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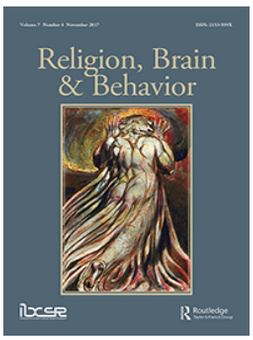

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ABSTRACT

We propose a Bayesian framework as an important theoretical and methodological tool to improve the scientific study of religion. At a theoretical level, the Bayesian predictive processing framework has the potential to provide a unifying account of religious beliefs and experience by stressing the central role of error monitoring and error correction in belief maintenance. At a methodological level, Bayesian statistics are needed to provide the extraordinary evidence for the extraordinary theoretical claims regarding the causes and consequences of religion.

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Bayesian statistics; cognitive science of religion; predictive coding; prediction error

We highlight two main problems that in our view have limited progress in the experimental study of religion. First, we argue that the field of the experimental study of religion lacks a unifying theoretical framework that allows us to relate evolutionary theories regarding the ultimate function of religion to the proximate psychological and cognitive mechanisms supporting supernatural beliefs (Tinbergen, 1963). Second, the methods used in the scientific study of religion cannot provide the necessary evidence to support the extraordinary claims that are often made and therefore it is unclear to what extent theories are actually supported by empirical data (van Elk et al., 2015).

In response to these problems, we propose a Bayesian framework that provides a unifying theoretical and methodological tool to advance the experimental study of religion. At a *theoretical level*, the Bayesian framework of predictive updating can be used to explain the emergence of religious beliefs, rituals, and experiences. At a *methodological level*, Bayesian statistics can directly quantify the evidential support for and against specific hypotheses, thereby allowing us to settle the debate over longstanding and controversial issues. Below we argue that the common thread that connects these two innovations is a focus on learning, that is, *belief updating through prediction errors*.

Bayes in the brain: theoretical innovation

At a theoretical level, "predictive processing" has been proposed as a powerful and unifying theoretical framework according to which the human brain should be conceived of as a Bayesian prediction machine (Clark, 2013). Following the basic principle of Helmholtz that perception is active inference, many studies have shown how sensory signals are "explained away" by top-down predictive signals, while bottom-up prediction errors result in the updating of the prior model. While predictive processing has been successfully applied to explain basic perception, recently the framework has been extended to more complex phenomena as well, such as delusional beliefs (Fletcher & Frith,

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2009), religious experience (Taves & Asperem, 2016), and religious rituals (Schjoedt et al., 2013). Central to these theoretical accounts is that religious beliefs are acquired and maintained through a process of reduced prediction error monitoring. Strongly grounded in the Bayesian framework, these approaches account well for the available empirical evidence and at the same time provide novel and testable predictions for future research (see, for instance, van Elk & Aleman, submitted). Importantly, the predictive processing framework can be integrated with evolutionary accounts of religion by specifying how proximate predictive mechanisms have evolved to solve adaptive problems. On this account, adaptive biases can be conceived as evolved priors that have been shaped by our evolutionary past (Barrett, 2014). This way the Bayesian approach can provide a unifying framework that allows us to account for both the involvement of evolved cognitive biases (Willard & Norenzayan, 2013) as well as the role of cultural learning (Gervais & Najle, 2015) in religious beliefs and experiences. The predictive processing framework is also compatible with dual-systems accounts of religion and magical thinking (Risen, 2015), according to which religious beliefs primarily originate from an intuitive processing mode and are sustained through a process of acquiescence or "reduced error correction" (cf. van Elk & Aleman, submitted).

However, we also note that there remain important challenges for the predictive processing framework. A predictive processing account needs to concede the possibility that for believers their supernatural beliefs have a different epistemic status than factual beliefs (Van Leeuwen, 2014) and are thus not always subject to prediction error monitoring (and relatedly, in some cases imperfect Bayesian updating could occur; Camerer & Hua Ho, 1999). The Bayesian approach also needs to bridge the gap between so-called low-level perceptual phenomena and more high-level aspects of human cognition and experience. We propose that a building-block approach to the study of religion (Taves, 2011) and a strong grounding of the study of religion in mainstream psychological and neuroscience research (e.g., on agency, free will, belief formation, and interoception) in the context of the Bayesian framework will provide a good starting point. Having identified the basic building blocks, research should next focus on how specific beliefs and experiences are "deemed religious" within a specific context (Taves, 2011).

Bayes on paper: methodological innovation

At a methodological level, the Bayesian framework has been proposed as an alternative to the use of classical or frequentist statistics (Edwards, Lindman, & Savage, 1963; Wagenmakers, 2007). The core premise of the Bayesian approach is that prior knowledge is continually updated by means of prediction errors to yield posterior knowledge. Applied to statistical hypotheses, this means that one can quantify the degree to which the data support the null hypothesis versus an alternative hypothesis; consequently, Bayesian inference allows one to draw a distinction between "absence of evidence" (i.e., the data are uninformative) and "evidence of absence" (i.e., the data support the null hypothesis). Finally, in the Bayesian framework, evidence and model parameters may be monitored over time, as data accumulate, indefinitely and without a sampling plan. The Bayesian approach to statistics thus offers many advantages over classical null-hypothesis testing and these advantages are especially relevant when the potential stakes are high (e.g., as in the field of parapsychology, but also in the scientific study of religion). Basically, extraordinary claims (e.g., that religious faith fosters mental and physical well-being) require extraordinary evidence (Wagenmakers, Wetzels, Borsboom, & van der Maas, 2011) that cannot easily be provided by classical frequentist statistics.

These methodological and statistical innovations are especially welcome given that the field of psychology has been plagued by concerns regarding the reproducibility of important research findings (Pashler & Wagenmakers, 2012) and the potential of questionable research practices underlying many of the effects reported (Simmons, Nelson, & Simonsohn, 2011). These problems are even more apparent in the scientific study of religion: for instance, many studies suffer from small sample sizes (van Elk et al., 2015), turn out to be difficult to replicate (Gomes & McCullough, 2015), unknown moderators could determine the boundary conditions for an effect to occur (Shariff & Norenzayan,

2015), and extraordinary claims (e.g., regarding the positive effects of religion on health or self-control; Rounding, Lee, Jacobson, & Ji, 2012) are often based on only marginally significant effects. Therefore, we argue that Bayesian statistics and Bayesian meta-analysis techniques should become standard practice in the scientific study of religion. Through these techniques, the evidential value of the studies conducted can be continuously evaluated and monitored (Wagenmakers, Morey, & Lee, 2016), thereby allowing support or refutation of extraordinary claims regarding the potential causes and consequences of religion.

In sum, its focus on prediction, learning, and knowledge updating makes the Bayesian approach useful both as a theoretical framework ("Bayes in the brain") and as a methodological innovation ("Bayes on paper") for the experimental study of religion. Similar to the mathematical problems identified by Hilbert, it is our hope that the Bayesian approach will spark the flame by encouraging rigorous scientific work on the experimental study of religion in the decade to come.

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