To be published in *Neurology of Religion*,

Cambridge, Cambridge University Press

Ed., A. Coles

Beyond reasonable doubt: Cognitive and neuropsychological implications for religious disbelief

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The authors declare no conflict of interest.

Journal articles and chapters on the cognitive science of religious belief often begin by highlighting the seeming ubiquity of supernatural beliefs (e.g., Pennycook et al., 2012). It is indeed rather striking that most of the world's population share a similar sort of belief in a deity or greater power. According to Zuckerman (2007), approximately 90% of the world's population believe in a deity. In 2011, more than 92% of Americans polled by Gallup answered "yes" when asked, "Do you believe in God?" – a number effectively unchanged since 1944 (96%, Gallup, 2011). These sorts of observations lead naturally to the conclusion that religious belief must be grounded in common and, perhaps, foundational cognitive mechanisms. We agree, though in this chapter we will instead emphasize religious doubt, a common experience among religious and non-religious alike (Hunsberger et al., 1993). In the same Gallup poll cited above, the number of respondents who answered "no" when asked, "Do you believe in God?" increased from 1% in 1944 to 7% in 2011. Moreover, only 80% identified as theists and 12% identified as deists when asked to distinguish between having belief in a personal God (theism) versus believing in a universal spirit/higher power (deism) in a 2010 poll (Gallup, 2011). Finally, in a 2006 version of the same poll, 73% indicated that they were *convinced* that God exists, with the remainder of the sample indicating some doubt or disbelief (Gallup, 2011).

Religious belief and disbelief are two sides of the same coin. Thus, in a sense, investigations of variation in religious belief ought to follow directly from previous approaches to the cognitive science of religious belief. However, it is noteworthy that these previous approaches have generally focused on the types of cognitive processes thought to *support* religious belief, such as agency detection (e.g., Guthrie, 1993), teleological thinking (Kelemen, 2004), and anthropomorphism (Barrett & Keil, 1996). A focus on religious *doubt*, we argue, highlights a different set of cognitive mechanisms altogether. Recent work that has taken this alternative perspective has uncovered novel neurological insights that help us understand where (and, ultimately, how) the backside of the religious belief coin operates in the brain. In this chapter we will review these insights.

We will begin with an overview of dual-process theory and a review of the evidence that links the disposition to think analytically (as opposed to intuitively) with religious disbelief. As with much of the cognitive science of religious *belief*, the research on religious *disbelief* posits general cognitive mechanisms that are *not* specific to religious cognition. Rather, religious disbelief is thought to occur via domain general cognitive functions (see Pennycook, 2014). We posit that religious disbelief is not *sui generis*; that is, doubt toward religious concepts is not qualitatively distinct from doubt toward non-religious concepts. These more general approaches will then be supplemented by specific theories regarding belief/disbelief. Finally, this theoretical review will be used to ground, and in some cases reinterpret, recent neuroscientific work coming from both patient and imaging studies.

Dual-process theories and religious disbelief

Dual-process theories represent a prominent approach to understanding general cognitive function. Although numerous versions have been proposed (see Evans & Stanovich, 2013) the common element is a distinction between automatic, fast, intuitive processing and deliberative, slow, and analytic processing. More directly, Evans and Stanovich (2013) have recently highlighted the defining features of the two types of processes: Type 1 processes are autonomous and do not require working memory whereas Type 2 entail a deliberative use of working memory resources as a means to decouple from a Type 1 output or support hypothetical thought. This distinction is rather basic but nonetheless has implications for religious cognition.

Consider the following problem (De Neys et al., 2008):

> In a study 1000 people were tested. Among the participants there were 995 nurses and 5 doctors. Paul is a randomly chosen participant of this study. Paul is 34 years old. He lives in a beautiful home in a posh suburb. He is well spoken and very interested in politics. He invests a lot of time in his career. What is most likely?
> (a) Paul is a nurse.
> (b) Paul is a doctor.

This type of problem was originally developed by Kahneman and Tverksy as part of their heuristics and biases research programme (Kahneman & Tverksy, 1973) and has since been used in numerous reasoning and decision making studies (see Barbey & Sloman, 2007). The problem is of particular interest for dual-process theorists because of the apparent conflict between two sources of information: 1) the base-rate probability, which in this case strongly suggests that Paul is a nurse (i.e., there are 995 nurses in a sample of 1000 people; 99.5% chance that Paul is a nurse) and 2) the personality description, which in this case contains stereotypical information that strongly suggests that Paul is a doctor (i.e., doctors tend to be more affluent than nurses, etc.). Participants tend to base their response on the stereotypical information in lieu of the base-rate probabilities, hence illustrating "base-rate neglect" (Kahneman & Tverksy, 1973, for a review see Barbey & Sloman, 2007). This is thought to occur because the belief-based stereotypical response comes to mind more quickly and fluently (i.e., more intuitively) than the base-rate response (Pennycook et al., 2014c; 2015). Consistent with this and crucially for present purposes, participants who are more willing to engage analytic (Type 2) reasoning processes to override intuitive (Type 1) outputs (i.e., those with a more analytic cognitive style) are more likely to respond according to the base-rates (Pennycook et al., 2014a).

The base-rate problem serves as an illustrative case. Participants who dispositionally engage more substantive analytic reasoning processes are more likely to doubt and ultimately override a prepotent belief-based response, leading to a more probabilistic and objective response. Participants who are more likely to question and ultimately override beliefs in the context of a reasoning experiment ought to be more likely to do so outside of a lab. Although not

a defining feature, Type 2 reasoning is thought to be domain general (Stanovich & West, 2003). In other words, reasoning in this very general form surely occurs outside of the lab. The question, then, is whether analytic reasoning has consequences for religious disbelief in particular.

Studies from four separate labs have converged on an affirmative answer to this question. Namely, those who perform better on problems that contain intuitive lures (i.e., those with a more analytic cognitive style) and/or who self-report having a more analytic (as opposed to intuitive) thinking disposition are less likely to hold supernatural religious beliefs (Gervais & Norenzayan, 2012; Pennycook et al., 2012; Shenhav et al., 2012; Svedholm & Lindeman, 2012; see Pennycook et al., 2016 for a review). Less religious individuals also spend less time on reasoning tasks (such as the base-rate problem above), indicating that they engage in lower levels of slow analytic thinking when solving problems (Pennycook et al., 2014a; Pennycook et al., 2013). Importantly, these correlations remain robust after controlling for numerous potential mediators across multiple studies, such as age, sex, ethnicity, socioeconomic status, income, education, political ideology, personality variables, traditionalist moral values, and intelligence (Browne et al., 2014, Pennycook et al., 2012; Pennycook et al., 2013; Pennycook et al., 2014b; Shenhav et al., 2012, but see Razmyar & Reeve, 2013).

This correlational evidence has also been supplemented by experimental studies. First, Shenhav et al. (2012) asking participants in a between-subjects design to either write about a situation where they used their "intuition/first instinct" or a situation where they employed a strategy of "carefully reasoning through a situation". The goal of this manipulation was to prime an "intuitive" or "reflective" mindset. Participants self-reported level of God belief was lower when primed to think in a more reflective mode relative to a more intuitive mode. A subsequent set of studies by Gervais and Norenzayan (2012) – completed independently – verified this result. Gervais and Norenzayan employed three additional manipulations intended to prime analytic thought: 1) a piece of art (namely, Rodin's *The Thinker*), 2) a word rearranging task that contained analytic thinking prime words (i.e., analyze, reason, ponder, think, rational), and 3) perceptual disfluency. In each case, these subtle manipulations successfully diminished self-reported levels of religious belief.

These experiments provide an existence proof for the mechanism implied by the negative correlation between analytic cognitive style and religious disbelief. Namely, analytic thought is the cognitive process that is used to doubt and ultimately disbelieve religious and supernatural conceptions. Nonetheless, it is worth pointing out that it is unlikely that such manipulations cause long term changes in religious belief. Moreover, it may be difficult to find manipulations that successfully increase analytic thinking (see Yonker et al., 2016). For this reason, the correlational data is perhaps the more compelling evidence for our hypothesis. Given the amount of evidence that supports the negative correlation between analytic thinking and religious belief (see Pennycook et al., 2016 for a meta-analysis with over 15,000 individuals) and the number of possible third-variables that have been ruled out (as described above), the most parsimonious

current explanation is that analytic thinking plays a role in religious disbelief. It is plausible that the causal effect of analytic thinking on religious disbelief is strongest over longer periods of time. Future longitudinal studies are required to rigorously test this conjecture.

Why does analytic thinking cause religious disbelief?

It seems clear that analytic thinking is used to revise beliefs, but it is unclear why this appears to typically lead to a *decrease* in religious belief *in particular*. Moreover, the general dual-process account expounded above does not explain what causes someone to think analytically about religious belief in the first place. Thus, dual-process theory provides a general framework under which religious doubt can be understood but ultimately falls short as a mechanistic account (and, as a consequence, further theorizing is necessary prior to interpreting the neuroscientific evidence).

Three key results from Pennycook et al. (2012) shed light on the question of why analytic thinking leads to religious disbelief. The first is that religious *engagement* (i.e., religious service attendance, importance of religion in everyday life, prayer frequency, etc.) was not associated with analytic cognitive style once religious belief was taken into account. Thus, in other words, there does not appear to be an association between analytic thought and religiosity in general; rather, the association is specific to religious beliefs.

Second, this association is not simply a matter of acceptance or rejection of religious belief. Rather, at least in terms of God belief, performance on the Cognitive Reflection Test (i.e., a 3 item performance measure used to assess analytic cognitive style) is associated with degrading levels of conventional religious belief. Those who reported believing in a personal God (i.e., the most conventional God belief in the United States) performed the worst, followed by increased performance in pantheists, deists, agnostics and, finally, atheists (see Figure 1). This indicates that religious doubt is not simply an all or nothing prospect. Some moderately analytic individuals may engage in modest levels of doubt about the predominant and presumably (on the aggregate) default personal God stance, leading to a moderate position on the matter (e.g., belief in God as a universal spirit that does not intervene in human affairs). Nonetheless, it should be noted that by far the starkest contrast is between personal God theists and atheists: the majority (over 50%) of the personal God theists failed to get a single Cognitive Reflection Test item correct whereas the majority (over 60%) of the atheists got either 2 or 3 out of 3 correct.

Third, noting the supernatural or immaterial nature of religious beliefs, Pennycook et al. (2012) reported a similar association between analytic cognitive style and paranormal beliefs (e.g., astrology, extrasensory perception). This finding indicates that there is something specific about immaterial beliefs that may cause them to be prone to doubt via analytic reasoning. Pennycook et al. (2012) speculated that the inherit conflict between supernatural beliefs and folk-conceptions of the materials world (see Atran & Norenzayan, 2004). Consider, for example, the proposed nature of angels. Angels are thought to watch over humans and potentially intervene at

the behest of God (e.g., by miraculously saving someone from a devastating car accident). This set of beliefs is inherently in conflict with innate conceptions of folk mechanics (i.e., beings cannot pass through solid objects). Neonates demonstrate surprise when naturally occurring rigid bodies occupy the same space (Spelke et al., 1995), indicating that humans have a low level set of "beliefs" about how the natural world works. Van Leeuwen (2014) recently summarized the evidence for the distinction between 'religious credence' and 'factual belief' that maps onto the distinction between material and immaterial beliefs.

The cognitive conflict between material and immaterial beliefs potentially provides a clue as to what causes someone to think analytically about religious belief in the first place. Recall the base-rate problem from above. A series of studies have demonstrated that the conflict between the base-rate and stereotypical information is actually a *source* of analytic engagement (De Neys et al., 2008). In other words, the conflict between the cognitive outputs causes an increase in analytic reasoning. The key role of conflict in reasoning has now been supported by a large number of measures (e.g., response time, confidence, eye-tracking, skin conductance) across multiple tasks (see De Neys, 2014 for a review). In these experiments, participants are given both conflict and no-conflict problems in a reasoning task[1]. The typical finding is that participants spend more time reasoning (or have lower confidence, or higher levels of skin conductance, etc.) in cases where there is a cognitive conflict, indicated a low-level recognition of the conflict followed by increased levels of analytic thinking (Pennycook et al., 2015).

This conflict detection process should, in principle, apply to any sort of task or situation that involves a conflict between two cognitive outputs. Thus, the inherent conflict between immaterial religious beliefs and folk conceptions of the material world may be the source of the negative association between analytic thinking and religious belief. Consistent with this line of reasoning, Pennycook et al. (2014a) found that religious believers were less efficient at detecting conflicts during reasoning than non-believers. Specifically, religious believers had a markedly smaller response time increase for conflict relative to no-conflict versions of the base-rate problems (see Figure 2). Thus, according to Pennycook et al., "one need not explicitly decide to critically examine religious beliefs. Rather, one's disposition toward analytic thought may determine the likelihood of implicitly detecting conflict between nonmaterial religious beliefs and our understanding of the material world." (p. 9).

[1] The following is an example of no-conflict version of the base-rate problem from above: In a study 1000 people were tested. Among the participants there were 5 nurses and 995 doctors. Paul is a randomly chosen participant of this study. Paul is 34 years old. He lives in a beautiful home in a posh suburb. He is well spoken and very interested in politics. He invests a lot of time in his career. What is most likely? (Note: All that has changed is the base-rate probabilities.)

Mechanisms for belief and doubt: the need for a vigilant conflict detector

As outlined above, one's ability to detect and revise conflicting cognitions may play an important role in constraining one's religious beliefs. Individuals that can efficiently monitor conflict and effectively update cognitions are more likely to reject beliefs that are inconsistent with their naturalistic worldview (e.g., religious beliefs, belief in miracles, etc.). However, *prima facie*, this appears to make little sense. Why is the ability to detect conflict needed for religious doubt? Why is it that those who are poor at detecting conflict cannot simply *a priori* withhold belief in religious concepts? Our position (detailed below) suggests that credulity is a necessary, involuntary process in how we understand information. Indeed, this position implies that belief is the default stance toward not only religious concepts but all cognitions. Here, we will unpack this conjecture by examining the psychological and neural mechanisms for belief and disbelief.

Our thesis hinges on the psychological mechanisms of belief or doubt toward some cognition. The *sine qua non* of belief is action; so we must ask, what makes a cognition empowered to be acted upon? And likewise, what process denies a cognition its veracity and inhibits action? Conventional wisdom would suggest the process of belief or doubt involves three stages: 1) comprehension of some proposition, 2) assessment of that proposition with other extant mental information, and 3) labeling or tagging of the assessed truth value to that proposition which could be indexed in the future (Gilbert, 1991). The understanding of a proposition precedes and is independent from the assessment and labeling of the cognition as true (or false). Thus, when we encounter the proposition, *All celestial stars are spheres*, we can first comprehend this information (understand what it means), and then, judge it to be true against our relevant extant mental knowledge. This belief procedure has been attributed to Descartes (Mandelbaum, 2014), so we will continue with this conventional nomenclature. However, many studies in cognitive science have shown us that the Cartesian arrangement is not how belief and doubt operate (Mandelbaum, 2014). In rebuttal to the Cartesian belief procedure, Spinoza argued that understanding is not the neutral process conventional wisdom would suggest. Instead, comprehension of a proposition necessitates belief in that proposition. Thus, in his model, when we encounter the proposition, *the heart produces all mental activity*, we must, initially believe this proposition for at least a split-second if we comprehend it. However, subsequently, we can use a secondary psychological process to assess, doubt, and label this information with a false tag. In the Spinozan model, doubt is a secondary revision to an untested initial belief (Asp & Tranel, 2013).

Cognitions are empowered in the Spinozan model by mere mental representation (Gilbert, 1993). They are ballistic; they will induce cognition-consistent action given the right circumstances. Alternatively, in the Cartesian model cognitions are static. Only following an assessment period in which cognitions are deemed true can they be believed and empowered. Indeed, this line of reasoning raises the question of whether assessment of every cognition that needs to be believed and acted upon is even possible (Egan, 2008). Our cognitive and perceptual

systems receive a constant stream of ever changing data that requires timely and accurate responses. What process constantly assigns truth to the voluminous incoming data to afford adaptive responses? The Spinozan model does not require this additional process. It appears to be the most parsimonious account; that cognitions do not need to be turned into belief, they in fact are beliefs.

Empirical studies have pitted the Cartesian and Spinozan belief models against one another. Gilbert and colleagues (Gilbert et al., 1993) used the principle of modular system degradation following resource depletion to examine the two theories. They reasoned that resource depletion (i.e., distraction) should prevent a Cartesian system from either believing or disbelieving propositions it only comprehends, but it should prevent a Spinozan system from disbelieving propositions it both comprehends and believes. They gave participants narratives with several explicitly-labeled false statements embedded. Gilbert and colleagues (1993) found that resource depletion acted to sway social judgments of the protagonists in the narratives toward the explicit false information. In effect, reduction of the participants' resources caused participants to believe the false information which later influenced social judgments. Thus, the participants' cognitions from the false statements were left comprehended and believed rather than simply comprehended, a finding consistent with Spinozan belief theory. Subsequent research has found support for the Spinozan model by investigating belief change through fictional narratives, false consumer claims, and acquiescence on questionnaires responses (Asp & Tranel, 2013). This belief procedure has been used to explain the well-known truth/belief bias and the tendency to rely on heuristical processing (Asp et al., 2013; Mandelbaum, 2014). Additionally, evidence for the Spinozan perspective has been offered in diverse research areas including: mental development, forced persuasions, attributions, psycholinguistics, mental evolution, and social psychological biases (Gilbert, 1991, 1993). Some studies have shown results that purportedly are against the Spinozan account (Hasson et al., 2005; Nadarevic & Erdfelder, 2013); however, they are either internally inconsistent (see Mandelbaum, 2014) or do not adequately test the veracity of the belief accounts[2].

Although the Spinozan account has the weight of theoretical and empirical evidence, it also demands an efficient mechanism to detect belief conflict and to modify discrepant beliefs that do not fit with extant knowledge. If all incoming cognitions are beliefs, then we need a vigilant system to correct all the errant beliefs following exposure. The consequences of an inability to detect and update beliefs would be severe and debilitating. One could not disbelieve propositions or random ruminations to which one was exposed. Credulity and fixed false beliefs that are epistemically unwarranted would be a defining feature. Indeed, this deficiency might be the etiological mechanism of delusions in patients with schizophrenia (Asp & Tranel, 2013).

[2] In a personal communication, regarding Nadarevic and Erdfelder's (2013) finding that source credibility improved true and false information memory, one of us (Asp, E.W.) argued that in the absence of resource depletion the Spinozan and Cartesian belief models cannot make differential predictions regarding memory accuracy for true, false, and uncertain information (in an age-controlled, healthy population).

Neural correlates of disbelief

One of the most established and well-studied brain-behavior relationships in cognitive neuroscience is the dorsal anterior cingulate cortex's (dACC) mediation of cognitive conflict monitoring (Botvinick et al., 2004). Neuroimaging studies have shown the dACC is activated in tasks which 1) require an overriding of prepotent responses, 2) involve choosing between a set of equally permissible responses, and 3) lead to the production of recognizable errors (Botvinick et al., 2001). The dACC has been theorized to play a key role in the initiation and modulation of cognitive control which is purportedly mediated by the broader prefrontal cortex (including the dorsolateral prefrontal cortex, dlPFC). However, it's important to note that this model, while being well supported by imaging (e.g., Kerns et al., 2004), does not address the overall functions of the dACC and cannot completely account for the results of neuropsychological studies (Botvinick et al., 2004; Gehring & Knight, 2000; Shackman et al., 2011). Nonetheless, the dACC is a prime neuroanatomical suspect in the ability to detect cognitive conflict and pass along this information to initiate doubt, or "belief control."

Indeed, De Neys et al. (2008) reported increased activation in the dorsal anterior cingulate cortex when participants gave stereotypical responses to conflict base-rate problems, indicating that conflict between base-rate information and stereotypes was successfully detected. Pennycook et al.'s (2014) hypothesis that cognitive conflict detection is associated with religious belief is also supported by neuroimaging work. Namely, Inzlicht and colleagues (Inzlicht et al., 2009; Inzlicht et al., 2011) found a negative association between religious conviction (namely, degree of 'religious zeal', belief in God, and religious service attendance) and dACC activation during a conflict monitoring/cognitive control task. We take this important individual difference data to support the proposed link between the ability to detect cognitive conflict and religious belief. It should be noted, however, Inzlicht and colleagues have a very different interpretation of these results (Inzlicht et al., 2011). They claim that religiosity *decreases* anterior cingulate activation in order to alleviate anxiety. We find this interpretation somewhat dubious given that the cognitive control task used (namely, the Stroop task) is not intended to cause anxiety. Moreover, the evidence for an association between religiosity and anxiety is very mixed (Shreve-Neiger & Edelstein, 2004). For example, in a sample of participants who suffered from sleep paralysis – an intensely fearful and aversive experience – belief in religious and supernatural explanations predicted *increased* post-episode distress (Cheyne & Pennycook, 2013). In the same study, participants with a more analytic cognitive style were less likely to have supernatural explanations for their sleep paralysis experience and, independent of supernatural explanations and all other measured variables, were less likely to be distressed about the experience in the following days. Thus, not only was religiosity associated with increased anxiety, but analytic cognitive style was associated with decreased religiosity *and* decreased anxiety. This, along with Pennycook et al.'s (2014a) direct correlation between conflict detection and religiosity, supports our reinterpretation of Inzlicht and colleagues' fMRI/EEG results.

The dACC and the broader prefrontal cortex are also heavily implicated in Asp and colleagues' neuropsychological model of doubt processes, the False Tagging Theory (FTT; Asp & Tranel, 2013). Under this perspective, belief is considered to be inherent in the process of comprehension (Spinozan belief model), and doubt is thought to be critically reliant on a network of brain regions: prefrontal cortex (PFC), dorsal anterior cingulate cortex (dACC), posterior parietal cortex (PPC), ventral tegmental area (VTA), amygdala, and the striatum. Central to this theory is the functions of the prefrontal cortex, which have been linked to the suppression of pathological confabulation, rejection of ad hoc beliefs, and inhibition of prepotent responses. The FTT asserts the prefrontal cortex acts to "false tag" initially believed representations in postrolandic association cortices. Neuroimaging has shown that in situations where doubt is necessary the prefrontal cortex is highly active (Asp & Tranel, 2013). It was argued that damage to the prefrontal cortex from strokes or tumor resections should lead to a general increase in credulity, where patients have a "doubt deficit" toward information that is compulsorily believed upon comprehension.

To test whether patients with lesions to the PFC had increased credulity to novel information, Asp, et al. (2012a) gave patients with focal brain lesions and heathy, age-matched adults magazine advertisements that had been deemed deceptive by the Federal Trade Commission. Patients with PFC damage were more credulous to the deceptive ads than patients with other lesions outside of the prefrontal cortex and healthy participants. This finding held even when the misleading ads contained a disclaimer rebutting the deceptive claim, suggesting that skepticism is generally lower in PFC patients. The results could not be explained by group differences in demographics or cognitive functioning, such as intelligence, memory, or reading ability. Lesion location was the only variable that was reliably associated with credulity to the deceptive ads. Although this result was intriguing, we wondered if this lesion-induced credulity could actually impact more abstract and structured social beliefs, such as religious beliefs.

Asp et al. (2012b) conducted an extensive religious belief and behavior survey in lesion patients to examine this hypothesis. The participants included: patients with prefrontal cortex damage (PFC, Figure 3), brain damage comparisons patients (BDC), and medical comparison patients (individuals who had undergone a life-threatening but non-neurological medical event, MC). The prefrontal cortex patients reported the highest specific religious beliefs (e.g., *belief in heaven*), and the greatest increase in specific religious beliefs following their brain injury/medical event (Figure 4). Compared to the other groups, prefrontal patients also reported the highest scores on scales of authoritarianism (e.g., *Our country will be great if we honor the ways of our forefathers, do what the authorities tell us to do, and get rid of the "rotten apples" that are ruining everything*) and religious fundamentalism (e.g., *God has given humanity a complete, unfailing guide to happiness and salvation, which must be totally followed*). The results cannot be accounted for by differences in religious affiliation, religious upbringing, religious service attendance, demographic variables, or general cognitive functioning. Moreover, neither an aversive medical event nor brain damage, *per se*, produced the high levels of religious beliefs in the prefrontal patients. Unfortunately, Asp et al. (2012b) had no way to gauge the

participants' beliefs prior to the lesion/medical event except to rely on their own memories of their past beliefs. Thus, it is possible that the authors happened to select prefrontal patients with *a priori* strong religious beliefs and they had worse belief recall than comparisons. However, this possibility was considered extremely unlikely as social attitudes in their rural Iowa samples tend to be relatively homogenous and there were no group differences on measures of memory. Moreover, in the 16 brain damaged patients that participated in both studies (8 were prefrontal patients), there was a strong bivariate correlation between credulity to the ads and religious fundamentalism ($r = .50$, $p = .05$). These data suggest that increased credulity is the cognitive mediator for high religious beliefs post lesion.

It should be noted that many of the prefrontal patients in Asp and colleagues' studies primarily had damage to the ventromedial prefrontal cortex (vmPFC) and frontal pole (Fig. 3). Neuroimaging studies have traditionally highlighted the dlPFC in the processes of cognitive control and the rejection of a stereotypical response during base-rate problems as described above (De Neys et al., 2008; Kerns et al., 2004). The vmPFC and dlPFC could serve distinct functions as suggested by many neuroimaging accounts and some lesion studies (e.g., Glascher et al., 2012). Alternatively, several studies argue that a more general function may be served by the prefrontal cortex that is not specific to dorsal or ventral subregions (Asp et al., 2013; Asp & Tranel, 2013; Duncan & Miller, 2002). Indeed, patients with exclusive damage to the dlPFC also tend to have increased credulity to deceptive advertisements and higher religious beliefs (Asp et al., unpublished).

Thus, it is possible the roles of the dlPFC and vmPFC are distinct and each offers a unique, but complementary contribution to disbelief. Under this thesis, the dlPFC is specific to the integration of Type 2 processing to decisions whereas the vmPFC represents an earlier, more basic doubt process that does not require substantive (or, perhaps, any) Type 2 processing. Analytic cognitive style, then, would represent the source of a *later* doubting process; one that operates on fully formed religious beliefs that have survived the false-tagging process. In both cases, however, it is the conflict between the incoming or default supernatural concept and previous materialistic conception of the world that allows doubt to occur.

However, it is also possible that the dlPFC and vmPFC broadly contribute the same function; the prefrontal cortex (in general) provides an adaptive resource which could increase or decrease availability due to task demands (Duncan & Miller, 2002). Asp and colleagues have argued this flexible resource is the function "false tagging" that contributes to a variety of perceptual and cognitive systems (Asp et al., 2013). In this model, "false tagging" is essential for Type 2 processing and analytic cognitive style, as doubt is necessary to reject immediate, intuitive answers (Asp et al., 2013; Mandelbaum, 2014). Future research will need to address the potential fractionation of the prefrontal cortex and the role of "false tagging" in Type 2 processing.

Conclusion

The cognitive science of religion has understandably focused primarily on explanations of religious belief. By focusing instead on the cognitive processes that lead to religious doubt and disbelief, the work reviewed here offers a much different perspective. This research highly implicates a critical role for the prefrontal cortex in the doubt, disbelief, and rejection of religious concepts. However, it should be emphasized that we regard the association between structural integrity of the prefrontal cortex and religiosity as one factor among many that contribute to religious belief and experience. Thus, while damage to the prefrontal cortex can lead to an increase in religious beliefs, the reverse is not necessarily true; i.e., individuals high in religious beliefs have prefrontal cortex brain damage. It is likely sociodemographic, cultural, and contextual variables all significantly impact one's religiosity independent of prefrontal cortex structural integrity.

Our theoretical and empirical work challenge the legitimacy of neuropsychological models that argue the prefrontal cortex is critical for religiosity and religious belief (e.g., Muramoto, 2004). Patients with extensive damage to the frontal lobe not only show belief and behavior consistent with religious concepts, but their conviction is often increased. We have argued the ability to detect cognitive discrepancies and revise cognitions on the basis of this conflict is necessary to doubt religious concepts. The evidence reviewed here strongly suggests the prefrontal cortex mediates these functions. However, the specific contribution of the prefrontal cortex's subregions (likely in conjunction with other brain regions) to religious doubt is still a matter for debate.

Perhaps there are two neuroanatomically-distinct levels of doubt that may undermine religious belief. First, a low level "false tagging" process located in the vmPFC may undermine an initially believed supernatural proposition by comparing it against extant (and conflicting) conceptions of the material world. Second, assuming an absence of a "false tag", higher level reasoning processes (in the dlPFC) may be recruited following successful conflict detection (in the dACC). Alternatively, "false tagging" or doubt may be a general resource that both the vmPFC and dlPFC can utilize following successful conflict detection. "False tagging" would play a critical role in higher reasoning processes (i.e., Type 2 processing). In this model, deficits in the ability to "false tag" should lead to a decreased analytic cognitive style and an increased reliance on heuristical responses.

The precise role of the prefrontal cortex toward religious doubt will need to be elucidated with future research. However, we believe this work represents an important first step for understanding the mechanisms of the backside of the religious belief coin.

Figure 1

Proportion of participants who failed to get a single problem correct (Left) on the Cognitive Reflection Test (CRT) or who successfully answered at least one out of three correct (Right) as a function of Type of Theistic Belief. The positive association between CRT performance and religious disbelief is evident across multiple levels of religious conventionality. The slight majority (52.8%) of Personal God Theists did not get a single CRT problem correct. In contrast, only 15.2% of Atheists fell into that group. Data from Pennycook et al. (2012), Study 1.

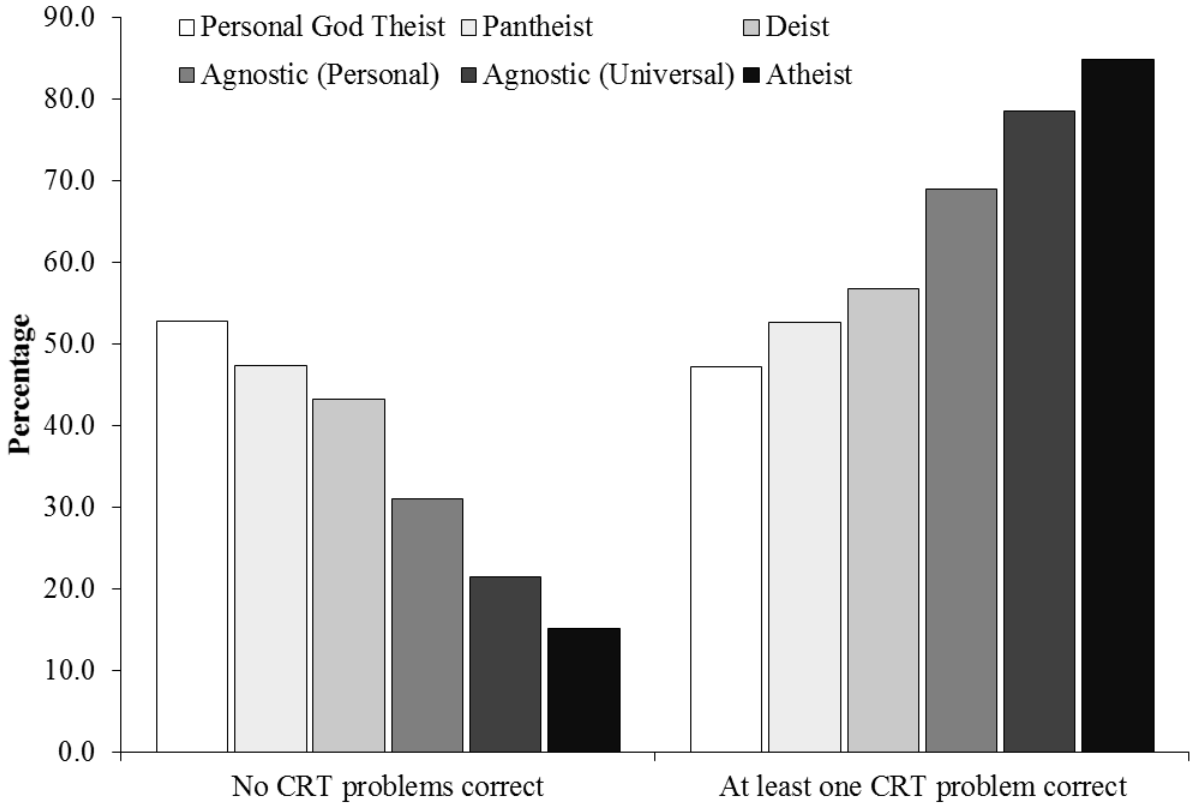


Figure 2

Mean RT difference between stereotypical responses to incongruent problems and congruent problems as a function of religious affiliation. The values represent RTs transformed via $\log_{10}$. A larger logRT difference indicates increasing sensitivity to the conflict between base-rate probabilities and stereotypical personality descriptions. These results indicate that agnostics/atheists are more efficient at detecting conflict during reasoning than the religiously affiliated. Data from Pennycook et al. (2014a), Experiment 3.

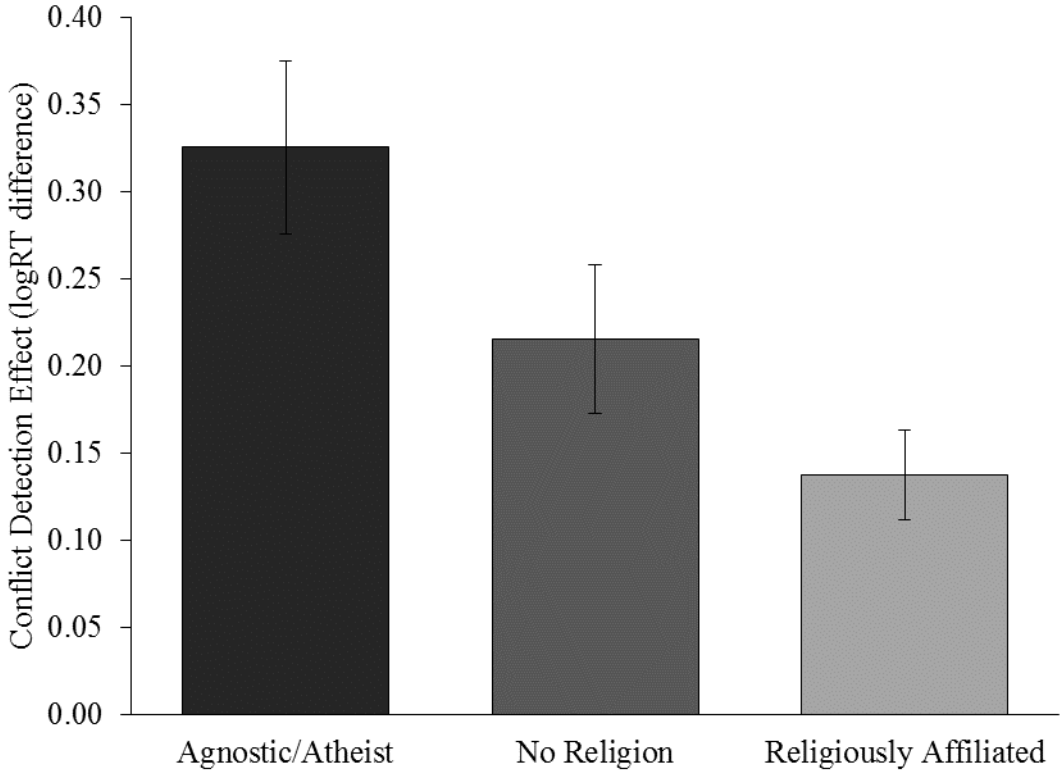


Figure 3. Data from Asp et al. (2012b). Lesion overlap of prefrontal patients. Lesions of the prefrontal patients are displayed in mesial and coronal slices. The color bar indicates the number of overlapping lesions at each voxel.

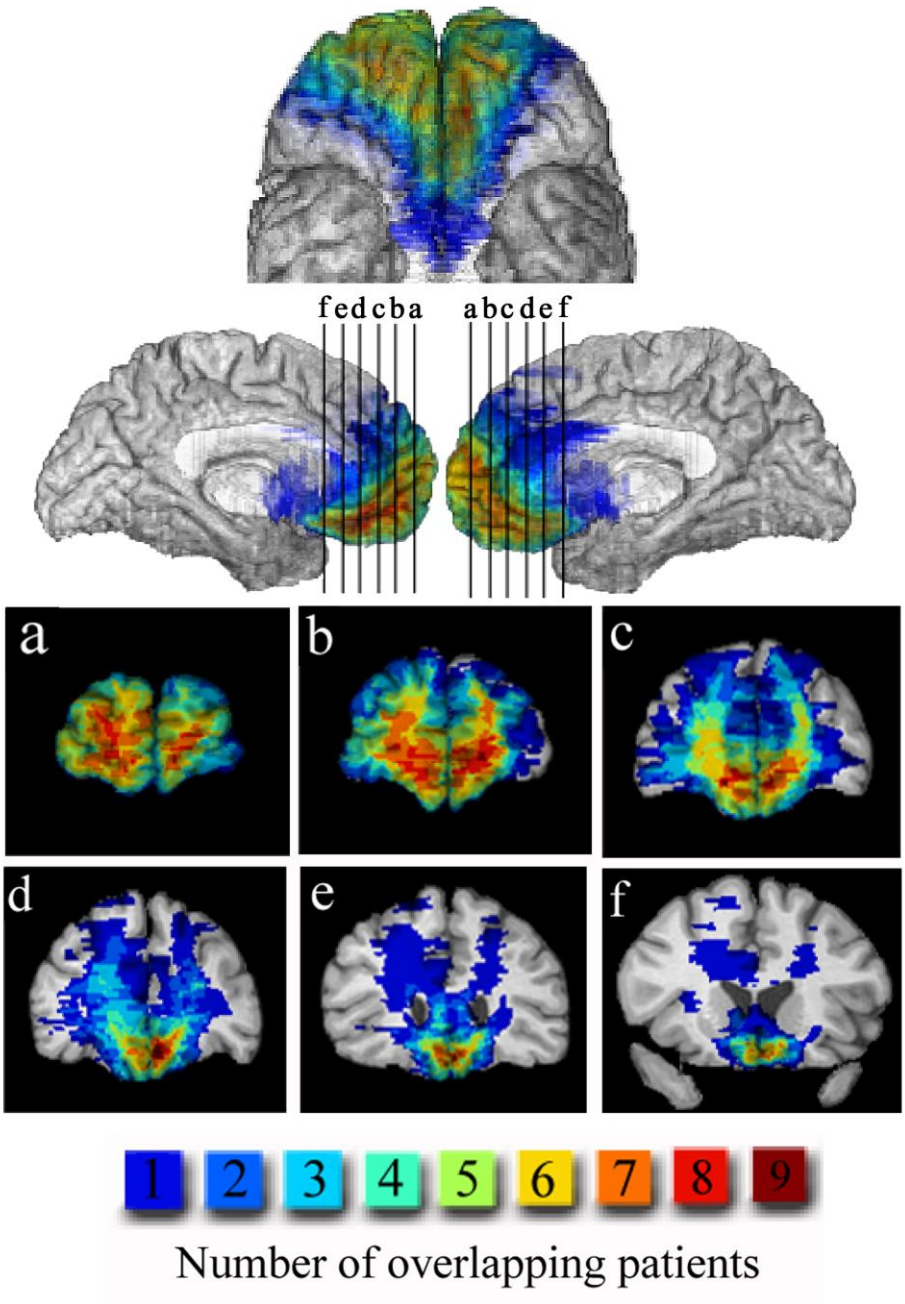
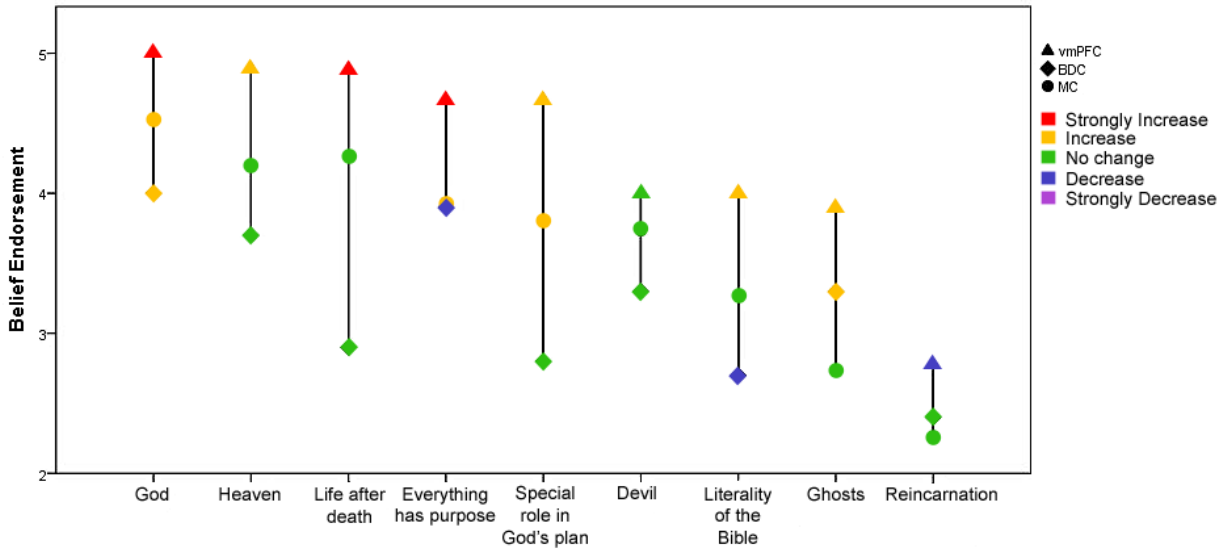


Figure 4. Data from Asp and Tranel (2013). Group religious belief endorsement means for specific beliefs. The y-axis represents belief endorsement, where 1 = low religious belief to 5 = high religious belief. The x-axis represents individual specific religious beliefs. MC, medical comparisons; BDC, brain damaged comparisons; vmPFC, prefrontal patients. Colors indicate reported changes in beliefs following a subject's medical event. Red and orange represent a mean increase in specific beliefs, green represents no change, and blue represents a mean decrease in beliefs. No group reported a strong decrease in any specific belief. Prefrontal patients reported the highest specific religious beliefs, and increases in beliefs.



References

Asp, E. W., Manzel, K., Koestner, B., Cole, C. A., Denburg, N. L., & Tranel, D. (2012a). A neuropsychological test of belief and doubt: Damage to ventromedial prefrontal cortex increases credulity for misleading advertising. *Frontiers in Neuroscience, 6*, 100.

This study showed that damage to specific structures in the brain lead to increased credulity to novel information.

Asp, E. W., Ramchandran, K., & Tranel, D. (2012b). Authoritarianism, religious fundamentalism, and the human prefrontal cortex. *Neuropsychology, 26*, 414-421.

Patients with damage to the prefrontal cortex report increased specific religious beliefs, religious fundamenalism, and authoritarianism.

Asp, E. W., Manzel, K., Koestner, B., Denburg, N. L., & Tranel, D. (2013). Benefit of the doubt: A new view of the role of the prefrontal cortex in executive functioning and decision making. *Frontiers in Neuroscience, 7*, 86.

Asp, E. W., & Tranel, D. (2013). False Tagging Theory: Toward a unitary account of prefrontal cortex function. In D. T. Stuss & R. T. Knight (Eds.), *Principles of Frontal Lobe Function* (2nd ed., pp. 383-416). New York: Oxford University Press.

This chapter details the False Tagging Theory, a neuroanatomical model of the belief and doubt processes, and discusses its implications to neuropsychology and neuropsychiatry.

Asp, E. W., Warner, K. A., Denburg, N. L., & Tranel, D. (unpublished). *Credulity and religious beliefs in patients with dorsolateral prefrontal cortex damage*. Department of Neurology. University of Iowa.

Atran, S., & Norenzayan, A. (2004). Religion's evolutionary landscape: Counterintuition, commitment, compassion, communion. *Behavioural and Brain Sciences, 27*, 713-770.

Barbey, A. K., & Sloman, S. A. (2007). Base-rate respect: From ecological rationality to dual processes. *Behavioural and Brain Sciences, 30*, 241-256.

Barrett, J. L. & Keil, F. C. (1996). Conceptualizing a nonnatural entity: Anthropomorphism in god concepts. *Cognitive Psychology, 31*, 219-247.

Browne, M., Pennycook, G., Goodwin, B., & McHenry, M. (2014). Reflective minds and open hearts: Cognitive style and personality predict religious and spiritual thinking in a community sample. *European Journal of Social Psychology.*

Botvinick, M.M., Braver, T.S., Barch, D.M., Carter, C.S., Cohen, J.D. (2001). Conflict monitoring and cognitive control. *Psychological Review, 108*, 624–52.

Botvinick, M. M., Cohen, J. D., & Carter, C. S. (2004). Conflict monitoring and anterior cingulate cortex: An update. *Trends in Cognitive Sciences, 8*, 539-546.

Cheyne, J. A., & Pennycook, G. (2013). Sleep paralysis postepisode distress: Modeling potential effects of episode characteristics, general psychological distress, beliefs, and cognitive style. *Clinical Psychological Science, 1*, 135–148.

De Neys, W. (2014). Conflict detection, dual processes, and logical intuitions: Some clarifications. *Thinking & Reasoning, 20*, 167-187.

De Neys, W., Vartanian, O., & Goel, V. (2008). When our brains detect that we are biased. *Psychological Science, 19,* 483-489.
Duncan, J., & Miller, E. K. (2002). Cognitive focus through adaptive neural coding in the primate prefrontal cortex. In D. T. Stuss & R. T. Knight (Eds.), *Principles of Frontal Lobe Function* (pp. 278-291). New York: Oxford University Press.
Egan, A. (2008). Seeing and believing: Perception, belief formation and the divided mind. *Philosophical Studies, 140,* 47-63.
Gallup (2011). U.S. Political ideology stable with conservatives leading. Aug 1, http://www.gallup.com/poll/148745/political-ideology-stable-conservatives-leading.aspx
Gehring, W. J., & Knight, R. T. (2000). Prefrontal-cingulate interations in action monitoring. *Nature Neuroscience, 3,* 516-520.
Gervais, W. M., & Norenzayan, A. (2012). Analytic thinking promotes religious disbelief. *Science, 336,* 493-496.
Gilbert, D. T. (1991). How mental systems believe. *American Psychologist, 46,* 107-119.
Gilbert, D. T. (1993). The assent of man: Mental representation and the control of belief. In D. M. Wegner & J. W. Pennebaker (Eds.), *Handbook of mental control* (pp. 57-87). Engelwood Cliffs, NJ: Prentice Hall.
Gilbert, D. T., Tafarodi, R. W., & Malone, P. S. (1993). You can't not believe everything you read. *Journal of Personality and Social Psychology, 65,* 221-233.
Glascher, J., Adolphs, R., Damasio, H., Bechara, A., Rudrauf, D., Calamia, M., . . . Tranel, D. (2012). Lesion mapping of cognitive control and value-based decision making in the prefrontal cortex. *Proceedings of the National Academy of Sciences, 109,* 14681-14686.
Guthrie, S. E. (1993). *Faces in the clouds: A new theory of religion*. Oxford: Oxford University Press.
Hasson, U., Simmons, J. P., & Todorov, A. (2005). Believe it or not. *Psychological Science, 16,* 566-571.
Hunsberger, B., McKenzie, B., Pratt, M., & Pancer, S. M. (1993). Religious doubt: A social-psychological analysis. *Research in the Social Scientific Study of Religion, 5,* 27-51.
Inzlicht, M., McGregor, I., Hirsh, J.B., & Nash, K. (2009). Neural markers of religious conviction. *Psychological Science, 20,* 385-392.
Inzlicht, M., Tullett, A. M., & Good, M. (2011). The need to believe: A neuroscience account of religion as a motivated process. *Religion, Brain, & Behavior, 1,* 192–212.
Kahneman, D., & Tversky, A. (1973). On the psychology of prediction. *Psychological Review, 80,* 237-251.
Kelemen, D. (2004). Are children "intuitive theists"? *Psychological Science, 15,* 295-301.
Kerns, J. G., Cohen, J. D., MacDonald, A. W., Cho, R. Y., Stenger, V. A., & Carter, C. S. (2004). Anterior cingulate conflict monitoring and adjustments in control. *Science, 303,* 1023-1026.
Mandelbaum, E. (2014). Thinking is believing. *Inquiry, 57,* 55-96.
Muramoto, O. (2004). The role of the medial prefrontal cortex in human religious activity. *Medical Hypotheses, 62,* 479-485.
Nadarevic, L., & Erdfelder, E. (2013). Spinoza's error: Memory for truth and falsity. *Memory & Cognition, 41,* 176-186.
Pennycook, G. (2014). Evidence that analytic cognitive style influences religious belief: Comment on Razmyar and Reeve (2013). *Intelligence, 43,* 21-26.

Pennycook, G., Cheyne, J.A., Barr, N., Koehler, D.J. & Fugelsang, J.A. (2014a). Cognitive style and religiosity: The role of conflict detection. *Memory & Cognition, 42*, 1-10.

This work showed that an important factor mediating the relationship between analytic cognitive style and religious disbelief is cognitive conflict detection.

Pennycook, G., Cheyne, J.A., Barr, N., Koehler, D.J. & Fugelsang, J.A. (2014b). The role of analytic thinking in moral judgements and values. *Thinking & Reasoning, 20*, 188-214.

Pennycook, G., Cheyne, J.A., Koehler, D.J. & Fugelsang, J.A. (2013). Belief bias during reasoning among religious believers and skeptics. *Psychonomic Bulletin & Review 20*, 806-811.

Pennycook, G., Cheyne, J.A., Seli, P., Koehler, D.J. & Fugelsang, J.A. (2012). Analytic cognitive style predicts religious and paranormal belief. *Cognition, 123*, 335-346.

This study helped establish the association between analytic cognitive style and religious disbelief and provided evidence for the domain generality of religious doubt.

Pennycook, G., Fugelsang, J.A., & Koehler, D.J. (2015). What makes us think? A three-stage dual-process model of analytic engagement. *Cognitive Psychology, 80*, 34-72.

Pennycook, G., Ross, R., Koehler, D.J., & Fugelsang, J.A. (2016). Atheists and agnostics are more reflective than religious believers: Four empirical studies and a meta-analysis. *PLoS ONE, 11*, e0153039.

Pennycook, G., Trippas, D., Handley, S. J., & Thompson, V.A. (2014c). Base-rates: Both neglected and intuitive. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 40*, 544-554.

Razmyar, S. & Reeve, C. L. (2013). Individual differences in religiosity as a function of cognitive ability and style. *Intelligence*, 667-673.

Shackman, A. J., Salomons, T. V., Slagter, H. A., Fox, A. S., Winter, J. J., & Davidson, R. J. (2011). The integration of negative affect, pain and cogntive control in the cingulate cortex. *Nature Reviews Neuroscience, 12*, 154-167.

Shenhav, A., Rand, D. G., & Greene, J. D. (2012). Divine intuition: Cognitive style influences belief in god. *Journal of Experimental Psychology: General*, *141*, 423-428.

Shreve-Neiger, A.K., & Edelstein, B.A. (2004). Religion and anxiety: A critical review of the literature. *Clinical Psychology Review, 24*, 379-397.

Spelke, E., Phillips, A. & Woodward, A. (1995) Infants' knowledge of object motion and human action. In: *Causal cognition*, ed. D. Sperber, D. Premack & A. Premack. Clarendon Press.

Stanovich, K. E., & West, R. F. (2003). Evolutionary versus instrumental goals: How evolutionary psychology misconceives human rationality. In D. E. Over (Ed.), *Evolution and the psychology of thinking: The debate*, Hove and New York: Psychological Press.

Svedholm, A. M., & Lindeman, M. (2012). The separate roles of the reflective mind and involuntary inhibitory control in gatekeeping paranormal beliefs and the underlying intuitive confusions. *British Journal of Psychology, 104*, 303-319.

Van Leeuwen, N. (2014). Religious credence is not factual belief. *Cognition*.

Yonker, J. E., Edman, L. R. O., Cresswell, J., Barrett, J. L. (2016). Primed analytic thought and religiosity: The importance of individual characteristics. *Psychology of Religion and Spirituality, 8*, 298-308.

Zuckerman, P. (2007). Atheism: Contemporary Numbers and Patterns. In M. Martin (Ed.), *The Cambridge Companion to Atheism* (pp. 47 - 65). New York, NY:Cambridge University Press.