Medial prefrontal cortex differentiates self from mother in Chinese: evidence from self-motivated immigrants

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Abstract Findings from neuroimaging studies suggest that the medial prefrontal cortex (MPFC) differentiates between self and mother in participants from Western cultures, but not in Chinese participants. However, previous research suggests that self-motivated immigrants possess more independent self-construal styles. Thus, it is possible that their independent self-construals might be reflected at the neural level. In the present study, we examined the contribution of the MPFC to self and close other-referential processing of psychological traits in Chinese participants, newly arrived to the United States, in both their native language and in English. We predicted that, contrary to prior findings, the MPFC would differentially represent psychological traits for self and mother. Moreover, this effect would be greatest when performing judgments in English. During fMRI scanning, participants (N = 18) completed a standard self-referential processing task in which they rated whether a series of psychological trait adjectives applied to themselves or to their mothers. Consistent with our hypothesis, we found that the MPFC strongly differentiated between self and mother judgments in both languages. However, we found no effect of language in this task. Finally, the posterior cingulate cortex was uniquely sensitive to self-referential judgments in Chinese. These findings indicate that the MPFC differentiates between self and mother among self-motivated immigrants.

Keywords Self · Self-construal style · Culture · Immigrants ·
Medial prefrontal cortex · Functional magnetic resonance imaging

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Introduction

Do people incorporate close others into their self-concept? Using a variety of methods social psychologists and, more recently, social neuroscientists have sought to answer this important question (for a review see Wagner et al. 2012). Research on interpersonal closeness has shown that people tend to incorporate close others, such as their mothers, fathers, or close friends into their own self concepts (Aron et al. 1991). For example, studies on the self-reference effect in memory show that people display similar improvement in recall for traits processed with reference to close others as they do for traits processed with references to the self (Bower and Gilligan 1979). More recently, researchers have begun to examine the neural basis of self-referential processing, revealing an important role for the medial prefrontal cortex (MPFC) in representing knowledge about the self as compared to knowledge about others (Denny et al. 2012; Heatherton et al. 2006; Kelley et al. 2002; Mitchell et al. 2006; Moran et al. 2006; Northoff and Bermpohl 2004).

Although a common finding across these studies is that activity in the MPFC differentiates between self and close others (Heatherton et al. 2006), research in non-western participants suggests that this pattern is far from universal (Wang et al. 2012; Zhu et al. 2007). For instance, Zhu et al. (2007) found that MPFC did not differentiate self from mother in Chinese participants, but did so in Westerners. More recently, this same group explored how MPFC represented different relationships in Chinese participants, and found a pattern of decreasing activity across four kinds of trait judgments: self, mother, father, and best friend (Wang et al. 2012). Consistent with their previous findings (Zhu et al. 2007), the difference between self- and mother-judgments was not statistically significant. Thus, the neural representation of mother in the MPFC appears to be culturally different for Easterners as compared to Westerners.

One theory for why this occurs is that easterners and westerners differ in self-construal style (Markus and Kitayama 1991; Triandis 1995). However, cultural psychologists have found that heterogeneity of self-construal styles often exists within the same society, even when the society is traditionally defined as more interdependent (Green 2005). For instance, among Chinese participants, the degrees of independence and interdependence can be quite variable (Li et al. 2006; Yan 2010). Other evidence (Kitayama et al. 2006, 2012) further suggested that voluntary immigrants possess more independent self-construal mindsets. Thus, it is plausible that individuals who voluntarily chose to move from a traditionally interdependent society (i.e., China) to a more independent one (i.e., the US) would demonstrate a more independent self-construal style. Furthermore, their independent-oriented self-construal styles may be reflected in differing patterns of neural activity when making judgments about themselves and a close other. In the present study, we sought to examine whether newly arrived Chinese immigrants, who are hypothesized to possess a more independent self-construal style, would, similar to westerners, demonstrate differential MPFC activity for self and mother.

Another goal of the current study is to examine the priming effect of different languages (Chinese and English) on self-referential processing. It has been shown

that activity in cortical midline structures [i.e., the MPFC and posterior cingulate cortex (PCC)] is modulated when bicultural participants were primed with individualist or collectivist cultural values (Chiao et al. 2009; Harada et al. 2010). For those who have learned a second language, particularly when that second language is from a different culture, it has been shown that language may prime construal style (Kemmelmeier and Cheng 2004). Therefore, Chinese participants who are fluent in both Chinese and English might demonstrate a shift in construal style depending on which language they are using. Thus, we predicted that the differentiation between self and mother in the MPFC would be greatest when participants performed judgments in English compared to Chinese.

Materials and methods

Participants

Nineteen newly arrived Chinese graduate students (7 females, age range 21–27) served as participants in this study. No participants had ever stayed or studied in a foreign country for more than 2 months prior to their arrival in the United States. All of the participants were fluent in both Chinese (mother language) and English (TOEFL mean score = 104). Participants were all right-handed based on the measurements of Edinburgh Handedness Inventory (Raczkowski et al. 1974), and reported no history of neurological problems, and had normal or corrected-to-normal vision. One of the participants was excluded because of excessive head movement during scanning (more than 2 mm in Z-direction). They were paid $40 for participation, and gave informed consent in accordance with the guidelines set by the Committee for the Protection of Human Subjects at Dartmouth College.

Tasks

Participants were imaged during four functional runs in an event-related design while making judgments about trait adjective words (following the methods of Kelley et al. 2002). Stimuli were projected to participants with an Epson ELP-7000 LCD projector on a screen positioned at the head end of the magnet bore, and participants viewed the screen via a mirror on the head coil. During each functional run, judgments were one of three types: SELF (Does this adjective describe you?), MOTHER (Does this adjective describe your mother?), or FONT (Is this word printed in bold-faced letters?). Each type was presented once in English and once in Chinese for a total of six judgments types. The participants indicated their responses via MR-compatible response boxes by pressing the buttons with the left or right index finger. Each trial lasted 2,500 ms and consisted of a 'cue' word (SELF, MOTHER, or FONT in either Chinese or English) presented for 2,500 ms above a central fixation, and a unique trait adjective (e.g. 'SMART') presented for 2,500 ms below a central fixation (Fig. 1). The text was presented in Xin Xi Ming Ti in Chinese, and in Calibri in English (white letters on a black background; letters subtended ∼0.5° of visual angle). Before scanning, the participants were asked to
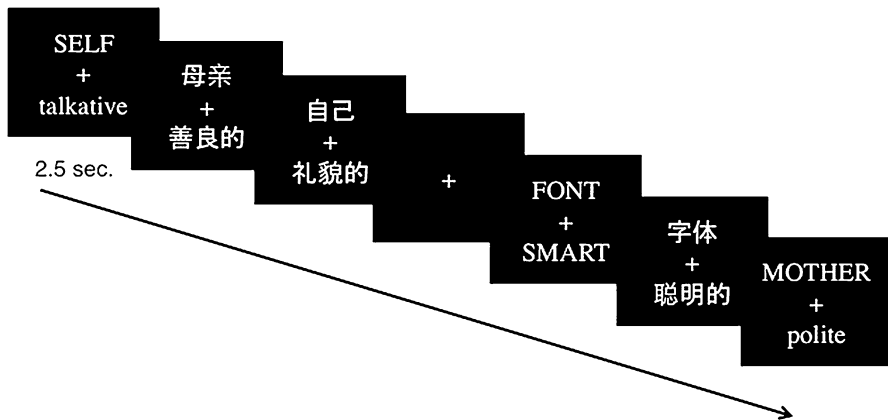
Fig. 1 fMRI experimental paradigm. Each trial lasted 2,500 ms and consisted of a 'cue' word (SELF, MOTHER, or FONT in either Chinese or English) presented for 2,500 ms above a central fixation, and a unique trait adjective (e.g. 'SMART') below a central fixation

practice the task to ensure proficiency. A total of 120 Chinese and 120 English trait words, matched for meaning, were selected from two established pools of personality trait words (English words from Anderson 1968, Chinese words from Wang and Tue 2005). Lists were counterbalanced for word length and valence (half of the words in each list were positive traits, and the remaining half were negative traits). Across participants, lists were rotated through conditions such that trait adjectives that appeared in SELF-judgments for one participant appeared in a different condition (MOTHER or FONT) for other participants. During each of the four functional runs, 60 trials (10 SELF in Chinese, 10 MOTHER in Chinese, 10 FONT in Chinese, 10 SELF in English, 10 MOTHER in English, 10 FONT in English) were pseudo-randomly intermixed with 20 fixation trials such that each trial type followed every other trial type equally often. The fixation trials consisted of a central fixation point presented on the screen for 2,500 ms. These trials were included to introduce 'jitter' into the time series so that unique estimates of the hemodynamic responses for the trial types of interest could be computed (Ollinger et al. 2001).

Questionnaires

Self-construal scale (SCS)

Participants completed the SCS (Singelis 1994), which consists of 30 items in a 7-Likert type scale (1 = strongly disagree and 7 = strongly agree). Two distinct dimensions of self-construal styles, independence and interdependence, are measured. These two styles correspond to two main cultural values: collectivism and individualism. Each participant was scored separately for independence and interdependence, indicating the tendency of each construal style.

Inclusion of others in the self scale (IOS)

The IOS (Aron et al. 1991) is a reliable graphical scale, consisting of seven graphs made by two circles with different degrees of overlap. The IOS is designed to measure the intimacy between the self and a target other (e.g. mother). We used this scale because the interdependence score may not be a good index of the relationship between participants and their mothers. Although highly interdependent individuals are generally more relationship-oriented and tend to incorporate others closer to the self, it is not necessarily the case that such persons will have a closer relationship with their mother.

fMRI procedure and analysis

Imaging data were collected on a Philips Intera Achieva 3T scanner with a thirty-two channel head coil. Structural images were acquired by using a T1-weighted MP-RAGE sequence (160 sagittal slices, TR = 9.9 ms, TE = 4.6 ms, 8 flip angles, $1 \times 1 \times 1$ mm voxels). Functional images were acquired using a T2*-weighted echo-planar sequence (TR = 2,500 ms, TE = 35 ms, 90 flip angle and FOV = 240 mm). During each of the four runs, 80 volumes covering the whole brain (36 axial slices, 3 mm thick with 0.5 mm gap, 3×3 mm in-plane resolution) were collected.

The fMRI data were analyzed using SPM8 (Wellcome Department of Cognitive Neurology, London, UK). The data were first preprocessed to remove sources of noise and artifact, and corrected for the differences in slice timing across slices. Second, images were realigned within and across runs for head motion correction and unwarped to reduce residual movement-related image distortions not corrected by realignments. Functional images were then normalized into standard space (3 mm isotropic voxels) based on the SPM8 EPI template that conforms to the ICBM 152 brain template space [Montreal Neurological Institute (MNI)]. Finally, a 6 mm full-width-at-half-maximum Gaussian kernel was applied to spatially smooth the normalized images. A general linear model incorporating task effects (convolved with a canonical hemodynamic response function) and covariates of no interest (linear trend, session mean and six movement parameters derived from realignment corrections) was used to compute t-contrast images comparing task effects to baseline. These contrast images were then entered into a second-level random effects analysis. Monte Carlo simulations using AFNI's AlphaSim were used to calculate the minimum cluster size at an uncorrected threshold of $P < 0.001$ for a whole-brain correction of $P < 0.05$. Simulations (1,000) were performed on the volume of our whole-brain mask using smoothness estimated from the residuals obtained from the GLM and resulting in a minimum cluster size of 45 contiguous voxels.

ROI analysis

The MPFC, the PCC, and inferior frontal cortex (IFC) ROIs were defined based on peaks in the mean t-image, comparing all six trial types to baseline in these three regions. As a result, each trial type contributed equally to the generation of ROIs. The map of relative deactivations was used to define the MPFC (6, 48, 3) and PCC

(0, −48, 48) whereas the IFC (−51, 21, 24) ROI was defined in the activation map (as in Kelley et al. 2002). Parameter estimates of each of the six trial types (SELF-/MOTHER-/FONT-judgments in both Chinese and English) relative to baseline condition (fixation) were computed across all voxels within the MPFC, PCC, and IFC ROIs. In order to represent the difference between person-judgments (SELF/MOTHER) and baseline (FONT-judgments), four difference scores from parameter estimates (SELF/MOTHER > FONT-judgments in Chinese and SELF/MOTHER > FONT-judgments in English) was calculated. For all ROIs, a repeated-measures analysis of variance (ANOVA) was carried out with task (SELF- and MOTHER-judgments) and language (Chinese and English) as within subject factors. In addition, we repeated this analysis in two spherical MPFC ROIs (8 mm radius) defined from two previous studies (Kelley et al. 2002, 10, 53, 4; Wang et al. 2012, 0, 40, 18), the former because it is a reliable area for assessing self-referential activity, the latter chosen because Wang et al. (2012) reported that MPFC did not differentiate the representation of self from mother in Chinese participants. Finally, we conducted an offline correlation analysis to test whether the independence, interdependence, and IOS scores were correlated with the four difference scores.

Results

Behavioral results

Reaction times

Table 1 shows the reaction time for each trial type. An ANOVA revealed that there were main effects of reaction time for both Task, $F[2, 32] = 17.2$, $P < 0.001$, and Language, $F[1, 16] = 149.5$, $P < 0.001$, as well as an interaction effect ($F[2, 32] = 35.7$, $P < 0.001$). Post-hoc statistical tests revealed that although the reaction time for FONT-judgments was significantly faster than for person-judgments (SELF and MOTHER), there was no significant difference between these person-judgments ($F[1,16] = 0.2$, $P = 0.6$). Furthermore, both of these person-judgments were significantly faster in Chinese than in English ($F[1, 16] = 63.8$, $P < 0.001$ for SELF, $F[1, 16] = 118.5$, $P < 0.001$ for MOTHER).

Table 1 Reaction time during each trial type	Trial type	Reaction time (ms)
	SELF in Chinese	1,307 (41)
	MOTHER in Chinese	1,279 (33)
	FONT in Chinese	1,277 (27)
	SELF in English	1,560 (26)
	MOTHER in English	1,614 (36)
	FONT in English	1,269 (27)

Questionnaires

Participants scored slightly higher on the Interdependence subscale of the SCS (M = 4.88, SD = 0.40) than on the Independence subscale (M = 4.79, SD = 0.58), but the difference was not significant [t(17) = 0.48, P = 0.63]. The mean IOS score was 5.28 (range from 3 to 7).

fMRI results

The whole-brain analysis ($P < 0.05$, corrected) comparing regions that displayed greater activity for SELF than MOTHER trials across the two languages revealed a system of regions including the MPFC, PCC/Precuneus, superior temporal gyrus, inferior parietal lobule, and supramarginal gyrus (Table 2; Fig. 2).

ROI analysis

The ANOVA of the difference scores from parameter estimates (SELF/MOTHER > FONT in Chinese and in English contrasts, respectively) in Kelley et al.'s MPFC ROI revealed a significant main effect of Task (F[1, 17] = 12.8, $P < 0.005$) (see Fig. 3a). Post-hoc analysis showed that MPFC activity was greater for SELF than for MOTHER in both Chinese (t(17) = 5.9, $P < 0.05$) and English (t(17) = 5.1, $P < 0.05$). The ANOVA of difference scores in Wang et al.'s ROI revealed significant main effects of Task (F[1, 17] = 12.7, $P < 0.005$) and Language (F[1, 17] = 5.0, $P < 0.05$) (see Fig. 3b). Post-hoc analysis also showed that MPFC activity was greater for SELF than for MOTHER in Chinese [t(17) = 4.9, $P < 0.05$], but only marginally greater in English [t(17) = 3.1, $P = 0.09$]. Furthermore, the ANOVA of difference scores in the MPFC ROI (6, 48, 3; BA 10) defined by our imaging data also revealed a significant main effect of Task (F[1,17] = 26.2, $P < 0.001$) and a marginal main effect of Language (F[1, 17] = 4.0, $P = 0.06$) (see Fig. 3c). Post-hoc analysis showed that

Table 2 Brain regions showing greater activity for self-judgments than mother-judgments across two languages

Brain region	Side	BA	*t*-value	Coordinates of peak activation		
				x	y	z
Supramarginal gyrus	R	40	6.19	60	−54	33
Superior temporal gyrus	R	42	5.55	63	−30	9
Inferior parietal lobule	L	40	4.69	−57	−57	39
Superior temporal gyrus	L	39	4.34	−60	−60	27
Precuneus	L	7	6.07	−3	−42	45
Posterior cingulate gyrus (PCC)	R	24	5.60	6	−21	39
Medial prefrontal cortex (MPFC)	R	32	5.22	6	48	6

Note: Regions showing greater activity for self-judgments than mother-judgments across two languages ($P < 0.05$, corrected) are listed along with their locations. Coordinates are in Montreal Neurological Institute (MNI) stereotaxic space

BA Brodmann's area
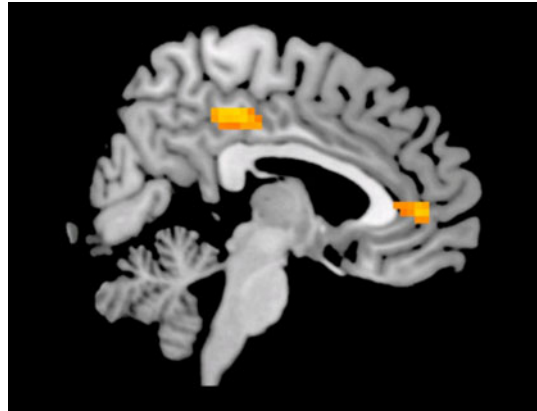
MPFC activity was greater for SELF than for MOTHER in both Chinese [$t(17) = 9.2$, $P < 0.01$] and English [$t(17) = 8.6$, $P < 0.01$]. The above analyses indicate that the SELF/MOTHER neural differentiation in English was not greater in Chinese, which contradicts our original prediction that the differentiation between self and mother in the MPFC would be greater when participants performed judgments in English than in Chinese.

The offline correlation analysis revealed none of the three scores (the independence, interdependence, and IOS scores) was significantly correlated with either the SELF > MOTHER in Chinese or in English contrast extracted from three different MPFC ROIs (Kelley et al.'s, Wang et al.'s, and the current study ROI), respectively. Although the intimacy score of IOS showed a marginally negative correlation with the difference scores of the SELF > MOTHER in Chinese contrast extracted from the MPFC ROI defined in the current study ($r = -0.39$, $P = 0.10$), the trend was in the expected direction.

The ANOVA of difference scores in PCC ROI (0, −48, 48) showed a significant main effect of Task ($F[1, 17] = 8.3$, $P < 0.05$) (see Fig. 4a). Post-hoc analysis also showed that PCC activity was greater for SELF in Chinese than all the other judgments. The ANOVA of difference scores in left IFC (−51, 21, 24), revealed a significant main effect of Task ($F[1, 17] = 6.3$, $P < 0.05$) and of Language ($F[1, 17] = 15.9$, $P < 0.005$), as well as an interaction effect of Task and Language ($F[1, 17] = 7.4$, $P < 0.02$) (see Fig. 4b). Post-hoc analysis showed that IFC activity was greater for SELF in English than in Chinese [$t(17) = 23.7$, $P < 0.001$], and was also greater for MOTHER in English than in Chinese [$t(17) = 8.5$, $P < 0.01$].

Discussion

We found that MPFC activation was greatest for self-judgments compared to mother-judgments, regardless of whether participants performed the task in Chinese or English. Furthermore, we showed that these results were consistent across two different MPFC ROIs derived from prior studies. We also found greater PCC activity during self-judgments when the trait words were presented in Chinese.

(a) Kelley et al. (10, 53, 4)
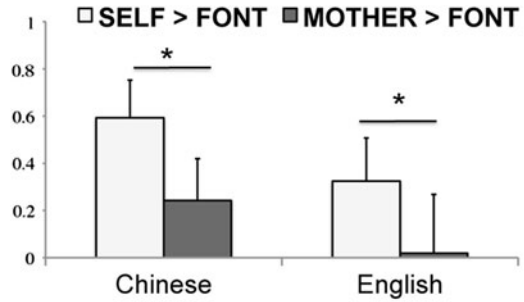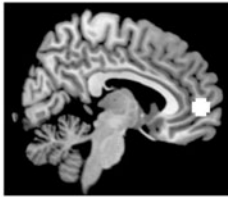
(b) Wang et al. (0, 40, 18)
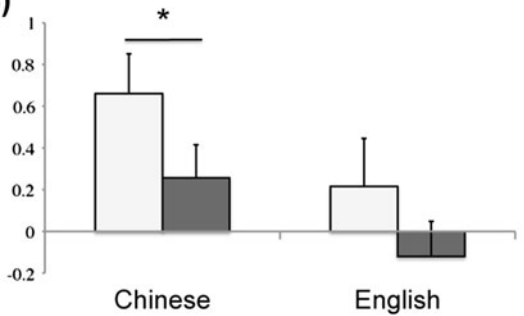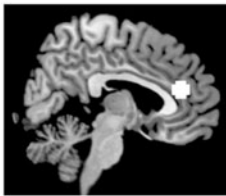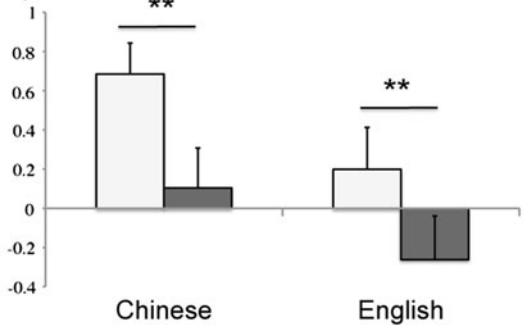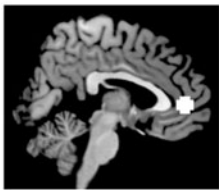
(c) Current study (6, 48, 3)

Fig. 3 Analysis of difference scores from parameter estimates in three different MPFC ROIs for SELF > MOTHER in Chinese and in English, respectively. MPFC activity was significantly greater for SELF- than MOTHER-judgments in both Chinese and English based on the results from three different MPFC ROIs. **a** The MPFC ROI defined by Kelley et al. (2002). **b** The MPFC ROI defined by Wang et al. (2012). **c** The MPFC ROI defined in the current study. *$P < 0.05$; **$P < 0.01$. *Bars* indicated standard error of the mean

Furthermore, the left IFC showed greater activity for the representations of self and mother when the trait words were presented in English rather than in Chinese, suggesting that participants may have been engaging in semantic processing (Buckner et al. 1999; Huang et al. 2012; Price 2010) required in order to translate English to Chinese.
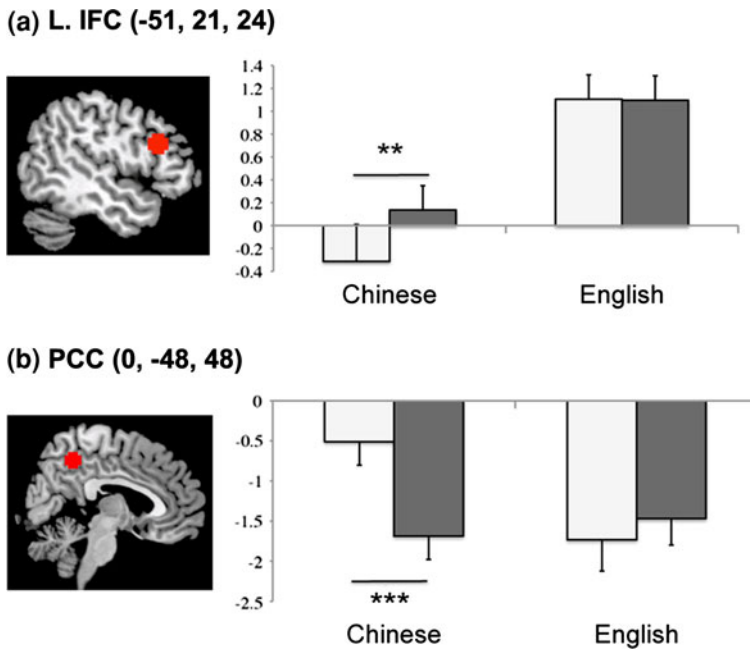
(a) L. IFC (-51, 21, 24)

(b) PCC (0, -48, 48)

Fig. 4 Analysis of difference scores from parameter estimates in Left IFC and PCC for SELF relative to MOTHER in Chinese and English, respectively. Results revealed that (**a**) left IFC activity was greater when judgments were presented in English than in Chinese, and (**b**) PCC showed greatest activity for SELF in Chinese. **$P < 0.01$; ***$P < 0.005$. *Bars* indicated standard error of the mean

In the current study, MPFC activation in newly arrived Chinese students was greater for self-judgments than for mother-judgments, suggesting that this population might possess a distinct self-construal style compared to students who choose to stay in China (Wang et al. 2012; Zhu et al. 2007). Furthermore, participants' identical scores in independence and interdependence SCS subscales supported the notion that these participants' self-construal styles were not primarily interdependent. This finding indicates that these self-motivated Chinese immigrants might be distinct in self-construal styles from those prototypical Chinese participants, whose interdependence scores tend to be significantly higher than their independence scores (Kitayama and Park 2010; Markus and Kitayama 1991; Wang et al. 2012). Our findings are consistent with the voluntary settlement hypothesis proposed by Kitayama (Kitayama et al. 2006, 2012; Kitayama and Park 2010). According to this hypothesis, voluntary immigrants moving to the frontiers (i.e. wilderness regions, foreign countries, or metropolitan cities) have more independent self-construal mindsets than those who choose to stay in their original countries. For instance, people living in Japan are regarded as being more interdependent in self-construal style when compared to most of the western countries. However, Hokkaido, the northern territory of Japan, which has a relative short voluntary settlement history, attracts individuals with more independent mindsets relative to other areas of Japan (Kitayama et al. 2006). Here, we found that

self-motivated immigrants also possess different self-construal styles. Moreover, these differences in self-construal styles were reflected in their pattern of brain activity when making trait judgments about self and mother. However, future studies are needed to directly compare the neural differentiations of self and mother in MPFC from the self-motivated immigrants to those who choose to stay in their home country.

Our result showed that the MPFC differentiates self from mother in both the participant's first (Chinese) and second language (English), indicating no priming effect of language on self-referential processing. Consistent with our findings, a number of behavioral studies have found no priming effect of language on several different cognitive processes. For instance, Ji et al. (2004) found Chinese participants were more relational in reasoning style than European Americans regardless of which languages the participants used in the task. Ishii et al. (2003) also found that bilingual Philippines had more attentional biases to verbal tone than to verbal content no matter what language (Taglog or English) the participants used in the study. Based on the findings from the above two studies, cultural factors, but not linguistic factors, appear to have a stronger impact on cognitive processes. This evidence might explain why no priming effect was found in the current study.

The greatest PCC activity was found only for self-judgments when the trait words were presented in Chinese, suggesting that PCC activity might be sensitive to the usage of different languages. PCC has been reported to be involved in diverse mental processes, including visual imagery formation, autobiographical memory retrieval, and emotional processing (Northoff and Bermpohl 2004; Vann et al. 2009). PCC is also commonly reported in imaging studies of self-referential processing (Denny et al. 2012; Kelley et al. 2002; Qin and Northoff 2011). Thus, the greatest PCC activity for self-judgments highlights the possibility that the PCC may reflect the ease of retrieval of autobiographical memories when the trait words are presented in the participant's first language rather than in the second language. Future studies are needed to clarify this possibility.

One potential limitation of the current study is the lack of a public person condition. Although it is possible that using a non-semantic task as a baseline condition may change the results (Zhang et al. 2011), it might be also plausible that a public person condition could become an anchor for self- or significant other-referential processing, reducing the differences between the self- and mother-judgments in MPFC. Future studies are needed to test whether the MPFC signal differences between self- and mother-judgments might be modulated when using font-judgments or public person-judgments as a baseline condition.

Conclusion

In the current study, we found that self-motivated immigrants from China to the US showed a different pattern of MPFC activity for self and mother compared to prior work on native Chinese participants. One possibility for this difference may be that immigrant Chinese students differ in self-construal style compared to non-immigrant Chinese persons. This is in part supported by our finding of a more prototypically western pattern of self-construal style among our participants.

Cultural neuroscience has become one of the most thriving sub-fields in cognitive neuroscience (Kitayama and Park 2010), and its interdisciplinary characteristics inspire researchers to explore how cultural values influence the underlying neural processing (Chiao and Bebko 2011). However, most studies compare people living in different cultures, and seldom use a more dynamic approach to explore the underlying neural processing changes of cultural adaptation. Future longitudinal studies should explore whether the neural representations of self and mother changes after prolonged exposure to an individualist culture in self-motivated immigrants.

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