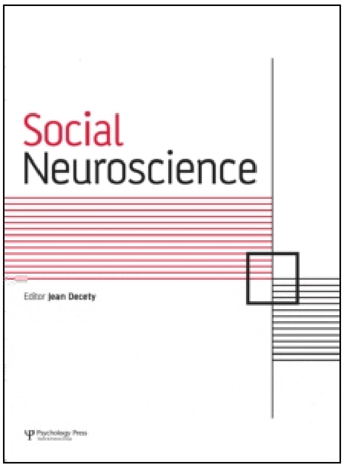

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Cultural difference in neural mechanisms of self-recognition

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Cultural difference in neural mechanisms of self-recognition

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Self-construals are different between Western and East Asian cultures in that the Western self emphasizes self-focused attention more, whereas the East Asian self stresses the fundamental social connections between people more. To investigate whether such cultural difference in self-related processing extends to face recognition, we recorded event-related potentials from British and Chinese subjects while they judged head orientations of their own face or a familiar face in visual displays. For the British, the own-face induced faster responses and a larger negative activity at 280–340 ms over the frontal-central area (N2) relative to the familiar face. In contrast, the Chinese showed weakened self-advantage in behavioral responses and reduced anterior N2 amplitude to the own-face compared with the familiar face. Our findings suggest that enhanced social salience of one's own face results in different neurocognitive processes of self-recognition in Western and Chinese cultures.

Keywords: Culture; Event-related potential; Face; Self.

INTRODUCTION

To distinguish between the self and others is a fundamental sociocognitive ability for humans to conduct appropriate social interactions. An example of such ability is recognition of one's own face (Keenan, Gallup, & Falk, 2003; Northoff et al., 2006). Human infants before age two are able to use reflection in mirrors to perform self-oriented actions (Anderson, 1984). Human adults respond faster to one's own face than to faces of others in visual search and face owner identification tasks (Keenan et al., 1999; Tong & Nakayama, 1999). The self-advantage in face recognition has been observed in both Westerners (Keenan et al., 1999; Tong & Nakayama, 1999) and Chinese (Ma & Han, under review; Sui & Han, 2007; Sui, Zhu, & Han, 2006).

To examine the neural substrate of self-recognition, recent functional magnetic resonance imaging (fMRI) studies compared blood oxygen level dependent (BOLD) signals associated with perception of one's own face and personally familiar faces (Devue et al., 2007; Platek et al.,

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2006; Sugiura et al., 2005). Data from Western subjects showed increased activation in the right frontal and parietal lobes to the own-face relative to faces of familiar others when the tasks required explicit identification of face owners (Devue et al., 2007; Platek et al., 2006; Uddin, Kaplan, Molnar-Szakacs, Zaidel, & Iacoboni, 2005). Similar increased activity in the right middle frontal cortex was observed in Chinese subjects who performed an implicit face recognition task that required judgment of head orientations of the own-face or a personally familiar face (Sui & Han, 2007).

Although previous studies reported similar behavioral and neural responses associated with self-recognition in different cultural groups, to our knowledge there has been no research to assess potential cultural difference in neural mechanism involved in self-recognition. Social psychologists have shown evidence for divergent self-concept across different cultures. Studies measuring self-reflective reports suggest the existence of distinct self-concept styles in European American, East Asian Americans, Chinese, etc. (see Oyserman, Coon, & Kemmelmeier, 2002 for review). Markus and Kitayama (1991) proposed a framework for understanding the cultural difference in conceptual representations of the self, i.e., people from Western (e.g., European and American) cultures view the self as an autonomous entity, resulting in an independent self, whereas people from East Asian cultures (e.g., Chinese) tend to emphasize the interconnectedness of human beings, resulting in an interdependent self. Although there is a debate among cultural psychologists concerning the extent to which the distinction of independence–interdependence in Western and East Asian cultures is stable across time and ubiquitous within Western and Eastern geographical regions, Markus and Kitayama's (1991) theory has been used to guide transcultural brain imaging research of neural mechanisms of human cognition (Han & Northorff, 2008). For instance, Zhu, Zhang, Fan, and Han (2007) scanned Chinese and English-speaking Westerners, using fMRI, when participants judged personal trait adjectives regarding the self and mother. They found that Westerners engaged the medial prefrontal cortex (MPFC) only in self-judgment whereas the MPFC was involved in both self- and mother-judgments. Recently, Lewis, Goto, and Kong (2008) examined cognitive style difference between European Americans and East Asian Americans by recording event-related potentials (ERP) in an oddball task. They found that European Americans showed greater target-related P3 amplitudes, reflecting enhanced attention to target events, whereas East Asian Americans displayed greater stimulus-novelty-related P3, indexing increased attention to contextually deviant events. These findings provide strong evidence for cultural modulations of neural mechanisms underlying human cognition.

However, to date it is unknown to what degree the cultural difference in self-concept may influence the neural mechanisms of self-face recognition. Our recent fMRI study (Sui & Han, 2007) found that priming Chinese subjects using independent self-construals (e.g., "I", "mine") increased right frontal activity associated with self-recognition, which was, however, weakened by the interdependent self-construal (e.g., "we", "our") priming. Our neuroimaging findings suggest that dynamic access to different self-construals may modulate the neural substrates of self-recognition and raise the question of whether self-construal differences arising from long-term cultural practice may give rise to distinct neurocognitive responses in people from Western and East Asian cultures. One possibility is that the Western independent self may assign greater social salience or positive association to one's own face than to others' faces (Ma & Han, under review), which in turn results in stronger attention to one's own face when presented among others' faces and induces deeper processing of the own-face. In contrast, as the East Asian interdependent self emphasizes social connections between the self and others, enhanced processing of one's own face may not be as strong as that in Westerners.

To test this hypothesis, we recorded ERPs to one's own face and familiar faces from two cultural groups, i.e., British and Chinese. Using the 24-item Independent and Interdependent Self-construals Scale (Singelis, 1994), Lu et al. (2001) showed that Chinese subjects scored higher on the interdependent self-construal scale of the own-face in two blocks of trials but to judge head orientations of a familiar face in other two blocks of trials. Thus subjects had to identify face owners (i.e., self vs. a familiar person) first and then discriminated head orientations. Such design helps to clarify neural mechanisms of self-recognition in the attended condition (i.e., when the own-face and familiar faces were targets) and in the unattended condition (i.e., when the own-face and familiar faces were nontargets).

Prior ERP studies indicate that a negative activity over the fronto-central electrodes peaking between 200 and 350 ms (anterior N2) is sensitive to perceptual salience of stimuli (Folstein & Van Petten, 2008). The anterior N2 is also involved in the processing of faces. For example, faces with neutral and happy expressions elicited larger N2 amplitudes compared with angry faces (Kubota & Ito, 2007). The anterior N2 also differentiates between faces of different races by showing larger amplitudes to racial ingroup than outgroup faces (Ito & Urland, 2003, 2005) and has been associated with deeper processing of faces to benefit individuating (Kubota & Ito, 2007). Our previous ERP work found that face recognition in Chinese subjects is characterized with enlarged N2 to familiar faces than the own-face (Sui et al., 2006), suggesting enhanced processing of familiar faces and increased attention to others. However, if the independent self-construals endow the own-face with higher social significance relative to familiar faces, one would expect larger amplitudes of the anterior N2 to the own-face than familiar faces in British subjects.

METHOD

Subjects

Sixteen Chinese college students (8 males and 8 females, 20.6 ± 2.4 years of age, range 17–27) in Beijing, China, and 16 British college students (8 males and 8 females, 22.6 ± 6.5 years of age, range 19–44, all were Caucasians) in Hull, UK, participated in this study as paid volunteers. All were right-handed, had normal or corrected-to-normal vision, and had no neurological or psychiatric history. Subjects in both groups were born and lived in their own countries. There was no significant age difference between the two cultural groups, $t(30) = -1.15$, $p = .26$. Informed consent was obtained prior to the experiment according to procedures approved by local ethics committees.

Stimuli and procedure

A digital camera was used to create 10 face images from each subject and a gender-matched schoolmate, whom the subject had known for two to four years. The images showed five left and five right profiles of each face, whose angle ranged from 15° to 90° in each direction with equal steps. All faces were shown in gray scale with a neutral facial expression. The images were normalized to 100×100 pixels, which subtended $3.1 \times 3.1^\circ$ of visual angle at a viewing distance of 90 cm. The luminance and contrast of all the images were scaled to their means to rule out the influence of low-level perceptual properties on behavioral performances and ERPs. The face stimuli were presented on a black background of a 21-inch monitor.

Each subject completed four blocks of trials. Each block consisted of 60 images of one's own face and 60 images of a familiar face that were displayed in a random order. Each block of trials began with the presentation of a white cross serving as a fixation point at the centre of screen for 1000 ms. A face image was then displayed at the centre of the screen for 200 ms, followed by a fixation cross presented randomly between 800 and 1200 ms (Figure 1a and 1b). In two blocks of trials, subjects were asked to judge head orientations of the own-face by pressing the left or right buttons on a response pad using the left or right index finger while ignoring the familiar face. In two other blocks of trials, subjects had to judge head orientations of the familiar face while ignoring the own-face. Thus the own-face and familiar face were attended when they were targets but unattended when they were nontargets. The order of the four blocks of trials was counterbalanced across subjects. Instructions emphasized both response speed and accuracy.

Electrophysiological data recording and analysis

After electrode cap placement, subjects were seated in a sound and electrically shielded room. The Chinese data were collected using the Neuroscan system in Beijing, and the British data were collected using the BP system in Hull.

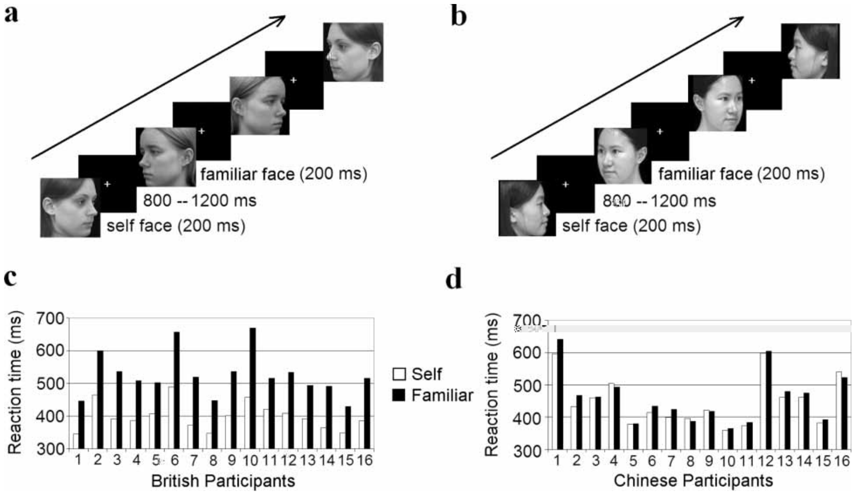

Figure 1. Experimental procedure and behavioral results. The stimuli and procedure for the British and Chinese subjects are illustrated in (a) and (b), respectively. The faces in (a) and (b) are example stimuli for the British and Chinese subjects. The task was to decide whether the self-face or the familiar face was shown in a left or right profile. The decision was made by a button press to target faces (own-face or the familiar face) using the left or right index finger and ignoring the other faces. Reaction times for the self-faces and familiar faces from the British and Chinese individual subjects are shown in (c) and (d), respectively. Informed written consent was obtained from all subjects before the experiment.

The electroencephalogram (EEG) was recorded from 62 Ag/AgCl scalp electrodes on an elastic cap according to the extended 10–20 system using a right mastoid as a reference. Grand averages were calculated after re-referencing individual ERPs to the common average reference. The electrode impedances of each electrode were kept less than 5 kω. The EEG was amplified by a band pass of 0.1–100 Hz and digitized at a sampling rate of 250 Hz. The eye blink artifacts were monitored with electrodes located above and below the left eye. The horizontal electro-oculogram (EOG) was recorded from electrodes placed about 1.5 cm lateral to the left and right external canthi. The ERPs in each condition were averaged separately offline with averaging epochs beginning 200 ms before stimulus onset and continuing for 800 ms. After filtering of the EEG with a 1–30 Hz bandpass filter, trials contaminated by eye blinks, eye movements, or muscle potentials exceeding ±60 μv at any electrode were excluded from the average. The baseline for ERP measurements was the mean voltage of a 200 ms pre-stimulus interval and the latency was measured relative to the stimulus onset.

EEG data with correct responses were computed for further analysis. The face stimuli elicited a negativity peaking between 160 and 192 ms over the temporal-occipital area (N170). Face stimuli also elicited a negative wave peaking at 100–140 ms (anterior N1) and a positivity at 160–192 ms at the central and frontal sites (vertex positive potential, VPP). The VPP was followed by a negative component peaking between 280 and 340 ms over the frontal-central area (anterior N2) and a long-latency positivity at 300–500 ms (P3) over the central-parietal area. The mean ERP amplitudes of the anterior N2 at 280–340 ms were computed at the frontal (Fz, F1, F2, F3, F4), front-central (FCz, FC1, FC2, FC3, FC4), and central (Cz, C1, C2, C3, C4) electrodes. The mean amplitudes of the P3 component at 300–500 ms were computed at the central (Cz, C1, C2, C3, C4), central-parietal (CPz, CP1, CP2, CP3, CP4), and parietal (Pz, P1, P2, P3, P4) electrodes. Because no significant difference was found between electrodes over the left and right hemispheres, we reported the most significant N2 effect at Fz, and the P3 effect at Pz. The N2 and P3 amplitudes were subjected to repeated-measures analyses of variance (ANOVAs) with Face (own-face vs. familiar face) and Attention (attended vs. unattended) as within-subjects variables and Cultural Group (British vs. Chinese) as a between-subjects variable. Significance was reported after Greenhouse-Geisser corrections. ANOVAs of the N1, N170 and VPP amplitudes did not show significant effect of Face and thus were not reported. Behavioral data were subject to ANOVAs with Face (own-face vs. familiar face) as a within-subject variable and Cultural Group (British vs. Chinese) as a between-subjects variable.

RESULTS

Behavioral performance

Table 1 shows mean reaction times (RTs) and response accuracies. Figure 1c and 1d illustrate the RT results from each individual subject from the two cultural groups. ANOVAs of RTs showed a significant main effect of Face, $F(1, 30) = 219.42$, $p < .001$, suggesting that subjects responded faster to the own-face than to familiar faces. Although there was no significant main effect of Cultural Group, $F(1, 30) = 0.15$, $p = .70$, we found a significant interaction between Face and Cultural Group, $F(1, 30) = 162.13$, $p < .001$, due to a greater self-advantage effect for British than for Chinese

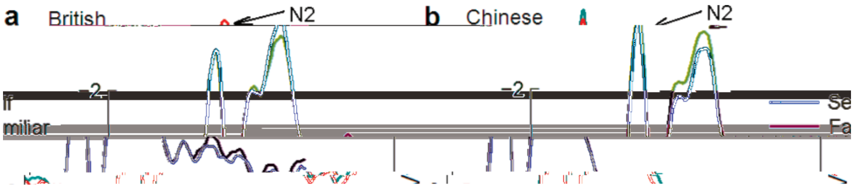

Figure 2. The results of N2 and P3 components elicited by self-faces and familiar faces. The results of the anterior N2 at Fz around 280–340 ms (collapsed across the attended and unattended conditions) are shown in (a)–(d). The N2 was enlarged to own-face relative to familiar face in British subjects (a) but was of smaller amplitudes to own-face than familiar faces for the Chinese (b). Top views of voltage topographies of N2 difference between self-faces and familiar faces from the British and Chinese are shown separately in (c). Difference waves between self-faces and familiar faces were computed at all electrode positions. The mean amplitude of N2 from the British and Chinese at Fz is shown in (d). The results of the P3 at Pz around 300–500 ms (combining British and Chinese results) are shown in (e)–(h). ERPs to self faces yielded more positive deflection than ERPs to familiar faces in the attended condition (e), but no difference in the unattended condition (f). Top views of voltage topographies of P3 difference between self and familiar faces in the attended and unattended conditions are shown in (g). Difference potentials between self and familiar faces were computed at all electrode positions. The mean amplitude of P3 at Pz in the attended and unattended conditions is shown in (h). Error bars in all figures represent one standard error.

responses (RTs to familiar faces minus RTs to one's own face) and the differential neural responses to one's own and familiar faces (N2 or P3 amplitudes to the familiar face minus N2 or P3 amplitudes to the own-face). Although separate analysis of the data from British and Chinese subjects did not show significant correlations, p values $> .05$, the combined data from the two cultural groups showed a significant correlation between the self-advantage in behavioral responses and the differential N2 amplitudes to the own-face and the familiar face, $r = 0.520$, $p < .001$. As shown in Figure 3, the greater the self-advantage in behavioral responses, the larger the

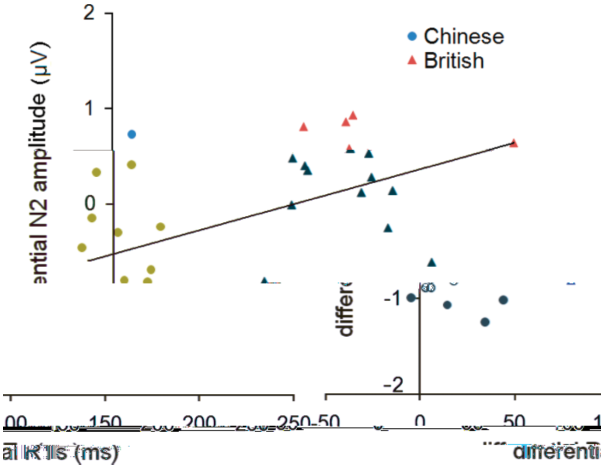

Figure 3. The results of correlation analysis. The *x*-axis shows the scale of self-advantage in behavioral responses (RTs to familiar faces minus RTs to one's own face) and the *y*-axis shows the differential N2 amplitudes to one's own and familiar faces (N2 amplitudes to familiar faces minus N2 amplitudes to one's own face).

differential N2 amplitudes to the own-face and familiar faces. This correlation reflects *per se* the fact that the mean differential RTs and differential N2 amplitudes were smaller in Chinese than in British subjects, as the results shown in Figure 3 separate the cultural groups clearly. Similar analysis of the P3 amplitudes failed to show significant correlation between the self-advantage in behavioral responses and the differential P3 amplitudes to the own- face and the familiar face, $r = -0.187$, $p = .306$.

We also calculated the correlation between the self-advantage in response accuracy and the differential neural responses (N2 or P3 amplitudes) to the own-face and familiar faces, but failed to find any significant correlation, N2: $r = 0.121$, $p = .510$, P3: $r = -0033$, $p = .856$, suggesting that cultural difference in neural mechanisms of face recognition can only predict differential response speeds to the own-face and familiar faces, possibly because the response accuracy was nearly at the ceiling.

DISCUSSION

Although previous work showed self-advantage in behavioral performances to the own-face in both Westerners and Chinese (Tong & Nakayama, 1999; Keenan et al., 1999; Sui, Zhu, & Han, 2006), it is difficult to compare the results from different cultural groups because the data were collected under different paradigms. The current work used the same procedure to measure behavioral performances and neural activities associated with processing of the own-face and personally familiar faces in British and Chinese subjects and provides the first evidence for cultural difference in self-recognition.

Our behavioral data showed that both British and Chinese subjects responded faster to their own faces relative to familiar faces. Unlike previous research that employed visual search (Tong & Nakayama, 1999) or face owner identification tasks (Keenan et al., 1999), we asked subjects to judge head orientation of faces in stimulus displays. These behavioral findings provide evidence for greater social salience of or positive association with the own-face than others' faces (Ma & Han, under review) regardless of sociocultural contexts in which subjects grew up. In addition, because it used similar stimuli and procedure, the present work allowed us to make cross-cultural comparison of self-recognition. We found that although both cultural groups showed behavioral evidence for self-advantage in face recognition, this effect was greater for British than for Chinese subjects, and such difference was consistent across all subjects in the two cultural groups. The cultural difference in behavioral performance is consistent with the idea that the social salience of one's own face is greater for the Western independent self than for the East Asian interdependent self and induces stronger attention to facilitate the processing of one's own face.

More interestingly, we found ERP evidence for cultural difference in the neural mechanism of self-recognition. While the early ERP components underpinning face structural encoding such as the N170 did not differentiate between the own-face and familiar faces, the anterior N2 showed evidence for modulation by face owners. Most importantly, the N2 modulation showed a reverse pattern for the two cultural groups. British subjects showed enlarged N2 to the own-face as compared to familiar faces, whereas Chinese subjects showed enlarged N2 to familiar faces as compared to the own-face. This cultural difference was evident regardless of whether the face stimuli were attended or unattended. As the anterior N2 is associated with deeper processing of faces to benefit individuation (Kubota & Ito, 2007), the cultural specific N2 modulation supports the view that, relative to Chinese subjects, British subjects with the independent self-construal pay more attention to the information about the self than about others. This in turn results in enhanced processing of one's own face at about 300 ms after sensory stimulation. We also found a correlation between the self-advantage in behavioral responses and the differential N2 amplitudes to the own-face and familiar faces, suggesting that the difference in the N2 modulation may contribute at least partially to the cultural difference in RTs to one's own and familiar faces.

We also found modulation of the long-latency ERP component by face owners. The P3 component to target stimuli was enlarged by one's own face as compared to personally familiar faces, similarly to our previous observations (Sui et al., 2006). However, the P3 effect was different from the N2 modulation by face owners in two aspects. First, the P3 modulation by face owners was evident only when the face stimuli were targets. Second, the P3 modulation by face owners did not differ between the two cultural groups. The P3 induced by face stimuli has been suggested to index attention to motivationally relevant stimuli because the P3 shows increased amplitudes to emotional faces as compared to neutral faces (Eimer & Holmes, 2002; Schupp et al., 2004). In addition, the P3 amplitudes are modulated by emotional faces only when emotional expression is task-relevant (Eimer et al., Holmes, & McGlone, 2003). Given the similar P3 modulation by facial expression and face owner, we suggest that, similarly to emotional faces, one's own face also induces enhanced attentional evaluation and increased motivation to respond compared with familiar faces during the processing of target faces. Such a mechanism helps one to make rapid responses to any information related to the self in a complex social context. In addition, our ERP results suggest that such a mechanism plays a similar role in the two cultural groups and contributes to the behavioral performances to a greater degree compared with the neural mechanism indexed by the N2 component.

Both the stimuli and paradigm of our study are different from Lewis et al.'s (2008) study that recorded ERPs to numbers or letters in an oddball paradigm and showed cultural difference in both target-related P3 and stimulus-novelty-related P3 that were respectively elicited by infrequent targets and nontargets. Lewis et al. (2008) suggest that the relatively larger target-related P3 in European Americans and the relatively larger stimulus-novelty-related P3 in East Asian Americans can be markers of culturally different object-dependent and context-dependent perception. The P3 component observed in our study, however, reflects comparable evaluative processes of self during face recognition in British and Chinese subjects although self-construals may be different between the two cultural groups.

One may notice that ERPs were recorded from British and Chinese subjects using different ERP systems and thus may wonder whether our results are due to the cross-site ERP variance rather than to culture. This issue is critical for all cross-cultural neuroimaging studies. Possible systematic cross-site variance of ERP signals may exist between any two ERP labs, such as differences in electrical signal noise and electrode resistance. Differences in ERP amplitudes between individuals also exist and may influence the difference in grand ERPs between two groups of subjects. To avoid such potential confounds in our study, we recorded ERPs to both the own-face and familiar faces and our data analysis focused on the comparison between differential ERPs to the own-face and familiar faces across the two cultural groups. The systematic cross-site variance of ERP signals should not depend on stimuli, and the effect of electrical signal noise and electrode resistance on ERPs to the own-face and familiar faces should be comparable since they were recorded in the same lab and at the same time. The comparison between differential ERPs to the own-face and familiar faces across two cultural groups should reduce the influence of systematic cross-site variance of ERP signals to a minimum degree. In addition, the effect of systematic noise from a specific EEG/ERP system such as a positive or negative baseline shift should be similar on different ERP components. Thus our ERP data analysis examined possible cultural difference on all ERP components such as N170, N2, and P3. We observed cultural difference in the anterior N2 associated with self/other face processing but not in N170 and P3. Such results cannot be explained by systematic noises from a specific EEG/ERP system. A more general question confronted by cultural neuroscience studies is how to disentangle the effects of culture and race. As pointed out by Chiao and Ambady (2007), cultural difference in neural substrates of human cognition can be confounded by race since racial group membership also affects neural processes underlying other basic aspects of cognition. Indeed, the subject groups in our study were different in both culture and race. However, race may contribute to our findings to a minimum degree because each subject group was presented only with faces of the same race during the experiment. This design does not remind subjects of race identity during the EEG recording procedure.

While the current ERP study suggests cultural difference in neural mechanisms underlying the processing of one's own face, one may ask how to reconcile the current ERP results with the previous fMRI studies of Westerns and Chinese subjects. fMRI studies of Westerners (Devue et al., 2007; Platek et al., 2006; Uddin et al., 2005) found increased activation in the right frontal and parietal lobes to the own-face relative to faces of familiar others whereas the fMRI study of Chinese observed only the right frontal activity linked to self-recognition (Sui & Han, 2007). Although these studies show culturally common activation (e.g., right frontal activity) and culturally specific activation (e.g., right parietal activation) related to self-recognition, it is unclear if the culturally differential parietal activity reflects the effect of cultural practice. This is because the tasks used in these studies were different (an explicit face recognition task was used in the studies of Western subjects, whereas an implicit face recognition task was used in the study of Chinese subjects). Moreover, one may ask how to reconcile our previous fMRI findings (Sui & Han, 2007) and the current ERP findings. Because of the low temporal resolution of the BOLD signals that usually reach peak amplitude around 4–6 s after stimulus delivery, the right frontal activity associated with self-recognition observed in Chinese (Sui & Han, 2007) may reflect a summary of the neural processes shown in the current ERP study that finish within 1 s after sensory stimulation. The fMRI results showed only increased neural activity to one's own face as compared to familiar faces, whereas the ERP results showed both increased (e.g., the P3) and decreased (e.g., the anterior N2) activity linked to self-recognition in Chinese subjects. It appears that the right frontal activity and the P3 effect (but not the N2 effect) are consistent with the faster behavioral responses to one's own face relative to familiar faces. As the neural sources of the P3 and N2 components elicited by face stimuli are unknown at this moment, it is difficult to relate the ERP components to the right frontal cortex. However, the ERP results showed more complicated neural processes compared with the fMRI results and indicate that the neural processes at different stages of self-recognition are either culturally similar (the P3) or culturally different (N2).

In summary, while our previous fMRI results indicate that neural substrates underlying self-recognition can be modulated by short-term self-construal priming (Sui & Han, 2007), the current ERP findings indicate that Western/East Asian cultures may influence the neurocognitive mechanisms underpinning self-recognition at a specific stage of face processing. Our findings indicate that the influence of cultural differences on self-concept may extend beyond the processing of personal traits (Han et al., 2008; Zhu et al., 2007). The neural mechanism underlying the processing of the physical self (e.g., face) may also undergo cultural influence. Taken together, the brain imaging results support the view that different sociocultural structure and practice modulate the processes of self-related information (e.g. Markus & Kitayama, 1991; Nisbett & Masuda, 2003; Nisbett & Miyamoto, 2005) and influence the neural substrates of multiple levels of human cognitions (Han & Northoff, 2008).

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