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# Neural basis of cultural influence on self-representation

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**Culture affects the psychological structure of self and results in two distinct types of self-representation (Western independent self and East Asian interdependent self). However, the neural basis of culture–self interaction remains unknown. We used fMRI to measured brain activity from Western and Chinese subjects who judged personal trait adjectives regarding self, mother or a public person. We found that the medial prefrontal cortex (MPFC) and anterior cingulate cortex (ACC) showed stronger activation in self- than other-judgment conditions for both Chinese and Western subjects. However, relative to other-judgments, mother-judgments activated MPFC in Chinese but not in Western subjects. Our findings suggest that Chinese individuals use MPFC to represent both the self and the mother whereas Westerners use MPFC to represent exclusively the self, providing neuroimaging evidence that culture shapes the functional anatomy of self-representation.**


*Keywords:* Culture; fMRI; MPFC; Self

## Introduction

Representation of self is ecologically important because it determines the relationship between ourselves and others in social behaviors. Social psychologists (Heine, 2001; Markus and Kitayama, 1991) have found that Westerners (North Americans and Europeans) tend to view the self as an autonomous entity separating from others and to behave according to their own internal attributes and thoughts (the independent self). In contrast, East Asians emphasize the interconnectedness of human beings along with contingencies between the individual's behavior and the thoughts and actions of others in the relationship (the interdependent self). However, it remains unknown how the cultural influence on self-representation is accomplished in the human brain.

Recent neuroimaging research used a self-referential task (Rogers et al., 1977) to localize the neural substrates of self-representation. In this task, subjects are first asked to judge whether a trait is suitable to describe the self or others. After this encoding phase, subjects are required to recall as many of the words as they can. Typically, self-descriptive traits are better remembered than traits descriptive of others (the self-reference effect; Symons and Johnson, 1997). Using such paradigms, neuroimaging studies found stronger medial prefrontal cortex (MPFC) activation linked to self- relative to other-judgments (Craik et al., 1999; Kelley et al., 2002; Lieberman et al., 2004; Zhang et al., 2006), indicating that MPFC is engaged in representation of self-knowledge such as one's own personality traits.

It has been shown that the self-referential effect can be influenced by culture. Westerners show better memory of self- than intimate-other-descriptive traits (Lord, 1980; Klein et al., 1989; but see Bower and Gilligan, 1979) whereas Chinese remember self- and intimate-other-descriptive traits equally well (Zhu and Zhang, 2002), suggesting that Chinese self may include intimate persons whereas Western self excludes any others. Consistent with this, Heatherton et al. (2006) observed stronger MPFC activation linked to self- than best-friend-judgment in American subjects. These results raise an interesting question, namely, whether MPFC is unique to representations of the individual's self for Westerners but not for Chinese. One possibility is that MPFC is engaged exclusively in self-representation for Westerners but is engaged by thinking about close relatives as well as self for Chinese. The current work assessed this hypothesis by recording neural activity using functional magnetic resonance imaging (fMRI) from Chinese and Western subjects while they performed a self-referential task. We tested whether MPFC can be activated by self- and intimate-other-judgments (i.e., mother) for Chinese but is activated only by self-judgment for Westerners. A third public person was chosen to provide a baseline condition for brain activity when making person-specific judgments. Similar to the previous work (Kelley et al., 2002), we used a font identification task to control general perceptual processing factors and to evaluate the contribution of semantic processing to the judgment tasks.

## Materials and methods

### Subjects

Thirteen Chinese college students (8 men and 5 women, mean (±SD) age 21.5±1.13 years) and thirteen Western college students

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(8 men and 5 women, mean age 23.1±2.33 years) participated in this study as paid volunteers. The Western subjects were Caucasians with their native language being English (6 English, 4 American, 2 Australian and 1 Canadian) and had studied in China for less than one year when they participated in this study. The two groups of subjects were matched on educational level (2–5 years university) and the time of living independently. All subjects had no neurological or psychiatric history and were right-handed. All had normal or corrected-to-normal vision. Informed consent was obtained prior to scanning. This study was approved by a local ethic committee.

*Behavioral tasks*

Subjects were first imaged while performing trait judgment tasks. The stimuli were presented through an LCD projector onto a rear-projection screen at the head end of the bore. The screen was viewed with an angled mirror positioned on the head-coil. Each of the four functional scans consisted of 9 sessions (Fig. 1). Four judgment tasks were conducted in each scan requiring subjects to judge if an adjective was proper to describe the self, mother, other (Bill Clinton, the former American president, for Western subjects, or Rongji Zhu, the former Chinese premier, for Chinese subjects) or to judge the font of the words (uppercase or lowercase letters for Western subjects, bold- or light-faced character for Chinese subjects). The questions and traits were in Chinese for the Chinese and in English for the Westerners. Subjects made judgments by pressing one of the two buttons with the left or right thumb. The judgment tasks were intervened by null sessions during which subjects passively viewed two rows of asterisks (*). The order of the judgment tasks was counterbalanced using a Latin Squire design.

Each trial in the judgment tasks consisted of a "cue" word (either self, mother, other or font, black on a white background) above a trait adjective presented for 2000 ms at the center of the screen. The trait adjective then disappeared while the "cue" word stayed on the screen for 1000 ms, during which subjects made response. Each of the Chinese characters subtended 0.65° ("cue" word) or 2.0° (trait adjective) of visual angle. Each letter of the English words subtended 0.5° ("cue" word) or 1.8° (trait adjective) of visual angle. Each symbol used in the null session subtended 0.3° (small ones) or 0.74°(large ones) of visual angle. Twelve trait adjectives were presented in each session. Each session of the judgment tasks lasted for 39 s including an instruction of 3 s. Each null session lasted for 33 s.

A total of 384 unique adjectives were selected from established personality trait adjective pools (Chinese words from Liu, 1990, English words from Anderson, 1968). The meanings of Chinese and English words were matched. The adjectives were classified into 32 lists of 12 words. Each Chinese adjective consisted of two characters. The English word lists were matched on word length and number of syllables. Half of the words were positive adjective and half were negative. Sixteen lists of words were pseudo-randomly selected for the judgment tasks while the remaining 16 lists of words were used in the memory test.

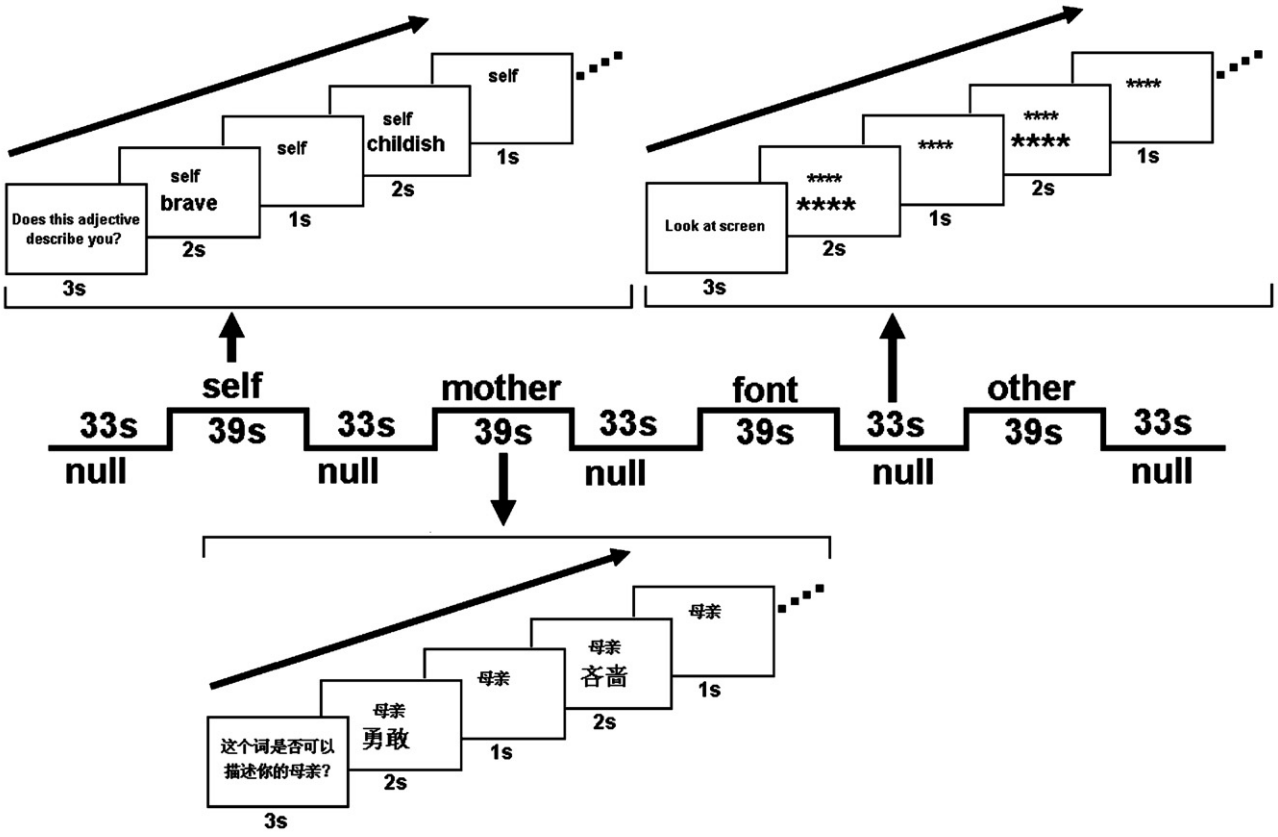


Fig. 1. Schema of the design of one scan of the current study. The stimuli and procedure of mother-, other- and font-judgments were the same as those of the self-judgment except that the word "self" on the screen was replaced by "mother", "Bill Clinton" for Western subjects or "Rongji Zhu" for Chinese subjects, or "font", respectively.

After the scanning procedure, subjects were given a "surprise" recognition memory test. The trait adjectives used in the judgment tasks were mixed with 192 new trait adjectives and presented in a random order. Subjects were asked to identify old or new items by button press without a time limit. Subjects were further asked to make an R/K judgment (Tulving, 1999) for old words by indicating whether 'remembering' (consciously recollect specific details of the item that appeared in the earlier list, '*R* score') or simply 'knowing' (not accompanied by recollective experience but has a feeling of knowing or familiarity to the subjects) the item.

### *MRI data acquisition*

Brain imaging was performed on a 3-T Siemens Trio MR scanner with a standard birdcage head coil at Beijing MRI Center for Brain Research. Pieces of foam were used to minimize head movement. A T2*-weighted gradient-echo planar imaging (EPI) sequence (TR=2000 ms, TE=30 ms and flip angle=90°, 3 mm thickness, skip 0.75 mm, FOV=220 mm, 64×64×32 matrix with 3.4×3.4×3.75 mm spatial resolution) was used to acquire a set of 32 axial slices of functional images. Four functional scans were obtained. Each scan lasted for 324 s. During each functional scan, 162 sets of mosaic images were acquired allowing complete brain coverage. High-resolution anatomic images were obtained using a standard 3D T1-weighted sequence with 0.9×0.9 mm in plane resolution and 1.3 mm slice thickness (256×256 matrix, TR=1600 ms, TE=3.93 ms).

### *fMRI data analysis*

Statistical Parametric Mapping software (SPM2, Wellcome Department of Cognitive Neurology, UK) was used for imaging data processing and analysis. Functional images were realigned to correct for head movement between scans and coregistered with each subject's anatomical scan. Functional images were transformed into a standard anatomical space ($2\times2\times2$ mm$^3$ isotropic vexes) based on the Montreal Neurological Institute (MNI) template. Normalized data were then spatially smoothed using a Gaussian filter with a full-width at half-maximum (FWHM) parameter set to 6 mm. The image data were modeled using a box-car function. A general linear model was used to compute parameter estimates and *t*-contrast images (containing weighted parameter estimates) for each comparison at each voxel. The contrasts between trait judgments and font judgment and between self- or mother-judgments and other-judgment were defined in each subject. These individual contrast images were then submitted to a second-level random-effect analysis (threshold at $p<0.05$, corrected for multiple comparisons). The SPM coordinates for standard brain from MNI template were converted to Talairach coordinates (Talairach and Tournoux, 1998) using a non-linear transform method (http://www.mrc-cbu.cam.ac.uk/Imaging/mnispace.html).

A regions-of-interest (ROI) analysis was conducted to explore the cultural effect on self-representation in MPFC and ACC. ROIs were defined separately for the Chinese and Western subjects using the coordinates of the centers of MPFC and ACC activation clusters in the contrast between self and other judgments. The mean fMRI signals of voxels in spheres with a radius of 3 mm were calculated from the raw fMRI data by contrasting the sessions of judgment tasks and the null sessions. The fMRI signals were subjected to a repeated measure analysis of variance (ANOVA) with factors being Judgment (self, mother, other) and Culture (Chinese vs. Western group). The fMRI signals in the other-judgment condition were also subtracted from the self- and mother-judgment conditions to index the self- and mother-reference effects. An ANOVA with factors being Reference (self vs. mother) and Culture (Chinese vs. Western group) was then conducted on the differential fMRI signals.

## Results

Corrected recognition scores (the proportion of hits minus false alarms) in the recognition memory test were subjected to a 2 (Subject: Western or Chinese)×4 (Task: self, mother, other or font) ANOVA. Corrected recognition scores were higher for judgments associated with deep semantic processing (self, mother or other) than for font-judgment ($F(3,72)=58.41$, $p<0.01$) and were higher for Chinese than for Western subjects ($F(1,24)=25.46$, $p<0.01$). The interaction of Subject×Task was significant ($F(3,72)=9.52$, $p<0.01$), suggesting different patterns of the recognition scores between the two groups of subjects. Separate analysis showed further that the adjectives used in the self-judgment task were remembered better than those used in the other-judgment task (Chinese: total score: $F(1,24)=4.69$, $p<0.05$; *R* score: $F(1,24)=4.87$, $p<0.05$; Westerner: total score: $F(1,24)=4.90$, $p<0.05$; *R* score: $F(1,24)=5.71$, $p<0.05$). The corrected recognition scores did not differ between the self- and mother-judgment conditions for Chinese subjects (total score: $F(1,24)=1.65$, $p>0.1$; *R* score: $F(1,24)=1.10$, $p>0.1$) but was higher in the self- than mother-judgment conditions for Western subjects (total score: $F(1,24)=3.68$, $p<0.06$; *R* score: $F(1,24)=5.80$, $p<0.05$; Fig. 2).

Self-, mother- and other-judgments were first contrasted with font-judgment to identify brain areas involved in the semantic encoding process. This revealed activations the inferior, middle and superior frontal cortex in the left hemisphere for both the Chinese and Western subjects (Table 1). The Western subjects also showed activation in the middle and superior temporal cortex and the posterior cingulate cortex.

The neural substrates underpinning the self-reference effect were defined as increased neural activities associated with self- than other-judgments. MPFC showed increased activity linked to self- than other-judgment for both Chinese (*x*/*y*/*z*=8/55/6, $Z=3.68$, BA 10) and Western subjects (0/51/3, $Z=4.07$, BA 10; Fig. 3a). Activation was also seen in ACC (−6/36/20, $Z=3.62$ and −2/33/30, $Z=3.76$, BA32) and the left frontal cortex (−24/57/12, $Z=4.27$, BA10) for Chinese subjects but only in ACC for Western subjects (−6/33/0, $Z=4.70$, BA24). The contrast between mother- and other-judgments showed stronger activation in MPFC (2/55/3, $Z=3.49$, BA10; Fig. 3b), ACC (0/18/18, $Z=3.50$) and the left prefrontal cortex (−22/59/15, $Z=3.49$) for Chinese subjects. However, the same contrast showed activation only in ACC (−4/35/−2, $Z=4.11$) for Western subjects. The contrast between the self and mother judgments showed activation in MPFC for Western subjects (−4/46/−6, $Z=3.78$, BA10; Fig. 3c) but not for Chinese subjects.

The ROI analysis calculated percent signal changes in MPFC (centered at 8/55/6 (Chinese) and 0/51/3 (Western)) relative to a low-level baseline (i.e., the null condition). Self-judgment increased MPFC activity whereas other-judgment decreased MPFC activity (Fig. 4). MPFC activity associated with mother-judgment was increased for Chinese subjects but decreased for Western subjects. A reliable interaction between culture and judgment

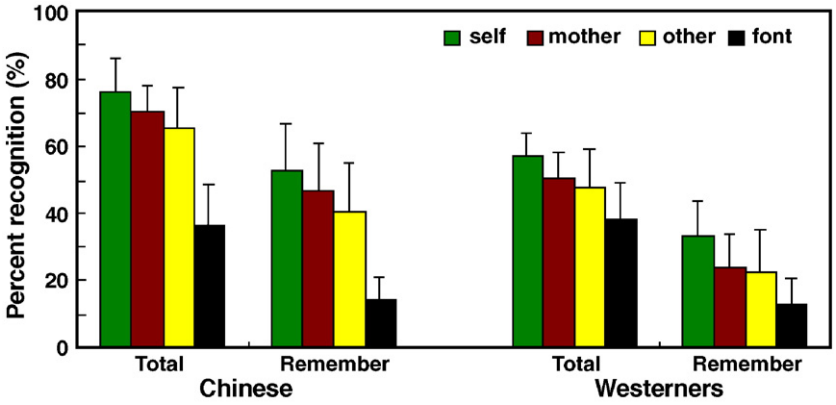


Fig. 2. Percent recognition in the memory tests for both groups of subjects. Bar graphs represent the total scores of correct recognition and the *R* scores. Error bars represent the standard errors in each condition.

confirmed the different patterns of MPFC activity between the two groups ($F(2,48)=3.58$, $p<0.05$). Paired *t*-tests confirmed that fMRI signals were larger in the self- than mother-judgment tasks for Western subjects ($t(12)=2.624$, $p<0.01$) but did not differ between the two conditions for Chinese subjects ($t(12)=1.138$, $p>0.05$).

To uncover the differential mother-reference effect between the two cultures, the mean fMRI signals linked to other-judgment were subtracted from those linked to the self- and mother-judgments. The ANOVAs of the differential fMRI signals showed a reliable interaction of Culture (Chinese vs. Western) × Reference (self vs. mother) ($F(1,24)=6.67$, $p<0.05$). Post hoc comparisons confirmed that the mother-reference effect was smaller than the self-reference effect for the Western subjects ($F(1,24)=5.96$, $p<0.05$) but did not differ from the self-reference effect for the Chinese subjects ($F(1,24)=1.47$, $p>0.05$).

Similar ROI analyses were conducted on the fMRI signals in ACC (centered at −6/36/20 (Chinese) and −6/33/0 (Western); Fig. 4). ACC signals showed a pattern similar to that of MPFC signals. However, neither the interaction of Culture × Judgment ($F(2,48)=1.17$, $p>0.05$) nor the interaction of Culture × Reference ($F(1,24)=0.35$, $p>0.1$) was significant, suggesting that the cultural effect on the neural substrates of self-representation was not reliable in the ACC activity. Finally, we conducted a three-way ANOVA on the differential fMRI signals with factors being Culture (Chinese vs. Western), Reference (self vs. mother) and Activation Foci (MPFC vs. ACC) as independent variables. There was a significant interaction of Culture × Reference × Activation Foci ($F(1,24)=5.90$, $p<0.05$), indicating that the cultural effect on the neural substrates of self-representation was mainly evident in MPFC activity.

Table 1
Regions of significant increased activation in comparison between semantic (self, mother and other) and non-semantic tasks ($p<0.05$ at the cluster level, corrected for multiple comparisons)

| Condition/region | Voxel no. | BA | *x* | y | *z* | Z value |
|---|---|---|---|---|---|---|
| *Chinese subjects* | | | | | | |
| Self minus font | | | | | | |
| Left inferior frontal gyrus | 747 | 47 | −42 | 22 | −12 | 4.92 |
| Medial frontal gyrus | 442 | 9 | 2 | 54 | 20 | 4.84 |
| Left superior frontal gyrus | *** | 9/10 | −14 | 60 | 32 | 4.56 |
| Mother minus font | | | | | | |
| Left inferior frontal gyrus | 409 | 47 | −50 | 32 | −6 | 4.00 |
| Medial frontal gyrus | 152 | 9 | −6 | 54 | 40 | 3.76 |
| Left superior frontal gyrus | *** | 10 | −8 | 64 | 20 | 3.22 |
| Other minus font | | | | | | |
| Left inferior frontal gyrus | 404 | 45 | −56 | 26 | 8 | 4.21 |
| *Western subjects* | | | | | | |
| Self minus font | | | | | | |
| Left middle temporal gyrus | 374 | 22 | −62 | −36 | 4 | 5.04 |
| Left inferior frontal gyrus | 232 | 47 | −30 | 16 | −14 | 4.59 |
| Superior frontal gyrus | 152 | 6 | −6 | 24 | 62 | 4.35 |
| Medial frontal gyrus | 217 | 8 | −6 | 52 | 44 | 4.18 |
| Mother minus font | | | | | | |
| Left inferior frontal gyrus | 1099 | 47 | −54 | 28 | −6 | 5.23 |
| Left middle temporal gyrus | 320 | 21 | −56 | −30 | 2 | 4.95 |
| Left superior frontal gyrus | 492 | 6 | −10 | 34 | 52 | 4.12 |
| Left posterior cingulated | 305 | 30 | −22 | −68 | 6 | 4.45 |
| Right cuneus | 193 | 17 | 16 | −96 | −2 | 4.07 |
| Right lingual gyrus | 156 | 19 | 22 | −60 | 0 | 4.05 |
| Other minus font | | | | | | |
| Left middle temporal gyrus | 942 | 21 | −58 | 0 | −18 | 4.78 |
| Right superior temporal gyrus | 157 | 38 | 54 | 10 | −20 | 4.55 |
| Right middle occipital gyrus | 286 | 18 | 32 | −90 | 2 | 4.47 |
| Left superior frontal gyrus | 244 | 9 | −6 | 58 | 34 | 4.60 |
| Right posterior cingulated | 123 | 30 | 20 | −66 | 10 | 3.68 |

Voxels no. = number of voxels in a cluster. BA = Brodmann's area. ***The left frontal gyrus and the medial frontal gyrus are in the same cluster.

## Discussion

Some studies found that intimate-other-reference judgments produce recall inferior to that found with self-reference judgments in Western subjects (Lord, 1980; Klein et al., 1989; Heatherton et al., 2006), whereas others found that the superior memory of self-referenced materials is diminished when compared with the material related to an intimate other (Bower and Gilligan, 1979). Nevertheless, these studies did not tell whether self and intimate persons share neural structures and whether cultures influence the relevant neural mechanisms. While some neuroimaging studies failed to find differential MPFC activity between self- and close-other judgments (Seger et al., 2004; Schmitz et al., 2004; Ochsner et al., 2005), Heatherton et al. (2006) recently reported stronger MPFC activity linked to the self relative to close others (best friends) in Western

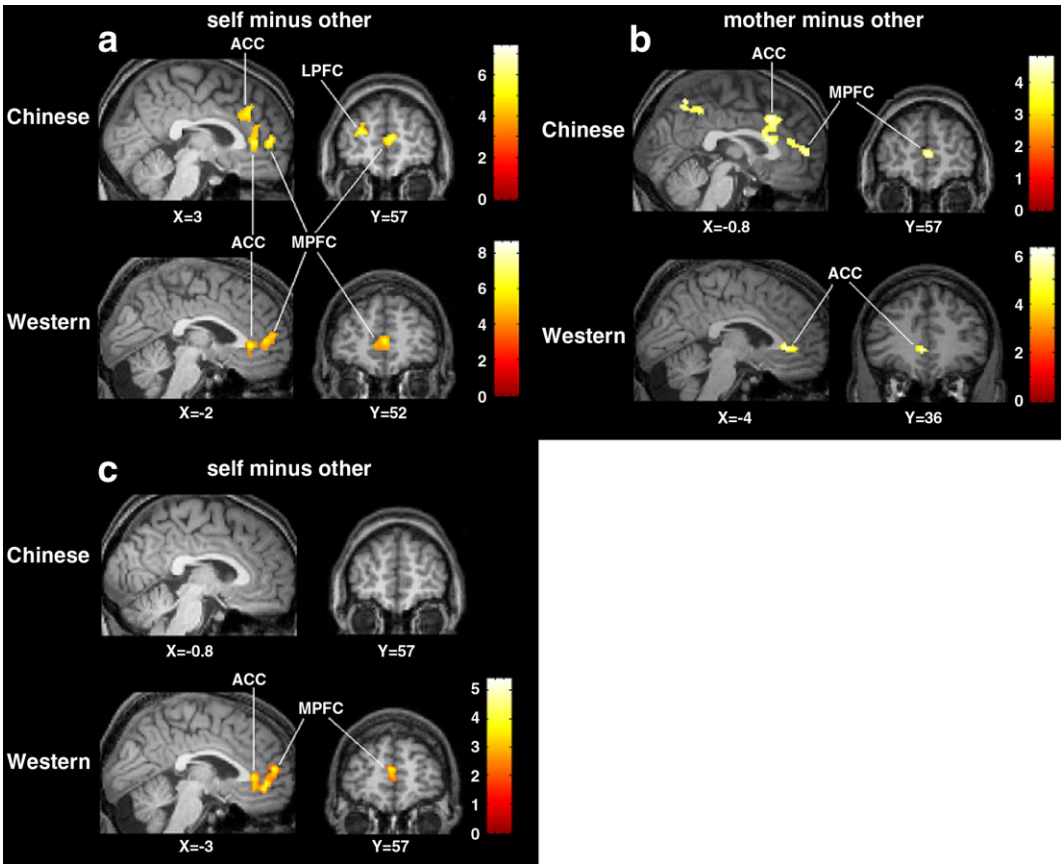


Fig. 3. Brain activations revealed in the contrast between different trait adjective judgment tasks. (a) Self minus other; (b) mother minus other; (c) self minus mother.

subjects.[1] The current research reinforces Heatherton et al's observation and showed evidence that such neural distinction between self and intimate persons was evident for Westerners but not for Chinese.

While observing a self-reference effect for both Chinese and Western subjects, we found that personal traits related to self-judgments were remembered better than those associated with mother-judgments for Western but not for Chinese subjects, replicating the results of our prior behavioral study (Zhu and Zhang, 2002). Our fMRI results showed stronger MPFC activation in the self- relative to other-judgments, consistent with previous studies of Western subjects (Kelley et al., 2002; Lieberman et al., 2004). In line with Heatherton et al. (2006), we demonstrate that self-judgments even induced stronger MPFC activation relative to mother-judgments in Western subjects. The ROI analysis showed further that self-judgments were qualitatively different from mother-judgments in that, relative to the null condition, self-judgments increased MPFC activity whereas mother-judgments reduced MPFC activity. The fact that Western individuals showed selective MPFC activity for judgments about themselves relative to their mothers, and that activity in mother-judgments did not differ from that in other-judgments, indicates that, for Westerners, MPFC is specific to the self.

We also found enhanced MPFC activity linked to self- relative to other-judgments in Chinese subjects. The locus of MPFC activity in these individuals was close to that found in Western subjects, indicating that MPFC is involved in self-representation irrespective of subjects' cultural background. Nevertheless, in Chinese individuals, mother-judgments generated enhanced MPFC activity compared with other-judgments and the null condition. Consequently, the representation of Chinese mother cannot be distinguished from the representation of their selves, in terms of the MPFC activity, indicating that Chinese individuals use MPFC to represent both mother and the self. In contrast, MPFC activity corresponds to a representation of only the individual self in Western subjects. These fMRI results showed strong empirical evidence that MPFC mediates cultural influence on the neural substrates of representation of self and close others. While social psychological studies suggest that cultures create habitual ways of processing information related to the self and one's important others (Heine, 2001; Markus and Kitayama, 1991), our fMRI results indicate that these habitual cognitive processes are accompanied by detectible parallel neural processes. The relatively heavy emphasis on interpersonal connectedness in Chinese culture has led to the development of neural unification of

[1] While Schmitz et al. (2004), Seger et al. (2004) and Ochsner et al. (2005) did not find difference in MPFC activity between self- and close-other judgments, the latter two studies failed to replicate the MPFC difference between self- and non-referential judgments. In addition, none of these studies tested subsequent memory for the reference materials. Of most important, none of these studies reported a contrast between close-other-judgment and judgment related to a public figure (used in previous studies as a critical controlled condition for the self-reference effect). The absence of MPFC activation in the contrast between self- and close-other judgments did not tell whether the close-other judgment is represented in MPFC.

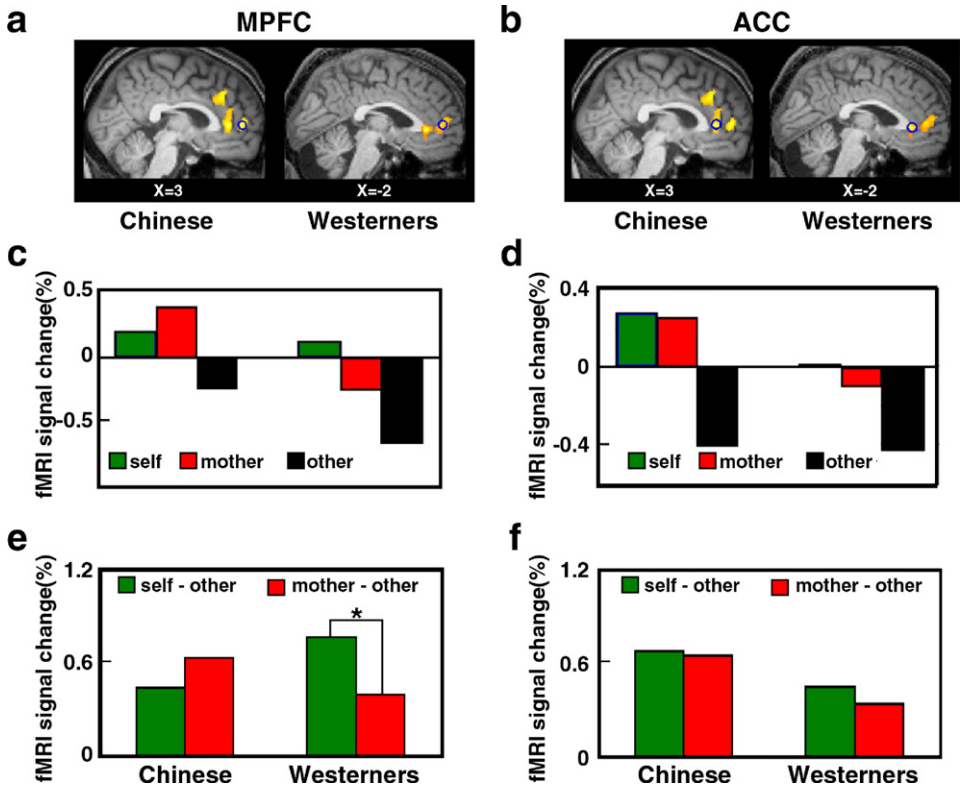


Fig. 4. fMRI results of the ROI analysis. Panels a and b illustrate the locus of the MPFC and ACC respectively (marked with blue circles); panels c and d represent fMRI signal changes in MPFC and ACC respectively in the self-, mother- and other-judgment tasks relative to the null condition; panels e and f represent differential fMRI signal changes (self minus other and mother minus other) in MPFC and ACC, respectively. The asterisk in panel e indicates a significance difference between the self- and mother-reference effects in percent signal changes.

the self and intimate persons such as mother, whereas the relative dominance of an independent self in Western cultures results in neural separation between the self and others (even close others such as mother).

Relative to other-judgments, self- and mother-judgments also induced activation in ACC for both groups of subjects. ACC has been shown to be activated when people think about their own physical appearance (Kjaer et al., 2002) or when they recognize their own face (Kircher et al., 2001). ACC is also activated in a number of emotional tasks (Bush et al., 2000) and is linked to emotional self-control (Allman et al., 2001). Given these findings, it may be speculated that judgments of personal traits related to oneself and mother in the current study might lead to think of their own or the mother's physical appearance and generate relevant emotional responses. Relative to ACC, MPFC maintains more abstract representation of the self, with culture producing a stronger influence on abstract self-representation than idiographic aspects of the corporeal self.

Finally, we found that, besides activity of MPFC and ACC, self-judgments activated the left frontal cortex compared with other-judgments in Chinese subjects; this was not observed in Western subjects. Similarly, mother-judgments by Chinese individuals induced activation in the left prefrontal cortex and ACC, which were not observed in Western subjects. The additional brain structures linked to self- and mother-judgments, in Chinese, compared with Western individuals, provide further neuroimaging evidence for the interdependent self formed by East Asian culture.

In summary, our fMRI results demonstrate that, in Chinese subjects, representation of both self and mother engages MPFC, whereas in Western subjects MPFC is reliably engaged only by self-judgments. The results suggest that Western independent self is mediated by unique neural substrates, whereas East Asian (e.g., Chinese here) interdependent self depends on overlapping of neural substrates for the self and close others. MPFC plays a unique role in self-representation in terms of whether being influenced by culture. Prior studies have shown that the Western self is different from the East Asian self at both social behavioral and cognitive levels. The current work extends this by providing neuroimaging evidence that the 'Western self' is different from the Chinese self at a neural level and suggests that culture influences the functional neuroanatomy of self-representation. These neuroimaging findings lend support to the view of interplay of biology and culture in shaping the mind and brain.

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