

Religious beliefs influence neural substrates of self-reflection in Tibetans

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Previous transcultural neuroimaging studies have shown that the neural substrates of self-reflection can be shaped by different cultures. There are few studies, however, on the neural activity of self-reflection where religion is viewed as a form of cultural expression. The present study examined the self-processing of two Chinese ethnic groups (Han and Tibetan) to investigate the significant role of religion on the functional anatomy of self-representation. We replicated the previous results in Han participants with the ventral medial prefrontal cortex and left anterior cingulate cortex showing stronger activation in self-processing when compared with other-processing conditions. However, no typical self-reference pattern was identified in Tibetan participants on behavioral or neural levels. This could be explained by the minimal subjective sense of 'I-ness' in Tibetan Buddhists. Our findings lend support to the presumed role of culture and religion in shaping the neural substrate of self.

Keywords: self-reflection; medial frontal cortex; religions; Buddhist

INTRODUCTION

Cultural differences can influence the neural activity of both low-level perception and attention processes and high-level social cognition (Han and Northoff, 2008). Neuroimaging studies have focused on the neural substrates of self-reflection

when low-level self-reflection is compared with other-reflection (Wang et al., 2015). However, no typical self-reference pattern was identified in Tibetan participants on behavioral or neural levels. This could be explained by the minimal subjective sense of 'I-ness' in Tibetan Buddhists. Our findings lend support to the presumed role of culture and religion in shaping the neural substrate of self.

Chinese ethnic groups (Han and Tibetan). Some previous studies showed that the Tibetan minority group in China has its own unique culture (Feng, 2007). Most Tibetan people are dedicated to Buddhism. In Tibet, many people hold the worldview that the material world is actually empty. The doctrine ‘anatta’ (i.e. no-self) requires Tibetan Buddhists to deny oneself. As a result, Tibetan Buddhists are inclined to be eccentric spiritual seekers through their religions practices, such as meditation.

Based on these analyses, we put forward a hypothesis that non-religious Han participants will perform differently and yield different brain activation patterns in self-processing conditions compared to Tibetan Buddhists. In other words, the Buddhist religious experience, as a form of cultural expression, can also shape our functional brain.

In this study, we adopted a similar paradigm to Zhu *et al.*'s study (2007; see also Rogers *et al.*, 1977; Lord, 1980; Klein *et al.*, 1989) in order to assess these hypotheses. During fMRI scans, both Han and Tibetan participants made a judgment on self, an intimate-other (i.e. mother) and a third public figure. Similar to the previous works (Kelley *et al.*, 2002; Zhu *et al.*, 2007), we used a font identification condition to control general perceptual processing factors and to evaluate the contribution of semantic processing to the judgment tasks.

METHODS

Participants

Sixteen Han participants (eight men and eight women) between the ages of 18–23 (mean 20.1 ± 1.4 years) and 16 Tibetan participants (eight men and eight women) between the ages of 17 and 22 (mean 19.6 ± 1.5 years)

were recruited from Minzu University of China. The Tibetan participants, their native language being Tibetan, had studied in Beijing for <1 year when they participated in this experiment. The two groups of participants were matched on the educational level and the time of living independently. Participants were all right handed and came from the region of south-west China. They reported no significant abnormal neurological history and all had normal or corrected-to-normal visual acuity. Informed consent was obtained prior to scanning. This study was approved by a local ethics committee. Participants were paid for their participation. One female Tibetan participant was removed from the data analysis as a result of rather low recognition ratio for total hit rate (0.34). The results reported here reflect the data of 31 participants (16 Han and 15 Tibetan, 16 men and 15 women, mean age 19.8 ± 1.4 years).

Behavioral tasks

Participants were scanned during four functional runs while making judgments about trait adjectives. 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 nine sessions (Figure 1). Four judgment tasks were conducted in each scan requiring participants to judge if an adjective was appropriate to describe themselves, their mother, or a famous public figure (Lu Xun, a famous Chinese writer, for Han participants; or Don-grub-rgyal, a famous Tibetan writer and poet, for Tibetan participants); furthermore, participants were asked to judge the font of the words (bold- or light-faced characters). The questions and trait words were

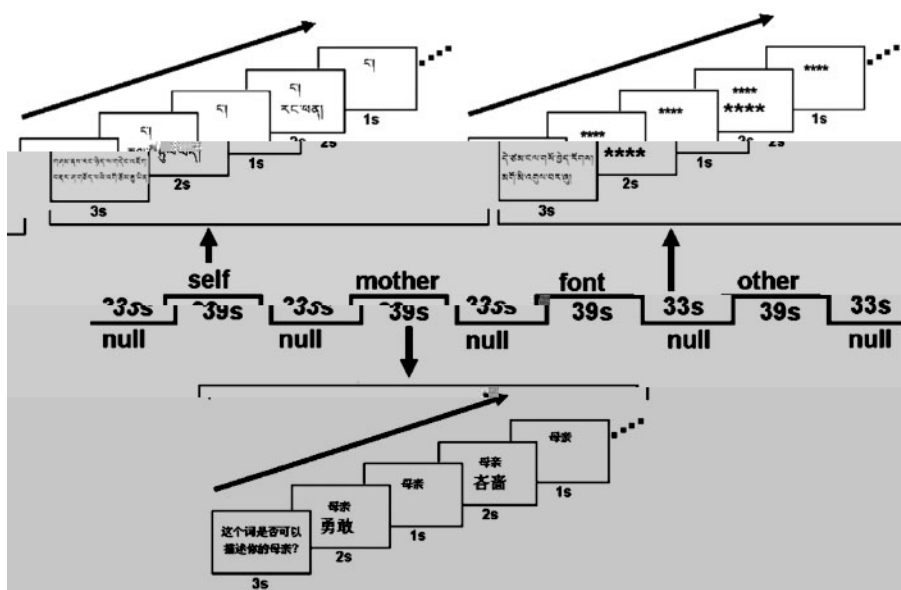


Fig. 1 Examples of experimental stimuli in one scan. The stimuli and procedure of mother-, other- and font-processing were the same as those of the self-processing except that the word ‘self’ on the screen was replaced by ‘mother’, ‘Lu Xun’ for Han participants and ‘Don-grub-rgyal’ for Tibetan participants, or ‘font’, respectively.

presented in their own native language (i.e. Mandarin for Han participants and the corresponding Tibetan language that was translated from Mandarin for Tibetan participants). The participants made judgments by pressing one of the two buttons with their left or right thumb. The judgment tasks were intervened by null sessions during which participants 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 time participants made their responses. Each of the Chinese characters subtended 0.65° ('cue' word) or 2.10° (trait adjective) of visual angle. Each letter of the Tibetan language words subtended 0.50° ('cue' word) or 2.40° (trait adjective) of visual angle. Each symbol used in the null session subtended 0.30° (small ones) or 0.74° (large ones) of visual angle.

A total of 384 unique adjectives were selected from established personality trait adjective pools (Chinese words from Liu, 1990); the Tibetan language trait adjectives were the corresponding translations. The adjectives were divided into 32 lists of 12 words that 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. Each Chinese adjective consisted of two characters. The Tibetan language 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 pseudorandomly selected for the judgment tasks while the remaining 16 lists of words were used in the memory test.

After the scanning procedure, participants were given a surprise recognition memory test. Participants viewed the 192 trait adjectives that were previously presented along with 192 novel trait adjectives that had not been presented during scanning. All the words were randomly presented and participants were asked to identify whether the word was old or new by pressing a button without a time limit.

MRI data acquisition

Brain imaging was performed on a 3-T Siemens Trio MR Scanner with a standard birdcage head coil at the Beijing MRI Center for Brain Research. Pieces of foam were used to minimize head movement. A T2*-weighted gradient-echo planar imaging sequence (TR = 2000 ms, TE = 30 ms and flip angle = 90° , 3 mm thickness, skip 0.75 mm, FOV = 240 mm, $64 \times 64 \times 32$ matrix with $3.4 \times 3.4 \times 3.75$ 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 spatial resolution, TR = 2530 ms, TE = 3.37 ms).

fMRI data analyses

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 participant's anatomical scan. Functional images were transformed into a standard anatomical space ($2 \times 2 \times 2$ mm³ isotropic voxels) 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 parameter set to 8 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 of self-, mother- and other-processing were defined in each participant. 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 were converted from MNI template to Talairach coordinates (Talairach and Tournoux, 1998) using a non-linear transform method.

A regions-of-interest (ROI) analysis was conducted to explore the cultural effect on self-processing in MPFC and ACC. ROIs were defined for both Han and Tibetan participants ($N = 31$) using the coordinates of the centers of MPFC and ACC activation clusters in the contrast between self- and other-processing. 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 Orientation tasks (self and other) and Group (Han and Tibetan). The fMRI signals in the other-processing conditions were also subtracted from the self-processing conditions to index the self-reference effects.

RESULTS

Behavioral results

Table 1 shows behavioral data for each trial type. An ANOVA showed no significant interaction between types of processing and religion. The comparison of response times between Hans and Tibetans was significant, Tibetans took longer to respond on self-, mother-, other- and font-processing compared to Hans. Also, there were significant response latencies among tasks in the encoding phase [Han: $F(3,45) = 84.49$, $P < 0.01$; Tibetan: $F(3,42) = 50.96$, $P < 0.01$]. *Post hoc* statistical tests revealed that response latencies were significantly faster for font processing than for self-processing [Han: $t(15) = 12.28$, $P < 0.01$; Tibetan: $t(14) = 11.84$, $P < 0.01$], mother processing

Table 1 Behavioral data during encoding and recognition phase

Tasks	Encoding Reaction Time (ms)	d'
Han participants		
Self	877 (19)	1.41 (0.02)
Mother	872 (19)	1.27 (0.03)
Other	875 (20)	1.15 (0.02)
Font	622 (15)	0.36 (0.02)
Tibetan Participants		
Self	1311 (20)	0.88 (0.03)
Mother	1247 (21)	0.77 (0.03)
Other	1258 (25)	0.70 (0.03)
Font	845 (23)	0.30 (0.02)

Note: Standard deviations are given in parentheses; The d' are the indexed in signal detection theory which is $Z(\text{hit}) - Z(\text{false alarm})$

[Han: $t(15) = 10.29$, $P < 0.01$; Tibetan: $t(14) = 6.89$, $P < 0.01$] and other processing [Han: $t(15) = 9.75$, $P < 0.01$; Tibetan: $t(14) = 6.96$, $P < 0.01$]. However, there were no differences among self-, mother- and other-processing for both Han and Tibetan groups [Han: $F(2,30) = 0.08$, NS; Tibetan: $F(2,28) = 2.68$, NS].

An ANOVA revealed a significant main effect of trial type [$F(3,87) = 59.14$, $P < 0.01$] and significant interaction between tasks and groups [$F(3,87) = 5.33$, $P < 0.05$]. *Post hoc* statistical tests revealed significant differences among all tasks for both Han and Tibetan participants [Han: $F(3,45) = 59.24$, $P < 0.01$; Tibetan: $F(3,42) = 15.93$, $P < 0.01$], except 'self and mother' in the Han participants [$t(15) = 1.78$, NS].

fMRI Results

The neural substrates underpinning the self-reference effects were defined as increased neural activities associated with self- compared to other-processing. Table 2 summarizes the Talairach coordinates and the Z -value of peak activation during the self-processing conditions compared to other- and mother-processing conditions ($P < 0.05$, corrected) for ethnic Han and Tibetan participants. When considering all participants, the bilateral anterior cingulate gyrus, medial frontal gyrus and left superior frontal gyrus showed greater activations while comparing self to other. When considering each group separately, only the Han participants showed significant contrast in the medial frontal and anterior cingulate regions, which repeated many previous studies (Zhang *et al.*, 2006; Zhu *et al.*, 2007). The Tibetan participants only showed significant contrast in the middle temporal gyrus (Figure 2), which suggests that Hans are engaged in more self-processing than Tibetans in the medial frontal and anterior cingulate.

The whole-group analysis had more power than the separate-group whole-brain analyses, the results are not inconsistent. When analyzing all participants' results, significant activation for self minus mother condition was found in the left inferior parietal lobule. When examining the same contrast in Han participants alone, only the right ACC

Table 2 Regions of increased significant activation among self-, other- and mother conditions.

Condition / Regions	Voxel no.	BA	x	y	z	Z-value
<i>Han Participants + Tibetan Participants</i>						
Self minus other						
L. Anterior Cingulate gyrus	3224	32	-8	39	5	5.25
R. Anterior Cingulate gyrus	***	24	6	29	-5	4.64
Medial Frontal Gyrus	***	10	0	49	-1	4.52
L. Superior Frontal Gyrus	453	8	-18	36	52	4.14
L. Superior Frontal Gyrus	***	8	-16	37	39	3.85
L. Superior Frontal Gyrus	***	9	-20	46	33	3.31
Self minus mother						
L. Inferior Parietal Lobule	881	40	-38	-54	43	4.63
Mother minus other						
No significant activation area						
<i>Han Participants</i>						
Self minus other						
Medial Frontal Gyrus	3846	10	0	53	5	5.45
L. Anterior Cingulate gyrus	***	32	-2	43	-2	5.02
L. Medial Frontal Gyrus	***	10	-18	60	4	4.99
Self minus mother						
R. Anterior Cingulate gyrus	953	32	-8	36	24	4.67
Mother minus other						
No significant activation area						
<i>Tibetan Participants</i>						
Self minus other						
R. Middle Temporal Gyrus	452	37	44	-70	5	3.74
R. Middle Temporal Gyrus	***	22	40	-57	18	3.71
Self minus mother						
No significant activation area						
Mother minus other						
No significant activation area						

$P < 0.05$ at the cluster level, corrected. Note: Voxel no. = number of voxels in a cluster. BA = Brodmann's area, as identified in Talairach and Tournoux (1988). Z value = significant value. R = Right. L = Left. ***The voxels are in the same cluster.

demonstrated significant activation, whereas no significant activation was found in Tibetan participants. Furthermore, there were no significant voxels showing greater activity for mother- compared to other-processing conditions in all groups.

The ROI analysis calculated percent signal changes in the medial frontal gyrus (MPFC, centered at 0/49/-1) relative to low-level baseline (i.e. the null condition). A significant interaction between groups and orientation tasks (self- and other-processing) further validated the different patterns of MPFC activity between the two groups [$F(1,29) = 4.53$, $P < 0.05$]. Paired t -tests confirmed that fMRI signals were larger in the self-processing conditions than in other-processing conditions for Han participants [$t(15) = 8.19$, $P < 0.01$], but not for Tibetan participants [$t(14) = 2.00$, NS].

Similar ROI analyses were conducted on the fMRI signals in anterior cingulate gyrus (ACC, centered at -8/40/8). ACC signals showed a pattern similar to that of MPFC signals. However, the interaction of group \times orientation task was not significant, both Tibetans and Hans used the ACC in

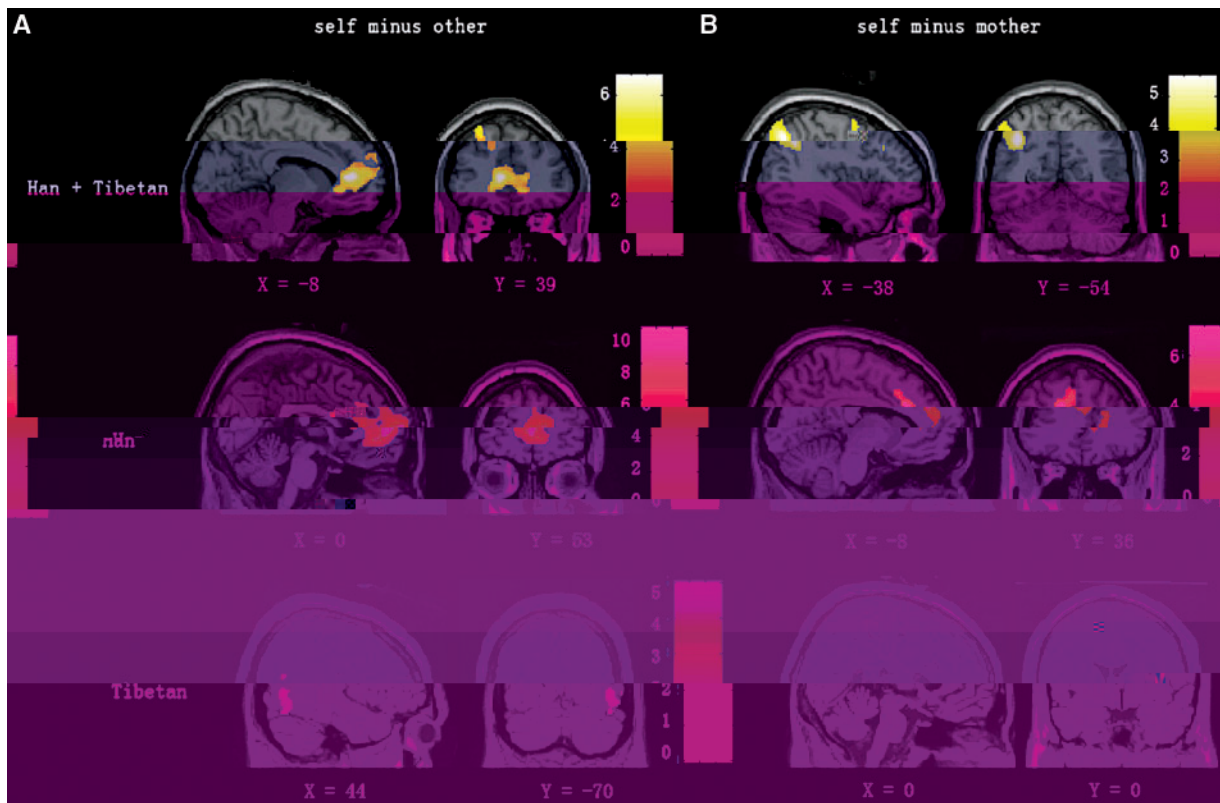


Fig. 2 Brain activations revealed in the contrast between different trait judgments. (A) Self minus other; (B) Self minus mother for both Han and Tibetan participants.

similar ways for self-processing decisions, which suggests that the effect of orientation condition did not change across groups. Finally, we conducted a 2×2 two-way ANOVA on the differential fMRI signals of self minus other with groups (Han vs Tibetan) and ROI (MPFC vs ACC) as independent variables. Results revealed a significant interaction [$F(1,29) = 6.27$, $P < 0.01$]. *Post hoc t*-tests revealed that the signal changes were significantly larger for Han than for Tibetan participants in MPFC [$t(29) = 2.13$, $P < 0.05$], whereas no significant differences existed between Han and Tibetan groups in ACC activity [$t(29) = 0.14$, NS]. These results seem to indicate that the effect of religious differences on the neural substrates of self-processing between Han and Tibetan was mainly driven by MPFC activity (Figure 3).

DISCUSSION

The behavioral data partly replicated results from previous studies among Han participants (Zhu *et al.*, 2007), which showed that there were no different recognition ratios between self- and mother-processing for Han participants. The materials used for Tibetan participants, which were directly translated into the Tibetan language from Mandarin, included longer words and more characters than the Mandarin materials (Figure 1). Therefore, it seems reasonable that the Tibetans took longer to respond

on both self-, mother-, other- and font-processing, while having poorer memory performance than Han participants. However, because Tibetans and Hans underwent very similar processing, these differences should not affect their neural consequences.

Previous studies have shown that Tibetan Buddhism exerts a powerful effect over the Tibetan people (Feng, 2007). Tibetan Buddhism makes unique claims about the nature of the self (Ching, 1984; Burns, 2003). The aim of this study was to investigate if this uniqueness can be reflected at the brain level. In other words, this study extended previous research that the neural activity of the human brain, in association with specific cognitive functions, can be modulated by religious beliefs as a form of cultural expression. Although both ethnic Hans and ethnic Tibetans belong to the 'oriental culture', they demonstrate significant cultural divergence in relation to religious beliefs, which leads to differences in cognitive patterns and representation of the human brain.

Based on the previous researches (Johnson *et al.*, 2002; Kelley *et al.*, 2002; Zhang *et al.*, 2006; Zhu *et al.*, 2007), we may deduce that the neural substrates of self-processing are mainly represented in the activation of VMPFC. In this study, we also found the VMPFC and ACC were activated in all participants when comparing self to others. It should be noted that only the MPFC is represented in self-processing. The ACC serves as an executive function in

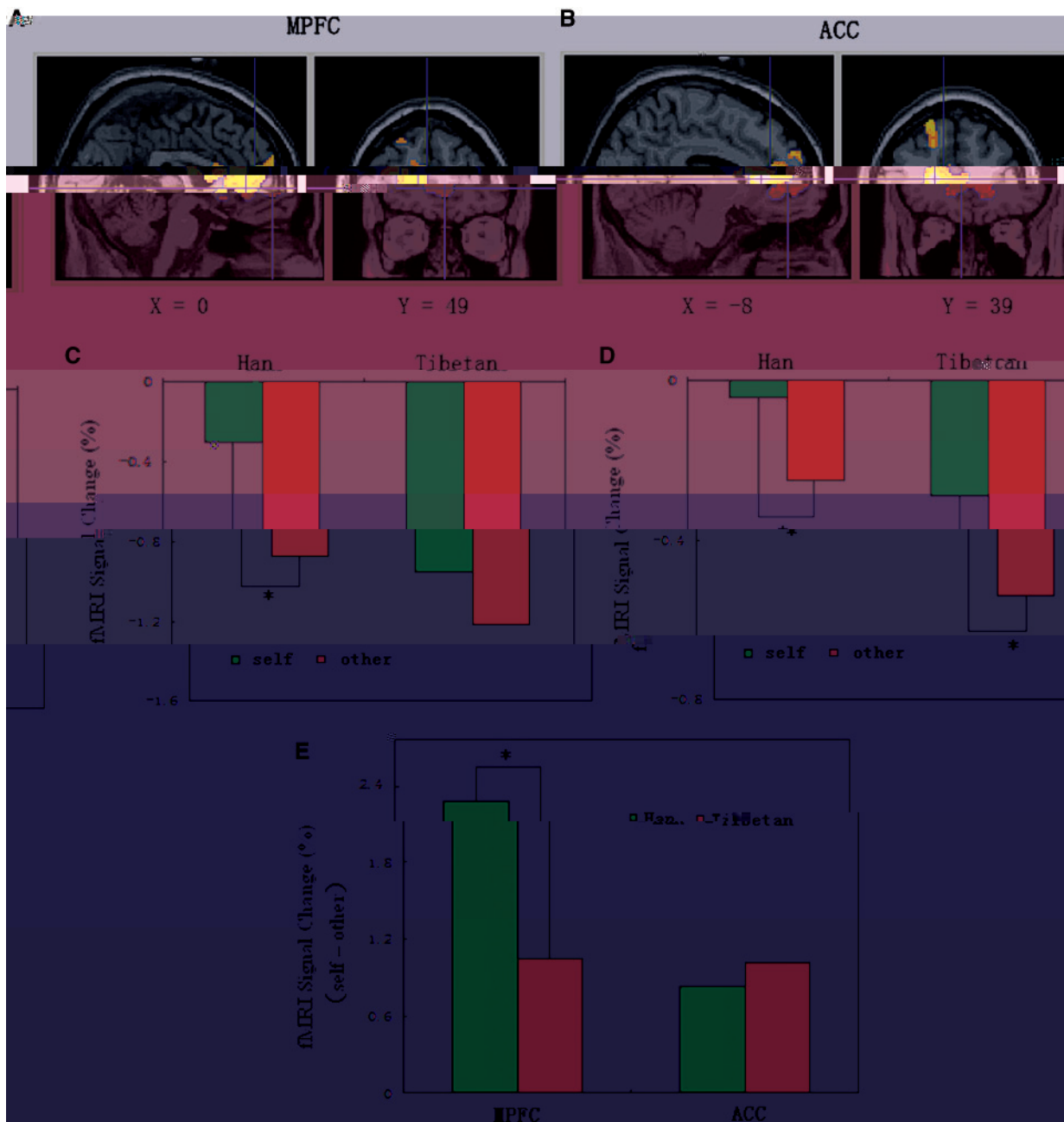


Fig. 3 ROI analyses. (A) and (B) illustrate the locus of the MPFC and ACC (the crosspoint of the blue line), respectively; (C) and (D) represent fMRI signal changes in MPFC and ACC, respectively, in the self- and other-processing conditions relative to the null condition; (E) represents the differential fMRI signal changes (self minus other) in MPFC and ACC for both Han and Tibetan participants. The asterisks indicate a significance differences in percent signal changes.

the monitoring system of the brain (Gazzaniga *et al.*, 2002). Because self-processing is a unique form of higher level semantic processing in executive behavioral, it is not strange that ACC was also activated in this study. Further ROI analysis verified these results, revealing that the interaction between groups and orientation tasks was significant in MPFC, but not in ACC.

However, when separately comparing between self and other, this activation pattern was only repeated in Han participants. The Tibetan participants showed no significant

activation in self-processing. Considering that the effects on the neural substrates of self-processing were reliable in MPFC, we may deduce that Tibetan participants have a distinct activation pattern from Han participants. In fact, it almost seems as if there were no ‘self’ among the ethnic Tibetans.

The finding that MPFC, as an indicator of self-involving, only activated in the Han group was in line with some philosophical bibliographies discussing Tibetan Buddhism. According to Levitt (1999), Tibetan Buddhism holds a

unique view of reality, wherein the 'self'—as experienced in the physical world—is illusionary. Tibetan Buddhist's view of self is considered to be artificial because it is seen as being tied into family, culture, desires, etc.—things which change across lifetimes and are hence seen to be fleeting aspects of an underlying constancy. The metaphor emptiness is used to represent the nature of this constancy that is void of these worldly means of identification. Wisdom in this culture occurs when identity is redefined such that the individual begins to identify with this metaphysics of existence. The Buddhists learned to distinguish this existence from the body. In another document, Lutz et al. (2007) postulated that Buddhist, not only in Tibetan Buddhist, hold a minimal subjective sense of 'I-ness' in experience. The nature of the self may be just like what Lutz (1992) emphasized 'although self-awareness is universal, cultures differ in how the self is conceptualized and experienced'. The minimal subjective sense of 'I-ness' of Tibetans indeed is different from the self of other people in other cultures.

It should be noted that in this study, ventral rather than DMPFCs were activated. The results were in line with Han et al.'s findings (2008), which suggest that the evaluation of self-referential stimuli from other's (such as God) perspective activated the DMPFC. We may deduce that when judging an adjective from a subjective perspective (e.g. am I honest?), VMPFC was activated. However, when judging an adjective from an objective perspective (e.g. does my friend see me as honest?), DMPFC was activated. In this study, all the tasks were in the subjective pattern, so it is reasonable that VMPFC was activated.

To be consistent with previous studies, we included 'mother' as a processing task. We found significant activation for the self minus mother condition in the left inferior parietal lobule for all participants. This area has been shown to be activated when retrieving episodic memory about one's self (Lou et al., 2004). In this study, when self minus mother, only the right ACC was found in Han participants, but no activation was found in Tibetan participants. This partly replicated previous findings (Zhu et al., 2007).

It is important to emphasize that MPFC have the highest baseline metabolic activity at rest and one that exhibits decreases from this baseline across a wide variety of goal-directed behaviors in functional imaging studies (Gusnard et al., 2001). This description fits well with our finding that MPFC is part of the default network, which tends to show deactivations during task trials relative to baseline (shown in Figure 3). Kelley et al. also postulated that self-referential mental activity may be the by-product of 'stimulus independent thoughts' and mediated by a specific, anatomically distinct brain region. MPFC activity seems to 'mirror' that of the MPFC at rest (Kelley et al., 2002). In our study, the self-reference task was significantly related to the resting state for Hans in comparison to Tibetans and the inhibition on MPFC was more powerful for Hans than for Tibetans, so it is reasonable that there existed significant difference

between Hans and Tibetans when comparing self to other (Figure 3). This result fits nicely with Kelley et al.'s arguments.

It is widely acknowledged by scientists that the disciplines of science (such as neuroscience) and religion (such as Buddhism) are simply different approaches toward understanding human development. They encourage alternative ways of thinking about reality. For example, Buddhism offers a tried and tested way of observing and altering, through careful attention to meditation, whereas neuroscience can show how meditation practices result in physiological changes in the brain (Bond, 2008). This study is an attempt to explore religious phenomena from a neuroscientific viewpoint.

Conflict of Interest

None declared.

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