Asian Journal of Social Psychology

Asian Journal of Social Psychology (2010), **13**, 83–91 DOI: 10.1111/j.1467-839X.2010.01303.x

Dynamic bicultural brains: fMRI study of their flexible neural representation of self and significant others in response to culture primes

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Where in the brain are the self and significant others (e.g. mother) represented? Neuroscientists have traced self-representation to the ventral medial prefrontal cortex for both Westerners and East Asians. However, significant others were represented alongside the self in the same brain area for East Asians but not for Westerners. In this experiment, Westernized bicultural Chinese were scanned using functional magnetic resonance imaging while performing trait judgments that referenced the self, mother, or a non-identified person (NIP) after Western or Chinese culture priming. Consistent with Western independent self-construals and Chinese interdependent self-construals, Western priming increased, whereas Chinese priming decreased the neural differentiation of mother and NIP from self.

Key words: culture priming, independent self-construal, interdependent self-construal, functional magnetic resonance imaging (fMRI), medial prefrontal cortex, self-inclusiveness.

Introduction

'Who am I?' is a question that interests not only social scientists (Ashmore & Jussim, 1997) but also neuroscientists (Damasio, 2003). One aspect of this broad question concerns the social contents of the cognitive structure of the self-concept, or, more specifically, who are included in or differentiated from the self-concept, and why. Three mechanisms of 'self-inclusiveness' and 'self-other differentiation' can be discerned from the social and cultural psychology literature, one affective (based on intimacy in interpersonal contexts), another cognitive (based on self-categorization in intergroup contexts), and the third cultural (based on independent and interdependent self-construals). In the present paper, we review the mechanisms and propose a bicultural frame switching model for understanding the flexible neural representation of the self and others in bicultural brains.

Self-inclusiveness and self-other differentiation: Evidence from social and cultural psychology

Interpersonally close or intimate others are referred to as 'we,' 'us' and 'our' in self-other descriptions, suggesting that they are perceived as part of the self (Agnew, Van Lange, Rushbult, & Langston, 1998). They are also more easily confused than less intimate others with self in 'source confusion' tasks that are designed to assess the overlap of different categories of people with the cognitive structure of the self (Mashek, Aron, & Boncimino, 2003). These and related findings point to affective processes in self-inclusiveness, as summarized in the self-expansion reference model: 'participants in a close relationship include each other in their selves in the sense that other's perspectives, resources, and identities are to some extent one's own' (Aron, Aron, & Norman, 2004, p. 111). Others not in a close relationship with the person are differentiated from the person's self.

Although intimacy enhances self-inclusiveness and the lack of it enhances self-other differentiation, it is not a necessary condition. Shared group membership resulting from cognitive self-categorization processes independently of interpersonal intimacy has been found to be sufficient for including ingroup members in and differentiating outgroup members from the self-concept (Turner, 1978; Turner, Hogg, Oakes, Reicher, & Wetherell, 1987). Corresponding to the interpersonal affective and the intergroup cognitive mechanisms are relational and collective self-definitions, respectively, which 'represent two different forms of social identification; that is, processes by which the individual self is extended to include others as integral to the self-concept' (Brewer & Chen, 2007, p. 137).

While the two mechanisms of self-inclusiveness and self-other differentiation are assumed to be universally applicable to all cultures, the cultural context that has shaped the self-concept also has a role to play. In cultural

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Received 28 April 2009; accepted 15 December 2009.

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psychology, two popular constructs for East-West comparisons are interdependent versus independent self-construal (Markus & Kitayama, 1991) and collectivism versus individualism (Hofstede, 1980; Triandis, 1995). Similar East-West contrasts are used in conjoint and disjoint models of agency (Markus & Kitayama, 2003), as well as relatedness and autonomy (Kagitçibasi, 2005). This family of concepts converges in proposing that whereas interdependent self-construal and collectivism are more typical of Eastern cultures (e.g. Chinese and Japanese), independent self-construal and individualism are more typical of Western cultures (e.g. Euro-American). Although the concepts have been criticized on conceptual and methodological grounds (e.g. Brewer & Chen, 2007; Levine *et al*., 2006; Oyserman, Coon, & Kemmelmeier, 2002), they remain useful for generating propositions with respect to cultural variations in self-inclusiveness and self-other differentiation. More specifically, others are more likely to be mentally represented as part of the self when the culture that has shaped it values social connectedness (interdependent self-construal, collectivism, and so forth) whereas others are more likely to be differentiated from the self in cultures that value individuating uniqueness (independent self-construal, individualism, and so forth).

Self-inclusiveness and self-other differentiation: Evidence from cultural neuroscience

Several cultural neuroscience studies provide neural evidence for the expectation that self-inclusiveness is stronger in Easterners whereas self-other differentiation is stronger in Westerners. Functional magnetic resonance imaging (fMRI) studies scanning Europeans found that only the self was represented in the ventral medial prefrontal cortex (VMPFC) (D'Argembeau, A., Collette, F., Van der Linden, M. *et al*., 2005; Fossati *et al*., 2003; Han *et al*. 2008; Heatherton *et al*., 2006; Macrae, Moran, Heatherton, Banfield, & Kelley, 2004; Northoff & Bermpohl, 2004; Northoff, DeGreck, Bermpohl, & Panksepp, 2006). For Chinese, however, both the self and mother were represented in the same brain area (Zhu, Zhang, Fan, & Han, 2007). Zhu *et al*. (2007) interpreted their neuroimaging results as supportive of Markus and Kitayama's (1991) theory of interdependent versus independent self-construal: the neural structure of the Chinese self is more closely connected with others (interdependent self-construal) whereas that of Westerners is more highly differentiated from others (independent self-construal). Chinese may use VMPFC to reference both the self and significant others such as mother, whereas Westerners use VMPFC exclusively in self-referential processing.

Self-inclusiveness and self-other differentiation in the bicultural brain: Bicultural frame switching model

A closer reading of Zhu *et al*.'s (2007) study calls for two improvements. First, the between-groups experimental design adopted therein, although widely used in comparative studies, may be confounded by variables such as language differences that covary with culture and, consequently, is in need of improvement by switching to a within-group paradigm for more rigorous experimental control. A promising development in within-group research is the use of Westernized bicultural Chinese and exposing them to Western and Chinese culture primes designed to call out culture-congruent cognitions and behaviour (e.g. Hong, Morris, Chiu, & Benet-Martinez, 2000; see also Chao, Chen, Roisman, & Hong, 2007; and Oyserman & Lee, 2008). If the brains of the same bicultural individuals resonate to culture primes and use the VMPFC region to reference both self and mother when Chinese culture primed, but reference only the self when Western culture primed, the results would provide more compelling evidence for cultural influence than those obtained from comparing the brains of Westerners and Chinese.

In Zhu *et al*. 's (2007) study, the neural overlap between self- and mother-referencing among Chinese is a striking contrast to the self-mother separation among Europeans, but the between-groups difference may be confined to intimate others and not generalizable to significant others who are not intimate. This is not a trivial limitation because a person may not feel close to or identify with significant others who affect his or her life, for example, bosses. Such a significant but non-identified person (NIP) would make an interesting comparison with mother. Can Chinese culture priming induce the bicultural brain to represent not only mother, but also NIP, in the same brain region as the self?

The present cultural neuroscience study adopts a within-group experimental design to test whether the bicultural brains of Westernized Chinese resonate to culture primes in representing the self, mother, and NIP. The working hypothesis is that Chinese culture priming will induce self-inclusiveness, whereas Western culture priming will induce self-other differentiation, regardless of whether the 'other' is mother or NIP.

Method

Bicultural participants first went through the culture priming procedures (Western priming on one day and Chinese priming on another day), and then carried out four personality trait judgment tasks that focused their attention on either self, mother, NIP, or font. Brain imaging was conducted during the judgment tasks.

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Bicultural participants

For nearly two centuries, Hong Kong has been at the confluence of Chinese and Western cultures, a period long enough to bring about biculturalism in languages, lifestyles, cinematic industries, values, education, commerce and businesses, as well as religious and child-rearing practices (Bond, 1993; Ng, 2007). It is a suitable milieu for biculturalism research, certainly among its population of bilingual university students (Hong *et al*., 2000; Ng & Lai, 2009; Ng & Lai, in press). As a precautionary measure, in the present study, only those students who were brought up in Hong Kong and scored above the mean on a bicultural self questionnaire were selected. The four-item questionnaire, developed by Ng and his associates (Ng & Lai, in press; Ng, Yam, & Lai, 2007), had been shown to be able to distinguish individuals who were high in both Chinese self and Western self from those who were high in only one or none, on such bicultural criteria as language use, preference for bicultural entertainments and festivals, and bicultural integration (Benet-Martínez & Haritatos, 2005; LaFromboise, Coleman, & Gerton, 1993).

Eighteen graduate or undergraduate students from the City University of Hong Kong (six men and 12 women between the ages of 20 and 27 years) participated in this study as paid volunteers. (Three of them were excluded from data analysis because of excessive head movement during scanning.) They were right-handed and had normal or corrected-to-normal vision. None had any neurological or psychiatric history. Their Chinese self and Western self scores were, respectively, above 4.74 and 4.68 on a seven-point scale where seven represented the strongest self. Informed consent was obtained before testing. This study was approved by a local ethics committee.

Western and Chinese culture primes

As Hong Kong is a receptacle of not only British but also American and continental European cultures, pictures for the Western culture priming condition were carefully chosen to represent these varieties of Western culture. Similarly, pictures for the Chinese culture priming condition were chosen to represent not only Mainland Chinese but also Hong Kong Chinese culture. Each set of culture primes consisted of 13 pictures covering five cultural domains (foods and drinks, music and arts, popular movie stars, religion and legend, as well as folklores and famous constructions), and were matched between Chinese and Western cultures as closely as possible; for example, Bruce Lee (Kung Fu) was matched with Roger Moore (James Bond). The pictures were therefore more relevant to the Hong Kong context than those used by Hong *et al*. (2000), and were found to be effective in inducing prime-consistent changes (Ng & Lai, 2009).

Scanning procedure

Half of the participants were Western culture primed on the first day of the study and Chinese culture primed a day later. The order was reversed for the other half of participants. The pictures were presented one after another, each lasting 10 s. After the first round of presentation, nine of the pictures were presented again one at a time, each time followed by the question 'Which culture does it represent, Chinese or Western?' All participants answered correctly. The remaining four pictures were then presented, each followed by the instruction 'Use three adjectives to describe the culture depicted in this picture.' Afterwards, the participant was asked to write a short paragraph in response to 'In what ways has the culture shown in the pictures helped you develop yourself?' The questions and instructions were written in Chinese and English, and the whole exercise was designed to deepen participants' attention to the primed culture.

There were two functional scans after either Chinese or Western culture priming, each consisting of four blocks (judgment tasks, Fig. 1). The participant was scanned while performing personality trait judgment tasks. The stimuli were presented through an liquid crystal display (LCD) projector onto a rear-projection screen mounted above the participant's head. The screen was viewed with an angled mirror positioned on the head coil. In each scan, the

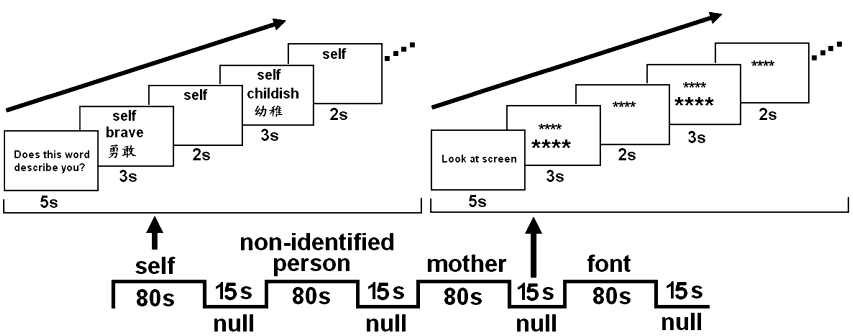

Figure 1 Illustration of the stimuli and procedure.

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participant conducted the following judgment tasks in random order. (i) Self judgment: Does this adjective describe you? (ii) Mother judgment: Does this adjective describe your mother? (iii) NIP: Does this adjective describe a person whom you would not identify with, excluding your parents? (iv) Font judgment: Is the word presented in bold or normal style?

Prior to testing, the experimenter explained the meaning of each task to ensure correct understanding. For example, in the NIP instruction, the participant was asked to think of a person who affected their lives, but with whom they did not identify. The NIP could be a classmate, supervisor, professor, and so forth, but not their parents. On the second day of testing under a different priming condition, participants were asked to recall the same NIP they had nominated before. This procedure ensured that the NIP was identical during the two priming conditions. Note that participants were asked to nominate their NIP, rather than to respond to a common figure. It would have been difficult to find a public figure who had affected the lives of all participants and was also not identified by all of them. Such a person would mean different things to different people. Self-nominated NIP, however, fulfilled both requirements to ensure a high degree of homogeneity of meaning for all participants.

The traits written in Chinese and English were presented bilingually. Bilingual presentation applied to both priming conditions in order to minimize language confounds. Participants made judgments after the presentation of each trait adjective by pressing one of two buttons with the right index or middle finger. They would not press either button if they were not sure about the judgment task. Both the response and its latency were recorded. The judgment tasks were intervened by a null block during which participants were presented with a light gray cross on a black background. Participants were asked to passively view the cross in the null condition. The order of the judgment tasks was randomized in each scan.

A total of 240 trait adjectives were selected from a large pool of personality trait adjectives compiled by Yang and Li (1971). The selection was made on the basis of a pilot test of 20 participants (similar to those in the main study) to ensure that the words were familiar to local participants and had either positive or negative connotations. Each trait consisted of two Chinese characters and their English translations had been verified through back-translation. Half of the traits (120), with an equal number of positive and negative traits, were randomly selected for each priming condition. They were grouped into eight 15-trait lists, four of which were randomly selected for the four judgment tasks in each of the two scans.

At the beginning of each scan, a sentence was presented to describe the task and lasted for 5000 ms. The instruction was followed by 15 trials (Fig. 1). On each trial, a Chinese-English bilingual trait word was presented below a 'cue' (either self, mother, NIP, or font) at the centre of the screen for 3000 ms. The word was light gray on a black background. It then disappeared while the 'cue' word stayed on the screen for 2000 ms. The Chinese 'cue' words and the trait words were presented in Song font and the English words were presented in Times New Roman font. The cue word subtended a visual angle of $0.7 \times 5.1°$ (height × width). Each of the Chinese and English trait words subtended a visual angle of $2.2 \times 4.4°$ or $1.5 \times 5.1°$, respectively. Each block of 15 judgment tasks lasted for 75 s (excluding the instruction that lasted for 5 s), which was long enough to provide reliable fMRI data. There were four blocks in each scan, which were intervened with a null block of 16 s.

fMRI data acquisition

Brain imaging was carried out on a 3 T Siemens Trio MR scanner (Siemens, Munich, Germany) with a standard birdcage head coil at the Beijing MRI Center for Brain Research. Pieces of foam were used to minimize head movement. A T_2*-weighted gradient-echo planar imaging (EPI) sequence (TR = 2000 ms, TE = 30 ms, and flip angle = 90 degree, 3 mm thickness, skip 0.75 mm, FOV = 220 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 lasting for 324 s. During a functional scan, 162 sets of mosaic images were acquired, allowing complete brain coverage. High-resolution anatomical images were obtained using a standard 3D T_1-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, London, 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 ($2 \times 2 \times 2$ 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 modelled 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, between self- and mother-

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judgments, and between self- and NIP-judgments were defined for 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 statistical parametric mapping (SPM) coordinates for standard brain from the MNI template were converted to Talairach coordinates (Talairach & Tournoux, 1998) using a non-linear transform method (http://www.mrc-cbu.cam.ac.uk/Imaging/mnispace.html).

Results

Brain imaging

A whole-brain SPM analysis was first conducted to identify the brain areas involved in the semantic encoding process during the scanning procedure by contrasting fMRI signals in the self, mother and NIP conditions with those in the (non-semantic) font condition. These include the left inferior frontal cortex and the superior frontal cortex after both Chinese and Western culture priming (Table 1). These results suggest that semantic processing was comparable for different judgment tasks in different priming conditions and, thus, the difference between self and mother or NIP could not simply be attributed to differential semantic processing during the judgment tasks between Chinese and Western culture priming conditions.

After Western culture priming, self judgment induced increased activity in the VMPFC (BA 10/32, Fig. 2a) relative to NIP judgment. The Talairach coordinates of VMPFC activation were −8, 44, −7 (Z = 4.27, Voxel number = 231, $p < 0.01$ corrected). Self judgment also produced increased activation in the right extrastriate cortex (26, −86, 19, Z = 3.89, Voxel number = 149, $p < 0.05$ corrected). Increased activity in VMPFC was also identified in the self-mother contrast (−10, 46, −2, Z = 4.56, Voxel number = 160, $p < 0.05$ corrected). The mother-NIP contrast did not show any brain activation. Overall, results under Western culture priming supported the expectation of self-other differentiation.

To assess whether there was any brain activation specific to self-referential processing after Chinese culture priming, the fMRI data in the Chinese culture priming condition were subject to a whole-brain statistical parametric mapping analysis. It turned out that the fMRI results after Chinese culture priming failed to show any brain activation in the contrast of self versus mother, self versus NIP, or

Table 1 Regions of significant increased activation in comparison between self, mother and NIP with font judgments (corrected, $p < 0.05$)

Condition/region	Voxel no.	BA	X	Y	Z	*Z*-value
Western culture priming						
Self minus font						
Left inferior frontal gyrus	683	47	−48	25	−2	4.70
Superior medial frontal gyrus	925	9	−4	50	30	4.66
Left middle frontal gyrus	230	6	−34	−18	60	4.36
Mother minus font						
Left inferior frontal gyrus	421	45	−38	23	−6	4.14
Superior medial frontal gyrus	817	6	10	4	50	4.73
Right precentral gyrus	194	4	−20	−28	62	4.07
Cerebellum	162	28	−73	−22	4.16	
Non-identified person minus font						
Left inferior frontal gyrus	1185	47	−38	29	−3	4.81
Superior medial frontal gyrus	707	9	8	21	30	4.34
Chinese culture priming						
Self minus font						
Left inferior frontal gyrus	532	47	−40	21	−13	4.91
Left post-central gyrus	365	12	−52	−15	46	4.09
Mother minus font						
Left inferior frontal gyrus	466	47	−40	21	−11	4.44
Superior medial frontal gyrus	161	6	−4	20	52	4.45
Cuneus	258	18	−71	16	4.60	
Non-identified person minus font						
Left inferior frontal gyrus	1046	47	−42	16	5	5.41
Superior medial frontal gyrus	1040	9	−4	22	50	5.14

BA, Brodmann's area; NIP, non-identified person; Voxel no., number of voxels in a cluster.

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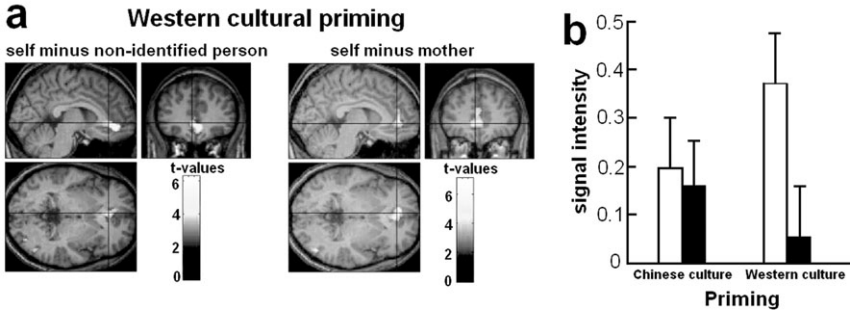

Figure 2 (a) Brain activation observed in the contrasts between self *vs* non-identified person and between self *vs* mother after Western cultural priming. (b) Results of region-of-interest analysis of the parameter estimates of signal intensity in the ventral medial prefrontal cortex. ■, non-identified person; □, self.

Table 2 Mean behavioural performances (*SD*) during the scanning procedure

	Self	Mother	Non-identified person	Font
'Yes' and 'Bold' responses (%)				
Western culture priming	45.3 (8.63)	43.4 (14.5)	55.4 (20.7)	48.4 (9.94)
Chinese culture priming	44.1 (10.1)	42.6 (12.5)	51.1 (20.2)	48.9 (3.89)
Reaction time (ms)				
Western culture priming	1729 (397)	1695 (378)	1921 (533)	1242 (356)
Chinese culture priming	1766 (393)	1760 (389)	1934 (513)	1318 (436)

'Bold' responses were responses to font-judgments, and 'Yes' responses were responses to the other three judgment tasks. There were no significant main or interaction effects due to culture priming. The only significant effect was a main effect of judgment ($F(3, 13) = 23.64$, $p < 0.001$) on reaction time.

mother versus NIP judgments. The overlap between self and others shown by the results of self-other contrast under Chinese culture priming supported the expectation of greater self-inclusiveness.

A region-of-interest (ROI) analysis was conducted to further assess the effect of culture priming on VMPFC activity associated with the processing of the self and others. We calculated parameter estimates of signal intensity in association with self and NIP judgments in the VMPFC centred at −8, 44, −7 in both Western and Chinese culture priming conditions. A two-way ANOVA with cultural priming (Western *vs* Chinese) and judgment (self *vs* NIP) as within-subject variables was carried out to examine the differential activation in the VMPFC with respect to self versus NIP judgment between the two culture priming conditions. There was a significant interaction between culture priming and judgment ($F(1,14) = 5.669$, $p < 0.05$, $MSE = 0.289$). Consistent with the hypothesis, the significant interaction showed a stronger activation in the VMPFC linked to the dissociation between self and NIP judgments after Western than after Chinese culture priming (Fig. 2b). However, another two-way ANOVA with respect to self versus mother judgment revealed no significant interaction effect.

Behavioural performance

Table 2 shows the proportion of 'Yes' and 'Bold' responses to the judgment of traits. 'Yes' responses indicated judgments that the traits described self, mother, or NIP, whereas 'Bold' responses indicated judgments that the traits appeared in bold font. Results of a 2 (priming) × 4 (judgment) within-subject ANOVA showed no significant priming or any other effects (Ps > 0.1). Table 2 also reports the reaction times. A similar ANOVA found no significant priming effects and only a significant main effect for judgment, $F(3, 13) = 23.64$, $p < 0.0001$. Participants responded faster to font judgment than to the other tasks. The overall results showing the absence of behavioural effects due to priming provide an interesting contrast with priming's significant neural effects, a point that will be revisited below.

Discussion

Whereas Zhu *et al.*'s (2007) cross-cultural neuroimaging study has demonstrated cultural influences on the content of self- and other-referential processing mediated by the VMPFC in different cultural groups, the current study examined the effects of culture priming on the differentiation between self and others mediated by the VMPFC in the same group of bicultural participants. In addition, a NIP-referencing condition was included in our design to test whether Chinese culture priming would increase self inclusiveness to cover not only mother but also a non-intimate person. As predicted, our fMRI results in the Chinese

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culture priming condition showed clear evidence that VMPFC activation did not differentiate between self and mother or even between self and NIP. By contrast, fMRI results in the Western culture priming condition showed that VMPFC activity differentiated between self and NIP judgments and even between self and mother judgments. The locus of VMPFC activity under Western culture priming is consistent with that observed in previous neuroimaging studies of Western participants (Kelley *et al*., 2002; Macrae *et al*., 2004; Moran, Macrae, Heatherton, Wyland, & Kelley, 2006; Zhu *et al*., 2007).

The statistical significance of the effect of culture priming was confirmed by the ROI analysis for the self versus NIP comparison that showed a reliable interaction between priming and self-NIP contrast. A similar pattern of weakened self-mother differentiation after Chinese culture priming was found, although the ROI analysis for the interaction effect between self versus mother comparison and culture priming did not reach a significant level. It appears that, whereas Western culture priming also dissociates mother from self, the dissociation is less clear-cut than the dissociation of NIP from self. The overall fMRI results indicate that self-representation in the VMPFC in bicultural brains is exclusive of NIP and even of mother when they are exposed to Western culture primes. However, such distinction between the self and others in the VMPFC can be weakened or eliminated by exposure to Chinese culture primes.

The present findings cannot be explained by any variables that covary with cultures, such as language differences, because the modulation of self-representation mediated by the VMPFC was observed in the same group of participants. Furthermore, culture priming had no significant effect on behavioural performances. The brain imaging results, by contrast, were significant. The contrasting pattern of behavioural and neural results demonstrates the methodological strength of examining culture priming at the neural level to reveal the effects of culture priming that may otherwise remain hidden or are difficult to detect behaviourally.

In accordance with previous research that indicates cultural influence on the neural mechanisms underlying self-representation by showing differential VMPFC activity in Chinese and Western participants (Zhu *et al*., 2007), the current study provides strong evidence for the effect of short-term culture priming on self-representation in bicultural participants. These results extend previous research in the domain of self-face recognition, which shows that self-face recognition in Chinese participants is enhanced by self-construal priming that emphasizes the independent over the interdependent self (Sui & Han, 2007). Taken together, our brain imaging results demonstrate that the mechanisms underlying self-representation involved in both thinking about self-personality (present study) and self-face recognition (Sui & Han, 2007) are culture sensitive.

Returning to the question of 'Who am I?' the present study, to our knowledge, is the first cultural neuroscience experiment that provides neuroimaging evidence for the effects of culture priming on self-inclusiveness and self-other differentiation. The NIP results are compelling evidence that the effect of Chinese culture priming is not limited to significant others who are interpersonally close, such as mother. At the neural level, the self-concept is inclusive of significant others regardless of intimacy when Chinese culture primed, and exclusive of them when Western culture primed. This pattern of results provides a neural basis for Markus and Kitayama's (1991) widely used cultural model of interdependent and independent self-construals.

Yet, much remains to be done. Culture priming is not an exact science, and its efficacy tends to vary across methods and across studies (Oyserman & Lee, 2008). Although the efficacy of the Chinese and Western culture primes and the elaborate priming procedure has been demonstrated in the present experiment, it remains unclear which cultural aspects were activated to produce the neural results. The closest clue is from Ng and Lai (2009), who used the same primes and the same judgment conditions in a memory experiment based on the self-reference effect paradigm (Rogers, Kuiper, & Kirker, 1977). They found self-like memory performance in both the mother- and the NIP-reference conditions under the Chinese but not under the Western culture priming condition. These memory results are consistent with the present neuroimaging results, and suggest that the priming has probably activated that part of culture responsible for self-construal. Admittedly, this remains speculative and begs further research that uses a more direct prime to activate self-construal.

Finally, the fact that bicultural individuals include/exclude mother and NIP in their self-concepts depending on the culture primes demonstrates not only the flexible and dynamic neural representation of self and significant others, but also the promising neuroscience linkages with cross-cultural and social psychology. For example, the neuroscience results provide a strong supportive link with Markus and Kitayama's (1991) cross-cultural model of independent and interdependent self-construals, as already noted. It addresses the call by Zhou and Cacioppo (2010) to integrate fMRI with the dynamic constructivist approach to culture. The results also offer a neural base for self-categorization theory in social psychology, according to which individuals can self-categorize at multiple levels of group inclusiveness in response to the intergroup context (Turner *et al*., 1987). A higher level of self-categorization that includes more people in the ingroup (e.g. 'I am Asian' instead of 'I am Chinese') would seem to correspond in an analogous way to the greater inclusiveness of significant others that has been demonstrated in the present study (see also the group-reference effect in Johnson *et al*., 2002).

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Future research in this area would substantiate the importance of the self in cultural neuroscience that has been identified by Ames and Fiske (2010).

Acknowledgements

Funding support for the present research was provided by the City University of Hong Kong (Project 9380024) and the National Natural Science Foundation of China (Project 30630025).

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