencies and neural responses in the bilateral amygdala in the Japanese-American group; a Japanese-American individual with a higher collectivistic tendency showed larger neural responses in the bilateral amygdala during processing of negative facial expressions of Japanese (Fig. 5A and B). A Japanese individual with a higher collectivistic tendency showed less neural responses in the left amygdala during processing of negative facial expressions of Caucasian (Fig. 5A). And, there was a marginally significant correlation between participants' collectivistic tendencies and neural responses in the right amygdala in the Caucasian-American group ($p = 0.055$); a Caucasian-

American individual with a higher collectivistic tendency showed larger neural responses in the right amygdala during processing of negative facial expressions of Caucasian (Fig. 5B).

Outside the hypothesized regions (i.e. the bilateral amygdala), there was an in-group effect observed in the Japanese-American as compared with Caucasian-American groups; Japanese-American participants showed greater activities in the right ventral prefrontal cortex, posterior cingulate cortex extending to precuneus and right superior frontal gyrus during processing of negative facial expressions of Japanese than Caucasian-American participants did (i.e. JA ($J_{\text{Face-Shapes}}$) > CA ($J_{\text{Face-Shapes}}$)) (Fig. 6 and Table 5). Furthermore, to examine whether people's collectivistic tendencies might affect neural responses to negative facial expression of in- and out-group members, we explored correlations between individuals' collectivistic tendencies and neural responses in those three brain regions (Fig. 7). There were significant linear correlations between participants' collectivistic tendencies and neural responses in the three brain regions only in the Japanese-American group; a Japanese-American individual with a higher collectivistic tendency showed larger neural responses in the three brain regions during processing of negative facial expressions of Japanese (Fig. 7).

There was no significant difference observed in other contrasts [i.e. CA ($C_{\text{Face-Shapes}}$) > JA ($C_{\text{Face-Shapes}}$), JA ($C_{\text{Face-Shapes}}$) > CA ($C_{\text{Face-Shapes}}$), JP ($C_{\text{Face-Shapes}}$) > CA ($C_{\text{Face-Shapes}}$), JA ($C_{\text{Face-Shapes}}$) > JP ($C_{\text{Face-Shapes}}$), JP ($C_{\text{Face-Shapes}}$) > JA ($C_{\text{Face-Shapes}}$), CA ($J_{\text{Face-Shapes}}$) > JA ($J_{\text{Face-Shapes}}$), CA ($J_{\text{Face-Shapes}}$) > JP ($J_{\text{Face-Shapes}}$), JP ($J_{\text{Face-Shapes}}$) > JA ($J_{\text{Face-Shapes}}$), JP ($J_{\text{Face-Shapes}}$) > JA ($J_{\text{Face-Shapes}}$)], but significant difference observed in the bilateral inferior occipital gyri when comparing the JP with CA groups [i.e. JP ($C_{\text{Face-Shapes}}$) > CA ($C_{\text{Face-Shapes}}$) and JP ($J_{\text{Face-Shapes}}$) > CA ($J_{\text{Face-Shapes}}$)], and the JP with JA groups [i.e. JP ($C_{\text{Face-Shapes}}$) > JA ($C_{\text{Face-Shapes}}$) and JP ($J_{\text{Face-Shapes}}$) > JA ($J_{\text{Face-Shapes}}$)]. According to the results from our cross-sites scanner comparison, it is likely that the differences of neural responses in the bilateral inferior occipital gyri reflect site-dependent differences in EPI signals between the two scanning sites. Therefore, we will not discuss those activations in more depth in the current study.

4. Discussion

Although the participants were instructed to respond as quickly and accurately as possible for both of the shape and face tasks, they responded faster and less accurately on the shape task than the face task irrespective of participants' groups. The results suggested there might be a speed-accuracy trade-off on the tasks used in the current study. There might be several possibilities which account for the speed-accuracy trade-off on the tasks. One possibility is difference in task difficulty; the shape task was more difficult to be responded as quickly as possible than the face task, because of the much smaller size of shapes as compared to faces. Another possibility is that human being is intrinsically sensitive to facial stimuli, and even automatically and quickly recognize faces from a given environment, and hence that might have facilitated participants' choosing a face (from a pair of faces at the bottom of the screen) that was the same as the target face at the top of the screen in the face task. Although one might think that there would be more appropriate control condition rather than using simple horizontal or vertical ellipses or circles, in the current study we made it a priority to exclude possible effects of culture on a control task as possible as we could because cultural effects on both of the face task and control task could be a likely explanation for the variability in the neural activation observed in the experiment. Simplifying stimuli (i.e. horizontal or vertical ellipses or circles in the current study) for a control condition does not necessarily mean that there would be no potential effect of culture on the control task. However, we used that control task (i.e. the shape task in the current study) to subtract neural activities related to basic cognitive processes (i.e. choosing a picture, button response) rather than higher cognitive processes, and furthermore the behavioral results showed no significant difference of accuracy or reaction time in the

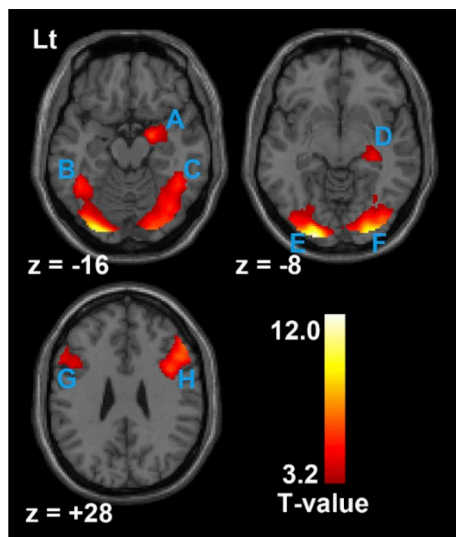


Fig. 2. Brain regions commonly involved in negative face recognition across Caucasian-American, Japanese-American and Native Japanese groups. Significant involvement was observed in the right amygdala (A), left fusiform gyrus (B), right fusiform gyrus (C), right hippocampus (D), left inferior occipital gyrus (E), right inferior occipital gyrus (F), left middle frontal gyrus (G) and right middle frontal gyrus (H). Lt = left hemisphere of brain. The activations are superimposed on the axial sections ($z = -16, -8$ and $+28$) of a standard anatomical brain. The height threshold was set at uncorrected $p < 0.001$ and the extent threshold at $p < 0.05$ FWE-corrected for multiple comparisons. Detailed cluster information is listed in Table 3.

Table 3

Brain regions commonly involved in negative face recognition across cultures.

FWE-corrected <i>p</i> -value (cluster-level)	Cluster size [voxels]	Z-value (peak-level)	x [mm]	y [mm]	z [mm]	BA	Brain area
<0.001	2596	Inf	−22	−94	−12	18	Lt. Inferior occipital gyrus
	*	6.34	−40	−50	−24	37	Lt. Fusiform gyrus
	*	6.26	−42	−72	−24		Lt. Cerebellum
<0.001	2820	Inf	28	−94	−2	18	Rt. Inferior occipital gyrus
	*	Inf	46	−50	−26	37	Rt. Fusiform gyrus
	*	6.79	38	−70	−22		Rt. Cerebellum
<0.001	1757	6.50	54	26	30	9	Rt. Middle frontal gyrus
<0.001	820	5.90	20	−6	−16		Rt. Amygdala
	*	5.58	30	−28	−4		Rt. Hippocampus
0.012	385	4.36	−56	16	32	9	Lt. Middle frontal gyrus

Notes: Coordinates (x, y, z) are of the voxel of local maximal significance in each brain region, according to the Montreal Neurological Institute (MNI) template. Brain areas were identified based on the stereotaxic coordinate system of Talairach and Tournoux (1988). The voxel dimension = 2 × 2 × 2 mm *, a peak is included in a large cluster. BA, Brodmann Area; Lt., left hemisphere of brain; Rt., right hemisphere of brain.

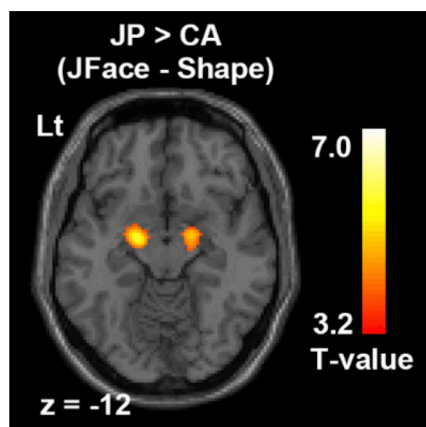


Fig. 3. Neural responses to negative facial expressions of Japanese. As compared to Caucasian-American (CA), Native Japanese participants (JP) showed significantly larger responses to Japanese faces (i.e. in-group members' faces) in the bilateral amygdala. Lt = the left hemisphere of brain. The activations are superimposed on the axial sections ($z = -12$) of an anatomical brain. The height threshold was set at uncorrected $p < 0.001$ and the extent threshold at $p < 0.05$ FWE-corrected for multiple comparisons. Detailed cluster information is listed in Table 4.

shape task across the participants' groups. Accordingly, the shape task used in the current study is thought to be still sufficient and appropriate for the purpose of the current study (i.e. exploring any cultural and/or racial effects on recognition of negative facial recognition of in- and out-group members, focusing on comparisons across the participants' groups rather than comparison between the face task and the shape task within each participants' group). Nevertheless, it is necessary to use a control condition appropriate for the purpose of study, and we might be able to use another control stimulus (e.g. neutral faces). Given that different control conditions might differently affect results observed in experiments, especially in neuroimaging studies, it would be helpful for a better understanding of cultural effect on facial expressions to use different control conditions and compare the results from them in future research.

Table 4

A cultural in-group effect in comparison of the JP with CA groups.

FWE-corrected <i>p</i> -value (cluster-level)	Cluster size [voxels]	Z-value (peak-level)	x [mm]	y [mm]	z [mm]	BA	Brain area
[JP (JFace-Shape) > CA (JFace-Shape)]							
0.025	315	6.01	−18	−10	−8		Lt. Amygdala
0.037	279	4.97	18	−6	−8		Rt. Amygdala

Notes: Coordinates (x, y, z) are of the voxel of local maximal significance in each brain region, according to the Montreal Neurological Institute (MNI) template. Brain areas were identified based on the stereotaxic coordinate system of Talairach and Tournoux (1988). The voxel dimension = 2 × 2 × 2 mm *, a peak is included in a large cluster. BA, Brodmann Area; Lt., left hemisphere of brain; Rt., right hemisphere of brain.

Emotion recognition of negative facial expressions is supported by a neural system of brain regions within the limbic, occipital and frontal cortices. The core affect hypothesis posits that discrete emotion categories, such as anger or fear, consistently and specifically are associated with a set of brain regions (Lindquist et al., 2012). Consistent with the core affect hypothesis, brain regions including the right amygdala, hippocampus, bilateral middle frontal gyri, bilateral inferior occipital gyri, fusiform gyri, and cerebellum were activated during recognition of negative emotional expressions across all the participants groups. The perception and experience of core negative affect relies on transformation of perceptual and conceptual information from the negative valence and high arousal system. Neural activation within brain regions of core negative affect reflects the functionality of information processing mechanisms that encode and decode perceptual units of negative emotion from facial expressions.

In the current study, a cultural in-group effect was observed in the bilateral amygdala, which is consistent with a previous study (Chiao et al., 2008); Caucasian-American and Japanese participants showed the highest amygdala activities to negative faces of the same cultural and racial members (i.e. in-group members) and the lowest amygdala activities to those of the different cultural and racial group members (i.e. out-group members). The cultural ingroup advantage hypothesis

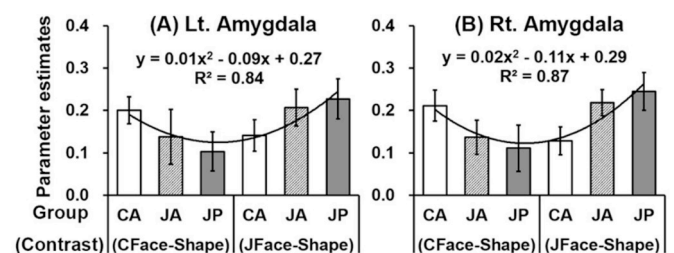


Fig. 4. The mean (column) and standard error (bar) of the activation in the (A) left and (B) right amygdala. The mean value of each condition was fitted using a quadric polynomial function for the bilateral amygdala (A and B). Lt. = the left hemisphere of brain; Rt. = the right hemisphere of brain; CA = Caucasian-American participants; JA = Japanese-American participants; JP = Native Japanese participants.

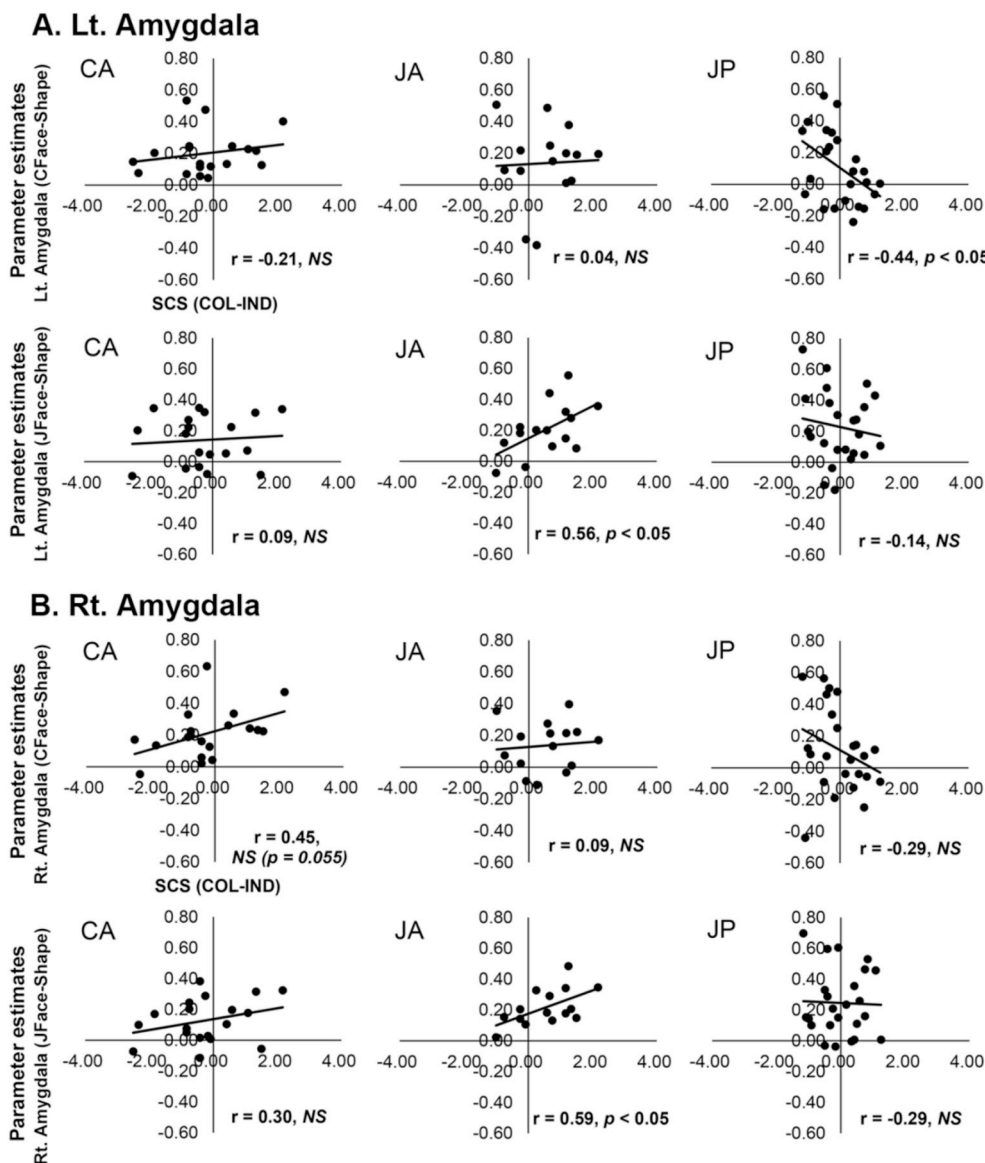


Fig. 5. Correlation of participants' collectivistic tendency with neural responses to negative facial expressions in the left amygdala (A) and the right amygdala (B). The vertical axes indicate parameter estimates. The horizontal axes indicate the individuals' collectivistic tendency index (i.e. SCS(COL-IND)), indicating that a participant with a larger value in the positive direction has higher collectivistic tendency. Lt, the left side; Rt, the right side; CA, Caucasian-American; JA, Japanese-American; JP, Native Japanese participants.

suggests that cultural group members show an advantage in the perception and recognition of signals of social communication from other group members (Elfenbein and Ambady, 2002; Marsh et al., 2003). Cultural group members show behavioral advantages such as greater accuracy and efficiency in the social inference of identity and mental state understanding from other group members. This cultural ingroup advantage manifests in mental and neural states as greater response to perceptual information from cultural in-group members (Eberhardt, 2005; Kubota et al., 2012). Although there was no in-group effect on reaction time or accuracy in the current study maybe due to usage of a remarkably simple task, greater response within the amygdala likely reflects greater informational demands when processing negative emotional facial expressions of *in-group* members, which facilitate values and practices that promote social harmony and interdependence. Interestingly, Japanese-American participants showed neural responses that were intermediate in height between those of Caucasian-American and Native Japanese participants to both of Caucasian and Japanese faces. This result indicates that bicultural individuals respond to negative facial expressions of members from the both cultural groups with slightly attenuated extent as compared to monocultural individuals. We hypothesized that JA individuals would show large amygdala responses to Caucasian negative faces as the same extent as CA individuals would if

the in-group bias was due to familiarity of faces learned in their daily life, while they would show large amygdala response to Japanese negative faces as the same extent as JP individuals would if the in-group bias was simply due to their racial identity. The results in the current study did not support either hypothesis. Previous studies have shown that neural responses to faces and emotions in the amygdala could be flexibly modulated by different factors, for instance, cultural practices such as racial attitudes (Kubota et al., 2012), recognition of in-group members due to racial identities (Chiao et al., 2008) and even an experimental situation tentatively given (Van Bavel et al., 2008). Bicultural individuals are required to appropriately and quickly switch their mind between two cultural modes in a given situation in their daily lives. Therefore, an possible interpretation might be that the activation pattern observed in the bilateral amygdala in the Japanese-American individuals in the current study reflected their mental processing; they always need to hold communicative signals from the both cultural members equally important in their mind, and consequently that causes less attentional assignment to either communicative signal as compared with monocultural individuals due to the extensive workload. It would be interesting to examine whether other bicultural individuals (e.g. Caucasians who was grown up in Japan) might show the similar activation patterns in the amygdala as Japanese-Americans in future

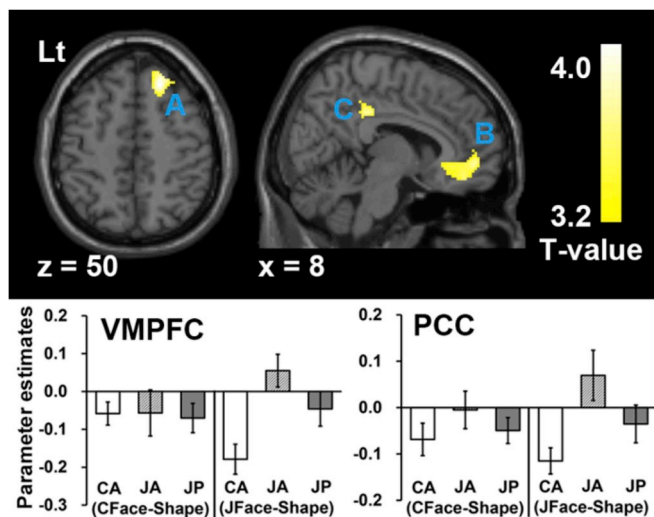


Fig. 6. Neural response to negative facial expression of Japanese in Japanese-American group (upper figures). As compared to Caucasian-American participants, Japanese-American participants showed significantly larger responses to Japanese faces in the right superior frontal gyrus (A), ventral medial prefrontal cortex (B) and posterior cingulate cortex (C). Lt = the left hemisphere of brain. The activations are superimposed on the axial ($z = 50$) and sagittal sections ($x = 8$) of an anatomical brain. The height threshold was set at uncorrected $p < 0.001$ and the extent threshold at $p < 0.05$ FWE-corrected for multiple comparisons. Detailed cluster information is listed in Table 5. Parameter estimates extracted from VMPFC (lower left) and PCC ROIs (lower right) were plotted as function of participant groups (i.e. CA, JA and JP). VMPFC, the ventral medial prefrontal cortex; PCC, the posterior cingulate cortex; CA, Caucasian-American; JA, Japanese-American; JP, Native Japanese participants.

research.

Outside the hypothesized regions (i.e. the bilateral amygdala), Japanese-American participants showed greater activities in the ventral medial prefrontal cortex, posterior cingulate cortex, precuneus and right superior frontal gyrus during negative facial recognition of Japanese faces (racially in-group members' faces). The ventral medial prefrontal cortex (Harada et al., 2010; Johnson et al., 2006; Lin et al., 2016; Moore et al., 2014; Northoff and Bermohl, 2004), posterior cingulate cortex (Ge et al., 2009; Johnson et al., 2006; Northoff and Bermohl, 2004; Ray et al., 2010), precuneus and right superior frontal gyrus (Chiao et al., 2010) have been related to self-related processing, including autobiographical memory (Northoff and Bermohl, 2004; Summerfield et al., 2009). A previous neuroimaging study has reported that the ventral prefrontal region was involved in automatic and implicit evaluation of self-related information due to the great importance for survival (Harada et al., 2010). Another neuroimaging study has shown that recollection of autobiographical events that really happened in the external world activated the ventromedial prefrontal cortex and posterior cingulate cortex (Summerfield et al., 2009). While Japanese-American individuals participated in the current study have grown up in the

United states where Caucasian-Americans was a racially majority group, they hold a racial identity as a Japanese and, at the same time, they are members of racially minority group in the United States. They are thought to spend much more time to contact with Caucasian-Americans than Japanese individuals in daily life (e.g. at school or work), but still have opportunities to communicate with Japanese individuals (e.g. their relatives living in Japan or their parents). Hence Japanese facial expression is thought to be low-frequent but important social cue to be processed for Japanese-Americans, and self-related memory might to be automatically more involved in Japanese-American as compared with Caucasian-American individuals when Japanese faces were presented. In the current study, greater response within the ventral medial prefrontal cortex and posterior cingulate cortex likely reflects greater informational demands of self-relevant memory, because their recognition of their racial identity might be automatically strengthened when negative facial expression of racially in-group members was presented. However, it is not clear whether Caucasians living in Japan may show the similar neural responses which were observed in Japanese-American individuals in the current study. Given that there might be different cultural and/or racial effects on neural responses in migrant groups with different racial and/or cultural backgrounds, it would be very interesting to explore whether or not Caucasians living in Japan might show the similar neural activities as Japanese-Americans in future neuroimaging research.

Furthermore, the results from correlation analyses revealed that a Japanese-American individual with a higher collectivistic tendency showed larger neural responses in the bilateral amygdala during processing of negative facial expressions of Japanese (i.e. racially in-group members based on their racial identity). Also, a Japanese individual with a higher collectivistic tendency showed less neural responses in the left amygdala during processing of negative facial expressions of Caucasian (out-group members), and a Caucasian-American individual who endorsed collectivistic view showed a tendency of larger neural responses in the right amygdala during processing of negative facial expressions of Caucasian (in-group members). The result is partially consistent with a previous study which have reported that members in collectivistic culture showed greater in-group preferences during emotion recognition and perception as compared to members in individualistic culture (Masuda et al., 2008; Stanley et al., 2013). Although, in the current study, Japanese individuals (i.e. members from collectivistic culture) did not necessarily show higher collectivistic tendency, it has been suggested that ones' cultural values such as individualism or collectivism might vary extents depending on their degree of sensitivity to cultural norms (Oyserman et al., 2002) across micro- (e.g. lifespan, generations) and micro-level (e.g. a given situation) time scales (Chiao et al., 2010; Chiao and Ambady, 2007; Mesoudi et al., 2006; Li, 2003). The results of current study suggest that ones' collectivistic tendency might expect extents of in-group preference at the individual level rather than the national cultural level, and the amygdala responses to in-group members' negative communicative signals might reflect at least partially the individuals' in-group biases. Additionally, there were significant linear correlations between participants' collectivistic tendencies and neural responses in the ventral prefrontal and posterior

Table 5
Racial effects on neural responses to negative facial expressions of culturally out-group members.

FWE-corrected p -value (cluster-level)	Cluster size [voxels]	Z-value (peak-level)	x [mm]	y [mm]	z [mm]	BA	Brain area
[JA (JFace-Shape) > CA (JFace-Shape)]							
0.013	372	4.39	22	32	50	8	Rt. Superior frontal gyrus
0.036	283	4.07	10	-34	36	31	Rt. Posterior cingulate gyrus
	*	3.60	-10	-36	36	31	Lt. Posterior cingulate gyrus
	*	3.49	0	-38	44	7	Precuneus
0.007	435	3.90	8	50	-4	10	Rt. Ventral medial prefrontal gyrus

Notes: Coordinates (x, y, z) are of the voxel of local maximal significance in each brain region, according to the Montreal Neurological Institute (MNI) template. Brain areas were identified based on the stereotaxic coordinate system of Talairach and Tournoux (1988). The voxel dimension = $2 \times 2 \times 2$ mm³, a peak is included in a large cluster. BA, Brodmann Area; Lt., left hemisphere of brain; Rt., right hemisphere of brain.

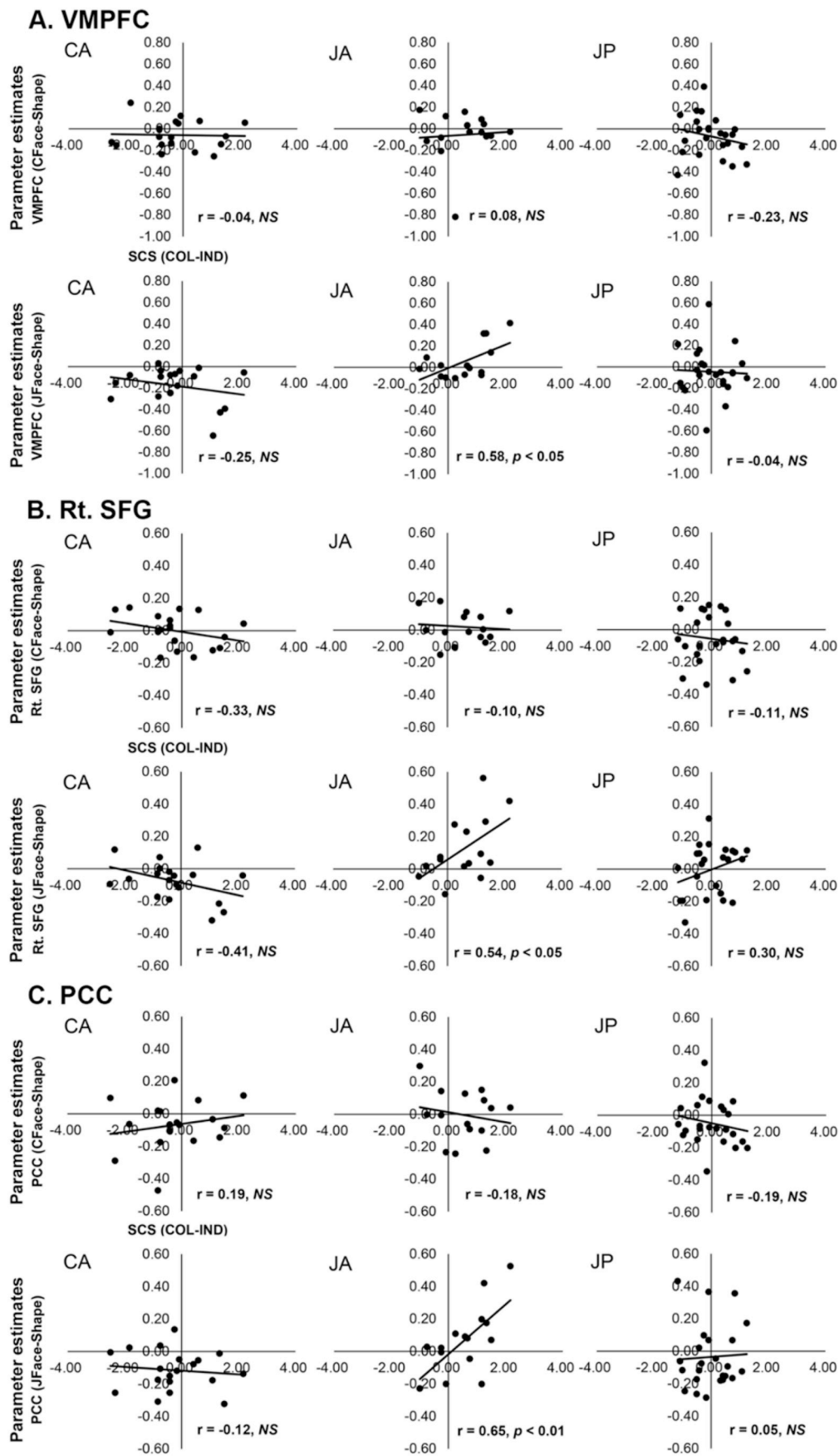


Fig. 7. Correlation of participants' collectivistic tendencies with neural responses to negative facial expressions in the ventral medial prefrontal cortex (A), the right superior frontal gyrus (B) and the posterior cingulate cortex (C). Parameter estimates were extracted from the three clusters shown in Fig. 6. The vertical axes indicate parameter estimates. The horizontal axes indicate the individuals' collectivistic tendency index SCS(COL-IND), indicating that a participant with a larger value in the positive direction has higher collectivistic tendency. VMPFC, the ventral medial prefrontal cortex; PCC, the posterior cingulate cortex; Rt, the right side; CA, Caucasian-American; JA, Japanese-American; JP, Native Japanese participants.

cingulate cortices and the right superior frontal gyrus in only the Japanese-American group; a Japanese-American individual with a higher collectivistic tendency showed larger neural responses in the three brain regions during processing of negative facial expressions of Japanese (i.e. in-group members based on their racial identity). Japanese-Americans showed higher collectivistic tendency than Caucasian-Americans in the current study. It is likely that Japanese-Americans, bicultural individuals in the United States, have a racial identity as a Japanese and, at the same time, recognize them as a member of racially minority group, and hence they might show greater sensitivity to collectivistic norms than Japanese, monocultural individuals, who might have few opportunity to have a strong awareness of collectivistic norms. Given that people living in multicultural environments are often required to switch their cultural modes depending on their immediate social contexts, it is likely that Japanese-Americans are automatically and unconsciously shifted to collectivistic mode when facing Japanese individuals, while shifted to individualistic mode when facing Caucasian individuals. Putting all this together, the neural responses in the ventral and posterior cingulate cortices and the right superior frontal gyrus might partially reflect the extent to which Japanese-American individuals endorsed collectivistic norms, in other words, the neural responses might reflect the extent of the resultant in-group biases of them during their recognizing Japanese faces.

One limitation of this study involves the generalizability of our findings, as the results were based on only facial expressions of fear and anger. Although fear and anger are some of the most basic emotions in humans, our species is also social, which means that positive and negative emotions are important because they are expressed and regulated in the cultural context of social relationships (Butler et al., 2007). Thus, future cross-cultural neuroimaging studies of emotion should examine not only negative, but also positive emotions, within distinct cultural contexts. Also, there is a critical issue to be considered; in the current study, we used a matching-faces judgment task in which the participants were simply asked to choose a face (from a pair of faces at the bottom of the screen) that was the same as the target face at the top of the screen, which is thought to have involved implicit rather than explicit processing of negative facial expressions. It might be likely that cultural/racial effect on processing of basic facial feature rather than emotional feature could explain the variability in the neural activation observed in the current study. A previous psychological study has reported that the emotional expression, especially negative rather than positive emotion, in a face can be perceived outside of the focus of attention (Eastwood et al., 2001). Neuroimaging studies have suggested that the amygdala, a subcortical brain region which plays an important role in perceiving and evaluating cues signaling impending threat, responded to subliminal facial fear stimuli (Anderson et al., 2003; Habel et al., 2007; Whalen et al., 1988). Given the profound significance in rapidly and automatically processing social cue signaling especially threat, it is likely that the participants in the current study responded to emotional feature rather than basic feature in faces. However, it does not necessarily rule out the possibility that cultural/racial effect on processing of basic face feature rather than emotional feature could explain the variability in the neural activation observed in the current study. It would be helpful to examine cultural/racial effects on different facial expressions (i.e. positive and neutral facial expressions as well as negative facial expressions) in future research.

There might be another limitation in the current study, that is a possible variation in the scanner performance between the two facilities which may have led to variations in the neural activation patterns across the two different scanning sites. The problem has been always in studies which needed cross-site comparisons of neural activations, therefore, they have suggested several solutions such as using nearly identical vendor instrumentation and imaging parameters and conducting an inter-scanner reliability test by scanning a separate cohort of participants prior to an experiment (Friedman and Glover, 2006). In the current study, we used the same scanning parameters for functional

scanning, but there were still variations of neural activities in several brain regions which is likely due to difference of MRI equipment (i.e. a 3.0-T Siemens Trio MRI scanner at US site and a 3.0-T Siemens Allegra MRI scanner at Japan site). Ideally, it would be better to scan all the participants' groups at the same facility or use the same MRI equipment at the both sites, however there would be still resolutions to deal with the issue of possible variations in the scanner performance between the different facilities. One possible solution may be excluding brain regions, which showed systematic variations across the facilities in a prior inter-scanner reliability test, from further analyses. Although this way might not necessarily eliminate the possibility of remaining variations, it would be still a possible solution and even more useful way by combining with an additional and detailed reliability test such as a ROI analysis for target brain regions that we have done in the current study. In the current study, we excluded the temporal and occipital regions from the analyses only when directly comparing the different facilities, and furthermore confirmed that there was no significant difference of neural activities in the hypothesized regions, that is the bilateral amygdala, in our prior reliability test. Hence, variation in scanner-site performance is not a likely explanation for the variability in the neural activation we observed in the current study.

5. Conclusion

Our findings are the first demonstration of the cultural as well as racial influences on neural activity during the perception of in- and out-group member's negative emotional faces, where we compared neural activities among three participants groups; two monocultural individual groups (i.e. Caucasian-Americans and native Japanese) and a bicultural individual group (i.e. Japanese-Americans). Our results show that neural responses in the bilateral amygdala reflected both of in-group biases based on ones' racial identities and cultural practices, such as ones' collectivistic tendencies, irrespective of participants' cultures. Furthermore, Japanese-Americans showed enhanced neural responses in the ventral and posterior cingulate cortices, which had been related to self-related processing, especially when they were shown negative facial expression of Japanese (i.e. in-group members based on their racial identities). Also, the neural activities in the ventral medial prefrontal and posterior cingulate cortices reflected individuals' collectivistic tendencies only in the Japanese-American group, that might be due to greater sensitivity to a specific cultural practice in bicultural individuals. Our results demonstrate that neural responses during the processing of emotional faces could be modulated by different social factors, such as cultural practice and racial identity, and furthermore cultural and racial influences are interlaced especially in bicultural individuals such as Japanese-Americans in the current study.

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Appendix A. Supplementary data

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