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# Neural consequences of religious belief on self-referential processing

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# Neural consequences of religious belief on self-referential processing

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Christianity strongly encourages its believers to surrender to God and to judge the self from God's perspective. We used functional MRI to assess whether this religious belief is associated with neural correlates of self-referential processing distinct from that of non-religious people. Non-religious and Christian participants were scanned while performing tasks of personal-trait judgments regarding the self or public persons. We found that, while self-judgment was linked to better memory of traits related to the self than to others, self-referential processing induced increased activity in the ventral medial prefrontal cortex (MPFC) for non-religious participants but in the dorsal MPFC for Christian participants. In addition, the dorsal MPFC activity was positively correlated with the rating scores of the importance of Jesus' judgment in subjective evaluation of a person's personality. Because the ventral and dorsal MPFC are respectively engaged in representation of stimulus self-relevance and evaluation of self-referential stimuli, our findings suggest that Christian beliefs result in weakened neural coding of stimulus self-relatedness but enhanced neural activity underlying evaluative processes applied to self-referential stimuli.

## INTRODUCTION

The significance of the ''self'' has been central to the study of philosophy and religion for centuries. The coed soe5oT4(cr)486iJ(ieplaycess0f)-4a.7(he)-5keyself-

increased activity related to self- relative to other-judgments in the ventral medial prefrontal cortex (VMPFC) and the perigenual anterior cingulate cortex (Craik et al., 1999; Fossati et al., 2003; Heatherton et al., 2006; Kelley et al., 2002; Lieberman, Jarcho, & Satpute, 2004; Macrae, Moran, Heatherton, Banfield, & Kelley, 2004; Moran, Macrae, Heatherton, Wyland, & Kelley, 2006; Zhu, Zhang, Fan, & Han, 2007). In addition, brain imaging studies suggest a crucial role of VMPFC in coding self-relatedness of stimuli (Northoff & Bermpohl, 2004; Northoff et al., 2006). For example, it has been shown that VMPFC activity is concomitant with better memory of descriptive traits for the self than for others (Kelley et al., 2002; Macrae et al., 2004; Zhu et al., 2007). Moreover, the increased blood flow in VMPFC was correlated with the amount of thoughts about the self (measured using subjective rating; D'argembeau et al., 2005). The VMPFC activity also increased in a linear fashion with increasing self-relevance of personal traits identi-

# METHODS

## Participants

Twenty-eight native-Chinese-speaking adults participated in this study as paid volunteers. None of the participants had any neurological or psychiatric history. All were right-handed, had normal or corrected-to-normal vision. Informed consent was obtained from all participants prior to scanning. This study was approved by a local ethics committee.

Fourteen participants were self-identified non-religious (8 males, 6 females, 19–41 years of age, mean $22.5 \pm 6.00$. Values are given as mean $\pm$ SD throughout). Fourteen participants were self-identified Christians (6 males, 8 females, 21–29 years of age, mean $23.6 \pm 2.87$) who were members of local faith communities and had been attached to them for 1 to 7 years (mean $3.6 \pm 1.7$ years) when they participated in this study. Of the Christians, 92.9% reported attending Church or fellowship at least once a week; 92.9% of them reported praying everyday; and 64.3% of them reported reading the Bible at least once a week. The participants' religious attitudes were evaluated using a questionnaire containing 6 religious items derived from Minnesota Multiphasic Personality Inventory such as: ''I believe there is a God,'' ''I believe the importance of praying to Jesus,'' ''I believe the importance of reading the bible.'' A 5-point scale was used to compare the difference in religious attitude between the two participant groups with 0 = absolutely disagree, 1 = disagree, 2 = agree to a certain degree, 3 = agree, and 4 = strongly agree. The mean ratings were $3.7 \pm 0.2$ and $0.7 \pm 0.3$, respectively for Christian and non-religious participants ($t = 26.99$, $p < .001$). The Christian and non-religious participants were matched on educational level (2–7 years at university). Religious knowledge was also tested for all participants using a questionnaire that included 50 questions. Twenty questions were about Jesus and twenty about the Buddhist leader, Sakyamuni. Ten questions were related to a historical figure to prevent subjects from adopting strategies when answering the questions. The percentage of correct answers to questions about Jesus was higher for Christians ($98.9\% \pm 2.9\%$) than for non-religious participants ($83.3\% \pm 10.3\%$), $t = 5.308$, $p < .001$, whereas the percentage of correct answers to questions about Sakyamuni did not differ between Christians ($94.6\% \pm 11.8\%$) and the non-religious participants ($91.3\% \pm 9.5\%$), $t = 0.363$, $p > .5$.

## Stimuli and procedure

Participants 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 5 sessions. Participants 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 characters?

The questions and traits were in Chinese. Participants 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 participants. The judgment tasks were interspersed with null sessions during which participants were presented with two rows of asterisks (*) replacing the words in the judgment tasks. The participants 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 a duration for 2.0 s. There was an interstimulus interval of 1.0 s before the next trait adjective was presented. Each of the Chinese characters in trait adjectives and cue words was 2.4 cm wide $\times$ 2.4 cm high, subtending a visual angle of $1.5 \times 1.5$ degrees at a viewing distance of 90 cm. The instruction and trait adjective words were black on a white background. In each session of the functional scans 16 trait adjectives were presented. 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 $1.1 \times 1.1$ cm ($0.7 \times 0.7$ degrees) and $0.5 \times 0.5$ cm ($0.3 \times 0.3$ degrees). Each null session included an instruction of 4 s, which asked participants 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 pseudorandomly selected for the judgment tasks while the remaining 15 lists of words were used in the later recognition memory test.

and Judgment (self vs. Zhu-Rongji) as independent variables.

Whole-brain statistical parametric mapping (SPM) analyses were performed and contrasts were then defined to reveal brain areas specifically involved in self-, Jesus-, and Sakyamuni-judgment relative to Zhu-Rongji-judgment. Contrasts were also defined to compare the difference between self-judgment and font-judgment tasks to identify brain areas involved in semantic processing. Random-effect analyses were conducted across each participant group based on statistical parameter maps from each individual participant to allow population inference. Areas of significant activation were identified at the cluster level for values exceeding a P-value of .05 (corrected for multiple comparison). The SPM coordinates for the standard brain from an MNI template were converted to Talairach coordinates (Talairach & Tournoux, 1998) using a non-linear transform method (http://www.mrc-cbu.cam.ac.uk/Imaging/mnispace.html). High-resolution anatomical brains were inflated with FreeSurfer (Dale, Fischl, & Sereno, 1999; Fischl, Sereno, & Dale, 1999). The results of SPM analysis were then projected onto the inflated brain using the FreeSurfer toolbox to illustrate activations in individual participants.

After the whole-brain SPM analysis confirmed that the dorsal medial prefrontal cortex (DMPFC) was involved in self-referential processing in Christian participants, ROIs were defined as spheres with a radius of 3 mm that centered at the coordinates of the peak voxel of VMPFC activation observed in non-religious participants and of DMPFC activation observed in Christian participants. The signal intensity of parameter estimate in the ROIs was then subject to ANOVAs with Participant (non-religious vs. Christian participants), Judgment (self- vs. Zhu-Rongji-judgment), and Location (VMPFC vs. DMPFC) as independent variables. The percent fMRI signals in the ROIs were also calculated from raw fMRI data to plot the time course of signal changes associated with self- and Zhu-Rongji-judgments. Percent fMRI signal changes in the ROI related to self-referential and Zhu-Rongji-referential processing was defined as (BOLD signals associated with self- or Zhu-Rongji-judgment minus BOLD signals associated with the null condition)/(BOLD signals associated with the null condition).

A statistical bootstrap method (Davison & Hinkley, 1997) was used to illustrate the population mean and variation of the fMRI signal intensity of parameter estimates in VMPFC and DMPFC for each participant group. A bootstrapped data set with the sample size of 14 was resampled with replacement for each participant group. The mean signal intensity of this bootstrapped sample was then calculated and saved as new data. This procedure was repeated 1000 times to estimate the population information.

## RESULTS

### Behavioral performance

A repeated measure analysis of variance (ANOVA) showed that participants made slightly more ''no'' than ''yes'' responses in the scanner, non-religious participants: $F(1, 13) = 10.92$, $p < .01$; Christians: $F(1, 13) = 6.74$, $p < .03$, see Table 1. Relative to non-religious participants, Christian participants responded more slowly to self-, Zhu-Rongji-, and Sakyamuni-judgments but faster to Jesus-judgment, $F(3, 24) = 14.127$, $p < .001$. Response speeds did not differ between self- and other-judgments for non-religious participants ($p > .2$) but were slower to self- than to Jesus-judgments for Christians ($t = 6.524$, $p < .001$). The recognition scores in the memory test (i.e., the proportion of hits minus false alarms) were higher for the traits related to the self than to others, for both non-religious

TABLE 1
Mean behavioral performances (SD) in different judgment tasks

| Group | Self | Sakyamuni | Jesus | Zhu-Rongji |
|---|---|---|---|---|
| Proportion of ''yes'' responses (%) | | | | |
| Non-religious participants | 44.6 (2.3) | 44.1 (2.7) | 45.0 (2.5) | 43.4 (2.7) |
| Christians participants | 45.4 (2.9) | 39.2 (3.2) | 40.7 (3.1) | 43.1 (2.7) |
| Response speeds (ms) | | | | |
| Non-religious participants | 1077 (46) | 1091 (59) | 1058 (55) | 1018 (51) |
| Christians participants | 1125 (50) | 1217 (56) | 983 (46) | 1040 (39) |

individuals ($t = 4.536$ to 6.321, $p < .001$) and Christians ($t = 4.124$ to 5.764, $p < .001$, see Table 2), indicating a self-referential effect regardless of religious beliefs.

## fMRI results

We first assessed whether self-judgment generated increased activation in VMPFC relative to other-judgments in both participant groups by conducting a region-of-interest (ROI) analysis of the fMRI data. To avtid any spurious artifacts, we used an a priori anatomically-defined ROI in VMPFC, Brodmann area (BA) 10, Talairach coordinates x/y/z = 8/55/6, Figure 1A, based on an entirely independent data set that also compared self- and other-judgments in Chinese subjects (Zhu et al., 2007), to calculate parameter estimates of signal intensity related to self- and Zhu-Rongji-judgments. An ANOVA with Participant (non-religious vs. Christians) and Judgment (self vs. Zhu-Rongji) as main effects revealed a significant interaction between Judgment and Participant, $F(1, 13) = 6.533$, $p < .02$, suggesting divergent activation in VMPFC linked to the dissociation of self- and Zhu-Rongji-judgments between the two participant groups. Post hoc analysis confirmed that VMPFC signal intensity was significantly larger to self- than Zhu-Rongji-judgments for non-religious participants ($t = 6.470$, $p < .001$), but did not differ between the two judgments for Christians ($t = 0.144$, $p = .888$, Figure 1B–D), indicating that Christian participants did not utilize VMPFC to differentiate the self from others in the trait-judgment tasks.

To investigate whether any other brain areas were engaged in self-referential processing in Christian participants, we performed a whole-brain statistical parametric mapping (SPM) analysis to compare self- with Zhu-Rongji-judgments. This revealed significantly increased activation in DMPFC with extension into the anterior cingulate cortex (BA 9/32, centered at x/y/z = 8/27/35 and −6/32/24; $Z = 4.05$ and 3.37, both $ps < .01$, corrected for multiple comparison, Figure 2A–B). Increased activation was also observed in the posterior visual cortex in association with self-judgments (BA 18, x/y/z = −2/−73/15; $Z = 3.69$, $p < .01$, Figure 2C). Similar analyses carried out on the fMRI data from non-religious participants identified activation only in VMPFC associated with self-judgments (BA 10/32, x/y/z = 2/53/7; $Z = 4.28$, $p < .01$, Figure 2D–E), consistent with the results of the ROI-based analysis. The results for the non-religious participants replicated the previous findings on the neural substrates of self-referential processing in personal trait-judgment tasks (D'argembeau et al., 2005; Heatherton et al., 2006; Kelley et al., 2002; Lieberman et al., 2004; Macrae et al., 2004; Moran et al., 2006; Zhu et al., 2007).

Signal intensity was also calculated from DMPFC and subjected to an ANOVA with Participant and Judgment as main effects (Figure 2F). There was a reliable interaction of Judgment and Participant, $F(1, 13) = 9.735$, $p < .005$. Post hoc analysis confirmed that DMPFC signal intensity was larger to self- than to Zhu-Rongji-judgment for Christians ($t = 5.303$, $p < .001$) but did not differ between the two judgments for non-religious participants ($t = 0.127$, $p = .901$). To further validate the distinct patterns of DMPFC and VMPFC activations related to self-referential processing in the two groups, the signal intensity in these brain areas was subjected to ANOVAs with main effects of Participant (non-religious vs. Christian participants), Judgment (self- vs. Zhu-Rongji-judgment), and Location (DMPFC vs. VMPFC). This revealed a highly significant three-way interaction of Participant × Judgment × Location, $F(1, 13) = 16.916$, $p < .001$, indicating stronger engagement of VMPFC than DMPFC for self-referential processing for non-religious participants but stronger engagement of DMPFC than VMPFC for self-referential processing for Christian participants.

TABLE 2
Corrected recognition scores (%) and standard deviations (in parentheses) in the recognition memory test

| Group | Self | Sakyamuni | Jesus | Zhu-Rongji | Font |
|---|---|---|---|---|---|
| Non-religious participants | 43.4* (10.4) | 27.7 (12.7) | 31.1 (15.1) | 32.2 (12.9) | 9.29 (12.4) |
| Christian participants | 48.3* (20.3) | 32.5 (18.4) | 37.0 (17.9) | 34.9 (17.4) | 13.6 (10.0) |

Note: *The recognition scores were higher for the traits related to the self than to others.

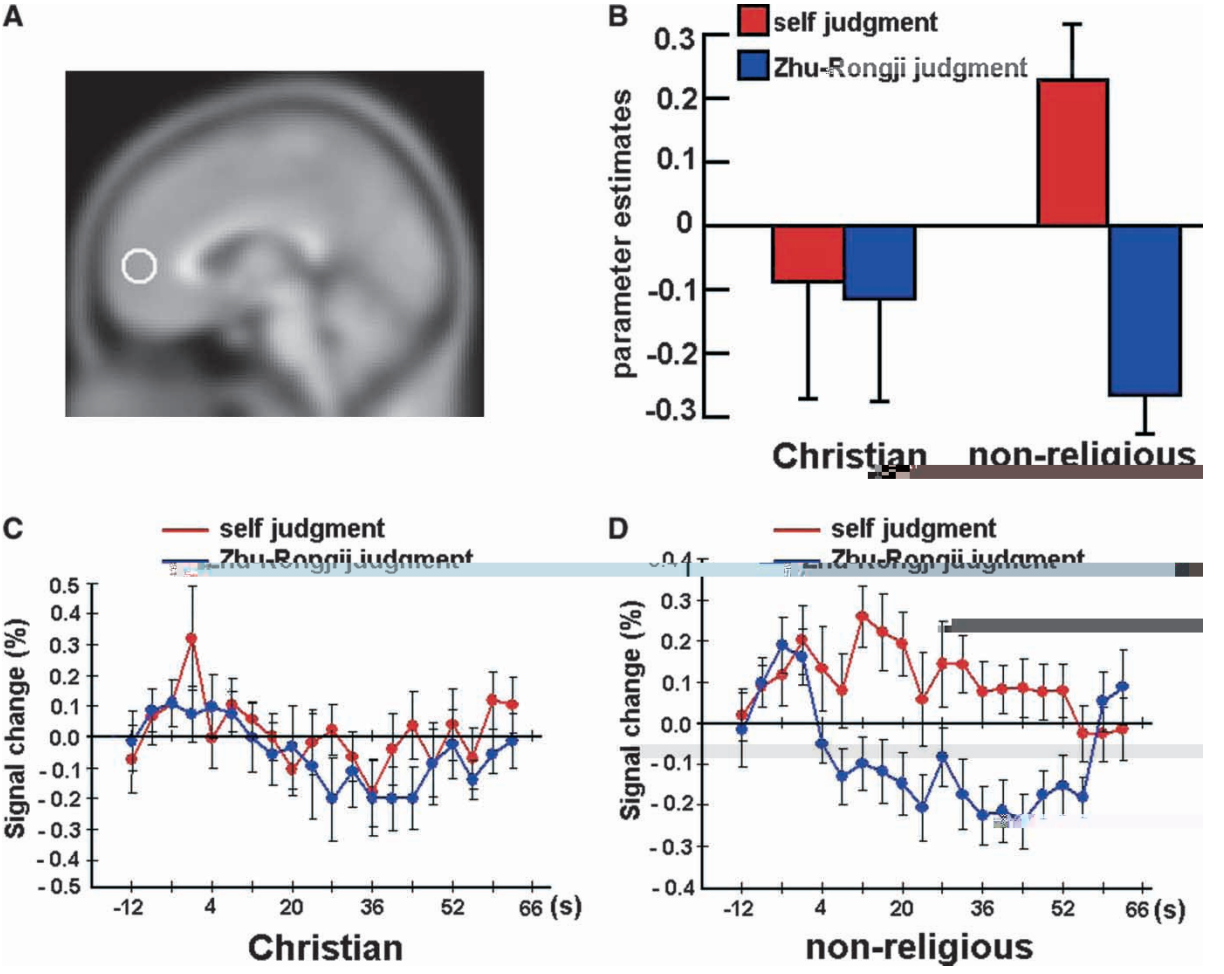


**Figure 1.** fMRI results of the ROI analysis of self-related activity in the VMPFC. (A) illustrates the ROI on the MNI model of the brain that was defined using an independent set of fMRI data (16). The ROI is defined as a sphere with a radius of 3 mm centered at 8/55/6 (BA 10). (B) shows the parameter estimates of signal intensity in the VMPFC ROI linked to self- and Zhu-Rongji-judgments in non-religious and Christian participants. (C) and (D) show the time course of percent signal changes in the VMPFC ROI associated with self- and Zhu-Rongji-judgments in non-religious and Christian participants, respectively. The signal change here was calculated relative to the null condition. Paired t-tests indicate that the signal change in VMPFC was significantly larger in association with self- than Zhu-Rongji-judgments for non-religious participants, $t(13) = 4.270$, $p < .001$, but not for Christian participants, $t(13) = 0.633$, $p = .538$.

We utilized a standard bootstrapping procedure (Davison & Hinkley, 1997) to further illustrate the distinct patterns of the population mean of VMPFC and DMPFC activities in each participant group. The signal intensities related to self- and Zhu-Rongji-judgments were dissociated along the vertical (y) axes showing VMPFC activity (Figure 3A) for non-religious participants whereas along the horizontal (x) axes showing DMPFC activity for Christians. The differential activities between self- and Zhu-Rongji-judgments showed clear separation between non-religious and Christian participants (Figure 3B), the differential activity was larger than zero in VMPFC for non-religious participants while it was larger than zero in DMPFC for Christians. As previous neuroimaging studies of self-referential processing did not report whether Christian participants were recruited, it is unclear how the involvement of Christian participants may affect the VMPFC and DMPFC activities that detach the self from others. We assessed this by comparing the difference in VMPFC and DMPFC activities, using t-tests, between self- and Zhu-Rongji-judgments in a group of fourteen participants who were selected randomly from non-religious and Christian participants. The t-values were plotted as a function of the number of Christian participants. As can be seen in Figure 3C and 3D, the more Christian participants

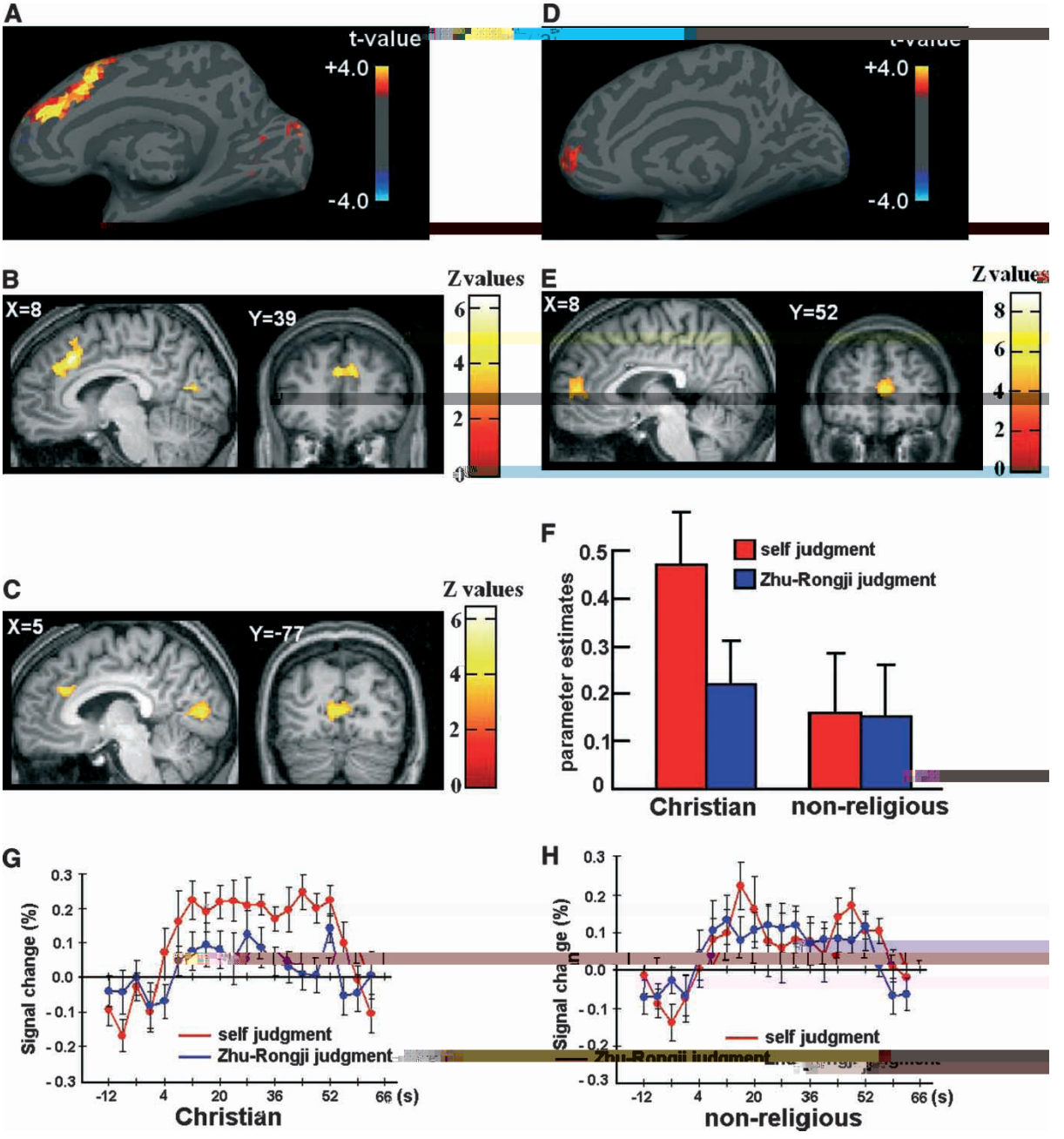


**Figure 2.** Brain activations related to self- and Zhu-Rongji-judgments in Christian and non-religious participants. (A) illustrates increased brain activations associated with self-judgment relative to Zhu-Rongji-judgment on an inflated brain of a representative Christian participant. (B) and (C) show Christian participants' fMRI results of the random effect analysis on a normalized brain. Brain activations associated with self-judgment relative to Zhu-Rongji-judgments were identified in DMPFC (B) and the visual cortex along the calcarine sulcus (C). (D) and (E) show increased brain activations associated with self-judgment relative to Zhu-Rongji-judgment on an inflated brain of a representative non-religious participant and the results of random effect analysis on a normalized brain, respectively. Brain activation was observed only in VMPFC in non-religious participants. (F) shows the parameter estimates of signal intensity in the DMPFC ROI linked to self-judgment and Zhu-Rongji-judgment in non-religious and Christian participants. (G) and (H) show the time course of percent signal changes in the DMPFC ROI associated with self- and Zhu-Rongji-judgments in non-religious and Christian participants, respectively. Paired t-tests indicate that the signal change in DMPFC was significantly larger in associated with self- than Zhu-Rongji-judgments for Christian participants, $t(13) = 3.376$, $p < .005$, but not for non-religious participants, $t(13) = 0.129$, $p = .900$.

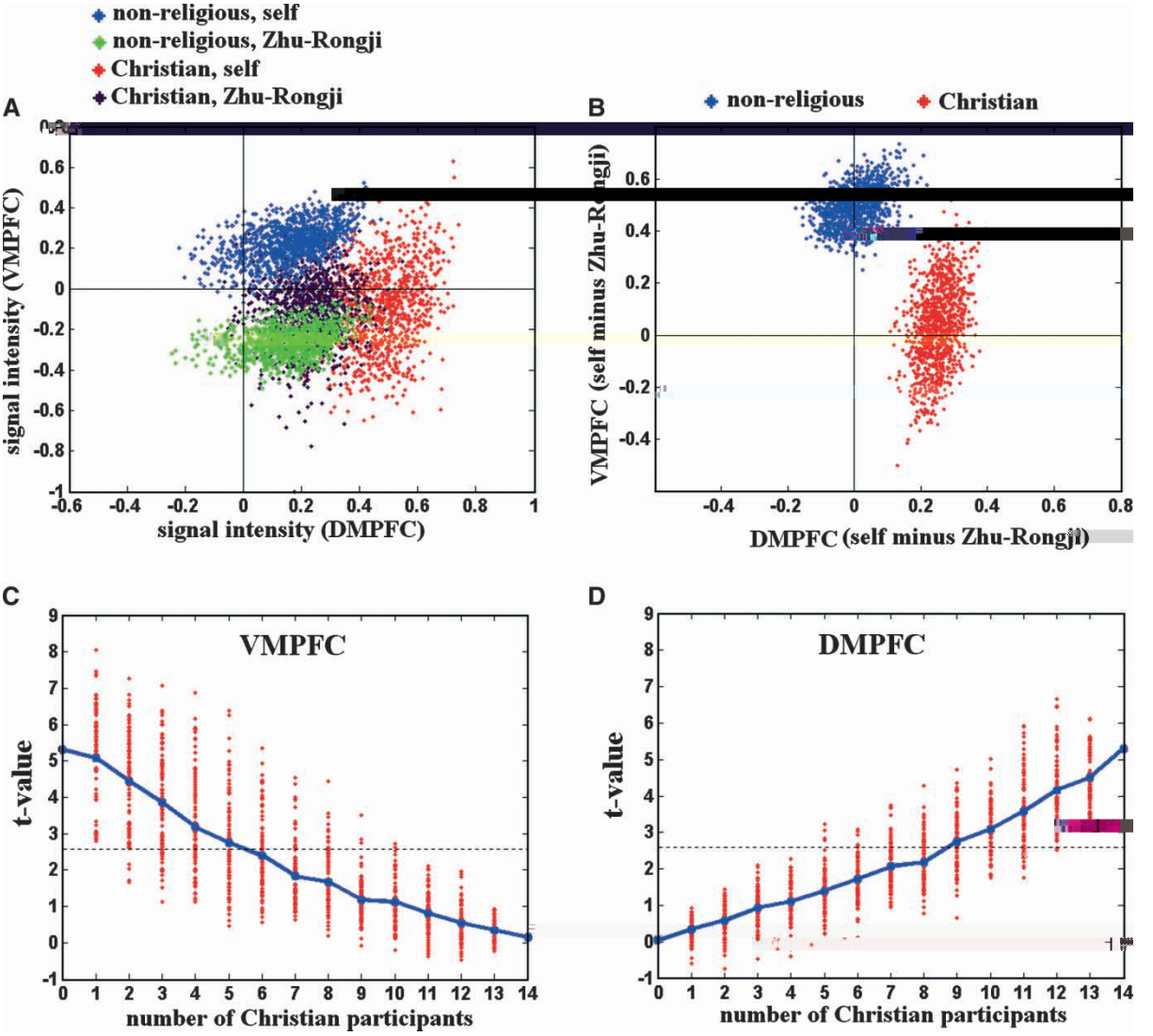


**Figure 3.** Dissociation of self- and Zhu-Rongji-judgments in VMPFC and DMPFC. (A) The mean signal intensity, related to self- and Zhu-Rongji-judgments, of the bootstrapped sample was plotted as one of the points (x, y) with the horizontal (x) and vertical (y) axes showing the mean signal intensity in DMPFC and VMPFC, respectively. The bootstrapped sample means of non-religious participants are separated along the vertical axes showing the VMPFC activity. The bootstrapped sample means of Christian participants are separated along the horizontal axes showing the DMPFC activity. (B) The neural activity that distinguished between self- and Zhu-Rongji-judgments (i.e., self-judgment minus Zhu-Rongji-judgment) was plotted as one of the points (x, y) with the horizontal (x) and vertical (y) axes showing the mean differential signal intensity in DMPFC and VMPFC, respectively. The bootstrapped sample means of non-religious participants fall mostly to the upper quadrants, indicating larger activity linked to self- than Zhu-Rongji-judgments in the VMPFC. The bootstrapped sample means of Christian participants fall mostly to the right quadrants, indicating larger activity linked to self- than Zhu-Rongji-judgments in the DMPFC. (C) and (D) The t-values calculated by comparing the VMPFC and DMPFC activities associated with self- and Zhu-Rongji-judgments were plotted as a function of the number of Christian participants. The blue lines connected the bootstrapped sample means of the t-values ($n = 100$). The dashed lines indicate the threshold of t-values for a significance of $p < .01$ with a sample of 14 participants.

were included in t-tests, the smaller the t-values for the VMPFC activity but the greater the t-values for the DMPFC activity that differentiates between self- and Zhu-Rongji-judgments.

We also tested for the involvement of the frontal cortex in differentiating between self and religious leaders. The contrast of self- vs. Jesus- and Sakyamuni-judgments revealed activations in DMPFC for Christian participants (BA 9/32, centered at x/y/z = −4/33/29 and 0/36/24; $Z = 3.63$ and 4.61, both $ps < .01$, Figure 4), but in VMPFC for non-religious participants (BA 10/32, x/y/z = 0/49/12 and −8/45/7; $Z = 5.07$ and 5.22, both $ps < .01$). Judgments of others were also

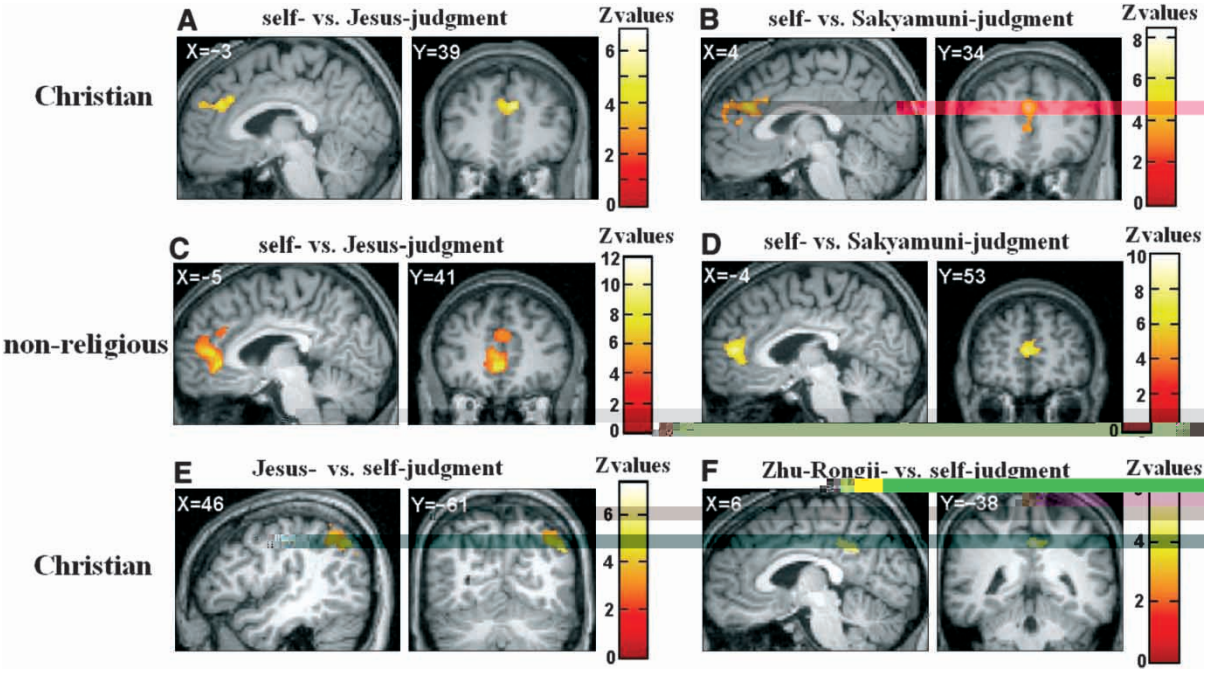


**Figure 4.** Brain activation linked to self-judgment relative to other-judgment shown in the random effect analysis. (A) and (B) show increased brain activation in DMPFC associated with self- relative to Jesus- and Sakyamuni-judgments in Christian participants. (C) and (D) show increased brain activation in VMPFC associated with self- relative to Jesus- and Sakyamuni-judgments in non-religious participants. (E) and (F) show deactivation associated with self- relative to Jesus- and Sakyamuni-judgments in Christian participants.

compared with self-judgments to investigate deactivation related to self-judgments. Christian participants exhibited significant deactivation in the right inferior parietal cortex relative to self- than Jesus-judgments (BA 39/40, x/y/z = 50/−64/36; $Z = 4.35$, $p < .01$) and deactivation in the precuneus relative to self- compared with Zhu-Rongji-judgments (BA 31, x/y/z = 14/−43/41; $Z = 3.81$, $p < .01$), whereas non-religious participants did not show any deactivation during self-judgment.

To inspect whether any brain areas were specifically involved in representation of the personal trait knowledge about religious leaders in Christian participants, the contrast of Jesus- vs. Zhu-Rongji-judgments was calculated but failed to reveal brain activation in both participant groups. Finally, we compared self-judgments with font-judgment to investigate whether semantic processing was different between the two participant groups. Similar increased activations were seen in the left inferior frontal gyrus, the superior MPFC, the left posterior middle temporal cortex, and the cerebellum in both groups (see Table 3). These replicate the previous observations (Craik et al., 1999; Kelley et al., 2002; Zhu et al., 2007) and suggest analogous neural substrates engaged in semantic processing in both participant groups in the trait-judgment tasks.

The rating results of how the factors (Jesus' judgment, friends' evaluation, the person's relationship with others, and the person's behavior) influence participants' judgment of the personality of the self or of others are shown in Figure 5. For non-religious participants, one's behavior was identified as the most important factor that determined their judgments. In contrast, for Christian participants, Jesus' evaluation was recognized as the most important factor that determined their judgments.[1] Such distinct results were confirmed by ANOVAs with Participant groups and Factors influencing personality judgment as main effects, which showed a highly significant interaction between Participant and Factor, $F(3, 24) = 79.992$, $p < .001$.

Finally, to quantify the relationship between subjective reports and the neural activity, we

[1] As well as the subjects involved in the fMRI study who were asked to perform the rating task we had asked two independent groups of Christian and non-religious subjects to rate the importance of factors that influence their judgment of personality. The results are similar to those from the subjects in the fMRI study, and thus are not reported here.

TABLE 3
Regions of significant increased activation shown in the comparison between self- and font-judgment tasks

| Condition/region | Voxel no. | BA | X | Y | Z | Z-value |
|---|---|---|---|---|---|---|
| Non-religious participants | | | | | | |
| Left inferior frontal gyrus | 1297 | 45/47 | −40 | 25 | −1 | 5.98 |
| Superior medial frontal cortex | 1972 | 9 | −4 | 45 | 44 | 5.21 |
| Left middle temporal gyrus | 654 | 21 | −61 | −33 | 3 | 4.32 |
| Cerebellum | 418 | 20 | −77 | −21 | 5.34 | |
| Christian participants | | | | | | |
| Left inferior frontal gyrus | 710 | 45/47 | −48 | 25 | 1 | 4.70 |
| Superior medial frontal cortex | 2149 | 9 | −10 | 52 | 36 | 4.73 |
| Left middle temporal gyrus | 138 | 21/37 | −53 | −61 | 17 | 4.00 |
| Cerebellum | 414 | 34 | −79 | −25 | 4.92 | |

Note: Voxels no. = number of voxels in a cluster. BA = Brodmann's area. $p < .01$ at the cluster level, corrected for multiple comparisons.

calculated the correlation between contrast values of parameter estimate of the BOLD signals in VMPFC and DMPFC (i.e., parameter estimate of BOLD signals related to self-judgment minus those related to Zhu-Rongji-judgment) and the rating scores shown in Figure 5. There was a significant positive correlation between the contrast value in DMPFC and the rating scores of the importance of Jesus' judgment ($r = .484$; $p = .014$) but a significant negative correlation between the contrast value in VMPFC and the rating scores of the importance of Jesus' judgment ($r = .407$; $p = .043$, Figure 6).

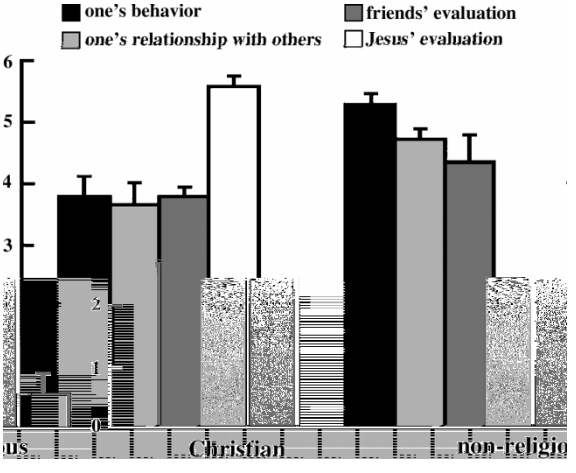


**Figure 5.** Rating scores of the factors that influenced participants' judgments of the personality of the self or of others obtained after the scanning procedure. Rating score of one's behavior was higher than that of other items for non-religious participants ($p < .02$), whereas rating score of Jesus' evaluation was higher than that of other items for Christian participants ($p < .001$). Error bars represent standard errors.

## DISCUSSION

Similar to previous research (Rogers et al., 1977), our behavioral data showed superior memory for self-referenced trait adjectives compared with those related to others in both non-religious and Christian participants, suggesting promotion of elaboration and organization of information related to the self regardless of religious beliefs. However, our brain-imaging results demonstrate reliable differences in the neural substrates involved in self-referential processing between the two participant groups. For non-religious participants VMPFC activity linked to other-judgments was decreased relative to the null condition in which participants passively viewed

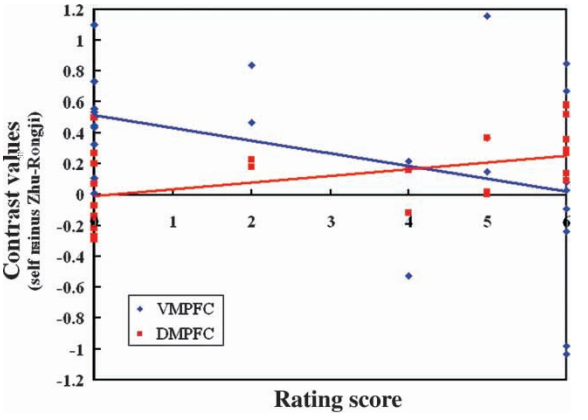


**Figure 6.** Correlation between contrast values of parameter estimates of the BOLD signals in VMPFC and DMPFC (i.e., parameter estimates of the BOLD signals related to self-judgment minus those related to Zhu-Rongji-judgment) and the rating scores of the importance of Jesus' judgment in subjective evaluation of a person's personality.

visual symbols. VMPFC activity associated with self-judgments, however, was associated with increases relative to the null condition, resulting in a clear distinction between the self and others in VMPFC. This is in agreement with previous findings (D'argembeau et al., 2005; Heatherton et al., 2006; Kelley et al., 2002; Lieberman et al., 2004; Macrae et al., 2004; Moran et al., 2006; Zhu et al., 2007). In contrast, for Christian participants VMPFC activity linked to both self- and other-judgments showed decreases from the null condition and could not distinguish self- from other-judgments. DMPFC activity linked to both self- and other-judgments was associated with increases from the baseline in both participant groups. However, DMPFC activity differentiated between self- and other-judgments in Christians but not in non-religious participants. The results from the ROI and bootstrapping analyses showed robust evidence for this double dissociation of VMPFC and DMPFC in self-referential processing in the two participant groups. These results indicate that Christian beliefs and practices not only weaken the neural representation of self-relevance in VMPFC when thinking about one's own personal traits, but also result in utilization of a different brain region, i.e., DMPFC, for self-referential processing.

The difference in MPFC activities underlying self-referential processing between Christian and non-religious participants could not arise simply from a disparity in semantic processing because our fMRI data identified a similar neural network for semantic processing in both participant groups. Nor could the distinct brain activations involved in self-referential processing arise from a unique representation of religious leaders in Christian participants since they failed to show any brain activation specifically related to the religious leaders. The results for Christian participants are distinctive because previous brain imaging studies, which did not take religious beliefs and practices into account, have linked self-referential processing of personal traits in the verbal domain mainly to VMPFC activity (D'argembeau et al., 2005; Heatherton et al., 2006; Kelley et al., 2002; Lieberman et al., 2004; Macrae et al., 2004; Moran et al., 2006; Zhu et al., 2007). Similarly, the current work observed increased activation in VMPFC related to self-judgment in non-religious participants. As VMPFC functions to label stimuli as self-referential or to represent stimulus self-relevance (Northoff & Bermpohl, 2004; Northoff et al., 2006), our fMRI results suggest that self-referential processing in non-religious participants was characterized by enhanced coding of the self-relatedness of stimuli. In contrast, VMPFC activity linked to self-judgment was surprisingly eliminated in Christian participants, indicating that the coding process of stimulus self-relatedness was weakened. This is the first neural consequence of Christian beliefs and practices on self-referential processing. We also noted that DMPFC plays an important role in reappraisal and evaluation of self-related stimuli (Northoff & Bermpohl, 2004; Northoff et al., 2006) and is engaged in inference and evaluation of others' mental states such as belief or intention (Gallagher et al., 2000; Grèzes, Frith, & Passingham, 2004; Han, Jiang, Humphreys, Zhou, & Cai, 2005; Mitchell, Banaji, & Macrae, 2005). It follows that the increased DMPFC activity linked to the self-referential processing in Christian participants indicates that religious beliefs and practices enhance the evaluative process of self-related stimuli mainly from God's perspective, and this represents the second neural consequence of Christian beliefs and practices on self-referential processing. Participants' behavioral performance and subjective reports were consistent with these neural consequences on self-referential processing. Relative to the non-religious participants, Christian participants had longer response times in making self-judgment and reported that their trait judgments were made mainly based on Jesus' judgment rather than their perspective of one's own behaviors. This is consistent with previous work (Spika, Shaver, & Kirpatrick, 1985) that proposed that the availability of thoughts of God influences whether believers make either secular or religious attribution for events. In contrast, non-religious participants emphasized behaviors related to the self when making personality judgment. In addition, the correlation analysis showed evidence that the emphasis of Jesus' judgment varied systematically with self-judgment related activity in DMPFC and VMPFC in reverse patterns, indicating different roles of these brain areas in mediating subjective evaluation of a person's personality.

Christian participants might also have to monitor the conflict between judgments from God's perspective and from their own perspective, resulting in activation of the anterior cingulate cortex close to DMPFC, which has been shown to be engaged in attention and conflict monitoring (Northoff & Bermpohl, 2004). Both

the fMRI and behavioral results are consistent with the spiritual request for denial of the self (in Christianity) and with the emphasis on how the self is judged from God's perspective. It appears that religious beliefs and practices result in different social behaviors as well as the neural correlates of the social cognition (e.g., self-referential processing here) related to those behaviors.

Self-referential processing in Christian participants was also characterized by the activation of the visual cortex along the calcarine sulcus. Such visual activation was not seen in non-religious participants, excluding the possibility that different visual features between the stimuli used in the self- and other-judgment tasks induced the visual activation. Since visual imagery can produce activation in the primary visual cortex and the occipital association cortex in the absence of visual stimuli (D'Esposito et al., 1997; Kosslyn et al., 1999), it is possible that the enhanced visual activity observed here was associated with mental imagery of self- or religion-related images when Christian participants performed the self-judgment task.

Self-referential processing was also different between the two participant groups in that Christians showed deactivation in the right inferior parietal cortex and the precuneus. The right inferior parietal cortex is engaged in self–other distinction during self-recognition (Uddin, Molnar-Szakacs, Zaidel, & Iacoboni, 2006). The precuneus is likewise correlated with retrieval of remembered episodes (Lou et al., 2004), assigning self- vs. other-perspectives (Vogeley et al., 2004), and experiential self-reflection (Johnson et al., 2006), possibly through the involvement of mental-imagery strategies (Cavanna & Trimble, 2006). If Christian participants mainly took God's perspective to evaluate self-related stimuli, as indexed by the enhanced DPMFC activity and subjective reports, then it is reasonable to assume that, relative to non-religious participants, religious beliefs in Christians promote inhibition of other aspects of self-related processing (such as retrieval from episodic memory and self-reflection based on experience), at least when compared with the processing referential to religious and government leaders. This assumption is consistent with the findings of behavior studies that the feeling of the self causing an action could be inhibited by subliminal priming of God among believers (Dijksterhuis, Preston, Wegner, & Arts, in press). The hypothesis of inhibition of other aspects of self-related processing is supported by the absence of VMPFC activity in Christian participants, despite this activity being linked to the labeling of stimulus self-relevance in non-religious participants.

In summary, although previous neuroimaging studies have examined the neural correlates of religious experience (Azari et al., 2001), we provide the first piece of neuroscientific evidence for the differences in the functional anatomy of social cognition (i.e., self-referential processing) between Christian and non-religious participants. In accordance with the recent study that showed evidence for differential neural structures of self-representation between Western and Chinese individuals (Zhu et al., 2007), the current findings provide further evidence for the dynamic and culture-sensitive characteristics of the neural mechanisms underlying self-referential processing. A religious culture (e.g., Christianity) that repudiates the distinctness of the self but underscores the evaluative process of the self by God scores thquari683acnsiti6848.4resemphas(the)-izidualial665ve

Burns, C. (2003). ''Soul-less'' Christianity and the Buddhist empirical self: Buddhist–Christian Convergence? Buddhist–Christian Studies, 23, 87–100.

Cavanna, A. E., & Trimble, M. R. (2006). The precuneus: A review of its functional anatomy and behavioural correlates. Brain, 129, 564–583.

Ching, J. (1984). Paradigms of the self in Buddhism and Christianity. Buddhist–Christian Studies, 4, 31–50.

Craik, F. I. M., Moroz, T. M., Moscovitch, M., Stuss, D. T., Winocur, G., Tulving, E., et al. (1999). In search of the self: A positron emission tomography study. Psychological Science, 10, 26–34.

D'argembeau, A., Collette, F., Van der Linden, M., Laureys, S., Del Fiore, G., Degueldre, C., et al. (2005). Self-referential reflective activity and its relationship with rest: A PET study. NeuroImage, 25, 616–624.

Dale, A. M., Fischl, B., & Sereno, M. I. (1999). Cortical surface-based analysis. I. Segmentation and surface reconstruction. NeuroImage, 9, 179–194.

Davison, A. C., & Hinkley, D. V. (1997). Bootstrap methods and their application. New York: Cambridge University Press.

D'Esposito, M., Detre, J. A., Aguirre, G. K., Stallcup, M., Alsop, D. C., Tippet, L. J., et al. (1997). A functional MRI study of mental image generation. Neuropsychologia, 35, 725–730.

Dijksterhuis, A., Preston, J., Wegner, D. M., & Arts, H. (in press). Effects of subliminal priming of self and God on self-attribution of authorship for events. Journal of Experimental Social Psychology.

Fischl, B., Sereno, M. I., & Dale, A. M. (1999). Cortical surface-based analysis. II: Inflation, flattening, and a surface-based coordinate system. NeuroImage, 9, 195–207.

Fossati, P., Hevenor, S. J., Graham, S. J., Grady, C., Keightley, M. L., Craik, F., et al. (2003). In search of the emotional self: An fMRI study using positive and negative emotional words. American Journal Psychiatry, 160, 1938–1945.

Gallagher, H. L., Happé, F., Brunswick, N., Fletcher, P. C., Frith, U., & Frith, C. D. (2000). Reading the mind in cartoons and stories: an fMRI study of ''theory of mind'' in verbal and nonverbal tasks. Neuropsychologia, 38, 11–21.

Grèzes, J., Frith, C. D., & Passingham, R. E. (2004). Inferring false beliefs from the actions of oneself and others: An fMRI study. NeuroImage, 21, 744–750.

Gusnard, D. A., Akbudak, E., Shulman, G. L., & Raichle, M. E. (2001). Medial prefrontal cortex and self-referential mental activity: Relation to a default mode of brain function. Proceeding of National Academy of Sciences USA, 98, 4259–4264.

Han, S., Jiang, Y., Humphreys, G. W., Zhou, T., & Cai, P. (2005). Distinct neural substrates for the perception of real and virtual visual worlds. NeuroImage, 24, 928–935.

Heatherton, T. F., Wyland, C. L., Macrae, C. N., Demos, K. E., Denny, B. T., & Keley, W. M. (2006). Medial prefrontal activity differentiates self from close others. Social Cognitive Affective Neuroscience, 1, 18–25.

Johnson, M. K., Raye, C. L., Mitchell, K. J., Touryan, S. R., Green, E. J., & Holen-Hoeksema, S. (2006). Dissociating medial frontal and posterior cingulate activity during self-reflection. Social Cognitive Affective Neuroscience, 1, 56–64.

Johnson, S. C., Baxter, L. C., Wilder, L. S., Pipe, J. G., Heiserman, J. E., & Prigatano, G. P. (2006). Neural correlates of self-reflection. Brain, 125, 1808–1814.

Kelley, W. M., Macrae, C. N., Wyland, C. L., Caglar, S., Inati, S., & Heatherton, T. F. (2002). Finding the self? An event-related fMRI study. Journal of Cognitive Neuroscience, 14, 785–794.

Kosslyn, S. M., Pascual-Leone, A., Felician, O., Camposano, S., Keenan, J. P., Thompson, W. L., et al. (1999). The role of area 17 in visual imagery: convergent evidence from PET and rTMS. Science, 284, 167–170.

Lieberman, M. D., Jarcho, J. M., & Satpute, A. B. (2004). Evidence-based and intuition-based self-knowledge: An fMRI study. Journal of Personality and Social Psychology, 87, 421–435.

Lin, H. (2005). Religious wisdom of no-self. In Y. Wu, P. Lai, & W. Wang (Eds.), Dialogue between Buddhisms and Christianity (pp. 317–338). Beijing, China: Zhong Hua Book Company.

Liu, Y. (1990). Modern lexicon of Chinese frequently used word frequency. Beijing, China: Space Navigation Press.

Lou, H. C., Luber, B., Crupain, M., Keenan, J. P., Nwak, M., Kjaer, T. W., et al. (2004). Parietal cortex and representation of the mental self. Proceeding of National Academy of Sciences USA, 101, 6827–6832.

Macrae, C. N., Moran, J. M., Heatherton, T. F., Banfield, J. F., & Kelley, W. M. (2004). Medial prefrontal activity predicts memory for self. Cerebral Cortex, 14, 647–654.

Mitchell, J. P., Banaji, M. R., & Macrae, C. N. (2005). General and specific contributions of the medial prefrontal cortex to knowledge about mental states. NeuroImage, 28, 757–762.

Moran, J. M., Macrae, C. N., Heatherton, T. F., Wyland, C. L., & Kelley, W. M. (2006). Neuroanatomical evidence for distinct cognitive and affective components of self. Journal Cognitive Neuroscience, 18, 1586–1594.

Northoff, G., & Bermpohl, F. (2004). Cortical midline structures and the self. Trends in Cognitive Science, 8, 102–107.

Northoff, G., Heinzel, A., de Greck, M., Bermpohl, F., Dobrowolny, H., & Panksepp, J. (2006). Self-referential processing in our brain—A meta-analysis of imaging studies on the self. NeuroImage, 31, 440–457.

Rogers, T. B., Kuiper, N. A., & Kirker, W. S. (1977). Self-reference and the encoding of personal information. Journal of Personality and Social Psychology, 35, 677–688.

Spilka, B., Hood, R. W., Hunsberger, B., & Gorsuch, R. (2003). The psychology of religion: An empirical approach. New York: Guilford Press.

Spilka, B., Shaver, P., & Kirkpatrick, L. A. (1985). A general attribution theory for the psychology of

religion. Journal of the Scientific Study of Religion, 24, 1–20.

Talairach, J., & Tournoux, P. (1998). Co-planar stereotaxic atlas of the human brain. New York: Thieme.

Uddin, L. Q., Molnar-Szakacs, I., Zaidel, E., & Iacoboni, M. (2006). rTMS to the right inferior parietal lobule disrupts self–other discrimination. Social Cognitive Affective Neuroscience, 1, 65–71.

Vogeley, K., May, M., Ritzl, A., Falkai, P., Zilles, K., & Fink, G. R. (2004). Neural correlates of first-person perspective as one constituent of human self-consciousness. Journal of Cognitive Neuroscience, 16, 817–827.

Zhu, Y., Zhang, L., Fan, J., & Han, S. (2007). Neural basis of cultural influence on self representation. NeuroImage, 34, 1310–1317.

Zysset, S., Huber, O., Ferstl, E., & von Cramon, D. Y. (2002). The anterior frontomedian cortex and evaluative judgment: An fMRI study. NeuroImage, 15, 983–991.