

Pilot Study of the Effect of Religious Symbols on Brain Function: Association With Measures of Religiosity

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Religious symbols are used throughout the world to evoke specific meaning in adherents. However, it is unclear if the impact of symbols is based upon their meaning or the inherent effect of the visual symbols on the brain. There has never been a study that has assessed the impact of religious symbols, of both positive and negative emotional content, on the brain. In addition, it would also be important to correlate the neurophysiological effect of various religious symbols to specific measures of a person's perspective on religion. Using functional magnetic resonance imaging to study 20 healthy subjects from different religious backgrounds, we found that neural activation in the primary visual cortex was significantly suppressed in response to religious negative symbols compared with neutral and nonreligious negative symbols. No such deactivation was observed for religious positive symbols. Subjects' scores on the Quest scale, an index of religious and spiritual orientation and belief, correlated significantly with activity in the primary visual cortex for negative symbols, but not for positive symbols. In addition, scores on the Beliefs About God Assessment Form (BAGAF), that measures the adaptability of a person's religious beliefs, correlated significantly with activity in the amygdala and insula when observing religious symbols. These findings suggest an early stage visual mecha-

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nism underlying the interaction between processing of visual religious symbols and both spiritual quest and adaptive religious beliefs. In addition, the emotional nature of a person's beliefs appears to interact with the emotional perceptions of different symbols.

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An important element of religions is the visual symbols that represent various ideas, doctrines, and concepts that pertain to a particular religion. Much has been written about how various symbols affect the human psyche (Jung, 1958; Laughlin, McManus, & d'Aquili, 1990). Scholars have pointed out the fundamental importance of various symbols in terms of their theological meaning. However, no study has ever directly assessed the impact of specific symbols on the human brain. An important question is whether symbols derive their impact from the ideas and beliefs that they are attached to or whether specific types of symbols have some inherent impact on the brain. One might pose the question regarding the psychological and neurobiological impact of the symbol of the cross as the following:

Does the cross have an impact on the brain because we recognize that it represents the crucifixion of Jesus Christ, or is there something inherent about two lines crossing each other that gives the cross a particularly strong impact on the brain, regardless of the beliefs associated with it?

The basis for this question can be elaborated if one considers a large variety of religious symbols from around the world. There are many symbols that involve crosses or crossing patterns. In addition, there are many symbols that involve circles and stars. However, there are few if any symbols that incorporate a square. There would seem to be no particularly fundamental reason why a square should be less likely to be a religious symbol than a cross or a circle. Therefore, the question that might be asked again is whether there are specific types of symbols that impact the brain in stronger ways, perhaps at an early stage of visual processing, even before cognitive processes, and their associated beliefs, affect the experience. Alternatively, it could be that an individual's religious or spiritual beliefs actually affect the way the brain responds to various visual symbols.

Religious or spiritual belief is an inherent and unique feature of human nature that can be broadly defined as a quest to answer existential questions (Batson & Schoenrade, 1991a, 1991b; Batson & Stocks, 2004). As human beings, our belief systems, whether religious or nonreligious, shape our conceptions of the world and attitudes to life, and modulate our attention, cognition, and decisions (Brock & Balloun, 1967; Colzato, van den Wildenberg, & Hommel, 2008; Fry & Debats, 2011; Klauer, Musch, & Naumer, 2000; Seale, 2010;). From an evolutionary perspective, human brains may more closely resemble believing or rationalizing engines as opposed to rational machines (Boyer & Bergstrom, 2008; Cook, 2012). Studies have shown that people automatically take subjective experience as the reflection of reality, and only occasionally reconsider their beliefs even when the experience is distorted by their own biases (Gilbert, 2002; Gilbert & Gill, 2000). Furthermore, the positive or negative emotional perspective that an individual has about their religious beliefs (i.e., a loving God or hatred for those of other religions) likely contributes substantially to how their brain experiences reality and religion.

Of course, there is a significant influence of religious belief on cognition. For example, religious orientation has been shown to bias attention to complex visual stimuli, with Calvinists attending less to global features than atheists (Colzato, van den Wildenberg, & Hommel, 2008). Older adults' beliefs of a just world and future time perspectives also predict long-term survival (Fry & Debats, 2011). Although the biological basis of religious or spiritual belief and its relationship to mental health remain controversial, a number of empirical studies have consistently linked religious involvement and spirituality to less anxiety and depressive disorders as well as greater coping skills (Carone & Barone, 2001; Koenig & Larson, 2001; Mueller, Plevak, & Rummans, 2001; Berry, 2002; Çoruh et al., 2005; Yeung & Chan, 2007).

Again, there is the suggestion that there is an important link between religious beliefs and emotions. However, research to date has largely ignored the interaction between religion and the brain, and particularly religious symbols. For this reason, the neural mechanisms and pathways by which religious or spiritual beliefs can positively or negatively influence human cognition remain largely unknown.

Given the unique emotional salience of religious beliefs, we propose that religious symbols may interact with the brain on a primary level, and that religiosity may interact with the processing of negative and positive visual symbols differentially in the brain. This is an important point regarding the basis for this study. The visual system is among the best understood aspects of the brain and visual processing occurs at both an unconscious primary level and on a higher, cognitive level. Thus, the basis for this study was to try to determine the relationship between different levels of visual processing, religious symbols, and religious beliefs and attitudes, with the goal of determining if religious symbols do, in fact, interact with the brain on a primary level.

To explore these issues, we used blood oxygen level dependent (BOLD) functional magnetic resonance imaging (fMRI) and scanned 20 healthy volunteers with a range of religious backgrounds, including atheists, Christians, Hindus, and Jews, while viewing emotional

symbols with or without religious content as well as neutral symbols (see Figure 1). These symbols were selected from a group of 120 pretested figures based on ratings of religious or nonreligious significance and positive or negative emotional valence, respectively. Before the scan, subjects also completed the Beliefs About God Assessment Form (BAGAF) and the Quest Scale (see below). Briefly, the BAGAF provides a quantitative measure of whether individuals have an adaptive or maladaptive emotional perspective toward God (Johnson, 1992). The Quest scale provides a quantitative measure of “the degree to which their religion involves an open-ended and responsive dialogue with existential questions raised by the contradictions and tragedies of life” (Batson & Schoenrade, 1991a, 1991b). Subjects’ scores on the BAGAF and Quest Scale were used as an index of religious and spiritual orientation and belief. The BAGAF and Quest scores were then correlated with brain activity for each type of religious and nonreligious symbol.

Therefore, we undertook this pilot study to test the following questions and their respective hypotheses as well as to obtain data that can be hypothesis generating for future studies with larger sample sizes:

1. Does the brain process religious and non-religious symbols differently, particularly in the primary visual cortex? We hypoth-



Figure 1. Symbols used in the study. RPE = religious positive; RNE = religious negative; NRP = nonreligious positive; NRN = nonreligious negative; Neu = Neutral.

esize that religious symbols will activate the primary visual cortex in a more robust manner than nonreligious symbols.

2. How does the emotional experience of a religious symbol relate to brain changes, particularly when positive emotional symbols are compared with negative ones? We hypothesize that religious symbols with positive emotional content will activate the primary visual cortex to a greater degree and will also activate emotional areas of the brain such as the insula. We further suspect that religious symbols that evoke a negative emotional response will activate the amygdala, but will result in reduced activity in the visual cortex and insula.
3. How do measures of religious orientation, particularly with regard to emotional components, interact with the impact of religious symbols on brain function? We expect that those subjects who score high on the Quest scale (indicating an open ended approach to religious ideas and a resistance to more doctrinal approaches) will be less reactive to religious symbols. We further hypothesize that the BAGAF scale (the BAGAF indicates the degree of positive or negative emotional responses to religious ideas) will demonstrate that individuals with stronger negative emotional perspectives on religious ideas will have greater activations in the primary visual cortex, amygdala, and also the insula. The basis for this hypothesis is that those individuals with stronger negative emotional perspectives are more likely to have emotional reactions to both positive and negative religious symbols.

Method

Participants

Written informed consent was obtained for each subject before the study according to the Institutional Review Board approval from the University of Pennsylvania. Twenty healthy participants with different religious backgrounds (10 male/10 female, mean age 31 years, range 21–55 years, including 9 atheists, 7 Christians, 1 Hindu, and 3 Jews) completed this study. Inclusion criteria included that they were

healthy individuals with no active neurological or psychiatric disorders and have no prior history of transient ischemic attack, stroke, significant head trauma, structural brain lesions, diabetes mellitus, or atherosclerotic vascular disease. Of the patients, 16 were right-handed and 4 were left-handed. All subjects were screened initially by phone for neurologic and psychiatric conditions. Subjects also underwent a structured clinical interview and evaluation with a trained physician to exclude any significant psychiatric or medical conditions. Two patients were taking a statin medication for high cholesterol whereas the other patients were medication free. One patient reported a history of attention deficit disorder but was not taking any medications currently and two patients had a history of migraines treated symptomatically with over the counter medications.

The Quest Scale

Subjects completed the Quest Scale to measure religious and spiritual orientation and beliefs. This scale is a 12-item questionnaire based upon a distinct motivational construct of intrinsic and extrinsic orientation characterized by how much an individual is purposely asking questions about existential or spiritual questions (Batson & Schoenrade, 1991a, 1991b). Each item on the Quest Scale is scored on a Likert scale from 1–9, with 1 = *strongly disagree* and 9 = *strongly agree*. This scale may help evaluate whether this domain of religious beliefs, namely an openness and inquisitiveness regarding religious ideas, modulates the brain's response to different religious symbols. In particular, we have hypothesized that those individuals who are more open to religious ideas, will have less responsiveness in the emotional areas of the brain to various religious symbols. However, if there is no relationship between the Quest score and activation in the primary visual cortex related to religious symbols, the results would imply that an open or closed approach to religious beliefs does not contribute to the primary processing of religious symbols.

The BAGAF

The BAGAF (Johnson, 1992) development was based upon the *Diagnostic and Statistical Manual for Mental Disorders-Third Edition-*

Revised (DSM-III-R) description of a paranoid personality disorder (PPD) and designed to measure whether an individual has an adaptive or maladaptive perspective on God. The BAGAF is a self-administered, forced choice assessment. Each assessment item has two choices. The individual is asked to select the alternative closest to one's God-concept. All of the "A" choices represent components of a positive or adaptive God-concept. All of the "B" choices represent components of the paranoid personality disorder. For example, the following two statements demonstrate the positive or negative view of God: (a) God views people as basically good but misguided much of the time; (b) God views all persons as sinners who rebel against God.

The diagnostic criteria of the *DSM-III-Rs* paranoid personality disorder were used to help formulate the individual items of the BAGAF. This allows the assessor to examine in detail the individual's responses to see which symptoms of the paranoid personality are found in the individual's God-concept. It would seem that this is an excellent questionnaire to determine if a more negative emotional perspective on religion and God is correlated with a greater response to emotionally negative religious symbols. Thus, we have hypothesized that a more negative emotional or maladaptive perspective on religious beliefs as measured by the BAGAF would correlate with greater cerebral blood flow responses measured with fMRI in the emotional areas of the brain when viewing religious symbols, particularly those symbols that elicit negative emotions. On the other hand, the BAGAF scores should not be correlated with the impact of religious symbols on the primary visual cortex unless there is a direct ability of the emotional areas of the brain and the cortex to modulate the functioning of the primary visual cortex.

Visual Stimuli and Tasks

The visual stimuli included 25 symbols (see Figure 1) selected from a group of 120 symbols that were pretested on a different group of college students by rating each symbol as religious or nonreligious and emotionally positive or negative. For example, a dove was considered a religious symbol with positive emotional content whereas a picture of the devil was con-

sidered a religious symbol with a negative emotional content. A dollar sign was a nonreligious symbol with positive emotional content whereas a gun was a nonreligious symbol with negative emotional content. The five symbols that were rated as the most religious and positive, most religious and negative, least religious and positive, and least religious and negative were selected. Therefore, there were four different types of stimuli with five symbols in each type: religious negative (RNE), nonreligious negative (NRN), religious positive (RPE), and nonreligious positive (NRP). A group of five neutral symbols (Neu) consisting of geometric shapes such as a square was also included as the control symbols. This group helps to clarify that any changes observed with the religious or emotional aspects of the symbols are not simply related to visualizing the symbol. The neutral group was rated nearest the mean in both the religious and nonreligious as well as the emotional ratings.

The visual stimuli were projected onto the center of a screen at the back of the magnet's bore and participants viewed the stimuli through a mirror. The stimuli were shown in a random order. Each picture was shown for 2.5 s with an inter stimulus interval between 2.5–5 s. Subjects were asked to passively view the stimuli but not to evaluate the symbols while in the scanner. Subjects were also required to press a button when each symbol disappeared to ensure participants remained awake and were viewing the symbols the entire time. After the scanning session, they rated the symbols for their degree of religiosity and emotional content to ensure that they were perceived in a similar manner to the pretesting.

Imaging Data Acquisition

Functional imaging was conducted on a Siemens 3.0T Trio whole-body scanner (Siemens AG, Erlangen, Germany), using a standard Transmit/Receive 32 channel head coil. Functional images, which measure the BOLD signal, were acquired using a standard echo-planar imaging sequence (TR = 2,000 ms, TE = 30 ms, flip angle = 90°, 33 interleaved axial slices with 4 mm thickness, in-plane resolution = 3.44 mm × 3.44 mm). All participants completed three functional runs,

with each run lasting 7 min and 36 s (228 brain volumes). After the functional scans, high-resolution ($1 \times 1 \times 1 \text{ mm}^3$) T1-weighted anatomic images were obtained using three-dimensional MPRAGE.

Imaging Data Processing

Functional data processing and analysis were carried out with SPM5 (Wellcome Department of Cognitive Neurology, United Kingdom). For each subject, functional images were realigned to correct for head motion, coregistered with the anatomical image, and smoothed in space with a three-dimensional, 8 mm FWHM (Full Width at Half Maximum) Gaussian kernel. A voxel-wise general linear model (GLM) was then conducted on the smoothed data. Low frequency fluctuations were removed by a high-pass filter with a cut-off at 128 s.

Imaging Data Analysis

Statistical analysis of imaging data were conducted based on general linear modeling approach using event-related design with a standard hemodynamic response function (HRF). Contrasts were defined for each of the four emotional symbols compared with neutral symbols initially to assess the effect of the main category of symbols individually (RNE vs. Neu, RPE vs. Neu, NRN vs. Neu, NRP vs. Neu), as well as direct comparisons between religious and nonreligious negative stimuli to more specifically test our hypotheses (RNE vs. NRN, RPE vs. NRP). Finally, we compared RNE versus RPE and NRN versus NRP to evaluate more directly the effect of positive versus negative emotional content of the symbols. These individual contrast images were then normalized to a MNI (Montreal Neurological Institute) stan-

dard brain template and entered into group level random-effects analyses using one-sample *t* tests. To examine the relationships between regional brain activity and the BAGAF and Quest scales, we also conducted regression analyses at group-level by correlating the contrast images of each individual subject with his or her BAGAF and Quest scores, respectively. Areas of significant activation were identified at a threshold of uncorrected $p < .001$ at voxel level and whole brain corrected $p < .05$ at a cluster level that accounts for multiple comparisons within the imaging and subjective data. Region of interest (ROI) analyses were also conducted on the primary visual cortex (V1), the amygdala, the insula, and lateral occipital cortex (LOC). The ROIs of V1, amygdala, and insula were structurally defined from an automated anatomical-labeling ROI library (Tzourio-Mazoyer et al., 2002), whereas the LOC ROI was functionally defined from the clusters that were significantly activated by the contrasts between the symbols. Mean parameter estimates, which represented regional activation levels, were extracted out and correlated with the BAGAF and Quest total scores.

Results

Effect of Religious Symbols on the Visual Cortex

All subjects correctly responded to more than 99% of stimuli offset and no differences in RTs were observed between different types of symbols (see Table 1). In addition, the results from the current subjects with regard to their interpretation of the symbols as being positive or negative and religious or nonreligious were highly similar to the original cohort used for

Table 1
Mean and SDs of Reaction Times for Each Type of Symbols

Symbols	RPE	RNE	NRP	NRN	Neu
Reaction times (ms)	405 ± 109	408 ± 113	407 ± 129	403 ± 109	402 ± 123
Religious score	5.68 ± 2.07	5.30 ± 1.62	2.10 ± 1.00	2.72 ± 1.15	1.51 ± 0.36
Emotional score	7.08 ± 1.50	3.90 ± 0.91	7.09 ± 1.01	3.22 ± 0.55	5.34 ± 0.34

Note. In addition, for each type of symbol, the mean and SDs for the religious score (higher represents more religious) and for the emotional score (higher is more positive, lower is more negative with “5” representing a neutral emotion) are provided. RNE = religious negative; NRN = nonreligious negative; RPE = religious positive; NRP = nonreligious positive; Neu = neutral.

selecting the symbols (see Table 1). Specifically, the neutral symbols were rated the lowest in terms of religiosity and also almost exactly “5” that is the midpoint between positive and negative. Positive emotional symbols, religious or nonreligious were rated over “7” on the emotional score while negative emotional symbols were rated below “4.” Religious symbols were rated above “5” while the nonreligious symbols were rated below “3.” One symbol, the swastika, was rated 4.65 ± 3.25 for religiousness, and was possibly interpreted as religious or nonreligious by different subjects. However, it was rated the most negative emotionally of any of the symbols. The implication is that the symbols were generally accurate in depicting their intended type.

With regard to the fMRI data, all findings reported below were statistically significant. Of interest to the authors, our fMRI results reveal that religious negative symbols showed significant deactivations in multiple brain regions compared with neutral symbols. The deactivations associated with religious negative symbols occurred in the medial occipital areas (mainly in the striate cortex/V1; Figure 2A), and inferior parietal, temporal, and anterior cingulate cortex (see Table 2). By contrast, compared with neutral symbols, nonreligious negative symbols showed no deactivations, whereas significant deactivations were further confirmed by direct comparison between religious and nonreligious negative stimuli, suggesting that visual processing of negative religious stimuli was suppressed in these brain regions. No striate cortex activation differences were found between religious positive and the neutral stimuli, whereas significant striate cortex activation was found for religious compared with nonreligious positive stimuli (Figure 2B, Table 3). All religious and nonreligious symbols showed significant activation in the lateral occipital cortex (LOC) compared with neutral symbols (Figure 2A and B, Tables 2 and 3). Taken together, these results suggest that early stages of visual processing for religious stimuli was different for religious positive and religious negative symbols.

Comparisons Between RNE, NRN, and Neu Stimuli

As shown in Figure 2 and listed in Table 1, compared with neutral stimuli, both nonreli-

gious negative and religious negative stimuli showed significantly greater activation in the bilateral lateral occipital cortex. Activation in the lateral occipital cortex may reflect visual processing of more complex shapes and objects. However, only religious negative stimuli showed significantly less brain activation in multiple brain regions than the neutral stimuli, including the occipital, inferior parietal, temporal, and anterior cingulate cortex. No deactivation was found when comparing nonreligious negative stimuli to neutral stimuli. Of interest to the authors, less brain activation in the visual processing areas, anterior cingulate cortex, and insula were observed when comparing religious negative stimuli to nonreligious negative stimuli. These results suggest that processing of negative religious stimuli may be suppressed in the brain.

Comparisons Between RPE, NRP, and Neu Stimuli

As shown in Figure 2 and listed in Table 2, compared with neutral stimuli, both nonreligious and religious positive stimuli showed significantly greater activation in the bilateral lateral occipital cortex. The activation of the lateral occipital cortex may reflect visual processing of more complex shapes and objects. However, only nonreligious positive stimuli showed significantly less brain activation in the primary visual cortex and cuneus than the neutral stimuli. No deactivation was found when comparing religious positive stimuli to neutral stimuli. Consequently, significant brain activation in the primary visual cortex and cuneus were observed by comparing religious positive stimuli to nonreligious positive stimuli. These results suggest that processing of religious stimuli is different for positive and negative stimuli.

Comparisons Related to Emotional Content of Symbolic Stimuli

Compared with RPE, RNE showed significantly increased activation in the LOC and decreased activation in the medial occipital cortex (mainly V1, extending to the precuneus) and anterior cingulate cortex (these results are shown in Table 4 and Figure 3). Compared with NRP, NRN also showed significantly increased activation in the LOC (extending to fusiform), but no decreased

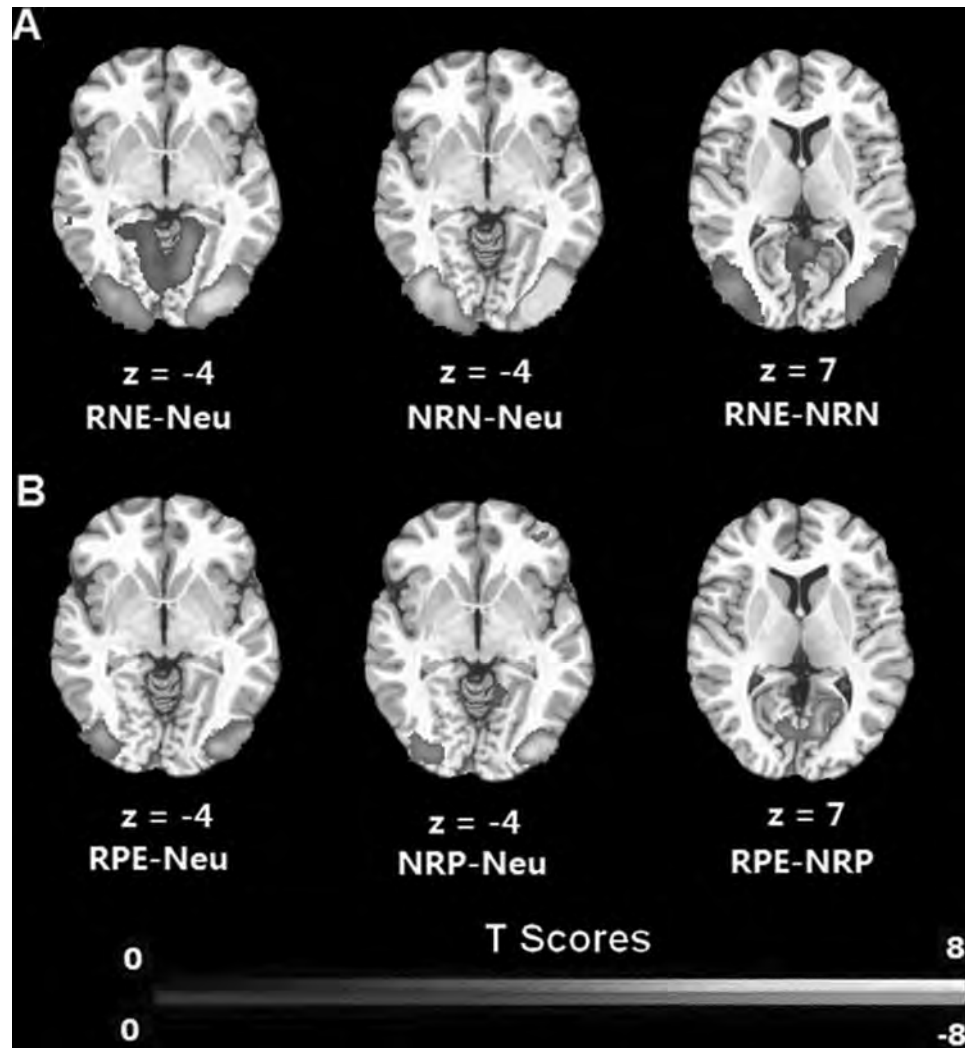


Figure 2. (A) Brain activation associated with the comparisons between negative symbols and neutral symbols. (B) Brain activation associated with the comparisons between positive symbols and neutral symbols. Threshold was set as voxel-wise uncorrected $p < .001$ and whole brain cluster corrected $p < .05$. The color version of this figure appears in the online article only.

activation in the medial occipital cortex and anterior cingulate cortex.

Correlations Between Quest Score and Brain Activation

To further explore the relationship between religious belief and early stage of visual processing, we correlated the Quest total scores with brain activation levels associated with each type of symbols. Using a structurally defined

region-of-interest (ROI), significant correlations were found between the Quest scores and V1 activity for both religious ($r = .75, p < .001$) and nonreligious negative symbols ($r = .71, p < .001$, see Figure 4A). However, no correlations were found between the Quest scores and V1 activity for both religious ($r = .18, p > .4$) and nonreligious positive symbols ($r = .32, p = .2$; see Figure 4B). Results from voxel-wise whole brain regression analysis further con-

Table 2
Brain Activation Differences Between Religious Negative (RNE), Nonreligious Negative (NRN), and Neutral (Neu) Stimuli

	Cluster size	MNI coordinates			Peak Z	Peak P (corrected)
		x	y	z		
RNE > Neu						
R. Lateral occipital	2,397	34	-84	-12	4.64	0.018
L. Lateral occipital	2,175	-38	-70	-14	4.17	0.018
NRN > Neu						
R. Lateral occipital	5,373	34	-82	-12	4.95	0.002
L. Lateral occipital	5,444	-38	-78	-16	4.65	0.002
R. Inferior frontal	57	34	-70	-24	3.48	0.012
L. Inferior frontal	32	56	36	10	3.42	0.014
Neu > NRN: No area survived the threshold						
RNE > NRN: No area survived the threshold						
Neu > RNE						
B. Occipital	6,684	10	-84	26	4.69	0.010
L. Inferior temporal	257	-50	-28	-26	4.11	0.011
L. Inferior parietal	172	-40	-34	36	3.87	0.016
R. Anterior cingulate	89	12	34	16	3.75	0.019
L. Middle frontal	49	-28	32	40	3.63	0.022
L. Middle temporal	136	-62	-40	10	3.62	0.022
L. Occipital	44	-36	-82	34	3.51	0.026
R. Occipital	138	52	-74	26	3.42	0.029
NRN > RNE						
B. Occipital	12,316	-42	-78	10	5.37	0.002
L. Precuneus/parietal	215	-10	-78	52	4.14	0.005
R. Anterior cingulate	89	12	24	34	4.06	0.005
L. Inferior temporal/amygdala	60	-28	2	-30	4.03	0.006
L. Posterior cingulate	98	-14	-46	36	3.79	0.008
L. Pallium	50	16	-26	-12	3.75	0.009
R. parahippocampal	36	-16	-4	0	3.74	0.009
L. Middle temporal	55	-62	-12	-20	3.68	0.009
R. Insula	106	34	24	0	3.66	0.010
R. temporal/amygdala	64	32	-2	-40	3.60	0.011
R. Inferior frontal	31	56	42	14	3.39	0.015

Note. Threshold was set as whole brain corrected $p < .05$.

firmed significant correlations of the Quest scores in V1 ($p < .001$, see Figure 5). These correlations did not change if we further stratified the subjects into atheistic (for RNE-Neu, $r = .82$, $p = .013$; for NRN-Neu, $r = .91$, $p = .002$) and believing groups (for RNE-Neu, $r = .65$, $p = .04$; for NRN-Neu, $r = .56$, $p = .09$; see Figure 6A). By contrast, no correlations were found between the Quest scores and activations in the LOC (for RNE-Neu, $r = .18$, $p > .4$; for NRN-Neu, $r = .08$, $p > .7$; see Figure 6B).

Correlations Between BAGAF and Brain Activation

To further evaluate the relationship between religious belief and emotional processing we

correlated the BAGAF scores to activity in several brain structures involved in emotions such as the amygdala and insula associated with different symbols. As shown in Figure 7, using structurally defined ROI, the BAGAF positively correlated with activations in the bilateral insula (left, $r = .47$, $p = .044$; right, $r = .51$, $p = .025$) and right amygdala ($r = .46$, $p = .05$) from the comparisons of religious negative stimuli to nonreligious negative stimuli (RNE vs. NRN). There was also a trend toward a positive correlation between BAGAF and anterior cingulate cortex activation ($r = .38$, $p = .1$) from the comparisons of RNE versus NRN stimuli. For the comparisons of RNE versus Neu, positive correlations were found between the BAGAF and activation in the bilateral fusiform gyrus

Table 3
Brain Activation Differences Between Religious Positive (RPE), Nonreligious Positive (NRP), and Neutral (Neu) Stimuli

	Cluster size	MNI coordinates			Peak Z	Peak P (uncorrected)
		x	y	z		
RPE > Neu						
L. Lateral occipital	591	−42	−84	0	4.09	<0.001
R. Lateral occipital	777	34	−88	4	4.05	<0.001
R. Fusiform	33	40	−46	−20	3.31	<0.001
NRP > Neu						
R. Lateral occipital	1,257	34	−88	−6	4.32	<0.001
L. Lateral occipital	758	−28	−94	4	3.74	<0.001
R. Inferior frontal	141	44	48	−8	3.52	<0.001
Neu > NRP						
B. Calcarine/cuneus	213	10	−80	22	3.69	<0.001
L. Precentral	49	−42	−28	66	3.57	<0.001
RPE > NRP						
B. Calcarine/cuneus	1,864	6	−78	16	4.95	0.028 ^a
L. Occipital	95	−50	−82	0	3.88	0.046 ^a
R. Occipital	166	36	−82	36	3.52	<0.001
NRP > RPE						
L. Occipital pole	285	−20	−108	12	3.91	<0.001
Neu > RPE: No area survived the threshold						

Note. Threshold was set as uncorrected $p < .001$.

^a FDR corrected $p < .05$.

(functionally defined ROI, left, $r = .69$, $p = .001$; right, $r = .76$, $p < .001$). These results suggest that the emotional adaptability of different beliefs is associated with how the brain perceives different emotional and religious symbols, particularly in the amygdala and insula.

Discussion

Our results reveal significant effects of religious symbols on both the primary visual areas and also on emotional areas of the brain. Furthermore, there were differences in neural activity during the processing of religious symbols and specifically as they relate to different emotional valence. Finally, it appears that different perspectives on religious beliefs, as measured by the BAGAF and Quest score are associated with differences in the brain's perception of religious symbols.

With regard to the first aim evaluating religious and nonreligious symbols, there were several interesting findings. Religious negative symbols showed decreased activity in the visual cortex compared with NRN and Neu symbols. Religious positive symbols showed greater vi-

sual cortex activity compared with NRP symbols but no difference in the visual cortex compared with Neu symbols. Previous cross-sectional and longitudinal studies have suggested that religious involvement and spirituality are associated with better mental health and well-being (Berry, 2002; Carone & Barone, 2001; Çoruh et al., 2005; Koenig & Larson, 2001; Mueller, Plevak & Rummans, 2001; Yeung & Chan, 2007). Clinical trials have also shown that religious interventions reduce depression and anxiety disorders and improve immune function for patients with religious backgrounds (Berry, 2002; Çoruh et al., 2005). It is believed that religious beliefs and practices reduce stress levels and enhance mental health by providing a sense of peace, increase social connections, and enhance social support (Koenig & Cohen, 2002). Our finding, that religiousness is associated with significantly reduced visual processing of negative stimuli, provides a plausible neural mechanism by which religiousness interacts with the processing of emotional stimuli.

With regard to the second aim, the current study provides some indication of the relationship between the positive and negative emotional elements of religious symbols and the

Table 4
Brain Activation Differences Between Positive and Negative Symbols for Nonreligious and Religious Stimuli

	Cluster size	MNI coordinates			Peak Z	Peak P (uncorrected)
		x	y	z		
NRP > NRN						
R. Medial prefrontal	70	18	46	46	3.81	<0.001
R. Inferior temporal	103	44	-28	-10	3.73	<0.001
NRN > NRP						
R. Lateral occipital/fusiform	3,862	36	-50	-24	5.05	0.004 ^a
		28	-92	0	4.85	0.004 ^a
L. Lateral occipital/fusiform	4,042	-20	-96	-14	4.74	0.004 ^a
		-32	-84	-2	4.39	0.004 ^a
RPE > RNE						
B. Calcarine/cuneus	5,689	10	-76	-2	4.6	0.018 ^a
L. Inferior temporal	115	-52	-28	-26	3.65	0.022 ^a
R. Anterior cingulate	135	8	42	0	3.56	0.025 ^a
L. Anterior cingulate	77	-2	28	14	3.49	0.027 ^a
L. Middle frontal	38	-38	44	18	3.48	0.027 ^a
RNE > RPE						
L. Lateral occipital/occipital pole	1,186	-16	-100	2	4.49	0.05 ^a
R. Lateral occipital occipital pole	1,204	-18	-104	0	4.26	0.05 ^a
L. Lateral occipital	83	-34	-66	-12	3.57	<0.001

Note. Threshold was set as uncorrected $p < .001$.

^a FDR corrected p value.

brain. In contrast to the religious content of the symbols, a direct comparison of positive versus negative emotional content in the symbols revealed higher activity in the LOC with nonreligious negative symbols compared with the positive symbols. However, when symbols were rated as highly religious, negative symbols had higher activity in the LOC, but decreased activity in V1 extending to the precuneus. Thus, negative versus positive emotional content was associated with changes in the LOC unless there was a religious content as well. When religious content was coupled with emotional content, the V1 region was affected.

Of interest to the authors, the location of the observed religious effect occurs mainly in the primary visual cortex, an area that is typically regarded as the beginning area of a feed-forward visual pathway. To that end, some studies have suggested that activation of V1 represents pure bottom-up salience of external stimuli (Melloni et al., 2012; Zhang et al., 2012) and occurs before any conscious influence such as a person's actual religious beliefs. However, the finding in the current study that the extent of reduced activity in the primary visual cortex correlated with individual variability in the

Quest scores challenges this view and is discussed in relation to our third aim.

With regard to our third aim, the findings suggest that prior beliefs and attitudes may, in fact, alter the primary visual cortex response to external stimuli. Our study shows that the more an individual's religion involves an open-ended, responsive dialogue with existential questions, the less activation will be suppressed in the primary visual cortex for both religious and nonreligious negative symbols compared with neutral symbols. These findings suggest that religious and spiritual quest modulates early visual processing in response to emotional symbols for both believers and atheists.

Furthermore, these results are consistent with other findings that increased religious and spiritual quest may reduce cognitive bias or prejudice, and further suggests a visual mechanism underlying this effect. In fact, some neuroscience studies have actually demonstrated significant effects of top-down attention on neural activity in the primary visual cortex (Martinez et al., 1999; Poghosyan & Ioannides, 2008). Such studies support the findings in this current study that V1 processing can be modified by processes supporting beliefs in higher parts of

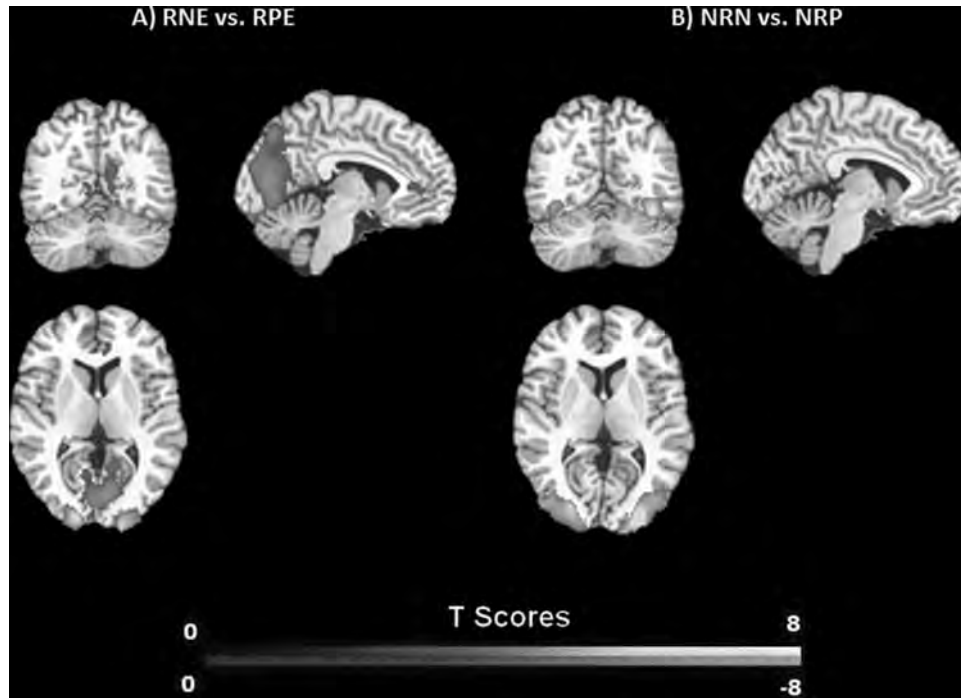


Figure 3. (A) Compared with religious positive stimuli (RPE), religious negative stimuli (RNE) showed significantly higher activation in the bilateral occipital pole/lateral occipital cortex and decreased activation in bilateral medial occipital cortex (mainly in V1, extending to the precuneus). Compared with nonreligious positive stimuli (NRP), nonreligious negative stimuli (NRN) showed significantly higher activation in the LOC (extending to fusiform), but no decreased activation in the medial occipital cortex. The color version of this figure appears in the online article only.

the cortex. A recent behavioral study comparing religious believers with atheists also showed that religious belief modified visual attention by reducing the global precedence in a visual global-local attention task (Colzato, van den Wildenberg, & Hommel, 2008). Therefore, a natural explanation for the observed correlations between religious and spiritual quest and the primary visual cortex activity may be via attentional modulation. However, although significant activations in the LOC were observed for all religious and nonreligious symbols compared with neutral symbols, no correlations were observed between Quest scores and activation levels in the bilateral LOC, areas that are modulated by top-down attention (Murray & Wojciulik, 2004). These findings suggest that attention cannot fully account for the correlations between V1 activity and religious quest because the areas modulated by attention are not activated. Thus, the findings implicate additional processes,

possibly preattentive, or perhaps a combination of religiosity paired with attention, that might affect the functioning of V1.

With regard to the effect symbols have on the brain and the emotional content of a person's beliefs, we found that the BAGAF positively correlated with activations in the bilateral insula and right amygdala when individuals were reviewing religious negative stimuli compared with nonreligious negative stimuli (RNE vs. NRN). A positive correlation indicates that those individuals who hold more negative and maladaptive beliefs about God are more likely to activate the insula and amygdala as hypothesized. It is well known that these structures are part of the network that supports negative emotional responses. Thus, the findings are consistent with the notion that individuals who hold negative emotional perspectives of God respond more strongly in the brain to emotionally neg-

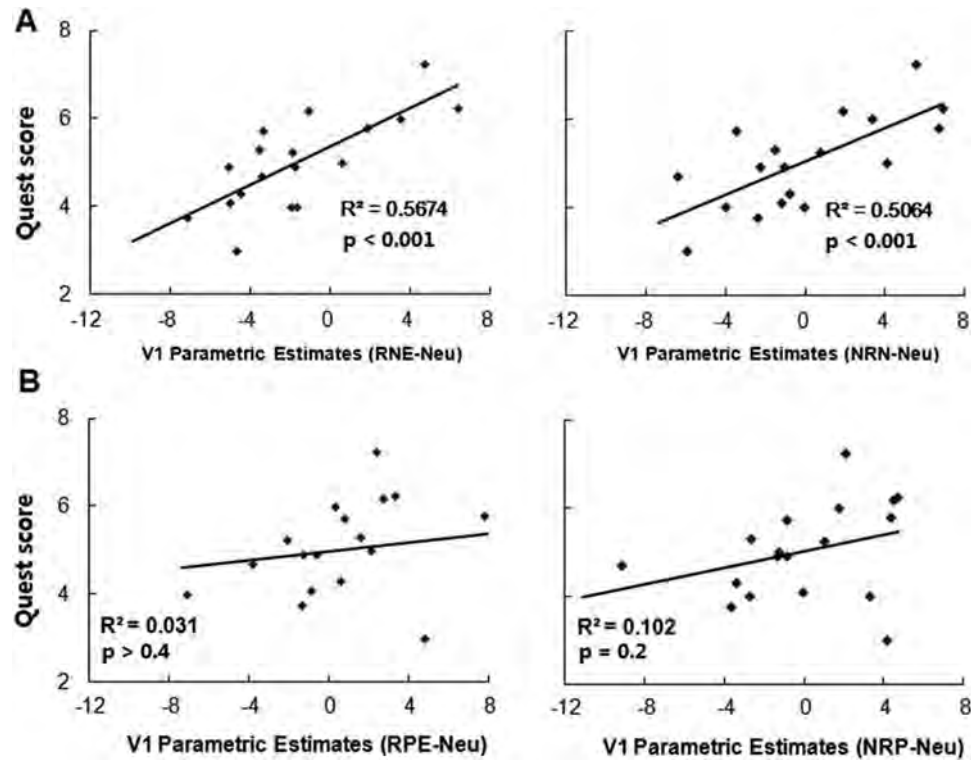


Figure 4. (A) Significant correlations were found between the Quest scores and brain activity in the V1 associated with negative symbols compared with neutral symbols. (B) No correlations were found between the Quest scores and brain activity in the V1 associated with positive symbols compared with neutral symbols.

ative religious stimuli. When the RNE symbols were compared with the neutral symbols, there were positive correlations found between the BAGAF and activation in the bilateral fusiform gyrus. It is interesting that this structure appears to be more related to the identification of visual objects. The positive correlation suggests that those individuals with a more negative emotional perspective on religion respond more robustly when identifying religious symbols. Although these positive correlations provide initial insight into how religious beliefs affect emotions and the perception of religious symbols, future studies will have to explore in more detail how an individual's prevailing religious beliefs affect the way in which their brain responds to external stimuli, particularly religious and emotional stimuli.

There are several important limitations of this study. First, the visual stimuli were chosen from a large sample of real-life symbols

based on subjective ratings of religious and emotional valence. Although the symbols initially chosen were purposely matched for overall content, the symbols are inherently different in certain physical features, including line orientation, spatial frequency, shape, and complexity. Thus, it is hard to determine how these feature differences contribute to the different visual activations found between different symbols. In addition, we had each participant evaluate the symbols to make sure that they continued to represent their specific type for this group as well. In general, the symbols were correctly assigned by subjects. However, we did not perform an additional analysis based upon a person's actual response to the symbols in part because of the limited sample size. Thus, it is possible that a symbol such as the swastika was viewed as a religious symbol by some and not others and this could have confounded the results. Stud-

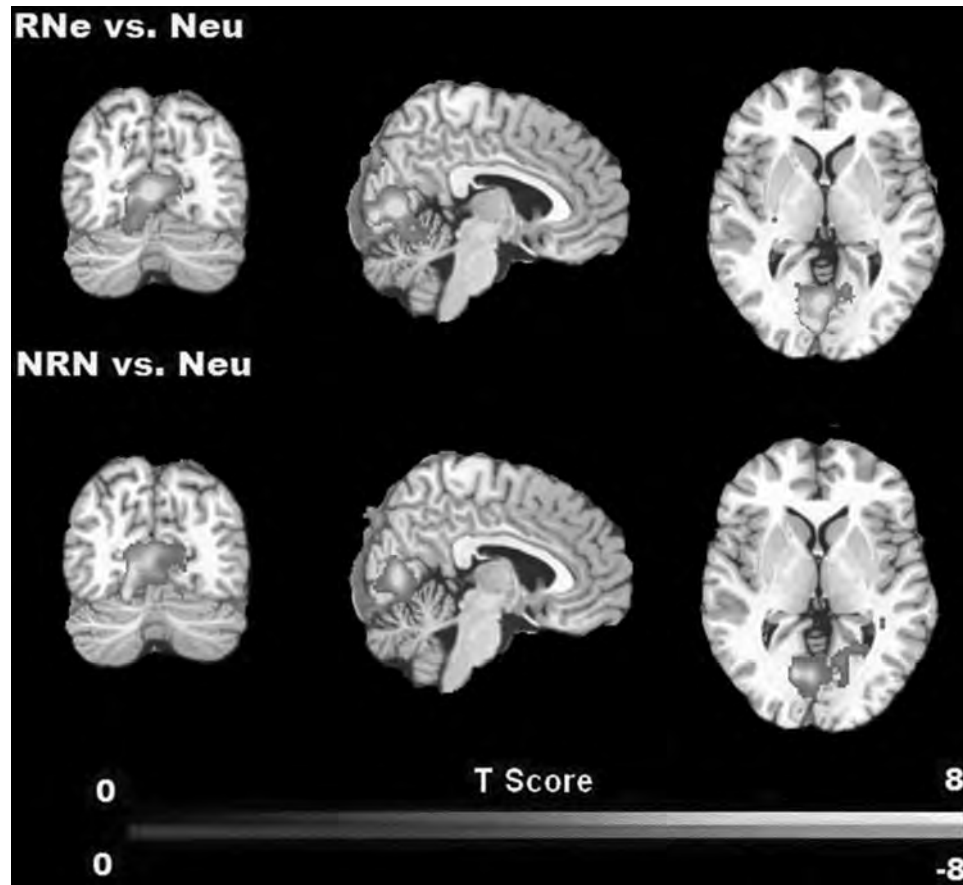


Figure 5. Brain region activations correlated with the Quest scores for religious negative and nonreligious negative symbols compared with neutral symbols. The threshold was set as whole brain cluster corrected at a $p < .05$. The color version of this figure appears in the online article only.

ies with more subjects and perhaps more symbols might be helpful to further assess these findings and help better evaluate the effects of symbols that are more ambiguous. The passive viewing task used in this study may not have been the optimal approach for evaluating brain function because subjects were asked to simply view the stimuli for a relative long duration of 2.5 s, only pressing a button when the stimuli disappears. It was also unclear whether subjects shifted their attention while viewing the stimuli. Further research with a better control of the confounding factors is necessary to provide a deeper insight into the modulation effect of high-level religious quest on low-level visual activity and

determine the contribution of attention to this effect. Finally, a larger sample size will be necessary to better assess a larger diversity of religious beliefs including atheists, as they pertain to the perception and response in the brain to different symbols. Having a larger sample size will also provide more power to assess the various interactions between religious and nonreligious elements and between emotional elements of the various symbols.

In conclusion, the current study is the first that we are aware of to investigate the neural mechanisms underlying visual processing of religious and nonreligious symbols in a cohort of healthy subjects with different religious backgrounds. We found that religious negative but

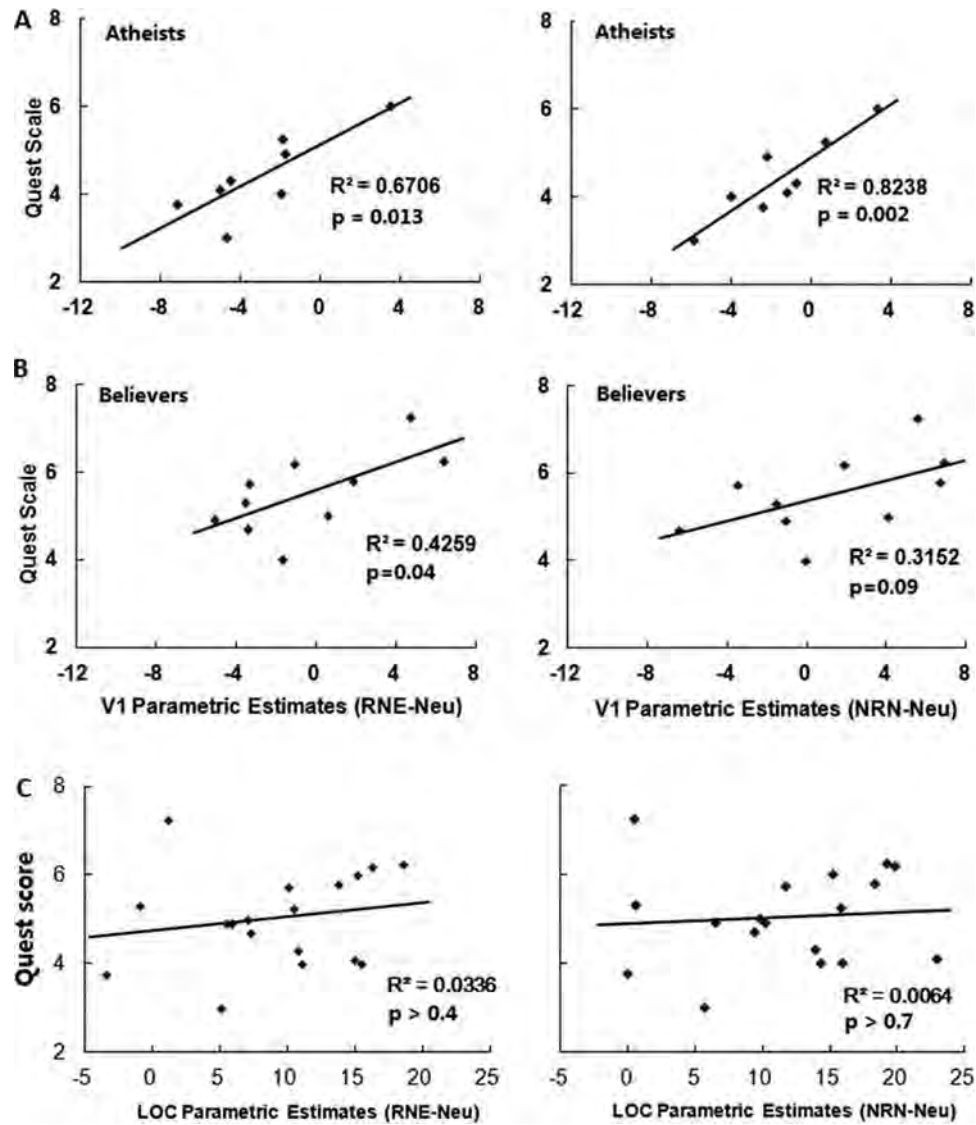


Figure 6. Significant correlations were found between the Quest score and V1 activity in response to religious and nonreligious negative symbols in both the atheistic (A) and believing subjects (B). No correlations were found between the Quest scores and brain activity in the LOC associated with negative symbols compared with neutral symbols (C).

not positive symbols are associated with decreased activation in the primary visual cortex. This decreased activation correlated with subjects' religious Quest scores. We also found that stronger negative emotional beliefs, as measured by the BAGAF, alter the way the brain perceives the symbols, particularly with regard to their emotional content. Overall, the findings

suggest that early visual processing of negative emotional stimuli is modulated by high-level religious and spiritual beliefs and orientation. Such modulation may also be mediated by activity in the amygdala, insula, and fusiform gyrus all of which are affected by the individual's prevailing beliefs. Further corroboration of the findings in the current article might lead to

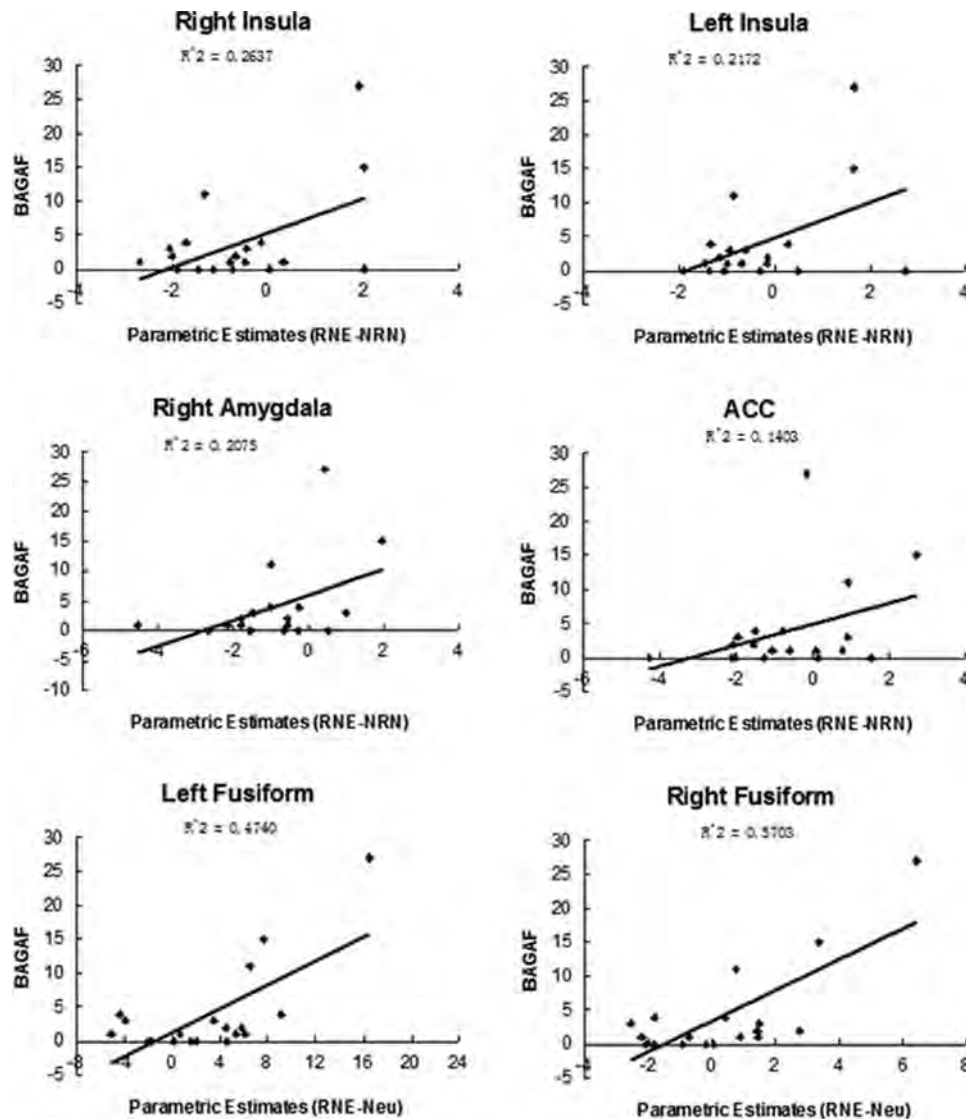


Figure 7. Brain activations correlated with BAGAF scores in the insula, right amygdala, left anterior cingulate, and fusiform gyrus. Threshold was set as whole brain cluster corrected $p < .05$.

the identification of a network of brain structures that are invoked by religious symbols in relation to emotional valence and religious beliefs.

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