doi:10.1093/scan/nsr002 SCAN (2012) 7, 222–229

Neural representations of close others in collectivistic brains

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Our recent work showed that close relationships result in shared cognitive and neural representations of the self and one's mother in collectivistic individuals (Zhu *et al.*, 2007, *Neuroimage, 34*, 1310–7). However, it remains unknown whether close others, such as mother, father and best friend, are differentially represented in collectivistic brains. Here, using functional magnetic resonance imaging and a trait judgment task, we showed evidence that, while trait judgments of the self and mother generated comparable activity in the medial prefrontal cortex (MPFC) and anterior cingulate (ACC) of Chinese adults, trait judgments of mother induced greater MPFC/ACC activity than trait judgments of father and best friend. Our results suggest that, while neural representations of the self and mother overlapped in the MPFC/ACC, close others such as mother, father and best friend are unequally represented in the MPFC/ACC of collectivistic brains.

Keywords: close other; self; medial prefrontal cortex; anterior cingulate; fMRI

INTRODUCTION

Close relationships influence life quality by providing physical and emotional support (Berscheid and Reis, 1998). Behavioral studies suggest that close relationships also shape and create self-concept by evolving shared cognitive elements of the self and close others such as mother, father, and best friend (Aron, 2002). Self-expansion implicated in close relationships helps to enhance potential efficacy and to accomplish goals by including to some extent close other's resources, perspectives, and identities as a part of the self (Aron *et al.*, 2004).

Given the important role of close relationships in an individual's life, close relationships may generate unique neural representation of close others in human brains. Indeed, recent functional magnetic resonance imaging (fMRI) research has shown that perception of kin faces activated posterior cingulate and cuneus relative to perception of friend faces, suggesting extended processing of close others in the perceptual domain (Platek and Kemp, 2009). Other studies have shown evidence for shared neural representations of mental aspects (i.e. trait) of the self and close others in the prefrontal cortex in the human brain (Zhu *et al.*, 2007; Ng *et al.*, 2010). Using a self-referential task that requires trait judgments of the self and others (Rogers *et al.*, 1977), previous studies found that, relative to trait judgments of a public person, self-trait judgments were associated with greater activity in the medial prefrontal cortex (MPFC) and rostral anterior cingulate (ACC) (Kelley *et al.*, 2002; Macrae *et al.*, 2004; Heatherton *et al.*, 2006; Mitchell *et al.*, 2006; Northoff *et al.*, 2006; Han *et al.*, 2008; Jenkins *et al.*, 2008; Ma and Han, 2011). Recent work suggests that the MPFC activity involved in self-referential processing is influenced by cultural values. For example, the degree of MPFC activity associated with general relative to contextual self-descriptions correlated with subjective ratings of individualism/collectivism cultural values (Chiao *et al.*, 2009a). Temporarily heightening individualism/collectivism cultural values also modulated MPFC activity underlying explicit self-judgments in bilcutural participants (Chiao *et al.*, 2009b).

More closely related to the current work, Zhu *et al.* (2007) found that the MPFC activity increased to trait judgments of mother compared to trait judgments of a public person but was comparable for trait judgments of the self and mother. These effects were evident in Chinese with the interdependent self-construals but not in English-speaking Westerners with the independent self-construals. More recent studies further showed that, relative to priming collectivism cultural values, priming individualism cultural values increased differentiation between the self and mother (Ng *et al.*, 2010) or between the self and father (Harada *et al.*, 2010) in the MPFC in bicultural individuals. The brain imaging findings indicate that collectivism cultural values may result in shared neural representations of the self and close others in the MPFC, whereas individualism cultural values may lead to differential neural representations of the self and close others in the MPFC. Taken together, the brain imaging

Received 9 September 2010; Accepted 6 January 2011
Advance Access publication 7 March 2011

This work was supported by National Basic Research Program of China (973 Program 2010CB833903), National Natural Science Foundation of China (Project 30630025, 30828012, 30910103901), and the Fundamental Research Funds for the Central Universities.

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findings suggest a neural basis for the interdependent self-construals in the collectivistic cultures (Markus and Kitayama, 1991).

However, previous studies only examined the neural representation of mother or father in relation to the self. This leaves an unresolved question about whether close others, such as mother, father and friends, are represented in collectivistic brains in a similar vein. Although humans have concerns about mother, father and best friend since preadolescent (Hodges *et al*., 1999), the concepts of close others may be constructed differently in human brains. For example, although peers comprise an important social context that helps to foster identity and to socialize youth into adult roles (Steinberg and Silverberg, 1986; Brown, 2004), the interpersonal significance of parents may be greater than that of peers (Rosenberg, 1979). Parental influence on adolescent personality development is also deeper and more enduring than that of peers (Brown, 1990). Thus, parents may be represented more strongly in the human brain compared to friends given the different social experiences one has with his/her parents and friends. In addition, social interactions between a child and his/her mother are different from those between a child and his/her father as mothers provide more direct care to their children than fathers do in most societies (Greary, 2000). For example, in Chinese culture, the care of infants and young children is exclusively the duty of mothers (Hou, 1987). Fathers have little to do with nurturing the young. Instead, fathers are expected to educate their children and teaching of children must be strict. Consequently, children may show more intense emotion toward their mothers than toward their fathers. The difference in children's interactions with mother and father may modulate the neural representations of mother and father so that MPFC activity associated with trait judgments of the mother may be greater than that associated with trait judgments of the father.

Using fMRI and the trait judgment task, the current work tested the hypothesis that close others such as mother, father and best friend are differentially represented in collectivistic (i.e. Chinese) brains in relation to the self. We monitored hemodynamic responses to trait judgments of the self and close others. The region of interest (ROI) in the MPFC was first defined by contrasting trait judgments of the self and a public person. Signal intensity in the MPFC was then calculated respectively for mother-, father- and best-friend-judgments. We were particularly interested in whether the MPFC engaged in self-judgments was also involved in trait judgments of others and whether MPFC activity was equally strong for trait judgments of mother, father and best friend.

METHODS

Subjects

Thirty-two healthy Chinese college students (16 women, aged between 19 and 27 years, mean = 22.7, s.d. = 1.9) participated in this study. All were right-handed, had normal or corrected-to-normal vision. Informed consent was obtained prior to scanning. This study was approved by a local ethics committee.

Stimuli and procedure

Subjects were first imaged while performing trait judgment tasks, followed by a memory test about 40 min after the scanning procedure. The stimuli used in the scanning procedure consisted of trait adjectives that were presented through an LCD projector (Shenzhan Sinorad Medical Electronics Inc., P. R. China) onto a rear-projection screen viewed with an angled mirror positioned on the head-coil. 240 positive and 240 negative trait adjectives consisting of 2–4 Chinese characters were selected from established personality trait adjective pools (Liu, 1990). The adjectives were classified into 10 lists of 48 words matched in word length and valence. Six lists of words were pseudo-randomly selected for trait judgment tasks while the remaining four lists of words were used in the memory test. After the scanning procedure, subjects were given a 'surprising' memory test. Thirty-two trait adjectives used in each judgment task were randomly selected and intermixed with 192 new trait adjectives for the memory test that required identification of old *vs* new items presented in a random order by pressing one of two buttons.

A box-car design consisted of six functional scans during the imaging procedure (Figure 1). Each scan consisted of six sessions of trait judgment tasks. Each session of 28 s began with a 4-s instruction that required subjects to judge if an adjective was proper to describe the self, mother, father, a gender-matched best friend or Xiang Liu (a well-known Chinese athlete). A font judgment (bold- *vs* light-faced) was included to control for semantic processing and motor responses. Eight trait adjectives were presented in each session. The judgment tasks were intervened by null sessions of 10 s during which subjects passively viewed two rows of asterisks (*). The order of the judgment tasks was counterbalanced using a Latin Squire design. Each trial consisted of a 'cue' word (either self, mother, father, best friend's name, Liu or font) above a trait adjective presented for 2 s at the center of the screen. The two successively trait adjectives were intervened by the cue for 1 s when subjects had to make a response by pressing one of the two buttons with the right index or middle finger. All instructions and traits were in Chinese. Each of the Chinese characters in the cue word and trait words subtended a visual angle of $0.34^\circ \times 0.45^\circ$ (width $\times$ height) and $0.85^\circ \times 1.14^\circ$, respectively at a viewing distance of 80 cm. Each symbol used in the null session subtended $0.23^\circ \times 0.23^\circ$ (small ones) or $0.56^\circ \times 0.56^\circ$ (large ones). All words and symbols were white on a black background.

The Individualism and Collectivism Attitude Scale (Triandis, 1995) with a 7-point Likert-type scale (1 = strongly disagree and 7 = strongly agree) was used to estimate the

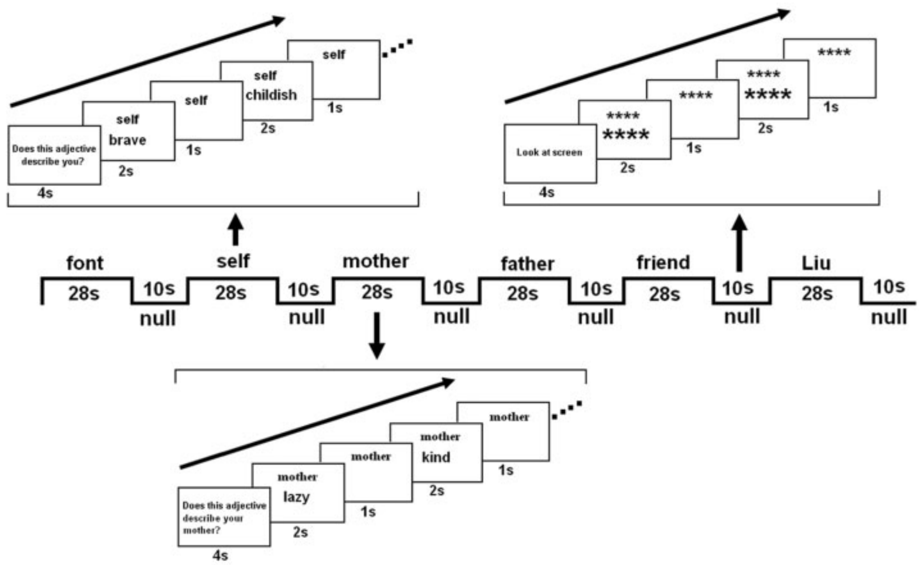

Fig. 1 Illustration of stimuli and procedure used in our study. Each scan consisted of six sessions of different judgment tasks. Two successive sessions were intervened by a null session of 10 s.

degree of endorsement of individualistic and collectivistic values. The intimate relationship between the self and others was measured using the Chinese Interpersonal Relationship Affective subscale (a 9-point Likert-type scale with 1 = to the lowest degree and 9 = to the highest degree, Zhang, 2001), which includes questions such as 'how long do you know this person?', 'how familiar are you with this person?", "how important is this person to you?", "how strongly does this person influence you?', etc.

fMRI data acquisition and analysis

Scanning was performed at Peking University First Hospital, on a GE 3-T scanner with a standard head coil. Thirty-two transversal slices of functional images covering the whole brain were acquired using a gradient-echo echo-planar pulse sequence ($64 \times 64 \times 32$ matrix with spatial resolution of $3.75 \times 3.75 \times 4$ mm, TR = 2000 ms, TE = 30 ms, FOV = 24×24 cm, flip angle = 90°). Anatomical images were obtained using a 3D FSPGR T1 sequence ($256 \times 256 \times 128$ matrix with spatial resolution of $0.938 \times 0.938 \times 1.4$ mm, TR = 7.4 ms, TI = 450 ms, TE = 3.0 ms, flip angle = 20°).

SPM2 (the Wellcome Trust Centre for Neuroimaging, London, UK) was used for data analysis. Functional images were realigned to the first scan to correct for head movement between scans and were co-registered with each participant's anatomical scan. Functional images were then normalized into a standard anatomical space ($2 \times 2 \times 2$ mm^3 isotropic voxels) using bilinear interpolation 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 8 mm.

Statistical analyses used a hierarchical random-effects model with two levels. In the first level of each subject, the onsets and durations of each session were modeled using a General Linear Model (GLM) according to stimulus conditions. All conditions (self-judgments, mother-judgments, father-judgment, best-friend-judgment, Liu-judgment, font-judgment and rest) were included in the model. A box-car function was used to convolve with the canonical hemodynamic response in each condition. Effects at each voxel were estimated and regionally specific effects were compared using linear contrasts in individual subjects using a fixed effect analysis. Random effect analyses were then conducted based on statistical parameter maps from each individual subject to allow population inference. Significant activations were identified using a threshold of $P < 0.05$ [family-wise error (FWE) corrected].

The contrast of self-judgment *vs* Liu-judgment was first calculated using a random effect model to define the brain regions involved in self-referential processing, which were used as ROIs. Signal intensity of parameter estimates was then extracted from the ROI in the MPFC [defined as the cluster above the threshold of $P < 0.05$ (FWE corrected) shown in the contrast of self- *vs* Liu-judgments with the peak at $x/y/z = 0/40/18$, MNI coordinates] linked to mother-, father-, best-friend- and font-judgments using MarsBaR 0.38 (http://marsbar.sourceforge.net). A repeated-measures analysis of variance (ANOVA) of contrast values (mother-/father-/best-friend-judgments *vs* font-judgments) was conducted with judgment (mother-, father-, best--friend-judgments) as independent within-subjects variables. Whole-brain statistical parametric mapping analyses were also conducted to calculate contrasts of mother-, father-, best friend- *vs* Liu-judgments and contrasts of self- *vs* mother-, father-, best friend-judgments.

RESULTS

Behavioral performances of trait judgments and memory tests are shown in Table 1. One way ANOVA of the proportions of 'yes' responses during the scanning procedure using Task (self, mother, father, best friend or Liu) as an independent within-subjects variable showed a significant main effect of Task [$F(4, 120) = 4.465$, $P < 0.01$]. Post-hoc analyses confirmed that the proportion of 'yes' response was slightly higher to self- than to father- ($P = 0.045$), best-friend- ($P = 0.067$) and Liu-($P = 0.016$) judgments, but did not differ from mother-judgment ($P > 0.05$). Reaction times were longer to trait judgments (self, mother, father, best friend and Liu) than to font-judgment [$F(5, 150) = 18.096$, $P < 0.001$].

One way ANOVA of corrected recognition scores (the proportion of hits minus false alarms) of the memory test conducted after the scanning procedure showed a significant main effect of Task [$F(5, 150) = 54.451$, $P < 0.001$], suggesting that corrected recognition scores were higher for words used for trait judgments (self, mother, father, best friend or Liu) than those used for font-judgments. *Post hoc* pairwise analyses showed that trait adjectives used in the self-judgment task were remembered better than those used in trait judgments of mother, father, best friend and Liu (P's < 0.05). Recognition scores of the adjectives related to mother- and father-judgments were higher compared to that related to Liu-judgments (P's < 0.05) but did not differ significantly from that related to best friend ($P > 0.1$).

Subjects scored significantly higher on the collectivistic subscale than on the individualistic subscale [5.48 ± 0.62 *vs* 4.82 ± 0.48, $t(31) = 4.98$, $P < 0.001$]. Intimacy scores were significantly higher for personal familiars (mother, father or best friend) than Liu [$F(3, 90) = 408.195$, $P < 0.001$]. Intimacy scores were higher on mother (8.31 ± 0.57) and father (7.90 ± 1.04) compared to best friend (7.12 ± 0.89) (P's < 0.01). We also examined if behavioral performances associated with self and close other judgments during the scanning procedure correlated with subjective ratings of cultural values and intimacy. We only found that RTs to mother-judgments negatively correlated with rating scores of intimacy with mother ($r = -0.585$, $P < 0.001$), suggesting that the more intimate with mother, the faster subjects responded to mother-judgments during the scanning procedure.

Table 1 Mean behavioral performances (s.d.) during the scanning procedure, memory test and subjective rating

	Self	Mother	Father	Best friend	Liu-Xiang	Font
Performance during scanning						
'Yes' responses (%)						
All	50.7 (9.9)	46.2 (8.1)	44.1 (10.4)	45.4 (9.0)	44.5 (9.3)	
Reaction time (ms)						
All	1143 (158)	1120 (101)	1110 (117)	1150 (114)	1167 (124)	999 (129)
Performance in memory test						
Total recognition score (%)						
All	44.5 (19.3)	38.6 (18.2)	36.6 (16.3)	36.1 (20.3)	29.2 (16.7)	7.0 (8.4)

Whole brain analysis first showed that self- *vs* Liu-judgments identified significant activation in the MPFC and the ACC (Figure 2A and Table 2), consistent with previous studies (Kelley *et al.*, 2002; Zhu *et al.*, 2007; Han *et al.*, 2008; Ng *et al.*, 2010; Ma and Han, 2011). To examine whether the MPFC involved in self-referential processing was differentially engaged in trait judgments of close others, signal intensity of parameter estimates in the MPFC was calculated for mother-, father-, best friend- and font-judgments, respectively. An ANOVA of the contrast values (mother-/father-/best-friend-judgments *vs* font-judgments) indicated that MPFC activity related to mother-, father-, and best-friend-judgments was significantly different [$F(2, 30) = 5.851$, $P = 0.022$]. *Post hoc* pairwise analyses further showed that MPFC activity was greater to mother- than father- and best-friend-judgments (both $P < 0.05$, Figure 2B) but did not differ between father- and best-friend-judgments ($P > 0.5$).

To assess if any other brain regions underlying semantic processing and the processing of general personal knowledge and memory retrieval during trait judgments differentiated between close others, we calculated BOLD signals associated with close other judgments in the brain areas identified in the contrast of self- *vs* font-judgments (e.g. the dorsal MPFC, left inferior frontal cortex, left temporal cortex, precuneus and caudate nucleus, see Table 2). However, the signal intensity in these ROIs failed to show any significant differences between mother-, father-, and best-friend-judgments (P's > 0.05).

To examine whether close others were differentially encoded in the MPFC relative to the public person, whole brain analysis was calculated to contrast close-other-judgments *vs* Liu-judgments. We found that MPFC and ACC activity was greater to mother- than to Liu-judgments (Figure 2C and Table 2). However, the contrast between father-/best-friend-judgments and Liu-judgments did not show any significant activation at the same threshold. Moreover, to assess whether close others were differentially encoded in the MPFC in relation to the self, contrasts of self-judgments *vs* close-other-judgments were conducted. We found that MPFC activity did not differ between self- and mother-judgments but was greater to self- than to father-/best-friend-judgments (Figure 2D and Table 2).

To examine whether the neural activity associated with the self or close others can predict subjective evaluations of one's own cultural values and intimacy with others, we calculated correlations between subjective rating scores and MPFC activity from the ROI defined in the contrast in association with self and close other judgments but did not find any significant correlations. We also conducted regression analyses to explore if any other brain areas, besides the ventral MPFC, were correlated with cultural values and subjective

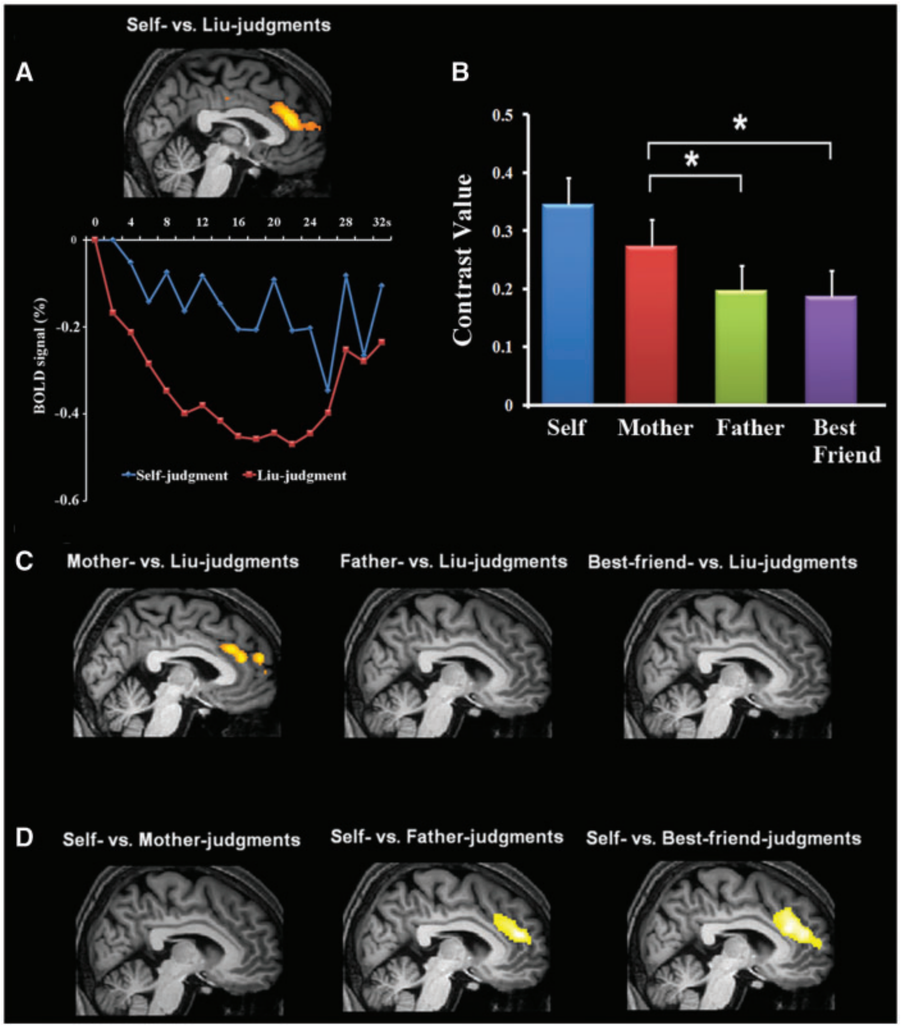

Fig. 2 (**A**) Increased MPFC activation in association with self- *vs* Liu-judgments. The top figure shows MPFC activation in an anatomical structure. The bottom figure shows BOLD responses in the MPFC to self- and Liu-judgments. (**B**) Contrast values in association with self-, mother-, father-, best-friend-judgments *vs*. font-judgment; (**C**) Increased MPFC activation was observed when contrasting mother- *vs* Liu-judgments; No increase activity was observed when contrasting father-/best-friend-judgments with Liu-judgments; (**D**) Increased MPFC activation was observed when contrasting self- *vs* father-judgments and self- *vs* best-friend-judgments, whereas the contrast of self- *vs* mother-judgments did not show any significant activation.

feelings of intimacy. We entered either rating scores of the collectivistic subscale, individualistic subscale and intimacy or the differential rating score (i.e. collectivistic subscale minus individualistic subscale) as repressors. However, these analyses failed to show any significant activation using a cluster-level threshold of $P < 0.05$ (corrected for multiple comparison).

DISCUSSION

Cultural values and behavioral performances

Cultural neuroscience studies investigate whether and how cultural values and beliefs modulate brain activity involved in multiple cognitive processes and behaviors (Chiao and Ambady, 2007; Han and Northoff, 2008, 2009; Chiao, 2009). One way to uncover cultural influences on neural activity is to compare subjects from two countries in which one cultural value dominates others (e.g. individualism or collectivism, Zhu *et al.*, 2007; Chiao *et al.*, 2009a). However, the globalization of economy and education has made it possible that college students in most countries are exposed to different cultural values and beliefs. Thus it is critical to assess which cultural value was dominant in our subjects even though they were recruited in China where collectivistic cultural values are dominant. Questionnaire measurements of the current work suggest endorsement of collectivistic cultural values in our Chinese subjects, consistent with the proposal of previous social psychological studies (Markus and Kitayama, 1991; Triandis, 1995). Questionnaire measurements also suggest subjective feeling of stronger intimate relationship between the self and parents than that between the self and best friend, possibly due to greater interpersonal significance of parents (Rosenberg, 1979)

Table 2. Brain activations shown in various contrasts ($P < 0.05$ FWE corrected)

Condition/region	Voxel no.	*x*	*y*	*z*	*Z*-value
Self- *vs* Liu-judgments					
MPFC/ACC	515	0	40	18	6.47
Mother- vs Liu-judgments					
MPFC	33	0	42	20	4.97
ACC	92	−2	26	30	5.82
Self- *vs* Father-judgments					
MPFC/ACC	37	−6	46	20	4.95
Self- *vs* Best-Friend-judgments					
MPFC/ACC	28	−6	34	24	4.76
Self- *vs* Font-judgments					
Superior MPFC	1851	−8	42	50	6.33
Left inferior frontal	354	−38	24	−14	5.98
Left temporal	35	−48	−60	20	4.78
Precuneus	251	−6	−64	16	5.65
Caudate	648	−10	16	8	6.97
Mother- *vs* Font-judgments					
Superior MPFC	1381	−12	56	34	6.33
Left inferior frontal	232	−46	26	−6	6.01
Left temporal	12	−64	−30	−2	4.89
Precuneus	406	−8	−54	28	5.81
Caudate	573	−12	14	8	5.90
Father- *vs* Font-judgments					
Superior MPFC	1213	−10	44	46	6.06
Left inferior frontal	319	−46	26	−4	5.88
Left temporal	52	−52	−24	−6	4.96
Precuneus	53	−6	−54	30	4.88
Caudate	655	−14	14	12	6.09
Best Friend *vs* Font-judgments					
Superior MPFC	816	−10	46	52	6.21
Left inferior frontal	188	−46	26	−6	5.76
Left temporal	146	−52	−26	−4	5.88
Precuneus	351	−8	−54	28	5.77
Caudate	424	−14	6	14	5.52

x, y, z = MNI coordinates; MPFC = medial prefrontal cortex.

and/or stronger parental influence on personal development (Brown, 1990). However, although mother and father play different roles in nurturing the young (Hou, 1987; Greary, 2000), our subjects reported similar rating scores of intimacy with mother and father.

The behavioral performances obtained inside the scanner showed evidence of slower responses to trait-judgments compared to font-judgments. Trait-judgments required enhanced semantic processing of words relative to font-judgments and thus took longer time for responses. However, reaction times did not differ between trait judgments of the self and close others, suggesting that different trait judgments were comparable in task demands and overall difficulty. However, subjects showed better memory of trait adjectives associated with the self than those associated with others. This typical self-referential effect in memory performances suggest elaborated encoding during trait judgments and/or better retrieval of self-related information in the memory task.

Overlap between the self and mothers

The increased MPFC activity to self-judgments compared to trait judgments of the public person replicated previous findings (Kelley *et al.*, 2002; Northoff *et al.*, 2006; Han *et al.*, 2008; Jenkins *et al.*, 2008; Ma and Han, 2011), providing evidence for the involvement of the MPFC in encoding self-related information during trait judgments. In addition, our fMRI results showed increased MPFC activity to mother-judgments relative to trait judgments of the public person, indicating that the MPFC is differentially involved in representation of mother compared to a familiar public figure. Moreover, our fMRI results confirmed the overlap of representations of the self and mother in the MPFC as the contrast of self- versus mother-judgments did not show any significant activation in this brain region. Together with our previous findings (Zhu *et al.*, 2007; Ng *et al.*, 2010), the fMRI results indicate a shared neural representations of the self and mother in collectivistic brains. This provides a neural basis for the overlap of conceptual representations of the self and mother in collectivistic cultures (Markus and Kitayama, 1991). The shared representations of the self and mother in the MPFC also support the self-expansion model (Aron *et al.*, 2004) that posits that in close relationships the close others become part of the self.

Differential neural representation of close others

Most importantly, our findings showed evidence that close others such as mother, father, and best friend are unequally represented in the MPFC of collectivistic brains. Specially, MPFC activity increased to mother-judgments compared to public person judgments whereas the activity in the same brain region failed to distinguish between farther/best friend and the public person during trait judgments. Moreover, activity in the MPFC that was engaged in self-referential processing was greater to mother-judgments relative to farther- and best-friend-judgments. Taken together, the results indicate that representation of mother in the MPFC was stronger than that of other close others such as father and best friend. Our results further showed that the activity differentiating between mother and father/best friend was specific to the ventral part of the MPFC that was defined in the contrast of self-judgments versus public person judgments. The brain regions defined in the contrast of self-judgments versus font-judgments including the dorsal part of the MPFC, posterior cingulate and caudate nucleus, which were involved in semantic processing and the processing of general personal knowledge and memory retrieval, did not differentiate between mother-, father- and best-friend-judgments. Thus, it seems that only the 'self-area' defined in the contrast of self-judgments *vs* public person judgments was engaged to differentiate between close others.

It has been proposed that the ventral region of the MPFC contributes to the encoding of self-relevance of stimuli (Nortorff *et al.*, 2006; Han and Northorff, 2009). In consistent with this, Macrae *et al.* (2004) found that trait words judged as suitable to describe the self evoked greater MPFC activity relative to trait words judged as unsuitable to describe the self. A recent work showed further that the MPFC mediates the processing of personal closeness. Krienen *et al.* (2010) asked participants to make inferences about friends and strangers who were either similar or dissimilar to oneself in political attitudes, personality, lifestyle, occupation and education. They found that the ventral region of the MPFC and rostral ACC increased to friends compare to strangers regardless whether the friends were similar or dissimilar to the self. The findings underscore the functional role of the MPFC activity in encoding the social relevance of the person (closeness) to oneself. The current study complemented previous research by showing that the MPFC also differentiate between close others. Thus the MPFC not only classifies persons in terms of close others *vs* strangers but also engages in encoding how close a familiar other is. The greater MPFC activity link to mother than father/best friend in relation to the self may arise from stronger behavioral connections during development between the self and mother (Geary, 2000) and provide a neural basis for the excessive concern of closeness with mother over other close others (Hodges *et al.*, 1999).

In consistent with differential neural representations of mother and best friend, our subjects reported stronger intimate feelings to mother than to best friend. However, differential neural representations of mother and father in the MPFC were observed even though questionnaire measurements of intimacy suggest similar close relationship between the self and mother/father. Thus markers of different close relationship can be found at the neural level (i.e. MPFC activity) even when such difference could not be disclosed in the questionnaire measurements of intimacy between mother and father. In addition, our fMRI results failed to reveal differential neural representation of father and best friend whereas questionnaire measurements of intimacy suggest different close relationship between father and the best friend. The inconsistency between subjective feelings and brain activity may arise from the influence of social desires on explicit subjective reports of social feelings. Alternatively, brain regions outside the MPFC may play a more critical role in encoding the intimacy between the self and close others. Given that self-report on behavioral surveys based on subjective Likert scales is strongly influenced by the reference group (Heine *et al.*, 2002), future research may also investigate Asian participants in Western cultural contexts to examine the neural representation of close others when referenced to a different cultural group.

Recent studies have shown evidence that socio-cultural contexts strongly shape neural basis of multiple levels of human cognition (Chiao and Ambady, 2007; Han and Northoff, 2008; Chiao, 2009). The current work further suggest that different social interactions between the self and individuals closely related to the self can also shape the neurocogntive processes of the close others. To what degree are neural representations of close others in the MPFC modulated by cultural values and beliefs? This cannot be addressed by our brain imaging results as the current work recruited subjects from only one culture. We conducted regression analyses but failed to find significant activations that correlated with subjective ratings of individualism/collectivism values across subjects. We also classified our subjects into two groups based on a median split on the cultural values and compared MPFC activity in associated with self and close other judgments between the two groups. However, this did not reveal reliable difference in MPFC activity between the two groups with high and low collectivism cultural values. This is possibly due to the small variation of cultural values among our subjects. Future research may investigate the difference in neural representations of close others between two cultural groups and employed a large sample to assess individual differences in brain activity underlying personal relatedness in close relationship.

CONCLUSIONS

The current fMRI research showed evidence that close others such as mother, father and best friend are differentially represented in human MPFC. Representation of mother's traits overlaps with that of the self in the MPFC whereas representations of father and best friend's traits do not. The distinct neural representations of mother, father and best friend in collectivistic brains may arise from one's different daily experiences with close others, and may affect social interactions between the self and close others. Our results support the proposal that the MPFC mediates a function to represent self-relatedness of others (Northoff *et al.*, 2006; Han and Northoff, 2009; Krienen *et al.*, 2010) and can be used as an objective measurement of close relationships, complementing subjective evaluations of close relationships.

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