◆ Human Brain Mapping 30:4012–4024 (2009) ◆

Neurocognitive Processes of the Religious Leader in Christians

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Abstract: Our recent work suggests that trait judgment of the self in Christians, relative to nonreligious subjects, is characterized by weakened neural coding of stimulus self-relatedness in the ventral medial prefrontal cortex (VMPFC) but enhanced evaluative processes of self-referential stimuli in the dorsal medial prefrontal cortex (DMPFC). The current study tested the hypothesis that Christian belief and practice produce a trait summary about the religious leader (Jesus) in the believers and thus episodic memory retrieval is involved to the minimum degree when making trait judgment of Jesus. Experiment 1 showed that to recall a specific incident to exemplify Jesus' trait facilitated behavioral performances associated with the following trait judgment of Jesus in nonreligious subjects but not in Christians. Experiment 2 showed that, for nonreligious subjects, trait judgments of both government and religious leaders resulted in enhanced functional connectivity between MPFC and posterior parietal cortex (PPC)/precuneus compared with self judgment. For Christian subjects, however, the functional connectivity between MPFC and PPC/precuneus differentiated between trait judgments of the government leader and the self but not between trait judgments of Jesus and the self. Our findings suggest that Christian belief and practice modulate the neurocognitive processes of the religious leader so that trait judgment of Jesus engages increased employment of semantic trait summary but decreased memory retrieval of behavioral episodes. *Hum Brain Mapp 30:4012–4024, 2009.*

Key words: episodic memory; functional connectivity; fMRI; self; trait judgment

INTRODUCTION

There has been recently increasing interests in cultural variation in neurobiological basis of human psychological processes and relevant studies give rise to the emergence of cultural neuroscience [Chiao and Ambady, 2007]. For example, transcultural neuroimaging studies have shown evidence that neural substrates of multiple-level human cognitions are influenced by cultures [Han and Northoff, 2008]. Cultural influences on the neural underpinnings of both low-level perceptual/attentional processing and high-level social cognition have been investigated mainly by comparing participants from Western cultures (e.g., Americans) and East Asian cultures (e.g., Chinese and Japanese). For example, while functional magnetic resonance imaging (fMRI) studies of North American subjects found that the ventral medial prefrontal cortex (VMPFC) was exclusively involved in self-referential processing in a trait judgment task [Fossati et al., 2003; Kelley et al., 2002; Macrae et al., 2004; Moran et al., 2006] even when relative to trait judgment of a close other [e.g., the best friend, Heatherton et al., 2006], a study of Chinese subjects found that the VMPFC was engaged in trait judgments of both the self and close others (e.g., mother) [Zhu et al., 2007]. Since the VMPFC activity underlies the coding process of self-relatedness of stimuli [D'argembeau et al., 2005; Moran et al., 2006; Northoff et al., 2006], the transcultural

Contract grant sponsor: National Natural Science Foundation of China; Contract grant number: 30630025, 30828012.

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Received for publication 4 January 2009; Revised 9 March 2009; Accepted 20 April 2009

DOI: 10.1002/hbm.20825

Published online 8 June 2009 in Wiley InterScience (www.interscience.wiley.com).

neuroimaging findings suggest that Western/East Asian cultures influence the psychological contents of the self mediated by the VMPFC. Chiao et al. [in press] showed further evidence that neural representations of the self in the MPFC are influenced by cultural values of individualism or collectivism endorsed by individuals. They found that MPFC activity in association with the processing of general and contextual self-judgments correlates with individualistic/collectivistic self-styles in both Caucasian-Americans and native Japanese. Moreover, priming individualism values increased MPFC activity during general self-judgments whereas priming collectivism values resulted in increased MPFC activity linked to contextual self-judgments in bicultural individuals [Chiao et al., in press]. Taken together, the neuroimaging findings indicate that Western/East Asian cultural values shape the neural substrates of self-related processing.

Interestingly, our recent work [Han et al., 2008] found that religious belief and practice, which are viewed as subjective culture by cultural psychologists [Chiu and Hong, 2006], also modulate the neural mechanism involved in self-referential processing. Specifically, we found that, while VMPFC activity was increased during trait judgment of the self relative to trait judgment of others in nonreligious subjects, VMPFC activity did not differentiate between trait judgments of the self and others in Christian subjects, who, however, showed increased activation in the dorsal medial prefrontal cortex (DMPFC) in association with trait judgment of the self. As the DMPFC is implicated in reappraisal and evaluation of self-related stimuli [Northoff et al., 2006] and in inference and evaluation of others' mental states [Gallagher et al., 2000; Han et al., 2005; Mitchell et al., 2005], we suggested that Christian belief and practice result in distinct neural mechanisms associated with self-referential processing compared with nonreligious subjects [Han et al., 2008].

The current work further examined if Christian belief and practice influence neurocognitive processes of personal traits of the religious leader. Klein et al. [1992; Klein and Loftus, 1993; see Klein et al., 2002, 2008 for review] suggested that trait judgments of the self and others are essentially different in cognitive processes such as memory. Specifically, they argue that self-judgment is achieved by accessing a database of summary traits in semantic memory that are abstracted from multiple experiences with one's own trait-relevant behaviors. Trait judgment of the self can be made without reference to behavioral evidence stored in episodic memory although trait-inconsistent episodes may be retrieved to constrain the use of trait summary about the self. In contrast, trait judgment of others requires retrieval of behaviors from episodic memory when there are no sufficient experiences to form a trait summary about the others. According to these propositions, one may propose that, relative to trait judgment of the self, trait judgments of others may require enhanced episodic memory retrieval to provide information for evaluation processes. However, Klein et al. [2002] also suggest that trait judgments of specific others may be accomplished by accessing trait knowledge in semantic memory if the amount of experience with him/her is sufficient to form a trait summary. Indeed, they found that judgments of traits that are highly descriptive of mothers can be made by directly accessing a trait summary [Klein et al., 1992]. In addition, trait judgments referenced to the self and mother elicit comparable behavioral performances [Zhu and Zhang, 2002] and comparable magnitude of VMPFC activity [Zhu et al., 2007]. While these findings suggest similar neurocognitive processes involved in trait judgments of the self and mother, they also raise an interesting question, i.e., may Christian belief and practice help to form a trait summary about the religious leader (Jesus) in the believers so that episodic memory retrieval is engaged to a minimum degree when making trait judgment of Jesus, similar to trait judgment of the self?

Experiment 1 tested this hypothesis by recording behavioral performances in a paradigm developed by Klein et al. [1992; Klein and Loftus, 1993]. This paradigm consists of two successive tasks that require responses to trait adjectives. The initial task asks subjects to think of the definition of a trait adjective (the define task) or to recall a specific incident in someone's behaviors to exemplify that person's trait (the recall task). The second task requires subjects to judge if a trait adjective can describe a specific person (the trait judgment task). The rationale is that, if trait judgment of a person engages episodic memory retrieval, the initial recall task that activates related episodic memory should prime or facilitate responses to the second trait judgment task compared with the initial define task. Applying this to the current work, if Christians have formed a trait summary about Jesus and engages episodic memory retrieval during Jesus trait judgment to a minimum degree, one would expect that the initial recall task results in much less facilitation of responses to the second Jesus trait judgment task in Christian than in nonreligious subjects since nonreligious subjects may not constitute a trait summary of Jesus and thus engage episodic memory retrieval during Jesus trait judgment.

Experiment 2 further assessed the hypothesis by reanalyzing the fMRI data of our previous work [Han et al., 2008] that asked nonreligious and Christian subjects to make trait judgment of the self, a government leader (the former premier Zhu-Rongji), Jesus, and Sakyamuni (the Buddhist leader). Previous brain imaging studies indicate that the posterior parietal cortex (PPC)/precuneus are involved in retrieval of information from episodic memory [Cavanna and Trimble, 2006; Fletcher et al., 1995; Wagner et al., 2005]. More specifically related to the current work, Lou et al. [2004] found that the enhanced process of episodic memory retrieval during trait judgment is associated with increased functional connectivity between MPFC and PPC/precuneus [also see Babiloni et al., 2006 for event-related brain potential evidence]. We hypothesized that, relative to self-judgment task that engages least retrieval of behavioral evidence in episodic memory [Klein et al.,

2002], trait judgments of others (both government or religious leaders) would induce enhanced functional connectivity between MPFC and PPC/precuneus in nonreligious subjects to support episodic memory retrieval. However, increased functional connectivity between MPFC and PPC/precuneus may be observed during trait judgment of the government leader but not during trait judgment of Jesus in Christians since they may have constituted a trait summary about Jesus. In addition, in Christians, the functional connectivity between MPFC and PPC/precuneus may be comparable for trait judgments of Jesus and the self but not for trait judgments of Sakyamuni and the self because of lacking a trait summary of the leader of other religions. The hypotheses and rationale of Experiments 1 and 2 are illustrated in Figure 1.

We also used classification analysis to further examine the hypothesis that subjects with distinct religious belief are characterized by unique patterns of neural activity associated with the trait judgment of religious leaders. Recent neuroimaging research has tried to categorize a person's conscious experience using his/her brain activity based on the assumption that "if the responses at any brain location differ between two mental states, then it should be possible to use measurement of activity at that brain location to determine which one of those two mental states currently reflects the thinking of the individual" [Haynes and Rees, 2006]. Researchers utilized blood oxygen level dependent (BOLD) signals recorded from specific brain areas to categorize the contents of an individual's perception [Haxby et al., 2001; Kamitani and Tong, 2005; Kay et al., 2008] and the outcomes of a person's decision making [Haynes et al., 2007; Soon et al., 2008]. Using the similar logic in the current work, if a specific pattern of neural activity linked to a cognitive task differs between two subject groups, examination of that specific pattern of neural activity in a person may then help us to classify that person into one group or another. For instance, if the functional connectivity between MPFC and PPC/precuneus during trait judgment of Jesus and Sakyamuni differs between Christian and nonreligious subjects, we may categorize a person into different subject groups based on specific patterns of that subjects' functional connectivity between MPFC and PPC/precuneus. To do this, we utilized a linear discriminant method of pattern recognition by creating a featured vector for each subject that was determined by two values, i.e., the MPFC-PPC/precuneus functional connectivity strength associated with Jesus and Sakyamuni judgments. A linear discriminant function was then constructed based on the vector from a sample consisting of both Christian and nonreligious subjects. This discriminant function was then used to assess which subject group a "leave-out" individual subject belongs to. The accuracy of such classification analysis helps to validate the conclusion obtained from the functional connectivity analysis since the classification analysis reduces any bias produced by precategorization of subjects in terms of their religious beliefs.

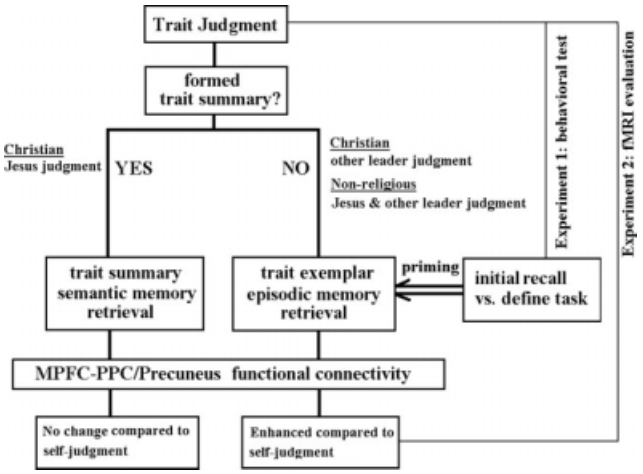

Figure 1.

Illustration of the hypotheses and rationale of our study. If a trait summary is formed about a person, trait judgment of that person then depends on semantic memory retrieval and is not influenced by an initial recall task. If a trait summary of a person is not available, trait judgment of that person depends on episodic memory retrieval mediated by enhanced functional connectivity between the MPFC and the posterior parietal cortex/precuneus and is facilitated by an initial recall task.

MATERIALS AND METHODS

Subjects (Experiment 1: Behavioral Test)

Thirty-two native-Chinese-speaking adults in Beijing participated in this study as paid volunteers. All participants had no neurological or psychiatric history. All were right-handed and had normal or corrected-to-normal vision. Sixteen participants were self-identified nonreligious (eight males, eight females, 19–30 years of age, mean 22.6 ± 3.32. Values are given as mean ± SD throughout). Sixteen participants were self-identified Christians (eight males, eight females, 20–38 years of age, mean 25.1 ± 4.98), who were members of local faith communities and had been attached to the Christian communities for 2 to 13 years (mean 5.8 ± 3.5 years) when they participated in this study. All the Christians reported to attend Church or fellowship at least once a week. About 93.8% of the Christians reported to pray everyday and 75.0% of the Christians reported to read the Bible everyday for at least half an hour. The Christian and nonreligious participants were matched on education (2–7 years, University). This study was approved by a local ethics committee at the Department of Psychology, Peking University.

Stimuli and Procedure

About 112 trait adjectives, all consisting of 2 Chinese characters, were selected from established personality trait

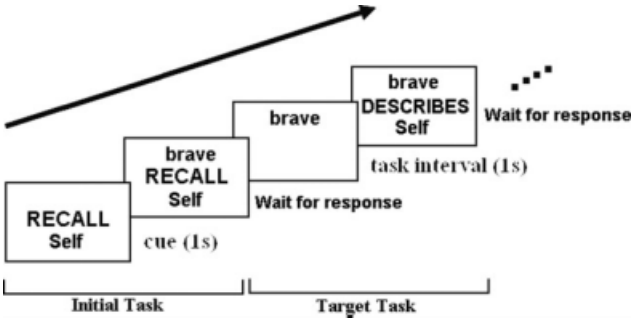

Figure 2.
Illustration of the stimulus procedure in Experiment 1.

adjective pools [Liu, 1990]. The adjectives were divided into 8 lists of 14 words (7 positive and 7 negative), which were pseudo-randomly assigned to 8 judgment tasks. Each trial consisted of presentation of a trait adjective in succession and subjects were instructed to perform two different tasks to the adjectives (see Fig. 2). The initial task required subjects to think of the definition of the trait adjective (the define task) or to recall a specific incident in which one's own or Jesus' behaviors exemplified the trait (the recall task). The second task asked subjects to judge if the trait adjective could describe the self or Jesus (the trait judgment task) or to perform the defined task. The target person in the recall task and the second trait judgment task was always identical. The self trait judgment task was preceded by the define task in half of the trials and by the recall task in the other half of trials. This was also true for the Jesus trait judgment task. The assignment of the two successive tasks was in a random order.

The initial task in each trial began with the presentation of a cue word ("DEFINE" or "RECALL") to indicate the initial task (define or recall) and a cue word to indicate the target person (self or Jesus) in the recall task. The stimuli were black on a gray background and presented on an 18-in. computer screen. Each Chinese character in trait adjectives and cue words was 1.6 × 1.6 cm^2 (width × height), subtending a visual angle of 1.5° × 1.5° at a viewing distance of 60 cm. After the cue words were presented for 1 s, a trait adjective was shown above the cue word and remained on the screen until the subject responded by a button press. The following task began with the presentation of the same trait adjective shown in the initial task with duration of 1 s. A cue word to indicate the following task ("DEFINE" or "JUDGTMENT") and a cue word to indicate the target person (self or Jesus, only in the trait judgment task) were then presented until subjects made a response with the left or right index finger. There was a 2-s delay between two successive trials. Each subject performed eight trials for practice. The instruction emphasized both response accuracy and speed.

RESULTS AND DISCUSSION

Table I shows RTs in the second trait judgment tasks. To assess if the initial recall task facilitated the following trait judgment task, we conducted a repeated measure analysis of variance (ANOVA) with Initial Task ("DEFINE" or "RECALL") and Target Person in the following task (Self or Jesus) as within-subjects variables and Subject Group (nonreligious and Christian) as a between-subjects variable. The ANOVAs showed a significant main effect of Subject Group ($F(1,30) = 5.198$, $P = 0.03$), suggesting faster responses in nonreligious than Christian subjects. The main effect of initial task was also significant ($F(1,30) = 31.15$, $P < 0.001$) since responses in the following trait judgment task were faster when preceded by the recall than by the define task. As there was also a reliable three-way interaction of Initial Task × Target Person × Subject Group ($F(1,30) = 6.51$, $P = 0.016$), RT data from nonreligious and Christian subjects were analyzed separately. The main effect of Initial Task was significant for both subject groups (nonreligious: $F(1,15) = 28.73$, $P < 0.001$; Christian: $F(1,15) = 11.03$, $P = 0.005$), suggesting that responses in the following trait judgment task were faster when preceded by the recall than by the defined task. The main effect of Target Person was not significant (nonreligious: $F(1,15) = 1.38$, $P = 0.258$; Christian: $F(1,15) = 1.41$, $P = 0.253$). However, there was a significant interaction of Initial Task × Target Person for nonreligious subjects ($F(1,15) = 15.68$, $P = 0.001$), suggesting that facilitation of responses to Jesus trait judgment by the recall task was greater than facilitation of responses to self trait judgment. No significant interaction of Initial Task × Target Person for the Christian subjects ($F(1,15) = 1.082$, $P = 0.315$), suggesting comparable facilitation of responses to both Jesus and self trait judgments.

Given that nonreligious subjects responded faster than Christian subjects in the following trait judgment tasks, an additional analysis of the normalized facilitation effect was conducted. The normalized facilitation effect was indexed by the percentage benefit of RTs in the following trait judgment task (i.e., ($RTs_{preceded\text{-}by\text{-}define\text{-}task}$ minus $RTs_{preceded\text{-}by\text{-}recall\text{-}task}$) divided by $RTs_{preceded\text{-}by\text{-}define\text{-}task}$,

TABLE I. Mean RTs ± SD (ms) in the trait judgment task in Experiment 1

	Self trait judgment		Jesus trait judgment	
The initial task	Define	Recall	Define	Recall
Nonreligious	2,020 ± 179	1,788 ± 156	2,298 ± 167	1,707 ± 150
Christian	2,897 ± 270	2,357 ± 205	2,608 ± 268	2,281 ± 180

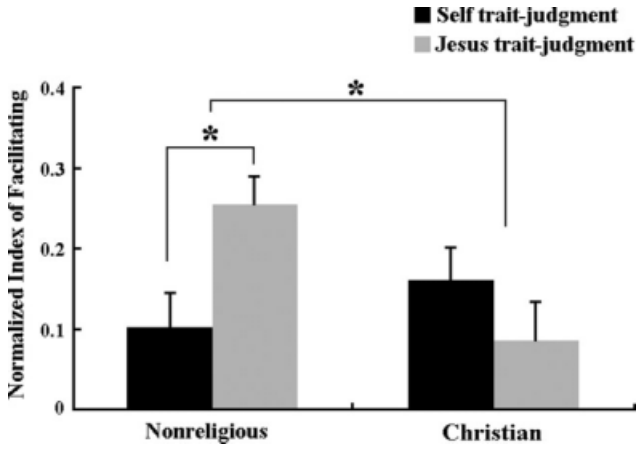

Figure 3.
Normalized facilitation effect in Experiment 1.

Fig. 3). A two-way ANOVA with Target Person (self vs. Jesus) and Subject Group (nonreligious vs. Christian) was conducted on the percentage benefit of RTs, which showed a reliable interaction of Target Person × Subject Group ($F(1,30) = 10.545$, $P = 0.003$). Post-hoc t-tests confirmed that nonreligious subjects showed greater percentage benefit of RTs to Jesus than self trait-judgment ($t(15) = 3.912$, $P = 0.001$), whereas the percentage benefit of RTs did not differ between Jesus and self trait judgments for the Christian subjects ($t(15) = 1.284$, $P = 0.219$). The results of Experiment 1 indicate that, for nonreligious subjects, the recall task facilitated behavioral performances to the following trait judgment to a greater degree when subjects judged Jesus than the self. For Christian subjects, the recall task also facilitated behavioral performances to the following trait judgment task. However, such facilitation did not differ significantly between Jesus and self judgments.

MATERIALS AND METHODS

Subjects (Experiment 2: fMRI Evaluation)

Fourteen self-identified nonreligious (eight males, six females, 19–41 years of age, mean 22.5 ± 6.00) and fourteen self-identified Christians (six males, eight females, 21–29 years of age, mean 23.6 ± 2.87) subjects participated in Experiment 2. None of them participated in Experiment 1. All had no neurological or psychiatric history. All were right-handed and had normal or corrected-to-normal vision. Informed consent was obtained from all subjects prior to scanning. This study was approved by a local ethics committee at the Department of Psychology, Peking University.

Stimuli and Procedure

Subjects were first imaged while performing trait judgment tasks. The stimuli were presented through an LCD projector onto a rear-projection screen mounted above the subjects' heads. The screen was viewed with an angled mirror positioned on the head-coil. There were three functional scans, each of which consisted of five sessions. Subjects performed the following judgment tasks in a random order in each scan: (1) self-judgment: Does this adjective describe you? (2) Jesus-judgment: Does this adjective describe Jesus? (3) Sakyamuni-judgment: Does this adjective describe Sakyamuni? (4) other-judgment: Does this adjective describe Zhu-Rongji (the former Chinese premier)? (5) font-judgment: Is the word presented written in bold faced character? The questions and traits were presented in Chinese. Subjects made judgments after the presentation of each trait adjective by pressing one of the two buttons with the left or right thumb. The assignment of "yes" and "no" responses to buttons was counterbalanced across the subjects. The judgment tasks were intervened by null sessions during which subjects were presented with two rows of asterisks (*) replacing the words in the judgment tasks. The subjects were asked to passively view the symbols in the null sessions.

Each session began with the presentation of a "cue sentence" on the screen for 4.0 s to designate the tasks. A trait adjective then appeared below the cue word with duration of 2.0 s. There was an interstimulus interval of 1.0 s before the next trait adjective was presented. Each of the Chinese character in trait adjectives and cue words was 2.4 × 2.4 cm^2 (width × height), subtending a visual angle of 1.5° × 1.5° at a viewing distance of 90 cm. The instruction and trait adjective words were black on a white background. Sixteen trait adjectives were presented in each session of the functional scans. Thus each session of the judgment tasks lasted for 52 s. Each judgment session was followed by a null condition of 16 s during which two rows of large and small asterisks were presented at the locations of the trait adjectives and cue words. The large and small symbols used in the null condition were 1.1 × 1.1 cm^2 (0.7° × 0.7°) and 0.5 × 0.5 cm^2 (0.3° × 0.3°). Each null session included an instruction of 4s, which asked subjects to view the screen passively.

A total of 480 unique adjectives were selected from established personality trait adjective pools [Liu, 1990]. The adjectives were classified into 30 lists of 16 words. Each adjective consisted of two to four Chinese characters. Half of the trait adjectives were positive and half negative. Word length (number of characters = 2 to 4) and valence were equated across the five judgment tasks. Fifteen lists of words were pseudo-randomly selected for the judgment tasks while the remaining 15 lists of words were used in the latter recognition memory test.

Following the functional and anatomy scans, subjects took 1-h break and then were given a "surprise" recognition memory test. All the trait adjectives used in the judgment tasks were mixed with 240 new trait adjectives and were presented in a random order. Subjects were asked to identify old or new items by pressing one of two buttons. During the recognition memory test, subjects were required to respond to every item without a time limit.

MRI Data Acquisition

Brain imaging was performed on a 3 T Siemens Trio MR scanner with a standard birdcage head coil at Beijing MRI Center for Brain Research. Pieces of foam were used to minimize head movement. A T2* weighted gradient-echo planar imaging (EPI) sequence (TR = 2000 ms, TE = 30 ms, and flip angle = 90°, 3 mm thickness, skip 0.75 mm, FOV = 220 mm, 64 × 64 × 32 matrix with 3.4 × 3.4 × 3.75 mm^3 spatial resolution) was used to acquire a set of 32 axial slices of functional images. Functional image data were acquired in three scans. Each scan lasted for 5 min and 24 s. About 162 full-brain volumes were acquired during each functional scan. High resolution anatomic images were obtained using a standard 3D T1-weighted sequence with 0.938 × 0.938 mm^2 in plane resolution and 1.3 mm slice thickness (256 × 256 × 176 matrix, TR = 1,600 ms, TE = 3.93 ms).

fMRI Data Analysis

Statistical Parametric Mapping software (SPM2, Wellcome Trust Centre for Neuroimaging, UK) was used for imaging data processing and analysis. Functional images were realigned to the first scan to correct for head movement between scans and were coregistered with each subject's anatomical scan. Functional images were then normalized into a standard anatomical space (2 × 2 × 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. The image data were modeled using a box-car function. A general linear model was used to compute parameter estimates and t-contrast images for each comparison at each voxel.

Whole-brain statistical parametric mapping (SPM) analyses were performed and contrasts were then defined to reveal brain areas specifically involved in self-judgment relative to Zhu-Rongji judgment in our previous work [Han et al., 2008], in which random effect analyses confirmed significant activation in the VMPFC (Talairach coordinates (x, y, z) were 2, 54, 10) in nonreligious subjects and in the dorsal MPFC (DMPFC, Talairach coordinates were 8, 26, 42) in Christian subjects that were defined with P value smaller than 0.05 (corrected for multiple comparison) at the cluster level. A psychophysiological interaction (PPI) analysis [Friston et al., 1997] was performed to identify brain regions that showed significantly increased covariation (i.e., increased functional connectivity) with VMPFC and DMPFC activity during trait judgment of others relative to trait judgment of the self. The coordinates of the peak voxel from the previous random effect analysis were used to serve a landmark for the individual seed voxels. An ROI in each individual subjects was defined as a sphere with 10-mm diameter centered at the peak voxel in the VMPFC and DMPFC that were defined from the group analysis in our previous work [Han et al., 2008]. The time series of each ROI were then extracted, and the PPI regressor was calculated as the element-by-element product of the mean-corrected activity of this ROI and a vector coding for the differential task effect of trait judgment of others versus trait judgment of the self. The PPI regressors reflected the interaction between psychological variable (trait judgment of others vs. trait judgment of the self) and the activation time course of MPFC. The individual contrast images reflecting the effects of the PPI between MPFC and other brain areas were subsequently subjected to one-sample t tests. The results of the group analysis identified brain regions of which the activity systematically showed increased correlation with MPFC activity during trait judgment of others. The threshold at the cluster level was set to $P < 0.05$ (corrected for multiple comparisons) for the identification of brain areas that showed significant functional connectivity with the seed ROIs. The SPM coordinates for the standard brain from MNI template were converted to Talairach coordinates [Talairach and Tournoux, 1998] using a nonlinear transform method (http://www.mrc-cbu.cam.ac.uk/Imaging/mnispace.html).

Classification Analysis

We first created a featured vector $\boldsymbol{x} = (x_S, x_J)$ for each subject that was determined by two values. x_S denotes the MPFC-PPC/precuneus functional connectivity strength during Sakyamuni judgment. x_J denotes the MPFC-PPC/precuneus functional connectivity strength during Jesus-judgment. x_S, x_J were normalized by the functional connectivity strength during Zhu-Rongji judgment to minimize baseline differences across subjects. A linear discriminant function was then defined as $g(\mathbf{x}) = w_S x_S + w_J x_J + w_0$, where w_S and w_J are the weight of the each vector value and w_0 is the bias. For each subject's vector $\mathbf{x}(x_S, x_J)$, the discriminant function should satisfy

$g(\mathbf{x}) > 0$ (if $\mathbf{x}$ is the featured vector of a nonreligious subject)
and
$g(\mathbf{x}) < 0$ (if $\mathbf{x}$ is the featured vector of a Christian subject)

The most optimal weight and bias of the linear discriminant function were calculated using a machine learning-pattern recognition algorithm. Linear support vector machines [SVM, Theodoridis and Koutroumbas, 2003] were used in the current work, which has been demonstrated to be an efficient algorithm for fMRI study [Cox, 2003]. The "leave-one-subject-out" method was used to test the efficiency of our classification analysis. The parameters of the discriminant function were determined by a training procedure based on a data set of 27 subjects. These parameters were then used to test the accuracy to classify the "leave-out" individual into one or another subject group.

RESULTS AND DISCUSSION

The behavioral performances during the scanning procedure and memory test were reported in our previous work [Han et al., 2008]. The recognition scores in the memory test were higher for the traits associated with the self relative to those associated with others in both nonreligious and Christian subjects, suggesting a self-referential effect regardless of religious beliefs. In addition, Christian subjects responded faster to Jesus-judgment than to Self-judgment during the scanning procedure, whereas no such difference was observed in nonreligious subjects.

To test the hypothesis that trait judgment of others involves enhanced process of episodic memory retrieval and thus induced increased functional connectivity between the VMPFC and PPC, we conducted PPI analysis to inspect whether, relative to self trait judgment, Zhu-Rongji-judgment produced enhanced functional connectivity between the two brain areas. The PPI analysis confirmed that, for nonreligious subjects, activities in bilateral and medial PPC and precuneus showed greater covariation with VMPFC activity during Zhu-Rongji-judgment compared with Self-judgment (see Fig. 4a and Table II), suggesting stronger functional connectivity between VMPFC and PPC/precuneus associated with judgments of others relative to Self-judgment. Similar PPI analysis was conducted in Christian subjects and verified that the activities in PPC/precuneus showed stronger covariation with the VMPFC activity during Zhu-Rongji-judgment compared with Self-judgment (Fig. 4b, Table II). The results of PPI analyses suggest enhanced memory retrieval during trait judgment of the public person compared with trait judgment of the self.

To assess the prediction that Jesus-judgment engages differential processes of memory retrieval between nonreligious and Christian subjects, we first defined a common ROI in the PPC/precuneus that showed significantly increased connectivity with the VMPFC in a random effect PPI analysis that combined the two subject groups (Fig. 4c). The contrast Zhu-Rongji vs. Self-judgment defined a cluster in the PPC/precuneus ($P < 0.00001$, voxel level, cluster size = 935, peak voxel at $-4/-68/44$, Talairach coordinates). The functional connectivity strength (i.e., beta values of the PPI analysis) associated with Jesus-judgment, Sakyamuni-judgment, and Zhu-Rongji-judgment compared with Self-judgment were then extracted from the ROI in each subject. The functional connectivity strengths linked to Jesus judgment was significantly greater than zero in nonreligious (mean value = 0.270, $t(13) = 4.801$, $P < 0.0001$), suggesting that, relative to Self-judgment, Jesus-judgment induced increased functional connectivity between the MPFC and PPC/precuneus. However, the functional connectivity strengths linked to Jesus-judgment did not differ significantly from zero in Christian subjects (mean value = 0.076, $t(13) = 1.910$, $P > 0.05$), suggesting comparable functional connectivity between the MPFC and PPC/precuneus associated with self and Jesus judgments. A two-sample t test confirmed the difference in functional connectivity between the VMPFC and PPC/precuneus in association with Jesus judgment between the two subject groups ($t(27) = 2.821$, $P < 0.01$). The functional connectivity strengths linked to Sakyamuni-judgment was significantly greater than zero in both nonreligious subjects (mean value = 0.322, $t(13) = 6.846$, $P < 0.0001$) and Christian subjects (mean value = 0.208, $t(13) = 6.605$, $P < 0.0001$), suggesting that, relative to Self-judgment, Sakyamuni-judgment induced increased functional connectivity between the VMPFC and PPC/precuneus in both subject groups.

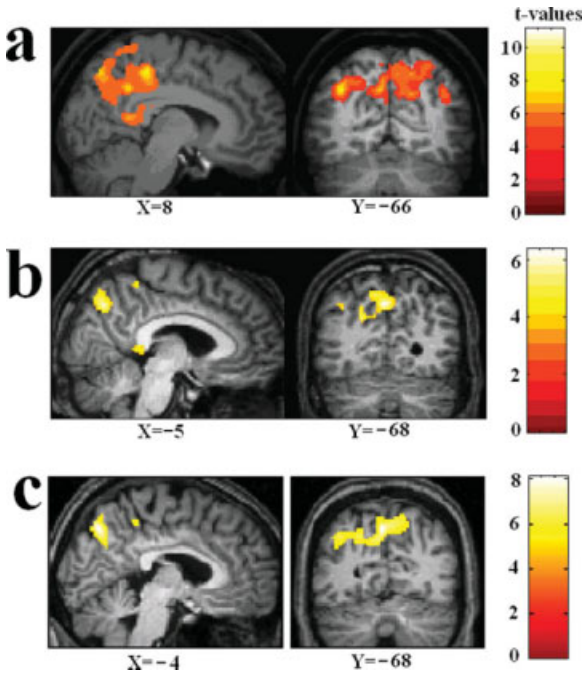

Figure 4.

Brain areas showing increased covariation with the VMPFC during Zhu-Rongji-judgment relative to Self-judgment. (**a**) The results from nonreligious subjects; (**b**) the results from Christian subjects; (**c**) the results from the combination of the data from nonreligious and Christian subjects. Scale bars indicate t values. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

Given that a two-sample t test confirmed that the functional connectivity between the MPFC and PPC/precuneus in association with Sakyamuni-judgment was slightly stronger for nonreligious than Christian subjects ($t(27) = 2.013$, $P = 0.055$), we further assessed if the difference in functional connectivity between the MPFC and PPC/precuneus between the two cultural groups was specific to Jesus-judgment. To rule out the possible confounds of individual difference in functional connectivity between the MPFC and PPC/precuneus associated with Zhu-Rongji-judgment, we conducted a two-way ANOVA of normalized functional connectivity strengths (i.e., the

TABLE II. Brain areas showing increased covariation with the ventral medial refrontal cortex during trait judgments of others relative to self-judgment

Condition/region	Voxel no.	Z value	X	Y	Z
Nonreligious participants					
Zhu-Rongji-judgment					
PPC/precuneus	1,607	4.68	10	−33	46
Right parietal cortex	144	4.35	36	−59	23
Left parietal cortex	406	4.76	−40	−64	35
Right superior frontal cortex	515	5.45	28	22	54
Sakyamuni-judgment					
Precuneus	95	4.44	−14	−50	17
Right parietal cortex	3,318	5.03	42	−63	29
Left parietal cortex	177	4.45	−34	−66	43
Right superior frontal cortex	376	4.85	26	22	56
Jesus-judgment					
PPC/precuneus	2,359	4.43	−12	−38	44
		4.38	16	−48	66
Right parietal cortex	202	3.65	38	−63	51
Right superior frontal cortex	106	3.96	26	28	52
Christian participants					
Zhu-Rongji-judgment					
PPC/precuneus	506	4.11	−4	−67	42
Right parietal cortex	172	4.22	30	−24	67
Sakyamuni-judgment					
PPC/precuneus	4,811	4.90	−16	−35	44
Right parietal cortex	288	5.30	36	−75	38
Left parietal cortex	171	4.94	−38	−77	35
Left superior temporal cortex	199	4.56	−64	−26	10
Right superior temporal cortex	114	4.09	60	−12	4

Note: trait judgment of Jesus did not induce increased covariation of neural activity in any brain areas with the VMPFC activity in Christian subjects.
Voxel no. = number of voxels in a cluster, PPC = posterior parietal cortex.

percentage of the connectivity strength of Jesus judgment and Sakyamuni judgment relative to that of Zhu-Rongji judgment, Fig. 5a) with Task (Jesus vs. Sakyamuni judgment) as a within-subject variable and Cultural Group (nonreligious vs. Christian) as a between-subjects variable. We found an significant interaction of Task × Cultural Group ($F(1,26) = 5.654$, $P = 0.025$), which confirmed that the functional connectivity difference between the two cultural groups was specific to Jesus judgment. The results of random effect analysis performed on each subject group were consistent with the results of ROI analysis and are illustrated in Figure 5b,c.

After the scanning procedure subjects were asked to assess the importance of Jesus' judgment in subjective evaluation of a person's personality using a seven-point scale (0 = not important; 6 = extremely important). This measurement reflected a degree of an individual's belief of Jesus' teaching and also reflects how strong an individual's opinion about Jesus is. We found that the rating scores of this evaluation significantly negatively correlated with MPFC-Precuneus/PCC functional connectivity strength during Jesus trait judgment (VMPFC: $r = -0.495$, $P = 0.012$; DMPFC: $r = -0.497$, $P = 0.012$, Fig. 6), suggesting that the stronger the conviction of Jesus' opinion, the weaker the functional connectivity between MPFC and Precuneus/PCC.

Finally, we examined whether the differential functional connectivity between VMPFC and PPC/precuneus observed in Christian and nonreligious subjects arose from the difference in the process of episodic memory retrieval during Self-judgment between the two subject groups. We conducted PPI analysis to compare self-judgment with a low-level control condition, i.e., font-judgment. This analysis, however, did not show increased activity in any brain areas that covaried with the VMPFC activity in Christian and nonreligious subjects. This suggests that the difference in the increased functional connectivity between VMPFC and PPC/precuneus associated with trait judgment of others observed in Christian and nonreligious subjects could not be attributed to the difference in the process of episodic memory retrieval related to self-judgment between the two participant groups.

The classification analysis was conducted using the VMPFC-PPC/precuneus functional connectivity strength to define two featured vectors (i.e., MPFC-PPC/Precuneus functional connectivity strength during Jesus and Sakyamuni trait-judgments). Figure 7 shows a scatter plot of bootstrapping analysis [Davison and Hinkley, 1997] to

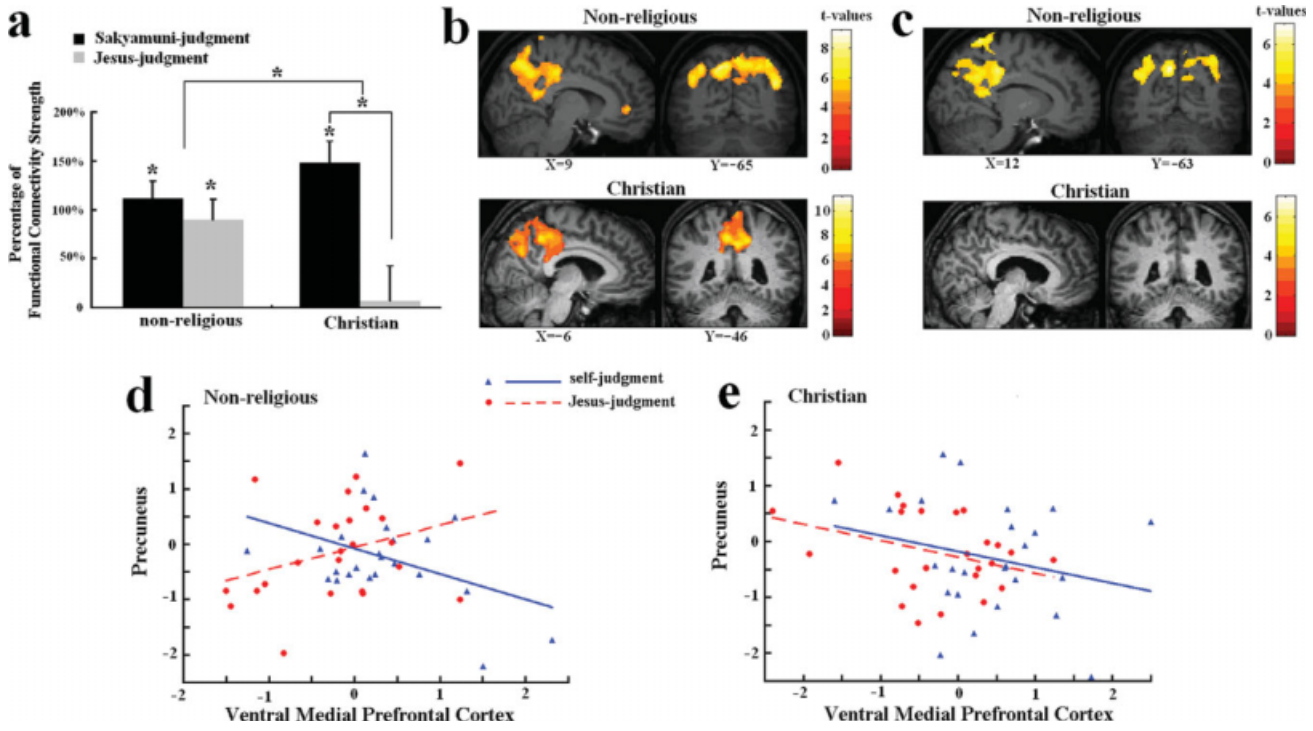

Figure 5.

(**a**) Normalized functional connectivity strength in association with trait judgment of religious leaders. (**b**) Brain areas showing increased covariation with the VMPFC in the contrasts of Sakyamuni-judgment vs. Self-judgment in nonreligious and Christian subjects. (**c**) Brain areas showing increased covariation with the VMPFC in the contrasts of Jesus-judgment vs. Self-judgment in nonreligious and Christian subjects. Note that, relative to Self-judgments, Jesus-judgment did not induce increased functional connectivity between the VMPFC and any other brain areas. Scale bars indicate *t* values. (**d**) Illustration of the regression of the precuneus activation on the medial prefrontal activation for a representative nonreligious subject, which shows different patterns between self- and Jesus-trait judgment tasks. (**e**) Illustration of the regression of the precuneus activation on the medial prefrontal activation for a representative Christian subject, which shows similar patterns in self- and Jesus-trait judgment tasks. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

illustrate the distribution of nonreligious and Christian subjects in a space defined by the two vectors. A bootstrapped dataset with the sample size of 14 was resampled with replacement for each subject group. The mean functional connectivity strength of this bootstrapped sample was then calculated and saved as a new data. This procedure was repeated for 3,000 times to estimate the population information. The results of the bootstrap analysis suggest separate distribution of the two subject groups. The classification analysis used a linear discriminant function with the most optimal weight and bias to classify the "leave-out" subject into different subject groups defined by religious beliefs. Figure 7 illustrates such a linear discriminant function (i.e., the classifier) calculated from a sample of 27 subjects. The mean accuracy of the classification was 71.4% for both nonreligious and Christian subjects, much higher than the chance level. Considering the small sample size of the training data, the results suggest that the VMPFC-PPC/precuneus functional connectivity strength associated with trait judgment of others may be used to classify an individual into subject groups that defined religious beliefs.

As our previous work showed that the DMPFC is involved in self-referential processing in Christian subjects [Han et al., 2008], similar PPI and ROI analyses were conducted using the DMPFC as the seed area. The results were similar to those obtained from the VMPFC data.

GENERAL DISCUSSION

While our previous neuroimaging research [Han et al., 2008] suggests that Christian belief and practice influence the neural mechanisms underlying trait judgment of the self, the current study assessed if Christian belief and practice also modulate neurocognitive processes of personal traits of the religious leader. Experiment 1 tested the hypothesis that Christian belief and practice may lead to constitution of a trait summary about the Christian leader (Jesus) stored in semantic memory in the believers so that

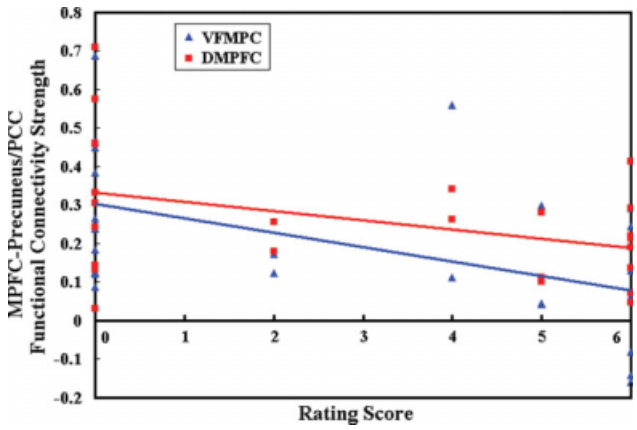

Figure 6.

Correlation between rating scores of the importance of Jesus' judgment in subjective evaluation of a person's personality and MPFC-Precuneus/PCC functional connectivity strength during Jesus trait judgment. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

the retrieval of behavioral episodes is recruited to a minimum degree for trait judgment of Jesus. We examined if recall of a specific incident that exemplified one's own or Jesus' behaviors facilitates the following trait judgment of self and Jesus. We first showed that, relative to the define task, the recall task facilitated responses to both Self-judgment and Jesus-judgment in nonreligious subjects. Moreover, the recall task produced greater facilitation effect on responses to Jesus-judgment than Self-judgments. This indicates that, relative to Self-judgment, retrieval of behavioral episodes of Jesus improved behavioral performances in the following trait judgment of Jesus. The stronger priming effect of the recall task on trait judgment of Jesus suggests that additional episodic memory retrieval was involved in Jesus-judgment compared to Self-judgment in nonreligious subjects. This is consistent with Klein et al.'s [2002] proposal that trait judgments about a person are computed online on the basis of retrieved behavioral episodes of that person if the amount of experience with that person is not sufficient and trait knowledge about that person is not represented in the form of trait summary. Nevertheless, a different pattern of behavioral performances was observed in Christian subjects. Although the recall task resulted in faster responses to trait judgment of both the self and Jesus compared to the defined task, this effect did not differ between the two trait judgment tasks. The different pattern of the effect of episodic memory retrieval on Jesus judgment between nonreligious and Christian subjects was evident even when behavioral responses were normalized to exclude the response speed difference between the two subject groups. The results fit well with the idea that Christians had formed a trait summary about Jesus and episodic memory retrieval was thus unnecessary during trait judgment of Jesus.

Experiment 2 further demonstrated that, relative to judgment of one's own personal traits, trait judgment of a government leader in nonreligious subjects was characterized by increased functional connectivity between the MPFC and PPC/precuneus. Given that the PPC/precuneus and its functional connectivity with MPFC are involved in episodic memory retrieval [Cavanna and Trimble, 2006; Lou et al., 2004; Wagner et al., 2005], our findings support the hypothesis that the process of episodic memory retrieval is involved in trait judgment of others so as to provide information of behavioral episodes for evaluation of personal traits of others. Our findings complement previous neuroimaging studies by showing that trait judgments of others are essentially different from trait judgment of the self in that the process of self-relatedness mediated by the VMPFC plays a crucial role in self-judgment [D'argembeau et al., 2005; Moran et al., 2006], whereas trait judgment of others is characterized by enhanced functional activity between the MPFC and PPC/precuneus to afford retrieval of information from episodic memory for evaluation. The fMRI findings are in agreement with Klein et al.'s [2002] theoretical framework that trait judgment of the self is conducted by accessing a trait summary in semantic memory whereas trait judgment of others engages relevant behavioral episodes.

Our fMRI results from nonreligious subjects showed similar increased functional connectivity between the MPFC and PPC/precuneus associated with trait judgments of a government leader and religious leaders (i.e., Jesus and Sakyamuni). This is consistent with the results

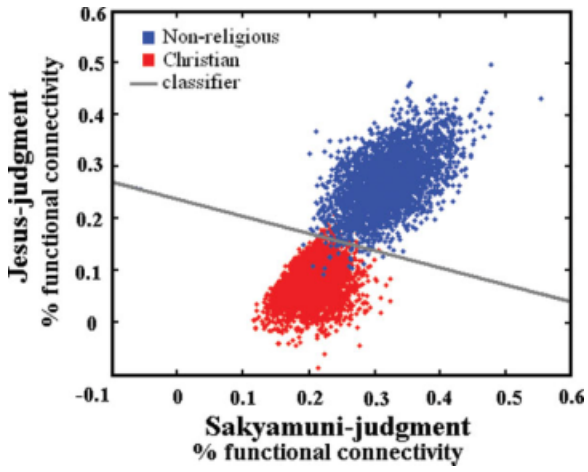

Figure 7.

The scatter plot of bootstrapping analysis to illustrate the distribution of nonreligious and Christian subjects in a space defined by two dimensions (MPFC-PPC/Precuneus functional connectivity during Jesus and Sakyamuni trait-judgments). The bootstrapped sample means of nonreligious and Christian subjects fall mostly above and below the classifier. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

of Experiment 1 and provides further evidence that the process of memory retrieval is involved in trait judgments of both government and religious leaders in nonreligious subjects. The nonreligious subjects did not have sufficient amount of experience with both the government and religious leaders to form trait summaries about them. Consequently, trait judgments of both government and religious leaders had to be computed based on inceptive behavioral memories.

Interestingly, our fMRI results suggest that Christian subjects may employ different neurocogntive processes of trait judgments of government and religious leaders. While trait judgment of the government leader induced enhanced functional connectivity between the MPFC and PPC/precuneus relative to self-judgment in Christian subjects, similar to that observed in nonreligious subjects, trait judgment of Jesus failed to produce increased functional connectivity between the two brain areas relative to self-judgment in Christian subjects. Moreover, we observed correlation between participants' attitude about Jesus and the functional connectivity strength between the MPFC and Precuneus/PCC, i.e., the stronger the conviction of Jesus' opinion about trait judgment of a person, the weaker the functional connectivity between MPFC and Precuneus/PCC. Thus, in accordance with the behavioral results, our fMRI results indicate that trait judgment of Jesus in Christian subjects engage memory retrieval of episodes to a degree as minimum as that during self-judgment. In addition, our fMRI results showed that the absence of increased functional connectivity between the MPFC and PPC/precuneus was specific to trait judgment of Jesus because trait judgment of Sakyamuni also induced increased functional connectivity between the MPFC and PPC/precuneus in Christian subjects, suggesting that memory retrieval of episodes was involved when Christian subjects conducted trait judgments of the leaders of other religions. Therefore the influence of Christian belief and practice on trait judgment of religious leaders was specific to the leader of the believers' own religion. It appears that the religious knowledge owned by subjects may play a critical role in modulation of the neurocognitive processes of the religious leader. Although the Bible tells stories about Jesus as a person, he is special in that he is the creator and leader of Christianity and is regarded as "the image of the invisible God" (Colossians 1:15). Christian believers may make trait judgment of Jesus based on their knowledge about Jesus instead of evaluation of his behaviors because of his special position in Christianity. The fact that Christian subjects even responded faster to trait judgment of Jesus than self-judgment is in agreement with this analysis.

Our recent research [Han et al., 2008] showed that VMPFC activity, which is supposed to subserve the processing of self-relatedness during self-judgment [D'argembeau et al., 2005; Moran et al., 2006], did not differentiate trait judgments of the self and others in Christian subjects. Instead, self-judgment in Christians was characterized by enhanced neural activity in the DMPFC that has been associated with reappraisal and evaluation of self-related stimuli [Northoff et al., 2006] and mental attribution of others' mind [Gallagher et al., 2000; Han et al., 2005; Mitchell et al., 2005]. Taken together, these fMRI findings indicate that Christian belief and practice influence the neural mechanisms underlying the process of both the self and the religious leader.

While the results of both behavioral and fMRI experiments indicate differential neurocognitive processes of trait judgment of special others between Christian and nonreligious subjects, the results of our classification analysis suggest that the specific pattern of functional connectivity between the MPFC and PPC/precuneus may be used to classify an individual into different subject groups in terms of Christian belief and practice. The classification analysis used the machine-learning pattern recognition algorithm to classify a leave-out subject into Christian or nonreligious groups. The parameters in this discriminant algorithm were defined after a training procedure using the MPFC-PPC/precuneus functional connectivity data associated with trait judgment of Jesus and Sakyamuni. The accuracy of the classification reflects how well the classification pattern of neural activity data pool fits the actual subject group. Despite the small sample size in our study, the accuracy of classification was quite high. While recent neuroimaging research trended to decode an individual's conscious or unconscious content by analyzing the neural activity in specific brain areas [Haxby et al., 2001; Haynes et al., 2007; Kamitani and Tong, 2005; Kay et al., 2008; Soon et al., 2008], our results of classification analysis suggest the possibility of classifying an individual into different social groups by examining his/her neural activity in a specific task.

Our recent work showed that the neural structure of the self is different between Westerners and Chinese in that the VMPFC is involved in representation of both the self and close others (e.g., mother) in Chinese whereas this brain area is used to represent only the self in Westerners [Zhu et al., 2007]. These findings provide neuroscience evidence for the diversity of neural mechanisms underlying self-referential processing across cultures that are different in geography, languages, and other aspects. In contrast, nonreligious and Christian subjects in our research lived in the same city and spoke the same language. The cultural diversities characterizing the two subject groups were religious beliefs and behavioral scripts, i.e., subjective cultures independent of geography and languages [Chiu and Hong, 2006]. The behavioral and neuroimaging findings illustrated how Christian belief and practice may influence the cognitive and neural mechanisms associated with the processing of the self and others, making contributions to the understanding of interplay between brain and religious belief and practice. Future research should explore if other religious beliefs and practice also lead to unique neurocognitive processes of the self and others.

Previous brain lesion and neuroimaging studies indicate that the memory system consists of multiple cortical

structures including the temporal and hippocampal cortex [Cabeza and Nyberg, 2000; Squire and Zola-Morgan, 1991]. These brain areas may be involved in the trait judgment tasks. However, as our data analyses contrast two trait judgment tasks (e.g., self- vs. Zhu-Rongji-judgments or Jesus- vs. self-judgments), such data analyses removed those cortical activations that are common for different trait judgment tasks. Only the neural activity specific to self-judgment (e.g., MPFC activity) or Jesus- or Zhu-Rongji-judgment (e.g., increased functional connectivity between MPFC and PPC/precuneus) was shown in the fMRI results.

In conclusion, our findings indicate that trait judgments of others are different from trait-judgment of the self in that the former is linked to memory retrieval of episodes mediated by increased covariation between the activities in the MPFC and PPC/precuneus. However, the enhanced process of memory retrieval is not necessary for trait judgment of Jesus in Christian subjects, as indicated by the equal facilitation of behavioral performances to trait judgment of the self and Jesus by the recall task and the comparable functional connectivity between the MPFC and PPC/precuneus during trait judgments of Jesus and the self. Together with our previous fMRI findings that Christian subjects did not differentiate between the self and Jesus in the VMPFC [Han et al., 2008], the current study suggests that, in Christians, trait judgment of Jesus is possibly achieved by accessing a trait summary in semantic memory rather than by an evaluation process based on retrieval of behavioral episodes. Together with other recent fMRI studies [Chiao et al., in press], our brain imaging results indicate that the neural substrates underlying trait judgment of both the self and others are shaped by cultural experiences and cultural values including religious belief and practice.

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