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Tokiko Harada*, Zhang Li*, Joan Y. Chiao*
* Northwestern University, Evanston, IL, USA

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Differential dorsal and ventral medial prefrontal representations of the implicit self modulated by individualism and collectivism: An fMRI study

Tokiko Harada, Zhang Li, and Joan Y. Chiao
Northwestern University, Evanston, IL, USA

Individualism and collectivism, or self-construal style, refer to cultural values that influence how people think about themselves and their relation to the social and physical environment. Recent neuroimaging evidence suggests that cultural values of individualism and collectivism dynamically modulate neural response within cortical midline structures, such as the medial prefrontal cortex (MPFC) and posterior cingulate cortex (PCC), during explicit self-evaluation. However, it remains unknown whether cultural priming modulates neural response during self-evaluation due to explicit task demands. Here we investigated how cultural priming of self-construal style affects neural activity within cortical midline structures during implicit self-evaluation in bicultural individuals. Results indicate that ventral MPFC showed relatively less deactivation during implicit evaluation of both self- and father-relevant information as compared to control condition (e.g., information of an unfamiliar person), irrespective of cultural priming. By contrast, dorsal MPFC showed relatively less deactivation during implicit evaluation of father-relevant information, but not self-relevant information, as compared to control condition, only when they were primed with individualism. Furthermore, dorsal MPFC showed relatively less deactivation during implicit evaluation of father-relevant information as compared to self-relevant condition only when they were primed with individualism. Hence, our results indicate that cultural priming modulates neural response within dorsal, but not ventral, portions of MPFC in a stimulus-driven rather than task-driven manner. More broadly, these findings suggest that cultural values dynamically shape neural representations during the evaluation, rather than the detection, of self-relevant information.

Keywords: fMRI; Self-construal style; Cultural priming; Medial prefrontal cortex; Implicit self; Culture; Self; Cultural neuroscience.

INTRODUCTION

One of the most fundamental ways in which culture shapes human thought and behavior is in self-construal, or how people think about themselves and their relation to others. In particularly, cultural psychologists have identified two main styles of self-construal: individualism and collectivism (Markus & Kitayama, 1991; Nisbett, Peng, Choi, & Norenzayan, 2001; Triandis, 1995). Individualists think of people as independent of each other and describe individuals using stable personality traits (e.g., I am honest) rather than situation-specific attributes. By contrast, collectivists think of people as highly interconnected to one another and describe themselves and others as embedded in a specific social context or situations (e.g., When talking to my mother, I am honest) rather than using generic trait adjectives. Cultural psychologists posit that the concepts of individualism and collectivism originate from divergences in notions of self and its relation to the environment introduced by early Western and Eastern
philosophers (Markus & Kitayama, 1991; Nisbett et al., 2001; Triandis, 1995).

While some aspects of cultures remain stable across time, other cultural traits are dynamic (Chiao et al., in press; Li, 2003; Mesoudi, Whiten, & Laland, 2006). Prior cultural psychological research has shown that biculturals primed with an individualistic orientation are more likely to describe themselves using general descriptions (e.g. I am honest), whereas biculturals primed with a collectivistic orientation showed a stronger propensity to describe themselves using contextual self-descriptions (e.g., “When talking to my mother, I am honest”) (Gardner, Gabriel, & Lee, 1999; Oyserman & Lee, 2007; Trafimow, Triandis, & Goto, 1991). Hence, when primed to orient more toward either an individualistic or a collectivistic schema, biculturals will think about themselves in a way that is consistent with the cultural schema temporarily brought to mind.

Cultural values of individualism and collectivism are associated with neural mechanisms underlying self-relevant processing. Numerous neuroimaging studies to date have implicated medial prefrontal cortex (MPFC) in processes related to the self (Amodio & Frith, 2006; Craik et al., 1999; D’Argembeau et al., 2005, 2007; Gusnard, Akbudak, Shulman, & Raichle, 2001; Gusnard and Raichle, 2001; Heatherton et al., 2006; Johnson et al., 2002; Kelley et al., 2002; Kjaer, Nowak, & Lou, 2002; Macrae, Moran, Heatherton, Banfield, & Kelley, 2004; Mitchell, Macrae, & Banaji, 2006; Northoff et al., 2006; Ochsner et al., 2004, 2005; Pfeifer, Lieberman, & Dapretto, 2007; Schmitz, Kawahara-Baccus, & Johnson, 2004). Prior research indicates a functional distinction between the ventral and dorsal portions of MPFC, whereby ventral portions of MPFC are involved in the representation of information as self-relevant, whereas dorsal portions of MPFC are involved in the evaluation of self-relevant information (D’Argembeau et al., 2007; Gusnard et al., 2001; Gusnard and Raichle, 2001; Mitchell et al., 2006; Northoff et al., 2006; Ochsner et al., 2004). Recent cultural neuroscience evidence suggests that cultural values dynamically shape neural representations of the self within the MPFC region at both macro and micro timescales (e.g., lifespan and situation) (Chiao, Li, & Harada, 2008). In one prior neuroimaging study, no difference in MPFC activation in Chinese subjects was found when they viewed general trait descriptions of oneself or a close other, such as one’s mother (Zhu, Zhang, Fan, & Han, 2007). More recently, another neuroimaging study found that degree of MPFC activity in response to general relative to contextual self-descriptions is positively correlated with degree of individualism and collectivism respectively in both Caucasian-Americans and native Japanese (Chiao et al., 2009). Moreover, temporarily heightening awareness of cultural values of individualism and collectivism via classic cultural priming techniques modulates neural response within MPFC and posterior cingulate cortex (PCC) during explicit self-judgments, in a manner consistent with the cultural prime (Chiao et al., in press). Hence, activity within the MPFC during self-evaluation is associated with cultural values of individualism and collectivism across cultures.

Although these prior cultural neuroscience investigations are provocative in their demonstration of cultural influences on neural representations of self, it remains unknown whether or not modulation of neural response during self-evaluation occurs due to external task demands as well as whether or not distinct subregions of MPFC may be differentially affected by cultural values during self-evaluation. Cultural psychologists argue that culture comprises a constellation of social facts (e.g., rituals, practices, conventions) that tacitly guide daily social interactions. While culture influences how people think about themselves and their relation to others, this occurs often in an implicit manner such that people rarely think explicitly about themselves or are consciously aware of how culture is affecting the way they think about themselves (Kitayama, 2002). Given that culture primarily operates in an implicit, rather than explicit, manner, an important question is the extent to which individualistic and collectivistic cultural values differentially modulate neural representations during implicit self-evaluation. Recent social neuroscience evidence indicates differential recruitment of dorsal and ventral regions of MPFC, depending on the implicit or explicit nature of the self-evaluation task. Moran, Heatherton, & Kelley (2009) show that ventral MPFC is recruited during the representation of information as self-relevant or not, such as during explicit self-evaluation, but that dorsal MPFC is recruited during the evaluation of self-relevant information, such as during implicit self-evaluation. Hence, it is possible that cultural values such as individualism and collectivism differentially modulate neural responses within ventral and dorsal subregions of MPFC depending on whether explicit or implicit self-evaluation occurs.

Here we used functional magnetic resonance imaging (fMRI) to examine whether or not cultural priming of individualism and collectivism in bicultural individuals affects neural activity within ventral and dorsal portions of MPFC during implicit self-judgments. We hypothesized that cultural priming would differentially modulate dorsal and medial prefrontal cortex activity during implicit self-judgments. More
specifically, we hypothesized that ventral MPFC would be engaged during implicit self-processing irrespective of cultural priming due to the self-relevant nature of the stimuli, but that dorsal MPFC activity would be differentially affected by cultural priming due to the absence of a demand to explicitly evaluate oneself. To test our hypotheses, we examined dynamic cultural influences on neural activity in bicultural individuals during implicit self-judgments.

MATERIALS AND METHODS

Participants

Eighteen bicultural Asian-American participants (13 males, 5 females; $M = 21.0$ years, $SD = 2.3$ years) living in Chicago, IL participated in the current study. All participants self-identified as bicultural, as defined by the Suinn-Lew Asian Self-Identity Acculturation scale (Suinn, Rickard-Figueroa, Lew, & Vigil, 1987). All participants had normal or corrected-to-normal vision and participated in this study for payment. None of the participants had a history of neurological or psychiatric illness. This study protocol was approved by the Institutional Review Board of Northwestern University and all participants gave their written informed consent prior to the experiment.

Stimuli

For the cultural priming procedure, all participants completed the “pronom circling task”, which has been shown to effectively prime individualistic or collectivistic values in a number of prior behavioral studies (Gardner et al., 1999; Oyserman, Coon, & Kemmelmeier, 2002; Oyserman & Lee, 2007). The cultural priming procedure consisted of four short stories (two stories each for IND-prime and COL-prime conditions): IND A, IND B, COL A and COL B (see Appendix A). IND A and COL B, and IND B and COL A priming conditions contained identical stories, except for the following target phrases: I, my, me in IND stories, and we, our, us in COL stories. In order to avoid potential habituation to a particular story, which may reduce the effectiveness of the cultural priming procedure, we gave participants a combination of either IND A and COL A, or IND B and COL B, in counterbalanced order. The number of words in each story was 127 (IND A), 131 (IND B), 130 (COL A) and 127 (COL B), so the length of the story was almost matched among all stories. All stories contained 30 target phrases.

For the fMRI scans, 72 black-and-white photographs (512 pixels x 384 pixels) consisting of 24 self-relevant descriptions (e.g., their name), 24 father-relevant descriptions (e.g., their father’s name), and 24 unfamiliar persons’ descriptions (e.g., a stranger’s name) were used. Personal information about subjects and their father (e.g., name, bank name, birth date, phone number) was acquired 24 h before the subject’s scan via online survey (procedure modified from Gray, Ambady, Lowenthal, & Deldin, 2004). The survey included 31 items, from which we selected 24 items based on the degree to which we had information from identical categories for both self and father (see Appendix B).

Procedure

Cultural priming

All participants completed two scanning runs, each preceded by a cultural priming procedure (i.e., individualism and collectivism). Prior to each scan, they were primed with either an individualistic (IND-prime condition) or a collectivistic self-construal (COL-prime condition) in a counterbalanced order; half of the 18 participants were primed with individualism first and the other half were primed with collectivism first (Figure 1). During cultural priming, a short story was presented in white font on a black screen. Participants read the story and counted the number of target phrases (e.g., I, my, and me in IND-prime condition and we, our, and us in COL-prime condition), indicating their response vocally via a speaker. Participants’ responses were then recorded by the experimenters.

fMRI scan

We employed a block design consisting of nine blocks within each functional run. There were three types of blocks consisting of self-relevant trials, father-relevant trials, or control trials (unfamiliar person). Each block consisted of eight unique trials of that block type. For each trial, a self-relevant, father-relevant or unfamiliar person’s description was displayed for 1500 ms. Trials were separated by a centered fixation cross which was presented in a jittered manner ranging from 2500 ms to 6500 ms (average duration of block = 48 s).

During scanning, all participants completed an implicit self-recognition task. During the task, participants saw a word phrase that was relevant to themselves (self-relevant condition: e.g., their name), their
father (father-relevant condition; e.g., their father’s name), or an unfamiliar person (control condition; e.g., a stranger’s name). Each word phrase was presented to the left or right of the center of the screen, as indicated by a fixation cross. Participants were asked to indicate whether or not the phrase was presented to the left or right of the center of the screen by pressing a button with their right index or middle finger, and to pay attention to each phrase because they might receive a memory test later (which was actually not conducted). Also they were told that they might recognize that some of the phrases were relevant to themselves or their father.

Imaging parameters

Functional brain images were acquired on a 3.0 T Siemens Trio MRI scanner at the Center for Advanced Magnetic Resonance Imaging (CAMRI) facility located in the Northwestern Medical Hospital in Chicago, IL, USA.

A time-course series of 228 volumes in each run was acquired by using T2*-weighted, gradient echo, echo planar imaging sequences (repetition time (TR) = 2000 ms; echo time (TE) = 25 ms; flip angle = 70°; 34 slices; voxel dimension = 3.0 × 3.0 × 4.0 mm) covering a whole brain. Additionally, a T1-weighted three-dimensional magnetization-prepared rapid-acquisition gradient-echo (MPRAGE) image was also acquired (TR = 2300 ms; TE = 2.91 ms; flip angle = 9°; 160 slices; voxel dimension = 1.0 × 1.0 × 1.0 mm) for each subject, in order to acquire a detailed structural whole-brain image. Foam padding was placed around each subject’s head to minimize head movement. All stimuli were presented using Presentation software (Neurobehavioral Systems, Albany, CA) and projected onto a half-transparent viewing screen located behind the head coil. Subjects viewed the projected stimuli through a mirror.

Imaging data analysis

Functional images were analyzed using SPM2 software (Wellcome Department of Imaging Neuroscience, London, UK) implemented in Matlab (Mathworks, Cherborn, MA, USA) (Friston, Ashburner, Frith, Heather, & Frackowiak, 1995a; Friston et al., 1995b).

Preprocessing

The first six volumes were discarded due to unsteady magnetization, all of the remaining volumes were realigned spatially to the first volume, and a mean image was created. After a high-resolution image was coregistered onto the mean image, all...
volumes were normalized to the MNI space (Montreal Neurological Institute (MNI) template) using a transformation matrix obtained from the normalization process of the high-resolution image of each individual subject to the MNI template. The normalized images were then spatially smoothed with a Gaussian kernel of 8 mm (full width at half-maximum) in the X, Y, and Z axes.

**Statistical analysis**

Statistical analysis was conducted at two levels. First, individual task-related activation was evaluated. Second, to make inferences at a population level, individual data were summarized into a random effect model (Friston, Holmes, & Worsley, 1999).

**Individual analysis**

Statistical analysis for each individual subject was conducted using the general linear model. At the first level, each block of trials was modeled by convolving with a hemodynamic response function and session effects. For each subject, a linear regressor was applied to filter noise. Three task conditions (self-relevant trials, father-relevant trials, and control trials) were modeled separately for each run. To test hypotheses about regionally specific condition effects, the estimates for each condition were compared by means of the linear contrasts: (self–control), (father–control), (self–father) and (father–self) for each IND-prime and COL-prime condition, resulting in a total of eight comparisons. The resulting set of voxel values for each contrast constituted a statistical parametric map (SPM) of the $t$ statistic, $\text{SPM}(t)$. The $\text{SPM}(t)$ was transformed to normal distribution units, $\text{SPM}(Z)$.

**Group analysis with the random effect model**

The contrast images obtained in the individual analyses, which consisted of the parameter estimates for the interested conditions or comparisons, were used for the group analyses (Friston et al., 1999). The one-sample $t$-tests for eight comparisons, as described above, were performed. The resulting set of voxel values for each contrast constituted an $\text{SPM}(t)$, transformed to $\text{SPM}(Z)$. The height threshold was set to uncorrected $p < .005$ and cluster size $>15$ at the extent threshold (Chiao et al., 2009), due to *a priori* hypothesized regions. Additionally, we applied small-volume corrections for multiple comparisons to our primary regions of interest (i.e., the ventral and dorsal portions of medial prefrontal cortex, VMPFC and DMPFC), by using the average maxima obtained from a meta-analysis of prior neuroimaging studies of self-relevant processing as the center of small volumes (defined as spherical ROIs with a 10-mm radius centered at $X = –12, Y = 42, Z = –12$ for VMPFC and $X = 0, Y = 45, Z = 24$ for DMPFC) (Ochsner et al., 2004, 2005). Corrected $p$ values reported later refer to this small-volume correction procedure. Consistent with prior studies, definition of dorsal and ventral portions of the medial prefrontal region was determined according to peak coordinates located higher (i.e., dorsal MPFC) and lower than $Z = 0$ (i.e., ventral MPFC) (Ochsner et al., 2004).

In addition to whole-brain neuroimaging analyses, we conducted functional ROI analyses. We defined the DMPFC ROI around the peak coordinate in father–control comparison of IND-prime condition (i.e., $[–9, 54, 15]$), as this was the only contrast that demonstrated greater activity within the DMPFC region. We defined the VMPFC ROI as the commonly activated region in VMPFC (i.e., $[–6, 42, –9]$) from all four comparisons (self–control and father–control comparisons in IND- and COL-prime conditions), using a statistical threshold of $p < .005$ and cluster size $>15$. Furthermore, we conducted ROI analyses based on functionally independent ROIs that were defined with the abovementioned method (i.e., $[–12, 42, –12]$ for VMPFC and $[0, 45, 24]$ for DMPFC) to confirm the consistency of the results with that when using functionally defined ROIs. We used these coordinates as the center voxels for the functionally independent and dependent ROIs. Signal change was extracted from the VMPFC and DMPFC ROIs with a 8 mm radius centered at the coordinates using Marsbar software implemented with SPM2 (http://marsbar.sourceforge.net/).

**RESULTS**

**Behavioral results**

**Cultural priming**

Prior to scanning, participants completed a cultural priming procedure (i.e., individualism and collectivism). Overall, mean accuracy during the cultural priming was very high, IND-prime: 92.6 ± 2.6 % (mean ± standard error of the mean, SEM) and COL-prime: 95.0 ± 1.2 % (see Table 1). There was no significant difference between the accuracy of individualistic and collectivistic priming ($p = .38$, paired $t$-test).
Behavioral results for self-judgment task (mean ± SEM)

<table>
<thead>
<tr>
<th></th>
<th>Self (Accuracy %)</th>
<th>Father (Accuracy %)</th>
<th>Control (Accuracy %)</th>
<th>Self (Reaction times (ms))</th>
<th>Father (Reaction times (ms))</th>
<th>Control (Reaction times (ms))</th>
</tr>
</thead>
<tbody>
<tr>
<td>IND-prime condition</td>
<td>98.1 ± 0.9</td>
<td>98.3 ± 0.9</td>
<td>98.9 ± 0.5</td>
<td>739.1 ± 68.1</td>
<td>756.4 ± 58.5</td>
<td>781.6 ± 66.3</td>
</tr>
<tr>
<td>COL-prime condition</td>
<td>99.4 ± 0.4</td>
<td>100.0 ± 0.0</td>
<td>100.0 ± 0.0</td>
<td>659.5 ± 31.1</td>
<td>649.4 ± 34.1</td>
<td>681.4 ± 31.4</td>
</tr>
</tbody>
</table>

**Self-judgment task**

During scanning, participants made judgments about word phrases presented to the left or right of the center of the screen. No responses were recorded in 3 of 18 subjects’ log files due to a technical problem; however, the remaining 15 subjects’ data were included in the behavioral analyses. Results from a 2 (cultural prime: IND-prime and COL-prime conditions) × 3 (self-judgment task: self-relevant, father-relevant, and control conditions) repeated-measures ANOVA of accuracy revealed that there was no interaction between cultural prime and type of self-judgment (p > .05) (see Table 1). Accuracy in the COL-prime condition was significantly higher than that in the IND-prime condition, *F*(1, 14) = 7.00, *p* < .05. Post-hoc pair-wise comparisons with a Bonferroni correction revealed that the accuracy in the COL-prime condition was significantly higher than that in the IND-prime condition (p < .05) during control trials. This main effect of cultural priming on accuracy is not attributable to an order effect because the order in which the cultural priming occurred was counterbalanced across participants. There were no significant differences in accuracy across the trial conditions for both IND-prime and COL-prime conditions (all p > .05).

Results of a 2 (cultural priming: IND-prime and COL-prime conditions) × 3 (self-judgment task: self-relevant, father-relevant, and control conditions) repeated-measures ANOVA of reaction time revealed that there were no significant main effects or interaction between cultural priming and self-judgment task (all p > .05) (see Table 1).

**fMRI results**

To investigate brain regions involved in implicit responses to stimuli related to self and close other, we first conducted whole brain analysis with one-sample *t*-tests for the eight contrasts of interest: self-relevant trials > control trials, father-relevant trials > control trials, self-relevant trials > father-relevant trials, and father-relevant trials > self-relevant trials for both IND-prime and COL-prime conditions. First, we conducted analyses for fMRI data to investigate any order effect, dividing participants into two groups (those primed with individualism first and those primed with collectivism first). There was no order effect of prime on VMPFC and DMPFC activities in results from the group analyses for all eight comparisons (i.e., self–control, father–control, self–father, and father–self comparisons in IND- and COL-prime conditions) (two-sample *t*-tests, in which height threshold was uncorrected, *p* < .005, and cluster size > 15 voxels for all comparisons).

Hence, we next analyzed all participants together as one group. This analysis showed greater activity within dorsal and ventral portions of medial prefrontal cortex, as well as several regions of occipitotemporal cortex (Table 2). When implicitly evaluating self-relevant information as compared to control condition, people in the individualistic prime condition showed relatively greater activity within VMPFC as well as bilateral fusiform gyrus, right parahippocampal gyrus, bilateral cuneus, and left angular gyrus, and as compared to father-relevant condition they showed relatively greater activity within right parahippocampal gyrus, right middle frontal gyrus and right fusiform gyrus. Similarly, when implicitly evaluating self-relevant information as compared to control condition, people in the collectivistic prime condition showed relatively greater activity within VMPFC, as well as bilateral lingual gyrus, left parahippocampal gyrus, right hippocampus, and right cuneus, and as compared to father-relevant condition they showed relatively greater activity within right parahippocampal gyrus, right middle frontal gyrus, and right cerebellum.

1 We did not include a physiological baseline condition (e.g., experimental trials where participants passively viewed a fixation cross). Thus, we are not able to determine whether or not the relative increment of activity observed in ventral and dorsal medial prefrontal regions occurred as the result of an increase above or a lesser decrease in neural activity relative to a physiological baseline condition. Hence, we will discuss potential functioning as to differential neural modulations observed in the current study based on the results from the subtraction analyses (e.g., the relative increment of activity in self condition as compared to control condition) in the following several sections.
<table>
<thead>
<tr>
<th>Location</th>
<th>Side</th>
<th>BA</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parahippocampal gyrus</td>
<td>Rt</td>
<td>37</td>
<td>Cuneus</td>
</tr>
<tr>
<td>Fusiform gyrus</td>
<td>Lt</td>
<td>37</td>
<td>Cuneus</td>
</tr>
<tr>
<td>Fusiform gyrus</td>
<td>Rt</td>
<td>37</td>
<td>Cuneus</td>
</tr>
<tr>
<td>Lingual gyrus</td>
<td>Rt</td>
<td>18</td>
<td>Angular gyrus</td>
</tr>
<tr>
<td>Ventral medial frontal gyrus</td>
<td>Lt</td>
<td>10/11</td>
<td>Angular gyrus</td>
</tr>
<tr>
<td>Dorsal medial frontal gyrus</td>
<td>Lt</td>
<td>20</td>
<td>Inferior temporal gyrus</td>
</tr>
<tr>
<td>Ventral medial frontal gyrus</td>
<td>Lt</td>
<td>10/11</td>
<td>Inferior temporal gyrus</td>
</tr>
<tr>
<td>Anterior cingulate gyrus</td>
<td>Rt</td>
<td>20</td>
<td>Angular gyrus</td>
</tr>
<tr>
<td>Precuneus</td>
<td>Lt</td>
<td>7</td>
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<tr>
<td>Middle occipital gyrus</td>
<td>Lt</td>
<td>19</td>
<td>Dorsal medial frontal gyrus</td>
</tr>
<tr>
<td>Middle frontal gyrus</td>
<td>Lt</td>
<td>8</td>
<td>Dorsal medial frontal gyrus</td>
</tr>
<tr>
<td>Parahippocampal gyrus</td>
<td>Lt</td>
<td>47</td>
<td>Inferior frontal gyrus</td>
</tr>
<tr>
<td>Cerebellum</td>
<td>Lt</td>
<td>39</td>
<td>Angular gyrus</td>
</tr>
<tr>
<td>Cingulate gyrus</td>
<td>Rt</td>
<td>24</td>
<td>Middle temporal gyrus</td>
</tr>
<tr>
<td>Parahippocampal gyrus</td>
<td>Lt</td>
<td>37</td>
<td>Fusiform gyrus</td>
</tr>
<tr>
<td>Caudate nucleus</td>
<td>Lt</td>
<td>10</td>
<td>Middle frontal gyrus</td>
</tr>
<tr>
<td>Caudate nucleus</td>
<td>Rt</td>
<td>20</td>
<td>Middle frontal gyrus</td>
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<tr>
<td>Dorsal medial frontal gyrus</td>
<td>Rt</td>
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<td>Superior temporal gyrus</td>
</tr>
<tr>
<td>Middle frontal gyrus</td>
<td>Lt</td>
<td>21</td>
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<tr>
<td>Superior frontal gyrus</td>
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<td>Superior temporal gyrus</td>
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<td>Inferior temporal gyrus</td>
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<td>Superior temporal gyrus</td>
</tr>
<tr>
<td>Thalamus</td>
<td>Lt</td>
<td>18</td>
<td>Lingual gyrus</td>
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<tr>
<td>Lingual gyrus</td>
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<td>Parahippocampal gyrus</td>
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</tr>
<tr>
<td>Hippocampus</td>
<td>Rt</td>
<td>17</td>
<td>Cuneus</td>
</tr>
</tbody>
</table>
When implicitly evaluating father-relevant information as compared to control condition, people in the individualistic prime condition showed relatively greater activity within both VMPFC and DMPFC as well as anterior cingulate gyrus, bilateral lingual gyrus, left precuneus, left inferior temporal gyrus, left amygdala, left parahippocampal gyrus, left inferior frontal gyrus, left cerebellum, and left angular gyrus. Relative to the self-relevant condition, the IND-PRIME participants showed relatively greater activity within DMPFC as well as bilateral caudate nucleus, bilateral middle frontal gyrus, left middle temporal gyrus, left thalamus, right anterior cingulate gyrus, right superior temporal gyrus, right middle temporal gyrus, and right inferior temporal gyrus.

By contrast, when implicitly evaluating father-relevant information as compared to control condition, people in the collectivistic prime condition showed relatively greater activity within VMPFC as well as anterior cingulate gyrus, bilateral lingual gyrus, left precuneus, left inferior temporal gyrus, left amygdala, left parahippocampal gyrus, left inferior frontal gyrus, left cerebellum, and left angular gyrus. Relative to the self-relevant condition, the IND-PRIME participants showed relatively greater activity within DMPFC as well as bilateral caudate nucleus, bilateral middle frontal gyrus, left middle temporal gyrus, left thalamus, right anterior cingulate gyrus, right superior temporal gyrus, right middle temporal gyrus, and right inferior temporal gyrus.

Based on our *a priori* hypotheses, we especially focused on examining effects of cultural priming on neural responses to self-relevant and father-relevant stimuli within ventral and dorsal medial prefrontal regions. The results showed that VMPFC showed greater activity due to relatively less deactivation during both self- and father-relevant trials as compared to control trial in both COL-prime and IND-prime conditions (Table 2 and Figure 2). By contrast, DMPFC and anterior part of cingulate cortex (ACC) showed greater activity due to relatively less deactivation during father-relevant trial as compared to control and self-relevant trials in the IND-prime condition only (Table 2, Figures 2 and 3). All regions survived multiple comparisons (all *p* < .05 corrected) after small volume correction.

### ROI analyses

In addition to whole-brain analyses, we conducted ROI analyses based on functionally dependent and independent ROIs. Results from 2 (*cultural prime: IND-prime and COL-prime conditions*) × 3 (*self-judgment task: self-relevant, father-relevant, and control conditions*) repeated-measures ANOVAs of signal change extracted from the functionally defined VMPFC and DMPFC ROIs revealed that there was interaction between cultural prime and type of self-judgment (all *p* < .05). Post-hoc pair-wise comparisons revealed significant differences between father-relevant and control conditions and self-relevant and control conditions in both IND- and COL-prime conditions.

### TABLE 2

**Continued**

<table>
<thead>
<tr>
<th>Location</th>
<th>X (mm)</th>
<th>Y (mm)</th>
<th>Z (mm)</th>
<th>Z value</th>
<th>Side</th>
<th>BA</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Father-relevant trials &gt; Control trials</td>
<td>6</td>
<td>−51</td>
<td>30</td>
<td>3.78</td>
<td>Rt</td>
<td>18</td>
<td>Precuneus</td>
</tr>
<tr>
<td></td>
<td>−42</td>
<td>−6</td>
<td>−12</td>
<td>3.55</td>
<td>Lt</td>
<td>21</td>
<td>Middle temporal gyrus</td>
</tr>
<tr>
<td></td>
<td>−51</td>
<td>6</td>
<td>−12</td>
<td>3.23</td>
<td>Lt</td>
<td>38</td>
<td>Superior temporal gyrus</td>
</tr>
<tr>
<td></td>
<td>−3</td>
<td>42</td>
<td>−9</td>
<td>3.20</td>
<td>Lt</td>
<td>10/11</td>
<td>Ventral medial frontal gyrus</td>
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<td>3.11</td>
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<tr>
<td></td>
<td>6</td>
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<td>−3</td>
<td>2.86</td>
<td>Rt</td>
<td>18</td>
<td>Lingual gyrus</td>
</tr>
<tr>
<td></td>
<td>−3</td>
<td>−21</td>
<td>45</td>
<td>3.08</td>
<td>Lt</td>
<td>31</td>
<td>Cingulate gyrus</td>
</tr>
<tr>
<td></td>
<td>6</td>
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<td>39</td>
<td>2.78</td>
<td>Rt</td>
<td>31</td>
<td>Cingulate gyrus</td>
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<tr>
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<td>15</td>
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<td>18</td>
<td>3.00</td>
<td>Rt</td>
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<td>Middle occipital gyrus</td>
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<tr>
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<td>33</td>
<td>−27</td>
<td>−21</td>
<td>3.53</td>
<td>Rt</td>
<td></td>
<td>Parahippocampal gyrus</td>
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<td>3.34</td>
<td>Rt</td>
<td>6</td>
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</tr>
<tr>
<td></td>
<td>21</td>
<td>−69</td>
<td>−54</td>
<td>3.15</td>
<td>Rt</td>
<td></td>
<td>Cerebellum</td>
</tr>
</tbody>
</table>

*Notes: Coordinates (x, y, z) are of the voxel of local maximal significance in each brain region according to the Montreal Neurological Institute template, based on the stereotaxic coordinate system of Talairach and Tournoux (1988). Uncorrected *p* < .005 at voxel level and cluster size > 15.*
The mean signal change from the independently defined VMPFC ROI for the three task conditions across all 18 subjects was \(-0.13 \pm 0.10\) (mean \(\pm\) SEM), \(-0.10 \pm 0.10\), and \(-0.18 \pm 0.10\) for self-relevant, father-relevant, and control conditions respectively. In the independently defined DMPFC ROI, the mean signal changes were \(-0.09 \pm 0.09\), \(-0.03 \pm 0.09\), and \(-0.08 \pm 0.08\) for self-relevant, father-relevant, and control conditions respectively.

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significant differences between father-relevant and control conditions in the IND-prime condition ($p < .01$), self-relevant and control ($p < .05$) and father-relevant and control conditions ($p < .05$) in the COL-prime condition, and a trend between self-relevant and control conditions in the IND-prime condition ($p = .065$) within the VMPFC ROI. In the DMPFC ROI, there was a significant difference between self-relevant and father-relevant conditions in IND-prime condition ($p < .05$) and a trend between father-relevant and control conditions in the IND-prime condition ($p = .06$). Although some comparisons in the independent ROIs revealed trends rather than significant differences, these results were nearly consistent with those observed in the functionally defined ROI analyses.

**DISCUSSION**

Here we examined whether cultural priming of self-construal style modulates neural responses during implicit self processing, within ventral and dorsal regions of medial prefrontal cortex, which have previously been related to both implicit and explicit self-relevant processes (Craik et al., 1999; D’Argembeau et al., 2005, 2007; Heatherton et al., 2006; Johnson et al., 2002; Kelley et al., 2002; Kjaer et al. 2002; Macrae et al., 2004; Moran et al., 2009; Ochsner et al., 2005; Schmitz et al., 2004), self-knowledge retrieval (Pfeifer et al., 2007), emotion attribution (Ochsner et al., 2004), self-referential process (Gusnard et al., 2001), and perspective taking (Jackson et al., 2006; Mitchell et al., 2006). Some of this evidence supports a functional distinction between ventral and dorsal medial prefrontal regions (D’Argembeau et al., 2007; Gusnard et al., 2001; Mitchell et al., 2006; Moran et al., 2009; Ochsner et al., 2004), whereby dorsal and ventral subregions of medial prefrontal cortex are associated with distinct functions during resting state. Dorsal medial prefrontal cortex is thought to be important for spontaneous and task-related self-referential or introspectively oriented mental activity, whereas ventral medial prefrontal cortex is related to continuous online monitoring of associations between sensory information, responses and outcomes under changing circumstances. Furthermore, the DMPFC has been shown to exhibit both enhanced and attenuated activity, whereas the VMPFC typically shows only attenuated neural activation during engagement in a wide variety of goal-directed actions (Gusnard and Raichle, 2001).

Here we show for the first time that temporarily heightening awareness of individualistic and collectivistic cultural values differentially modulates neural activity within ventral and dorsal subregions of medial prefrontal cortex during implicit self-relevant processing. Relatively less deactivation within ventral medial prefrontal cortex was observed in this study in a region located adjacent to the border of ventromedial and orbitofrontal cortex, the latter of which has been previously related to emotional processes (Simpson, Drevets, Snyder, Gusnard, & Raichle, 2001a; Simpson, Snyder, Gusnard, & Raichle, 2001b;
Simpson et al., 2000). Because this region has dense connectivity with limbic structures, which receive multisensory input, one possibility is that the relative increment of activity due to relatively less deactivation within VMPFC observed in the current study may be related to automatic extraction and representation of information that is self-relevant. Additionally, VMPFC may receive self-relevant input and then act as a neural node, transferring this information to connected and/or adjacent brain region, such as DMPFC, for further evaluation critical to social interaction and mentalizing (Northoff & Bermpohl, 2004). Some studies have shown differential response within medial prefrontal cortex when comparing self-relevant condition to other/close other-relevant condition (D’Argembeau et al., 2007; Kelley et al., 2002; Kjaer et al., 2002), while other studies suggested no difference in neural activity within the region (Craik et al., 1999; Ochsner et al., 2005; Schmitz et al., 2004), which is consistent with the pattern of ventral medial prefrontal activity observed in the current study.

In the current study, VMPFC was recruited during implicit evaluation of both self and father autobiographical information compared to control condition, irrespective of individualistic or collectivistic priming. Given the importance of VMPFC in the representation of self-relevant information, it is likely that this processing occurs in an automatic fashion: a notion that is consistent with the current findings that the VMPFC region was similarly recruited during implicit evaluation of self and father information, irrespective of type of cultural priming. In addition, relatively greater activity due to relatively less deactivation within VMPFC in both self-relevant and father-relevant trials as compared to control trials may also reflect variance in amount of attentional allocation afforded to self and father information during implicit processing. More specifically, participants were asked to pay attention to each phrase they were shown because they might receive a memory test later. Furthermore, participants were told that they might recognize some of the phrases as relevant to themselves or their father. Consequently, participants may have paid more attention to the self-relevant and father-relevant phrases, resulting in relative increment of activity in VMPFC for both self- and father-relevant phrases irrespective of cultural priming.

Whereas VMPFC was relatively less deactivated during both self and father-relevant trials as compared to control trials during both priming of individualism and collectivism, dorsal medial prefrontal cortex (BA10/anterior cingulate cortex (BA32) showed relatively less deactivation during father-relevant trials as compared to control and self-relevant trials only during priming of individualistic cultural values. This region has been related not only to self-relevant processing, but also other social cognitive processes, more broadly construed, such as perspective-taking, mentalizing, intentional causality inference, social categorization and moral judgments (Amodio & Frith, 2006; Frith & Frith, 2003; Greene, Sommerville, Nystrom, Darley, & Cohen, 2001; Northoff et al., 2006; Ochsner et al., 2004). One plausible explanation for the current finding is that when participants are primed with individualistic cultural values, additional processing is needed to distinguish father-relevant from self-relevant information, relative to when participants are primed with collectivistic cultural values and father- and self-relevant information are treated more similarly. We suggest that this enhanced processing of father-relevant information during individualistic priming occurs automatically and is unrelated to overt task demand, given that the task employed was implicit in nature. Another possibility is that the greater engagement of DMPFC may reflect a mismatch between the individualistic cultural priming orientation of the participants and the task. That is, evaluating familiar, but less self-relevant information about another person, such as for father-relevant trials in IND-prime condition, requires greater self-relevant processing and hence recruits DMPFC to a greater extent relative to the COL-prime condition. Here it should be noted that the region of DMPFC that showed differences in neural activity for the father–control comparison was slightly more dorsally located than that for the father–control comparison. One possible interpretation of this anatomical distinction is that more complicated computations may be conducted in more dorsal regions of MPFC, based on the information received from more ventral regions of MPFC. In the current study the more dorsal region in DMPFC, which showed difference in activity for the father–control comparison, may be related to evaluating familiar, but less self-relevant information about another person, while the more ventral region in DMPFC may act as a neural node, transferring the information received from more ventral regions (i.e., more ventral DMPFC) to connected and/or adjacent brain regions (i.e., more dorsal DMPFC) for further evaluation of the information.

Here we were able to observe modulation of neural response within dorsal MPFC by cultural priming, even in the absence of observable cultural priming influences in behavior. Neural assays may be better situated to illuminate cultural influences on mental processes relative to behavioral measures for several reasons (Chiao & Ambady, 2007; Chiao et al., 2008). For instance, participants may not have conscious access to knowledge about their self-construal style and thus may not be able to accurately answer related questions (Kitayama, 2002). Depending on cultural
display rules about appropriate public and private behavior, participants may feel reluctant to disclose information about themselves and close others within an experimental setting (Kitayama, 2002). Studying situational influences of culture at the neurobiological level of analysis may provide a novel and powerful tool for examining how cultural values, such as individualism and collectivism, dynamically influence self-relevant social cognition, within the same cultural group and even within the same individual. For instance, in a recent study of native Chinese participants, activity within right middle frontal cortex was greater when participants viewed their own face relative to another familiar face, and this difference was more pronounced when participants were primed with individualism relative to collectivism (Sui & Han, 2007). These findings complement the current evidence illustrating the utility of directly measuring or manipulating cultural values when studying the dynamic process by which culture shapes the mind and brain (Chiao & Ambady, 2007; Oyserman & Lee, 2007). Although we conducted this experiment with bicultural Asian-Americans because of prior work (Oyserman & Lee, 2007) showing that self-construal priming effects are slightly more robust with bicultural relative to monocultural individuals, it is possible that the self-construal priming would similarly affect monocultural individuals (e.g., Caucasian-Americans and native Japanese). Future research is needed to determine whether or not the findings in the current study would be similarly observable in monocultural individuals who are primed with individualistic and collectivistic cultural values. Another important direction for future research is to determine whether or not fluctuations in neural activity within VMPFC and DMPFC as a function of cultural prime may be associated with deeper encoding of and enriched memory for personally relevant information.

**CONCLUSION**

Taken together, the current findings support the notion of differential neural self-relevant functioning with the ventral and dorsal subregions of MPFC. Our findings further illustrate how these portions of MPFC are differentially engaged as a function of temporary heightened awareness of individualistic and collectivistic cultural values. VMPFC showed relative increment of activity due to relatively less deactivation during both self- and father-relevant trials as compared to control trials in both collectivistic and individualistic priming conditions, which may be related to representation of self-relevant information involved in all the four conditions due to the self-relevant nature of the stimuli and automaticity of the processing. On the other hand, DMPFC showed relative increment of activity due to relatively less deactivation during father-relevant trials as compared to control and self-relevant trials in the individualistic priming condition only, which may be related to additional processing to evaluate perceived information, which is distinguishing self-relevant from father-relevant information only under the individualistic concept because people primed with individualism may think their father relatively independent from themselves. These results suggest that cultural priming modulates activity within DMPFC, but not VMPFC, and this functional distinction may be due to differential computations performed within these two regions during implicit self-relevant processing; cultural values dynamically shape neural representations during the evaluation, rather than the detection, of self-relevant information under implicit task demand. We suggest that the extent to which these two subregions of MPFC are activated may be variable depending on the degree of self-relevance of the information perceived and an individual’s temporarily heightened self-construal style. The current work lays the foundation for future research examining how cultural values may dynamically modulate neural mechanisms of the implicit self and implicit socioemotional processes, more broadly construed.

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**REFERENCES**


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**APPENDIX A: FOUR STORIES USED IN THE CULTURAL PRIMING PROCEDURE PRIOR SCANNING**

**IND-prime A**

I go to the city often. Before I go I like to anticipate what I will see. My anticipation fills me as I see the skyscrapers come into view. I allow myself to explore every corner, never letting an attraction escape me. My voices fill the air and street. My feeling touches all the places I have seen. I see all the sights, I window shop, and everywhere I go I see my reflection looking back at me in the glass of a hundred windows. I walk, I run, I let my imagination fly throughout my exploration. At nightfall I linger, my time in the city almost over. When finally I must leave, I do so knowing that I will soon return. The city belongs to me.

**IND-prime B**

I go to the beach often. Before I go I like to anticipate what I will see. My anticipation fills me as I see the palm trees come into view. I allow myself to explore every corner, never letting an attraction escape me. My noises fill the sea air and saltwater. My feeling touches all the places I have seen. I watch the sea gulls, I build sand castles, and everywhere I go I see my reflection looking back at me in the calm of the beautiful ocean water. I swim, I sunbathe, I let my imagination fly throughout my exploration. At nightfall I linger, my time at the beach almost over. When finally I must leave, I do so knowing that I will soon return. The beach belongs to me.

**COL-prime A**

We go to the beach often. Before we go we like to anticipate what we will see. Our anticipation fills us as we see the palm trees come into view. We allow ourselves to explore every corner, never letting an attraction escape us. Our noises fill the sea air and saltwater. Our feeling touches all the places we have seen. We watch the sea gulls, we build sand castles, and everywhere we go we see our reflection looking back at us in the calm of the ocean water. We swim, we sunbathe, we let our imaginations fly throughout our exploration. At nightfall we linger, our time at the beach almost over. When finally we must leave, we do so knowing that we will soon return. The beach belongs to us.

**COL-prime B**

We go to the city often. Before we go we like to anticipate what we will see. Our anticipation fills us as we see the skyscrapers come into view. We allow ourselves to explore every corner, never letting an attraction escape us. Our voices fill the air and street. Our feeling touches all the places we have seen. We see all the sights, we window shop, and everywhere we go we see our reflection looking back at us in the glass of a hundred windows. We walk, we run, we let our imaginations fly throughout our exploration. At nightfall we linger, our time in the city almost over. When finally we must leave, we do so knowing that we will soon return. The city belongs to us.

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**APPENDIX B: SURVEY QUESTIONS ADMINISTERED TO ACQUIRE INFORMATION FROM PARTICIPANTS ABOUT THEMSELVES AND THEIR FATHER**

**Questions about themselves**

1. What is the name of your bank?
2. What is your best friend’s first name?
3. What is your birth day?
Questions about their father

1. What is the name of your father’s bank?
2. What is your father’s best friend’s first name?
3. What is your father’s birth date?
4. What is your father’s birth town?
5. What is your father’s birth year?
6. What kind of car does your father have?
7. Where does your father have club membership?
8. What is your father’s father’s first name?
9. What is your father’s Doctor’s name?
10. What is your father’s E-mail address?
11. What is the nationality of your father’s family?
12. What is your father’s grandmother’s first name?
13. What is your father’s grandfather’s first name?
14. What is the name of your father’s high school?
15. What is the name of your father’s home state?
16. What is the name of your father’s high school mascot?
17. What is the name of your father’s home street?
18. What is the name of your father’s hometown?
19. What are your father’s high school colors?
20. What is your father’s hometown zip code?
21. What is your father’s hometown area code?
22. What are your father’s initials?
23. What is your father’s last name?
24. What is your father’s first name?
25. What is your father’s middle name?
26. What is your father’s mother’s first name?
27. What is your father’s pet’s name?
28. What is your father’s phone number?
29. What is your father’s religion?
30. What is your father’s social security number (last four digits)?