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Research Article

Neural Markers of Religious Conviction

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ABSTRACT—*Many people derive peace of mind and purpose in life from their belief in God. For others, however, religion provides unsatisfying answers. Are there brain differences between believers and nonbelievers? Here we show that religious conviction is marked by reduced reactivity in the anterior cingulate cortex (ACC), a cortical system that is involved in the experience of anxiety and is important for self-regulation. In two studies, we recorded electroencephalographic neural reactivity in the ACC as participants completed a Stroop task. Results showed that stronger religious zeal and greater belief in God were associated with less firing of the ACC in response to error and with commission of fewer errors. These correlations remained strong even after we controlled for personality and cognitive ability. These results suggest that religious conviction provides a framework for understanding and acting within one's environment, thereby acting as a buffer against anxiety and minimizing the experience of error.*

In a May 2006 open letter to George W. Bush, Mahmoud Ahmadinejad, president of Iran, wrote that "whether we like it or not, the world is gravitating towards faith in the Almighty" (Ahmadinejad, 2006). Religion, he was convinced, is thriving. Worldwide, about 85% of people have at least some form of religious belief, with only 15% describing themselves as atheist, agnostic, or nonreligious (Zuckerman, 2005). Belief is especially widespread in the United States, with 94% of Americans believing in God, 82% saying that religion is at least fairly important to them, and 76% saying that the Bible is the actual or inspired word of God (Gallup Poll, 2008).

Religion, then, forms a major part of people's meaning systems around the globe (Silberman, 2005). But just as religion provides benefits—most notably, better mental and physical health (Seybold & Hill, 2001) and lower mortality rates (Powell, Shahabi, & Thoresen, 2003)—it also extracts costs: Although some varieties of religious practice can be tentative and open-minded (Batson, 1976), others can be dogmatic and abounding with fervent, even aggressive, religious certainties (Harris, 2004). Religion has contributed to violence and war throughout history and, in recent years, has factored in many interdenominational conflicts and terrorist attacks occurring in such places as Russia, India, Nigeria, and the United States ("In God's Name," 2007, p. 12). How is it that religion can bring about both peace of mind and zealous conviction? We suggest that religious conviction buffers against anxiety by providing relief from the experience of uncertainty and error, and in so doing, strengthening convictions and narrowing attention away from inconsistencies. We hypothesize that this muted response to uncertainty and error is evident neurophysiologically such that religious conviction is associated with reduced activity in the anterior cingulate cortex (ACC), a cortical system involved in a form of attention that serves to regulate both cognitive and emotional processing (Bush, Luu, & Posner, 2000).

THE NEUROPSYCHOLOGY OF ANXIETY

Regardless of the field of inquiry, whether that be artificial intelligence, neuroscience, or social or personality psychology, self-regulation is invariably characterized by feedback-loop models (e.g., Friston, 2002). These models establish autoregulation via three components whose central function is the minimization of prediction errors. These components include *standards* or *ideals*, which in vertebrates are cognitive maps that generate predictions (Gray & McNaughton, 2000); *comparators*, which scan current states to detect mismatches with standards, called prediction errors; and *effectors*, which are called upon to operate on the current state to minimize prediction error.

This type of feedback-loop model, so central to self-regulation, also plays a major role in the experience of anxiety. According to Gray and McNaughton's (2000) neuropsychological theory of anxiety, which is based on animal models, lesion research, and the pharmacological effects of classic and modern anxiolytic drugs such as Valium and Xanax, the detection

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of prediction errors, or state-standard mismatches, activates an "alarm system" that is experienced as anxiety. The types of mismatches that produce anxiety include states of uncertainty, simultaneous activation of conflicting goals, and erroneous responding.

In vertebrates, the septo-hippocampal system is of vital importance to these types of feedback loops and is considered a phylogenetically old system. Humans share this circuitry with other vertebrates, but also have a "cortical alarm bell" in the ACC (Gray & McNaughton, 2000, p. 137). This alarm has elaborate projections to and from the septo-hippocampal system, and they allow for abstract conceptual goals to be regulated in much the same way as simple, concrete goals. Neuroimaging, electrophysiological, and lesion studies suggest that the ACC is important for the types of inhibited responding characteristic of anxiety (Hajcak & Foti, 2008; Hajcak, McDonald, & Simons, 2003) and for the minimization of prediction errors (Ridderinkhof, Ulsperger, Crone, & Nieuwenhuis, 2004). The ACC, then, forms part of a general system for regulating and modifying behavior by signaling when control is needed, usually as a result of some anxiety-producing event such as the commission of an error (Holroyd & Coles, 2002), the detection of conflict (Yeung, Botvinick, & Cohen, 2004), or the experience of uncertainty (Critchley, Mathias, & Dolan, 2001; Hirsh & Inzlicht, 2008).

We suggest that religious conviction curbs ACC activity because conviction acts very much like an anxiolytic and buffers the affective consequences of errors and uncertainty. Some research indicates that religion reduces anxiety (Tapanya, Nicki, & Jarusawad, 1997; but see Shreve-Neiger & Edelstein, 2004). We suggest that it does so because religious convictions provide meaning systems that order the world by offering guides for action, while also fostering a type of thinking that constrains thought and perception away from discrepant or erroneous predictions.

XANAX OF THE PEOPLE

One of religion's primary functions may be to help people cope with existential uncertainty. In the words of St. Ambrose (ca. 390 AD), "amid the agitations of the world, the Church remains unmoved; the waves cannot shake her. While around her everything is in a horrible chaos, she offers to all the shipwrecked a tranquil port where they will find safety" (quoted in Durant, 1950, p. 79). Religion provides people with a meaning system that helps them navigate through and understand an infinitely complex and uncertain world (Peterson, 1999). It meets the fundamental need to comprehend the deepest problems of existence. Scholars of religion, from James (1902/2002) to Durkheim (1912/1954), have noted that religion imbues life with motivation, purpose, and meaning. As is the case with other sources of meaning, religion helps people make predictions about how to act, serving as a core schema that informs beliefs about the self, the world, and their interaction (Heine, Proulx, & Vohs, 2006). In particular, religion provides standards for behavior by specifying appropriate and inappropriate actions. In terms of feedback-loop models, religion imposes prescriptive beliefs that act as standards and guides for behavior (Silberman, 2005). These standards provide reasonably adequate frameworks for understanding and acting within one's environment, thereby reducing uncertainty and minimizing the experience of error. For example, when something unexpected occurs or when someone blunders, the belief that "it is God's will" can alleviate anxiety and provide peace of mind (Park, 2005). In short, religion serves as an explanation that can accommodate many of life's observations, thus providing adequate predictions for the future and reducing the anxiety associated with uncertainty.

These same anxiolytic effects explain why people turn to religion when they are threatened by or mired in uncertainty. The absence of a cognitive map providing clear standards and goals is uncomfortable and leads people to search for and assert belief systems that quell their anxiety by allowing for clearer goal pursuit (McGregor, Zanna, Holmes, & Spencer, 2001). Once a person identifies and pursues a compensatory belief system, such as religion, his or her attention becomes sharply focused on belief-relevant thoughts, such that inconsistent or discrepant thoughts are suppressed and not perceived (see Gable & Harmon-Jones, 2008). Threats to certainty and meaning, then, result not only in compensatory beliefs, but in compensatory beliefs that are zealous and conflict resistant. For example, contemporary social psychological research indicates that uncertainty threats can cause people to become more extreme in their opinions, so that they exaggerate their religious convictions and become more willing to support a war to defend those convictions (McGregor, Haji, Nash, & Teper, 2008). In fact, even nonbelievers bolster their personal convictions to near-religious levels in order to reduce uncertainty-related distress (McGregor et al., 2001). Thus, in terms of feedback-loop models, the standards and predictions provided by religious convictions are strong enough that they can resist any discrepant feedback that might alert the comparator system.

A complementary, albeit controversial, explanation for why religion would quell the self-regulatory alarm system is that religious conviction, like other firmly held convictions, represents a mode of thinking that is closed, certain, and structured (Webster & Kruglanski, 1994). According to this explanation, religion offers simple maps of meaning and attracts people who prefer simple, structured solutions to life's complexity and uncertainty (Jost, Glaser, Kruglanski, & Sulloway, 2003). Religious belief, then, may be characterized by a need for certainty, with a motivated denial of uncertainty. In terms of feedback-loop models, this explanation suggests that the standards and predictions provided by religion are inadequate and should, in fact, result in prediction errors; however, because religious beliefs are rigid, inconsistent information is reinterpreted in such a way that it becomes assimilated to preexisting convictions, further sustaining beliefs (Park, 2005). Religious belief, then, like political conservatism, may be characterized by a high need for

cognitive closure that results in people being unable to adapt to context and circumstance, an effect that can predict cortical brain activity (Amodio, Jost, Master, & Yee, 2007).

In summary, we suggest that religious conviction reduces the incidence of uncertainty, conflict, and error because it provides meaning systems that successfully accommodate experience, results in zealous goal pursuit that narrows attention away from discrepancy, or provides rigid predictions that assimilate inconsistent observations. Thus, we hypothesize that religious conviction acts like an anxiolytic, buffering precisely those states that are detected by the cortical alarm bell—the ACC.

OVERVIEW OF THE CURRENT STUDIES

Given our hypothesis relating conviction to reduced ACC activity, we conducted two studies examining the relationship between religious conviction and cortical brain activity. In both studies, we recorded electroencephalographs (EEGs) as participants completed a color-naming Stroop task. Regulatory ACC activity was indexed by an event-related potential—which reflects the summation of the postsynaptic potentials of a large ensemble of synchronously active neurons—called the error-related negativity (ERN). The ERN is a sharp negative voltage deflection that typically peaks within 50 to 100 ms postresponse and reflects the preconscious monitoring of error, conflict, and uncertainty localized to the ACC (Ridderinkhof et al., 2004). We measured the amplitude of each participant's ERN during the Stroop task and correlated these values with participants' self-reported religious zeal (Study 1) and self-reported belief in God (Study 2). In both studies, we also measured other psychological variables to control for their impact on the hypothesized correlation between religious conviction and ACC activity. We expected greater religious conviction to predict lower ERN amplitudes in both studies, even after controlling for important personality traits and cognitive capacities.

STUDY 1: RELIGIOUS ZEAL

Method

Participants

Twenty-eight right-handed participants (18 females, 10 males) from the University of Toronto Scarborough subject pool participated in Study 1 for course credit (mean age = 20.93 years, $SD = 3.94$). The participants in our sample came from a diverse set of religious backgrounds: 39% Christian, 21% Muslim, 14% Hindu, 11% Buddhist, and 15% other (including nonreligious).

Measures

Participants completed scales measuring their need for cognitive closure (Webster & Kruglanski, 1994; $M = 3.16$, $SD = 0.35$), behavioral inhibition and behavioral activation (Carver & White, 1994; Behavioral Inhibition Scale: $M = 3.58$, $SD = 0.54$; Behavioral Activation Scale: $M = 3.64$, $SD = 0.45$), and self-esteem (Rosenberg, 1965; $M = 3.78$, $SD = 0.52$). They also completed the Religious Zeal scale (McGregor et al., 2008), which assesses ardent religious conviction. Items on the latter scale included "I aspire to live and act according to my religious beliefs," "My religious beliefs are grounded in objective truth," and "I would support a war that defended my religious beliefs" ($M = 3.26$, $SD = 0.66$; Cronbach's $\alpha = .81$).

Participants completed a standard color-naming Stroop task, which consisted of a series of color words, each presented in a color that either matched (congruent) or mismatched (incongruent) the semantic meaning of the word. Participants were instructed to respond to each stimulus using a response box, pressing the colored button that corresponded to the font color of the stimulus word. On each trial, a fixation cross ("+") appeared for 500 ms, and then the stimulus word appeared for 200 ms; the maximum response window was 800 ms. Following one practice block, each participant completed five blocks, each containing 24 congruent and 12 incongruent trials.

Electrophysiological Recording and Processing

EEG was recorded from 32 Ag/AgCl sintered electrodes embedded in a stretch Lycra cap. Recordings were digitized at 512 Hz using ASA acquisition hardware (Advanced Neuro Technology B.V., Enschede, The Netherlands) with average-ear reference and forehead ground. EEG was corrected for vertical electro-oculogram artifacts and digitally filtered between 1 and 15 Hz. The average voltage occurring 400 to 200 ms before the key press was used for baseline correction. For each artifact-free trial, a 1,000-ms epoch of EEG signal locked on the button press was selected for averaging; this window started 200 ms before the response and ended 800 ms after the response. Event-related potentials for correct and incorrect trials were averaged across participants and grand-averaged within their respective conditions. The ERN was quantified as the mean minimum deflection between 50 ms before and 150 ms after response at the central midline electrode (Cz).

Results and Discussion

Results revealed that greater religious zeal was correlated with less ERN activity (more positive activity) following Stroop errors, $r(27) = .43$, $p_{rep} = .92$ (see Figs. 1a–1c). That is, greater religious zeal was associated with significantly less control-related neural activity after the commission of error. In contrast, neural activity following correct responses was not associated with religious zeal ($p_{rep} < .60$). Dipole source localization confirmed that the ERNs were generated in an area approximately consistent with the ACC (pre-auricular-nasion coordinates, in millimeters, were as follows: $x = 2.2$, $y = 1.5$, $z = 43.5$; dipole strength = 106.9 nAm; this source accounted for 97.8% of the variance of the signal; see Fig. 1d).

Table 1 lists all interitem correlations, and Table 2 shows the partial correlations between ERN amplitude and religious zeal, controlling for the other measured variables. The correlation

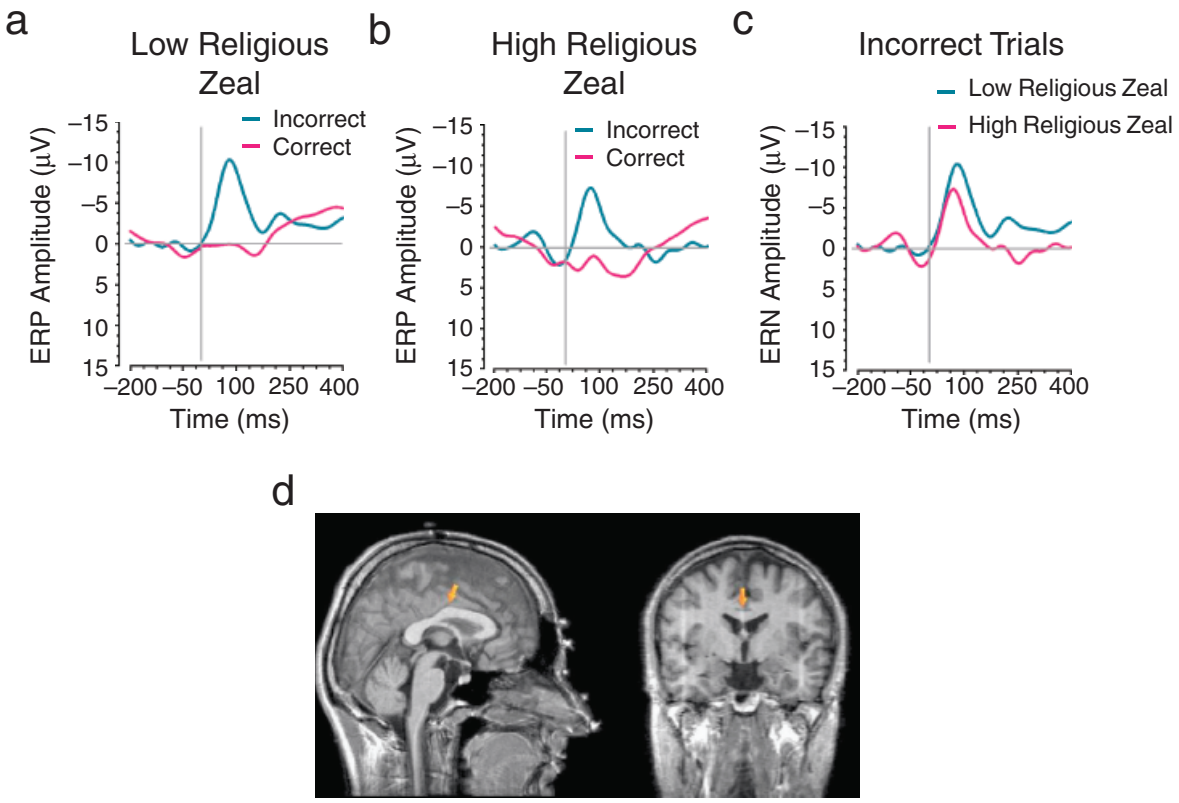

Fig. 1. The relation between religious zeal and anterior cingulate cortex activity: event-related potentials (ERPs) at electrode Cz for (a) participants low in religious zeal and (b) participants high in religious zeal, (c) error-related negativities (ERNs) at electrode Cz for people high and low in religious zeal, and (d) illustration of the generator for the ERN (in anterior cingulate cortex), as determined by source localization.

between the ERN and religious zeal did not diminish after we controlled for need for cognitive closure, self-esteem, behavioral inhibition, or behavioral activation (all rs $> .42$, all p_{rep}s $> .90$). These other variables, therefore, cannot explain the relation between the ERN and religious conviction. Results also indicated that greater religious zeal was correlated with greater accuracy on the incongruent trials: The more zealous participants were, the fewer errors they made, $r(27) = -.34$, $p_{rep} = .89$. In contrast, zeal was unrelated to errors on the congruent trials ($p_{rep} < .70$). This finding, along with the fact that need for cognitive closure did not account for the observed neural effect, suggests that religious conviction is not the result of some inflexible persistence of habitual response patterns. Rather, religious conviction appears to be associated with deliberate and

TABLE 1

Zero-Order Correlations Among Amplitude of the Error-Related Negativity (ERN), Religious Zeal, Stroop Incongruency, Stroop Errors, and the Personality Variables Assessed in Study 1

Measure	1	2	3	4	5	6	7
1. Cognitive closure							
2. Behavioral inhibition	.04						
3. Behavioral activation	−.06	−.06					
4. Self-esteem	−.11	−.64**	.10				
5. Stroop errors (incongruent trials)	.12	−.22	.11	.07			
6. Stroop incongruency (reaction time on incongruent trials minus reaction time on congruent trials)	−.01	.03	−.10	−.07	−.49**		
7. ERN amplitude	−.25	.11	−.23	−.22	.16	−.04	
8. Religious zeal	.01	.13	−.11	−.07	−.34*	.42**	.43**

*$p_{rep} > .89$. **$p_{rep} > .94$.

TABLE 2

Partial Correlations Between Amplitude of the Error-Related Negativity (ERN) and Religious Zeal in Study 1

Variable controlled	Partial correlation
Cognitive closure	.44**
Behavioral inhibition	.42**
Behavioral activation	.42**
Self-esteem	.42**
Stroop errors (incongruent trials)	.56**
Stroop incongruency (reaction time on incongruent trials minus reaction time on congruent trials)	.49**

**$p_{rep} > .94$.

careful responding. Religious zeal was also correlated with the Stroop incongruency effect (reaction time on incongruent trials minus reaction time on congruent trials), $r(27) = .42$, $p_{rep} > .90$, which is consistent with the idea that participants who were high in religious zeal sacrificed speed for accuracy, and again indicates deliberate, as opposed to inflexible, responding. These behavioral findings are consistent with trends found in recent work relating anxiety to behavioral accuracy (Hajcak et al., 2003) and with the relationship we observed between religious zeal and error-related neural activity. We extended these results in Study 2 by examining not religious zeal, but belief in God.

STUDY 2: BELIEF IN GOD

Method

Participants

Twenty-two right-handed participants (13 females, 9 males) from the University of Toronto Scarborough subject pool participated in Study 2 for course credit (mean age = 19.00 years, $SD = 1.41$). The participants in this sample came from a diverse set of ethnic and racial backgrounds (33% East Asian, 33% South Asian, 28% Caucasian, and 6% other), reflecting the diversity of the larger campus community. We did not record religious affiliation for this study.

Measures and Recording

Participants completed a single-item measure of belief in God (reverse-scored scale ranging from 1, *certain God exists*, to 5, *certain God does not exist*), as well as a single-item measure of political conservatism (Amodio et al., 2007; scale ranging from 1, *extremely liberal*, to 5, *extremely conservative*). They also completed the Wonderlic IQ Test (Wonderlic, 1983; $M = 21.86$, $SD = 5.77$) and the Big Five Inventory (John & Srivastava, 1999; extraversion: $M = 3.34$, $SD = 0.67$; agreeableness: $M = 3.70$, $SD = 0.58$; conscientiousness: $M = 3.22$, $SD = 0.60$; emotional stability: $M = 3.10$, $SD = 0.73$; openness: $M = 3.50$, $SD = 0.30$). As in Study 1, we recorded continuous EEG activity while participants completed the Stroop task. The EEG measurement parameters and Stroop task were the same as in Study 1 with the exception that the Stroop task consisted of 10 blocks containing 48 trials each (32 congruent and 16 incongruent) and the EEG used an average electrode reference.

Results and Discussion

Much as in Study 1, results revealed that greater belief in God was correlated with less ERN activity (more positive activity) following Stroop errors, $r(21) = .63$, $p_{rep} = .99$ (see Figs. 2a–2c), but was unrelated to neural activity following correct responses ($p_{rep} < .84$). Dipole source localization confirmed that the ERNs were generated in an area approximately consistent with the ACC (pre-auricular-nasion coordinates, in millimeters, were as follows: $x = 4.3$, $y = 35.5$, $z = 23.1$; dipole strength = 94.8 nAm; this source accounted for 95.8% of the variance of the signal; see Fig. 2d). Table 3 lists all interitem correlations, and Table 4 shows the partial correlations between ERN amplitude and belief in God, controlling for the other measured variables. The correlation between the ERN and religious conviction did not diminish after we controlled for conservatism, IQ, or any of the Big Five personality factors (all rs $> .57$, p_{rep}s $> .97$). As in Study 1, therefore, none of these "third" variables could explain the relation between the ERN and religious conviction. Finally, the stronger participants' belief in God, the fewer errors they made on incongruent trials, $r(21) = -.48$, $p_{rep} = .95$, an effect that held even after we controlled for closed-mindedness (i.e., reverse of openness) and conservatism (both rs $> -.44$, p_{rep}s $> .91$).

Study 1 found a connection between ACC activity and a form of conviction that is ardent, even aggressive, but this study found a connection between ACC activity and a milder form of conviction: the simple belief in God. That greater belief in God predicted less cortical activity along with greater behavioral accuracy, even after we controlled for closed-mindedness and conservatism, implies that conviction is not the product of a rigid need for certainty; rather, the pattern of neural and behavioral results is characteristic of low anxiety (e.g., Hajcak et al., 2003). We suggest that conviction provides frameworks for understanding and acting within one's environment, thereby acting as a bulwark against anxiety-producing uncertainty and minimizing the experience of error.

GENERAL DISCUSSION

Our results indicate that religious conviction is associated with reduced neural responsivity to uncertainty and error on a generic decision-making task. This was the case for religious zeal in Study 1 and simple belief in God in Study 2. Specifically, we found that greater religious conviction was associated with reduced activity in the ACC, a cortical system that serves to regulate both cognitive and emotional processing. Although recent work implies that religious concepts and experiences activate brain systems that are part of normal human cognition (e.g., Boyer, 2003), this is the first set of studies connecting individual differences in religious con-

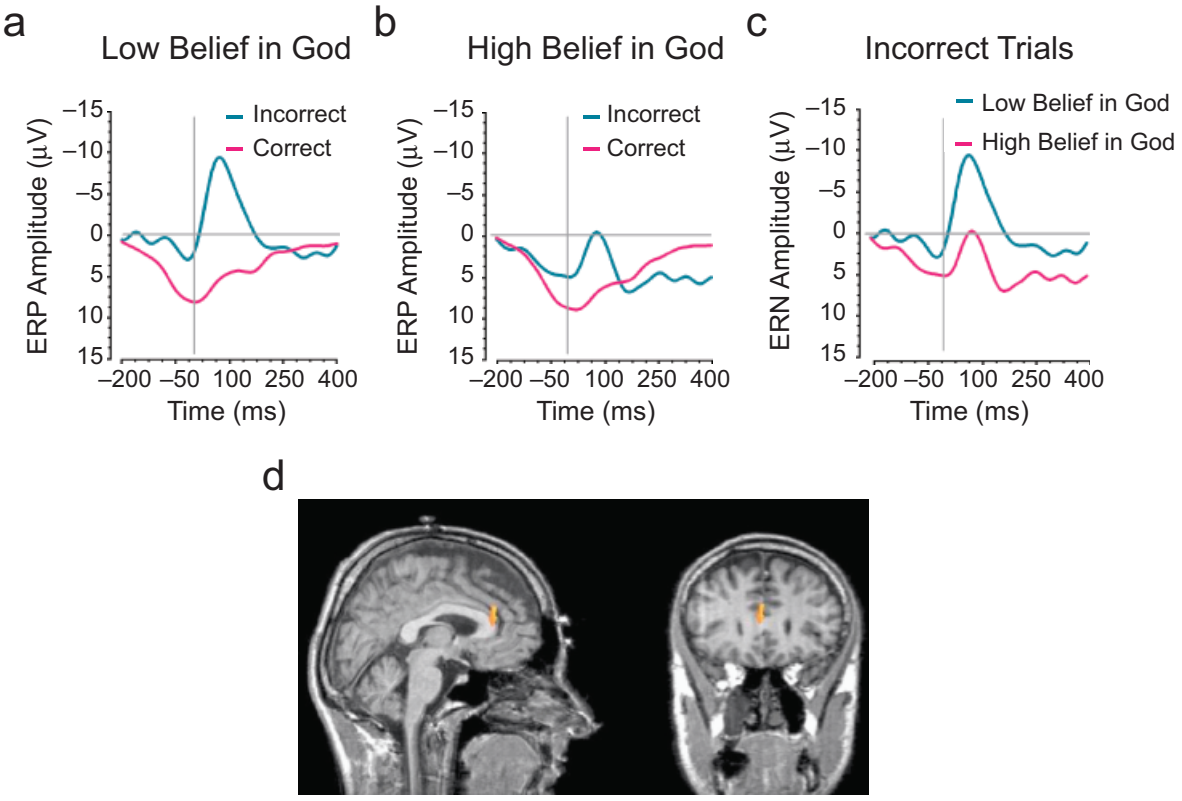

Fig. 2. The relation between belief in God and anterior cingulate cortex activity: event-related potentials (ERPs) at electrode Cz for (a) participants low in belief in God and (b) participants high in belief in God, (c) error-related negativities (ERNs) at electrode Cz for people high and low in belief in God, and (d) illustration of the generator for the ERN (in anterior cingulate cortex), as determined by source localization.

viction to basic cortical processes. We suggest that religious conviction buffers against anxiety by providing meaning systems that specify standards for behavior and serve as guides that inform predictions about the self and the world (Heine et al., 2006). Although these meaning systems can provide relief from anxiety by successfully accommodating experience, they can also reduce anxiety by focusing thought and perception away from anxiety-inducing events (McGregor et al., 2001). In short, a suppressed reaction to uncertainty appears to be one mechanism by which religious beliefs can help reduce distress.

TABLE 3

Zero-Order Correlations Among Amplitude of the Error-Related Negativity (ERN), Belief in God, Stroop Incongruency, Stroop Errors, and the Control Variables Assessed in Study 2

Measure	1	2	3	4	5	6	7	8	9	10
1. Extraversion										
2. Agreeableness	−.10									
3. Conscientiousness	.13	.46**								
4. Emotional stability	−.11	.02	−.14							
5. Openness	−.14	.16	.04	.34						
6. IQ	−.14	−.37*	.05	−.08	−.21					
7. Conservatism	−.35	.09	.09	−.01	.23	.31				
8. Stroop errors (incongruent trials)	.29	−.38*	−.12	−.34	−.33	.09	−.31			
9. Stroop incongruency (reaction time on incongruent trials minus reaction time on congruent trials)	.10	.11	.33	−.13	−.15	−.13	−.25	.19		
10. ERN amplitude	.09	.27	−.23	−.19	.30	−.14	.01	−.31	−.12	
11. Belief in God	.02	.33	.03	−.11	−.01	−.13	.24	−.48**	.01	.63**

*$p_{rep} > .89$. **$p_{rep} > .94$.

TABLE 4

Partial Correlations Between Amplitude of the Error-Related Negativity (ERN) and Belief in God in Study 2

Variable controlled	Partial correlation
Extraversion	.63**
Agreeableness	.60**
Conscientiousness	.66**
Emotional stability	.63**
Openness	.67**
IQ	.63**
Conservatism	.68**
Stroop errors (incongruent trials)	.58**
Stroop incongruency (reaction time on incongruent trials minus reaction time on congruent trials)	.63**

**$p_{rep} > .94$.

Our findings are an important step toward understanding the appeal of religious conviction, but the direction of causality remains to be determined: Does religious conviction buffer ACC responsivity to error and uncertainty? Or, alternatively, does lower ACC activity (and its associated cognitive style) incline people toward religious belief? We have been suggesting that religion provides prescriptive beliefs for goal pursuit, thereby narrowing attention away from anxiety-evoking events and reducing the incidence of uncertainty and error (along with the attendant cortical activity). In other words, we suspect that religion lowers anxiety-related neural activity, and not the other way around. This suspicion is indirectly supported by research demonstrating that religious belief and conviction are significantly heightened by experimentally manipulated anxieties (Kay, Gaucher, Napier, Callan, & Laurin, 2008; McGregor et al., 2008). Future experiments that invoke religious conviction and assess subsequent changes in ACC activity, however, are needed to directly answer this remaining question.

Our results indicate that religious conviction is associated with an attenuated response to errors and uncertainty, although it is unclear whether these effects are unique to religion per se or would occur with any form of ideological commitment. Recent work by Amodio et al. (2007), for example, shows that conservatism is associated with similar levels of reduced ACC activity, implying that political ideology serves an anxiolytic function similar to that of religious belief. Indeed, the same laboratory-induced threats that heighten belief in God also heighten conviction about political issues and governments (e.g., Kay et al., 2008). Recent theorizing also offers the possibility that belief systems and ideologies of all stripes serve a palliative function by allowing individuals to feel that the social context is stable, understandable, and predictable (Jost & Hunyady, 2002). Strong convictions of all kinds, then, may lower anxiety and uncertainty and their attendant brain activity. This implies that religion may not be so out of the ordinary: Other systems of belief may also provide maps for understanding and acting within the world, and we propose that the extent to which they do could predict ACC activity.

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