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Reflecting on God: Religious Primes Can Reduce Neurophysiological Response to Errors

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Abstract

The world is a vast and complex place that can sometimes generate feelings of uncertainty and distress for its inhabitants. Although religion is associated with a sense of meaning and order, it remains unclear whether religious belief can actually cause people to feel less anxiety and distress. To test the anxiolytic power of religion, we conducted two experiments focusing on the error-related negativity (ERN)—a neural signal that arises from the anterior cingulate cortex and is associated with defensive responses to errors. The results indicate that for believers, conscious and nonconscious religious primes cause a decrease in ERN amplitude. In contrast, priming nonbelievers with religious concepts causes an increase in ERN amplitude. Overall, examining basic neurophysiological processes reveals the power of religion to act as a buffer against anxious reactions to self-generated, generic errors—but only for individuals who believe.

Keywords

religion, meaning, neuroscience, error-related negativity

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The belief in a life after death, in a world beyond the grave, has been a hallmark of human thought for at least 100,000 years. Archaeological remains of Neanderthal graves indicate that the Neanderthals buried their dead with tools, weapons, and clothing—presumably provisions for the new life ahead (Joseph, 2000). Neanderthals, it appears, developed proto-religious beliefs. And these beliefs persist to this day. Indeed, more than 85% of the globe's population has at least some form of religious belief, with only a small minority of individuals describing themselves as atheists (Zuckerman, 2005). Whether these beliefs are factual or not, "God won't go away" (Newberg, D'Aquili, & Rause, 2001). Why have religious beliefs survived for more than 100,000 years, and why are they so pervasive in human societies?

Recent work in psychology, neuroscience, cultural anthropology, and archaeology has been addressing such questions in building toward a cognitive science of religion (e.g., Boyer, 2008). One of the core themes of this research is that religious beliefs are a natural by-product of the way human minds and brains work, meeting a number of people's myriad needs, the most pressing of which may be the need to understand.

Religion as Explanation

Without meaningful explanations, the world would appear to people as a vastly complex and random place, much like the "blooming, buzzing confusion" James (1890, p. 462) thought young children experience. People everywhere feel a mental drive to understand and explain the stimuli and events around them (Kruglanski & Webster, 1996). This drive may explain why categorization is essential to higher cognition (Anderson, 1991) and why people are often more bothered by uncertainty than by certain negativity (Hirsh & Inzlicht, 2008). Religion and myth, then, may help satisfy this need for order, explanation, and prediction (Kay, Gaucher, Napier, Callan, & Laurin, 2008).

As is the case with other sources of meaning (Proulx & Heine, 2008), religion provides prescriptive norms about what to do and when to do it (Silberman, 2005). Knowing what to expect reduces uncertainty and resultant anxiety. Although religious teachings may explicitly address some of the more

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glaring sources of uncertainty in life—death, for example (Jonas & Fischer, 2006)—religious belief and its explanatory power may quell anxiety in a much broader array of situations.

Notably, religious conviction is associated with reduced distress in response to errors (Inzlicht, McGregor, Hirsh, & Nash, 2009). Although these previous results make tantalizing the possibility that religious belief has the power to reduce distress, they are correlational and leave open the question of causation. The alternative possibility is that people with dispositionally muted distress reactions are attracted to religion—that broad and heritable neurocognitive differences predispose people to certain beliefs and ideologies (Amodio, Jost, Master, & Yee, 2007).

We propose that religious belief directly causes a dampening of distress reactions. If this is correct, theists should display significant declines in error-related distress when they ponder their beliefs—consciously or otherwise. Critically, this muted distress response should be evident in basic neuropsychological systems. We focus specifically on activity in the anterior cingulate cortex (ACC), a region of the medial prefrontal cortex that plays a key role in cognition and emotion (Bush, Luu, & Posner, 2000).

Anterior Cingulate Cortex: Cortical Alarm Bell

The ACC is richly interconnected with both limbic and prefrontal areas of the brain, and one of its principal functions is the regulation of bodily states of arousal to meet current behavioral demands (Critchley et al., 2003). Although several prominent models have highlighted the specific cognitive functions of the ACC (e.g., Yeung, Botvinick, & Cohen, 2004), these models often overlook the many sources of evidence highlighting its role in the experience of arousal and distress. For example, lesions to the ACC reduce autonomic reactivity (Critchley et al., 2003), and patients with anxiety disorders and healthy volunteers induced into an anxious state show elevated ACC activity (e.g., Benkelfat et al., 1995). Although patients with ACC damage show flat affect, they do not exhibit losses to cognitive control (Critchley et al., 2003).

In addition, electroencephalographic (EEG) studies reveal that activation of the ACC is associated with an event-related potential called the error-related negativity (ERN), which emerges between 50 and 100 ms after people make errors (Dehaene, Posner, & Tucker, 1994). Although there is agreement that the ERN reflect aspects of performance monitoring, recent research casts doubts on a purely cognitive, conflict-monitoring function for this wave (see Olvet & Hajcak, 2008). For example, whereas a strict cognitive account would predict stronger ACC activity with greater conflict, direct tests have demonstrated that increasing the temporal overlap of competing responses actually decreases the ERN, casting doubt on this classic account (Burle, Roger, Allain, Vidal, & Hasbroucq, 2008). Instead, there is growing support for an alternative model of ERN functioning that incorporates affective experience and posits that the ERN is a product of anxious reactions to one's performance, or a neural "distress signal" (Bartholow et al., 2005, p. 41). Studies have demonstrated that the ERN is larger for patients with various anxiety disorders than for healthy control subjects (e.g., Gehring, Himle, & Nisenson, 2000), is diminished by anxiolytic drugs (Johannes, Wieringa, Nager, Dengler, & Munte, 2001), and is associated with the defensive startle threat response (Hajcak & Foti, 2008).

Although a handful of studies have looked at the ERN as a state variable (e.g., Amodio et al., 2004), the bulk of research on the ERN has treated it as a dispositional trait or as an endophenotype (Olvet & Hajcak, 2008), thereby focusing on the ERN's heritability (Anokhin, Golosheykin, & Heath, 2008). In the study reported here, however, we explored the possibility that brief situational changes, even something as subtle as a nonconscious prime (Bargh & Chartrand, 2000), may produce fluctuations in ERN amplitude—and specifically that conscious and nonconscious religious primes might actually cause the ERN to decrease.

Overview of the Experiments

If religion insulates people from distress by providing meaning and structure, then focusing on religious beliefs should cause decreases in ACC activity. To test this hypothesis, we conducted two experiments: In the first, we asked theists to think about their religion; in the second, we subconsciously primed God concepts for both theists and atheists. In both experiments, we recorded EEG while participants completed the Stroop task. What makes this task useful for our purposes is that it generates errors, and thus produces states of defensive arousal (Hajcak & Foti, 2008). Therefore, if religious belief lowers distress in response to generic errors, this effect should be observable in this task. Note that errors made on the Stroop task are not clear violations of religious teachings, and so should be free from the potentially confounding effects that a religious prime might have on reactions to sins. In addition, the Stroop task allowed us to investigate the impact of religion on executive control (McCullough & Willoughby, 2009).

Experiment 1

Method

Participants. Forty-one introductory psychology students (17 males, 24 females) at the University of Toronto Scarborough (mean age = 19.16 years, SD = 2.97) participated for course credit. In a mass testing session at the beginning of the semester, participants used a 5-point Likert scale (1 = *not at all*, 5 = *completely*) to answer the following question: "To what extent do you believe in God?" They also identified the type of God they believed in. We preselected only those students who were strong believers in a theistic God, having answered with a 4 or 5 on the first question and chosen "a theistic God that created the world and intervenes in human affairs" for the second question. We eliminated 3 participants from all analyses because of equipment malfunction ($n = 1$), an excessive error rate ($n = 1$), or outlying ERN values ($n = 1$). Thus, data from 38 participants were included. They were affiliated with a wide variety of religious denominations (18 Christian, 8 Hindu, 8 Muslim, 2 Buddhist, 1 agnostic[1], and 1 "other").

Procedure. Participants were randomly assigned to one of two conditions. In the religious-affirmation condition, participants wrote a paragraph describing what their religion means and explains in their lives. In the control condition, participants wrote a paragraph about their favorite season. Typically, participants spent 5 to 10 min on this writing task.

We included a measure of affect to determine whether changes in mood might be the proximal cause of our results. After the prime, participants completed the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988), which asks respondents to indicate the extent to which they are feeling various positive and negative moods ($\alpha = .84$).

The main behavioral measure was performance on a color-naming Stroop task, which typically took around 15 to 20 min. This task comprised a series of color words, each of which was presented in a color that either matched (congruent) or did not match (incongruent) the semantic meaning of the word. Participants identified the color in which each word was presented by pressing the corresponding button on a response box. A trial consisted of a fixation cross ("+") presented for 500 ms, followed by the stimulus word presented for 200 ms. Participants completed 10 blocks, each consisting of 32 congruent trials and 16 incongruent trials. From the Stroop task, we calculated an incongruency effect (reaction times on incongruent trials minus reaction times on congruent trials) and tallied the number of errors on incongruent trials.

EEG during the Stroop task was recorded using a stretch Lycra cap embedded with 32 tin electrodes. Recordings were digitized at 512 Hz using ASA acquisition software (Advanced Neuro Technology B.V., Enschede, The Netherlands) with average-ear reference. EEG was corrected for vertical electro-oculogram artifacts (Gratton, Coles, & Donchin, 1983) and digitally filtered between 1 and 15 Hz. The period between 300 and 200 ms before key press was used for baseline correction. For each artifact-free trial, an epoch was defined between 200 ms before and 800 ms after the response. Data for these epochs were averaged within participants independently for correct and incorrect trials, and then grand-averaged within the respective conditions. The ERN was defined as the minimum deflection between 50 ms before and 150 ms after the key press at the frontocentral midline electrode (FCz). ERNs were based on no fewer than six artifact-free error trials, a number that is an adequate minimum for maintaining reliability (Olvet & Hajcak, in press).

Results and discussion

We predicted that participants who consciously affirmed their religious belief would have a smaller ERN than those who wrote about their favorite season. As Figure 1 indicates, theists had lower-amplitude ERNs when they wrote about what their religion explains in their life ($M = -4.38$ μV, $SD = 2.30$) than when they wrote about something positive but less meaningful ($M = -6.39$ μV, $SD = 3.58$), $t(36) = -2.04$, $p < .05$, $d = 0.68$. Dipole source localization confirmed that the ERNs were generated in an area consistent with the dorsal ACC. Pre-auricular-nasion coordinates, in millimeters, were as follows: $x = 1.6$, $y = -3.5$, $z = 39.8$; dipole strength was 65.48 nAm, and this source accounted for 83.3% of the variance of the signal. Participants did not show different levels of affect as a function of condition, $t(36) < 1$, $p > .85$, and entering the PANAS as a covariate had no effect on our results. Thus, it appears that making religion salient can buffer activity originating from the ACC and quell defensive responses to errors.

Analysis of the behavioral data offered mixed support for a link between religious beliefs and executive control. Although theists who consciously affirmed their religious beliefs made fewer errors on incongruent Stroop trials ($M = 14.38$, $SD = 7.58$) than did theists in the control group ($M = 24.40$, $SD = 15.93$), $t(36) = 2.48$, $p < .02$, $d = 0.83$, the incongruency reaction time effect did not differ between the two conditions, $p > .39$. Because differences in executive control can pose a confound when one compares the ERN across participants, we also analyzed our ERN data after controlling for number of errors, and found that the effect of condition was still reliable ($p < .03$). Consciously contemplating what one's religion means and explains, then, appears to buffer activity originating from the ACC and (although the results are not unequivocal) to improve executive control.

Experiment 2

Method

Participants. Forty introductory psychology students (21 male, 19 female) at the University of Toronto Scarborough (mean age = 20.68 years, $SD = 3.74$) participated for course credit. One participant was eliminated from all analyses because of equipment malfunction, leaving 39 participants. They came from a wide variety of religious denominations (11 Christian, 9 Muslim, 5 Hindu, 5 Buddhist, 3 atheist, and 6 "other" or nonspecified). There were no preselection criteria.

Procedure. Participants were assigned to a religious-prime or a control condition. The manipulation involved a scrambled-sentence task in which participants were presented with five words on each trial and were asked to rearrange four of them in order to make a grammatical English sentence (e.g. "reveal the future simple prophets" would be rearranged to make "prophets reveal the future"). In the religious-prime condition, 5 of the 10 scrambled sentences contained words that were religious in nature (e.g., *spirit*, *divine*, *sacred*). The stimuli in the control condition did not include words associated with religion (Shariff & Norenzayan, 2007). This type of

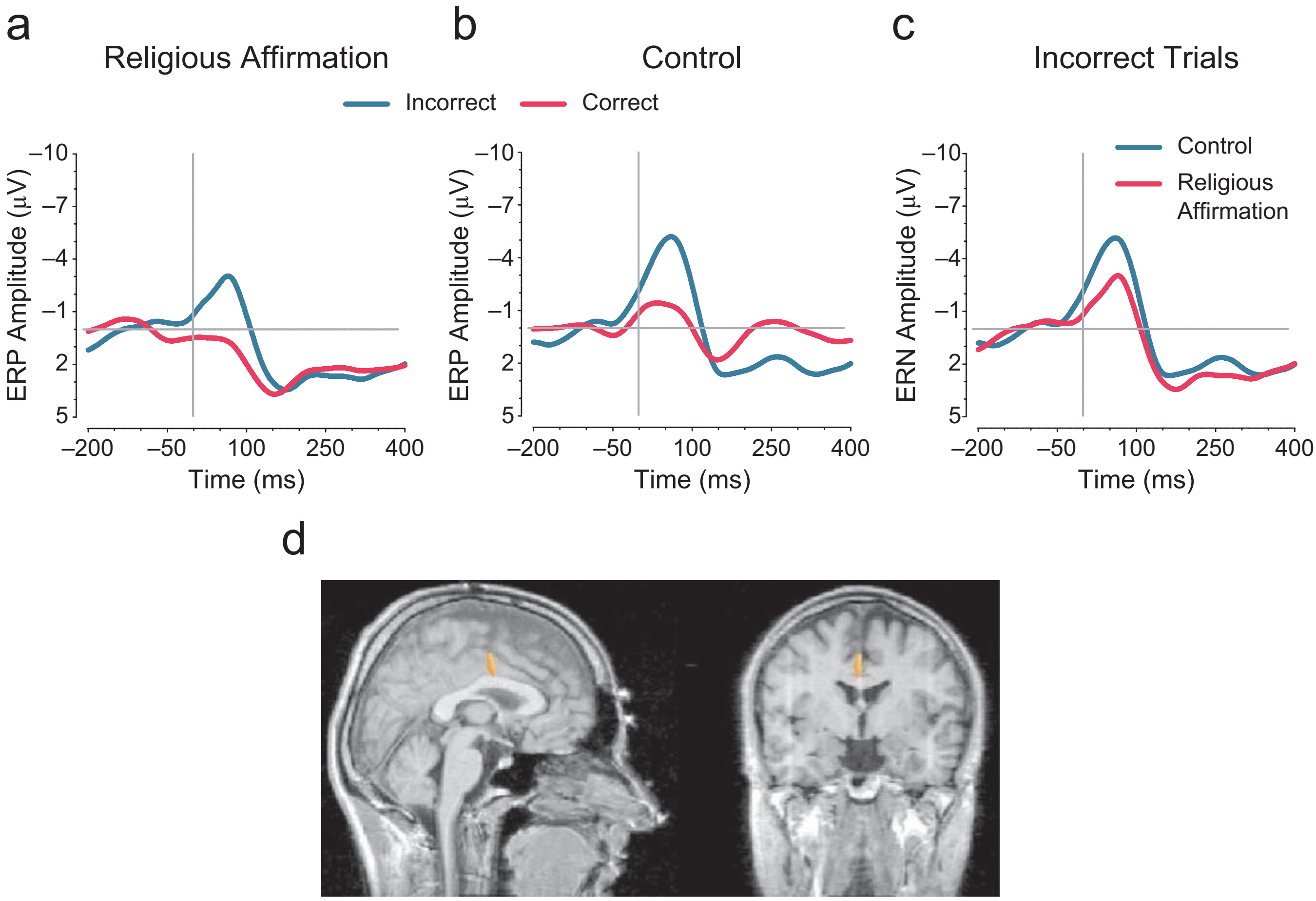

Fig. 1. Results from Experiment 1: event-related potentials (ERPs) at electrode FCz in the (a) religious-affirmation and (b) control conditions on correct and incorrect trials, (c) the error-related negativity (ERN) on incorrect trials for participants in the two conditions, and (d) illustration of the generator for the ERN as determined by source localization.

scrambled-sentence task is commonly used to prime concepts nonconsciously, and we confirmed that the priming was nonconscious with a funneled debriefing procedure that examined suspicion and awareness (Bargh & Chartrand, 2000).

As in Experiment 1, after being primed, participants completed the PANAS ($\alpha = .83$) and then the Stroop task, which was framed as a separate study. They then answered one question assessing their belief in God on a 7-point Likert scale ($M = 5.33$, $SD = 1.88$). EEG was recorded and processed according to the procedure outlined in Experiment 1.

Results and discussion

Data were analyzed with hierarchical linear regression, by first entering condition (effect coded: –1 = religion prime; 1 = control prime) and mean-centered belief in God (as a continuous variable), and then entering the interaction of the two. Because the mean score on the belief-in-God scale was higher than the scale midpoint, when we probed simple effects, we defined theists as 1 standard deviation above the mean and atheists as 2 standard deviations below the mean. We expected that the religious-prime condition would be associated with smaller ERNs than the control condition, but only for theists. For atheists, we hypothesized that priming religion unconsciously could cause the ERN to increase because of distress produced by the activation of an incompatible meaning system.

Our overall regression model was significant, $F(3, 35) = 3.61$, $p < .03$. As we had observed with conscious affirmation, theists had lower-amplitude ERNs when they were nonconsciously primed with religious concepts ($M' = –1.39$ μV) than when they were exposed to control primes ($M' = –3.60$ μV), $t(35) = –2.13$, $p = .04$, $d = 0.72$. However, as Figure 2 indicates, belief in God interacted with religious prime, $t(35) = –2.63$, $p < .02$, $d = 0.89$, such that atheists displayed greater, not lower, ERN activity after religious primes ($M' = –6.27$ μV) than after control primes ($M' = –2.69$ μV), $t(35) = 2.20$, $p < .04$, $d = 0.74$.[2] Dipole source localization confirmed that the ERNs were generated in an area consistent with the dorsal ACC. Pre-auricular-nasion coordinates, in millimeters, were as follows: $x = –10.8$, $y = –2.4$, $z = 39.4$; dipole strength was 30.01 nAm, and this source accounted for 86.9% of the variance of the signal. Again, there were no significant effects or interactions for the PANAS, $t(35) > 1$, $p > .65$, and treating this scale as a covariate did not affect our results; this result suggests that it is religious thoughts specifically, not positive thoughts generally, that produced our findings.

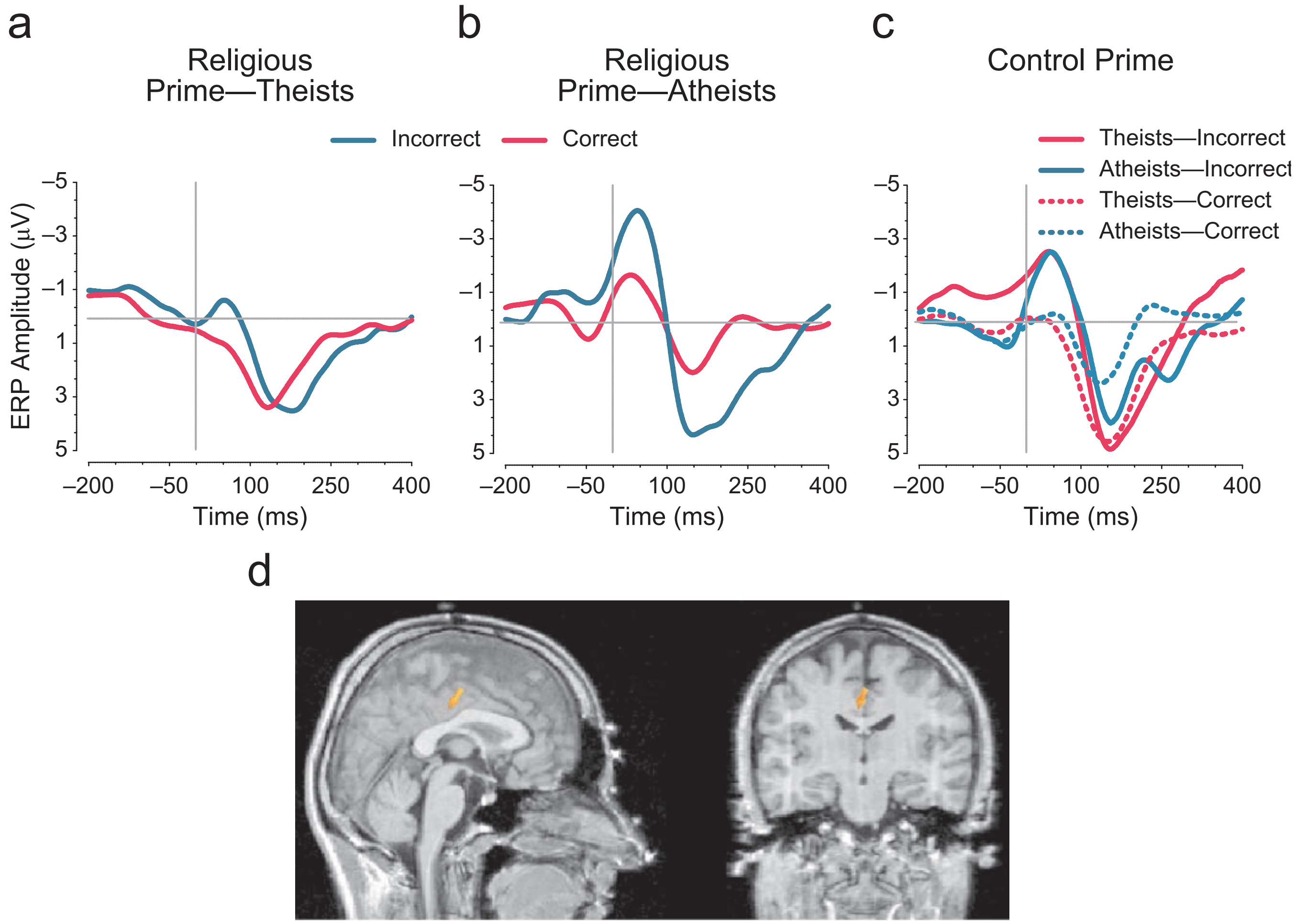

Fig. 2. Results from Experiment 2: event-related potentials (ERPs) at electrode FCz (a–c) and (d) illustration of the generator for the event-related negativity as determined by source localization. ERPs are shown for (a) theists and (b) atheists who were exposed to religious primes and (c) for theists and atheists who were exposed to control primes. Results are shown separately for correct and incorrect responses. Classification as a theist or atheist was determined by a tertiary split.

We failed to find a significant relationship between religion and executive control. The regression model, $F(3, 35) < 1$, n.s., indicated that theists and atheists did not differ in number of errors on incongruent trials in either the control ($M' = 12.74$ vs. 11.84) or the religious-prime ($M' = 16.72$ vs. 17.31) condition. Although there was a trend for a main effect of prime condition, this too was not significant, $t(35) = –1.36$, $p = .18$. We found similar nonsignificant results for incongruency reaction time effects, all $ps > .40$. The pattern of ERN brain data remained significant after controlling for differences in number of errors, $F(4, 34) = 2.65$, $p = .05$, which suggests that religious primes affected distress-related neural activity beyond any influence on behavioral performance.

All told, nonconscious exposure to religious concepts affected theists and atheists very differently. For theists, the religious prime served as a palliative against the affective consequences of their own errors, as they showed low levels of distress-related neural activity. Atheists, in contrast, showed a heightened neural response; it appears that they reacted to their own errors more defensively, responding as if the primes challenged their system of meaning and explanation.

General Discussion

Overall, the findings from these two experiments suggest a causal link between religion and the way the brain processes reactions to generic errors: Thinking about one's religion, consciously or otherwise, acts as a bulwark against defensive reactions to errors; it muffles the cortical alarm bell. To our knowledge, these are some of the only experiments to show that subtle situational manipulations (e.g., nonconscious primes) can lead to reliable changes in ERN amplitudes, and they suggest that attempts to change the ERN through environmental manipulations may provide a fruitful avenue for learning more about this neural signal, as well as the ACC and distress reactions more generally.

More broadly, our results may offer a mechanism for the finding that religion is linked to positive mental health and low rates of mortality and morbidity (Powell, Shahabi, & Thoresen, 2003). If thinking about religion leads people to react to their errors with less distress and defensiveness—an effect that occurs within a few hundredths of a second—in the long run, this effect may translate to religious people living their life with greater equanimity than nonreligious people, being better able to cope with the pressures of living in a sometimes hostile world. More broadly still, these results suggest a neural implementation for the effects of self-affirmation in helping people overcome threats to the self and attendant states of defensiveness (Steele, 1998). We did not, however, find a reliable connection between religiosity and improved executive control (cf. McCullough & Willoughby, 2009).

Because of the reverse-inference problem, which is inherent in much neuroscience research (Poldrack, 2006), it is impossible to say for certain that religion's impact on the ERN indicates changes to error-related distress and not changes in some other process (e.g., conflict monitoring). Although this problem cannot be completely eliminated with the current approach, pilot data in our lab may strengthen our interpretation. In a correlational study, we triangulated religious belief with the ERN and a well-validated index of defensive activation—the startle blink threat response (Lang, Bradley, & Cuthbert, 1998). We found that the more participants believed in God, the lower the amplitude of their ERNs, $r(19) = .37$, $p < .05$, and the lower their electromyographic startle blink response following incongruent trials, $r(19) = -.43$, $p < .03$; further, higher ERN amplitudes predicted greater startle blink responses on incongruent trials, $r(19) = -.39$, $p < .05$ (all correlations one-tailed). The most coherent explanation for these results is that religion buffers against defensive arousal during times of error and conflict.

There is evidence that our results are not unique to religion and would generalize to other beliefs that provide meaning and structure (Amodio et al., 2007). Indeed, thinking about strong beliefs in general may serve to affirm the self, whereas thinking about conflicting beliefs might do the opposite (Steele, 1988). In other words, when people think about one of their cherished values—be it when environmentalists ponder their ideological commitment to the environment, when atheists discuss their certainty that God does not exist, or even when biologists wax about the inherent superiority of the scientific method—they may become less defensive and anxious as a result. Meanwhile, when avowed conservatives consider the potential advantages of liberal ideologies, their hackles will likely go up. The point here is that religion may not be so special; many varieties of beliefs could serve a palliative function if they allow people to feel that their world is stable, understandable, and predictable.

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The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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Notes

1. Although it is unusual for someone to self-identify as a strong believer in a theistic God and also as an agnostic, we suspect that this participant did not interpret the term "agnostic" as indicating doubt about the existence as God. Removing this person from the analyses did not qualitatively change our results.
2. Figure 2c suggests that the ERP during the baseline period preceding incorrect trials was different for theists and atheists, $t(35) = -2.12$, $p < .05$. We therefore reanalyzed the data using a –200- to –50-ms baseline period. Using this baseline period, however, did not change our effects or pattern of results, $F(3, 35) = 4.27$, $p < .02$.

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