



Analytic Thinking Promotes Religious Disbelief

Will M. Gervais and Ara Norenzayan

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Supplementary Materials

www.sciencemag.org/cgi/content/full/science.1219328/DC1
Materials and Methods

Figs. S1 to S20

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Analytic Thinking Promotes Religious Disbelief

Will M. Gervais* and Ara Norenzayan*

Scientific interest in the cognitive underpinnings of religious belief has grown in recent years. However, to date, little experimental research has focused on the cognitive processes that may promote religious disbelief. The present studies apply a dual-process model of cognitive processing to this problem, testing the hypothesis that analytic processing promotes religious disbelief. Individual differences in the tendency to analytically override initially flawed intuitions in reasoning were associated with increased religious disbelief. Four additional experiments provided evidence of causation, as subtle manipulations known to trigger analytic processing also encouraged religious disbelief. Combined, these studies indicate that analytic processing is one factor (presumably among several) that promotes religious disbelief. Although these findings do not speak directly to conversations about the inherent rationality, value, or truth of religious beliefs, they illuminate one cognitive factor that may influence such discussions.

Although most people fervently believe in God or gods, there are nonetheless hundreds of millions of nonbelievers worldwide (1), and belief and disbelief fluctuate across situations and over time (2). Religious belief and disbelief are likely complex, multi-determined, psychologically and culturally shaped phenomena, yet to date little experimental research has explored the specific cognitive underpinnings of religious disbelief (3, 4). Here we begin to address this important gap in the literature by applying a dual-process cognitive framework, which predicts that analytic thinking strategies might be one potent source of religious disbelief.

According to dual-process theories of human thinking (5, 6), there are two distinct but interacting systems for information processing. One

(System 1) relies upon frugal heuristics yielding intuitive responses, while the other (System 2) relies upon deliberative analytic processing. Although both systems can at times run in parallel (7), System 2 often overrides the input of system 1 when analytic tendencies are activated and cognitive resources are available. Dual-process theories have been successfully applied to diverse domains and phenomena across a wide range of fields (5, 6, 8, 9).

Available evidence and theory suggest that a converging suite of intuitive cognitive processes facilitate and support belief in supernatural agents, which is a central aspect of religious beliefs worldwide (10–13). These processes include intuitions about teleology (14), mind-body dualism (13), psychological immortality (15), and mind perception (16, 17). Religious belief therefore bears many hallmarks of System 1 processing.

If religious belief emerges through a converging set of intuitive processes, and analytic processing can inhibit or override intuitive processing,

then analytic thinking may undermine intuitive support for religious belief. Thus, a dual-process account predicts that analytic thinking may be one source of religious disbelief. Recent evidence is consistent with this hypothesis (4), finding that individual differences in reliance on intuitive thinking predict greater belief in God, even after controlling for relevant socio-demographic variables. However, evidence for causality remains rare (4). Here we report five studies that present empirical tests of this hypothesis.

We adopted three complementary strategies to test for robustness and generality. First, study 1 tested whether individual differences in the tendency to engage analytic thinking are associated with reduced religious belief. Second, studies 2 to 5 established causation by testing whether various experimental manipulations of analytic processing, induced subtly and implicitly, encourage religious disbelief. These manipulations of analytic processing included visual priming, implicit priming, and cognitive disfluency (18, 19). Third, across studies, we assessed religious belief using diverse measures that focused primarily on belief in and commitment to religiously endorsed supernatural agents. Samples consisted of participants from diverse cultural and religious backgrounds (20).

Study 1 was a correlational study with Canadian undergraduates ($N = 179$). We correlated performance on an analytic thinking task with three related, but distinct, measures of religious belief. The analytic thinking task (6) contains three problems that require participants to analytically override an initial intuition. This task was designed to specifically measure analytic processing because an intuitive reading of each problem invites a quick and easy, yet incorrect, response that must be analytically overridden (Table 1). Furthermore, experimental manipulations known to induce analytic processing

University of British Columbia, Vancouver, BC V6T1Z4, Canada.

*To whom correspondence should be addressed. E-mail: will@psych.ubc.ca (W.M.G.); ara@psych.ubc.ca (A.N.)

Table 1. Summary of measures used. Asterisks (*) denote reverse-scored items.

	Intuitive answer	Analytic answer
Study 1. Analytic thinking task (5)		
A bat and a ball cost \$1.10 in total. The bat costs \$1.00 more than the ball. How much does the ball cost? ____cents	10	5
If it takes 5 machines 5 min to make 5 widgets, how long would it take 100 machines to make 100 widgets? ____minutes	100	5
In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake? ____days	24	47
Intrinsic religiosity (21), study 1 $\alpha = 0.90$		
My faith involves all of my life.		
I try hard to carry my religion over into all my other dealings in life.		
In my life I feel the presence of the Divine.		
Nothing is as important to me as serving God as best I know how.		
My faith sometimes restricts my actions.		
One should seek God's guidance when making every important decision.		
My religious beliefs are what really lie behind my whole approach to life.		
*It doesn't matter so much what I believe as long as I lead a moral life.		
*Although I am a religious person, I refuse to let religious considerations influence my everyday affairs.		
*Although I believe in my religion, I feel there are many more important things in life.		
Intuitive religious belief, study 1 $\alpha = 0.80$		
I believe in God		
When I am in trouble, I find myself wanting to ask God for help		
* When people pray they are only talking to themselves		
* I just don't understand religion		
* I don't really spend much time thinking about my religious beliefs		
Belief in supernatural agents, study 1 $\alpha = 0.91$		
God exists		
The devil exists		
Angels exist		

reliably improve performance on the task (18). After completing the analytic thinking task, participants completed three different measures of religious belief, including a widely used 10-item intrinsic religiosity scale (Religiosity) (21), a new five-item intuitive religious belief scale (Intuitive), and another scale assessing belief in religious supernatural agents (Agents: God, angels, the devil). Table 1 presents all items from all measures. The three religious belief scales were all highly interrelated, providing evidence for convergent validity; all correlation coefficients (r 's) were between 0.77 and 0.80, and all P values (P 's) were <0.001 .

In study 1, as hypothesized, analytic thinking was significantly negatively associated with all three measures of religious belief, $r_{\text{Religiosity}} = -0.22, P = 0.003$; $r_{\text{Intuitive}} = -0.15, P = 0.04$; and $r_{\text{Agents}} = -0.18, P = 0.02$. This result demonstrated that, at the level of individual differences, the tendency to analytically override intuitions in reasoning was associated with religious disbelief, supporting previous findings (4).

Studies 2 to 5 tested causation by using experimental manipulations to elicit analytic thinking. We took considerable steps to remove potential effects of experimental demand. In all experiments, instructions were fully automated. In addition, all experimental manipulations used subtle techniques to elicit analytic thinking. Across studies, funnel debriefings revealed that partic-

ipants only very rarely detected a connection between manipulations and religious belief measures (20). Study 2 used a visual priming paradigm in which a sample of Canadian undergraduates rated their belief in God (from 0 to 100) after being randomly assigned to view four images (samples provided in Fig. 1) of either artwork depicting a reflective thinking pose (Rodin's

The Thinker; $N = 26$) or control artwork matched for surface characteristics like color and posture (*Discobolus* of Myron; $N = 31$). A pilot test with different participants ($N = 40$) revealed that this novel priming procedure significantly improved performance on a syllogistic reasoning task that measures analytic tendencies (20). In the present study, as hypothesized, viewing *The Thinker* significantly promoted religious

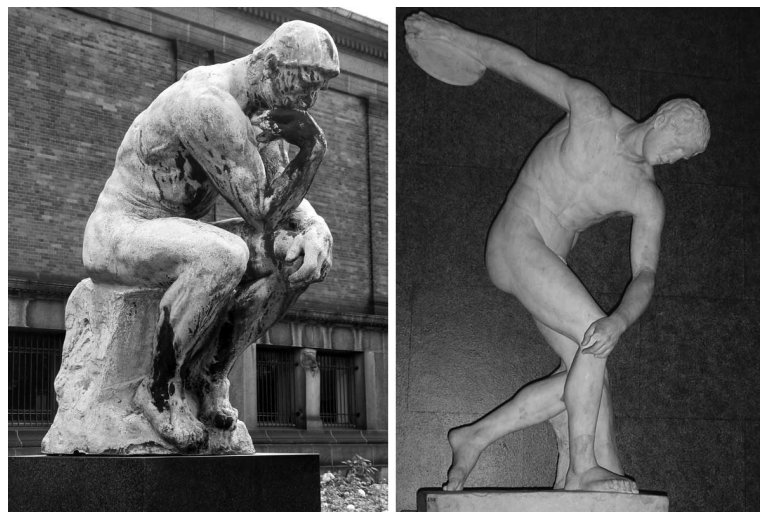


Fig. 1. Sample images of *The Thinker* (left) and *Discobolus* (right) used in study 2. The images shown here are similar to, but not the exact same ones used in the study. [Source: Wikimedia]

Table 2. Summary of experimental methods and findings (studies 2 to 5). *d* reflects effect size estimates (Cohen's *d*).

Study Belief measure (possible range)	Condition: sample stimuli	<i>N</i>	<i>M</i>	<i>SD</i>	<i>t</i>	<i>P</i>	<i>d</i>
2: Art Belief in God (0–100)	Control: <i>Discobolus</i>	31	61.55	35.68	2.24	0.03	0.59
	Analytic: <i>The Thinker</i>	26	41.42	31.47			
3: Implicit Supernatural agents (3–21)	Control: hammer, shoes, jump, retrace, brown	43	12.65	5.29	2.11	0.04	0.44
	Analytic: think, reason, analyze, ponder, rational	50	10.12	6.13			
4: Implicit Intrinsic religiosity (10–70)	Control: hammer, shoes, jump, retrace, brown	75	40.16	16.73	2.20	0.03	0.36
	Analytic: think, reason, analyze, ponder, rational	70	34.39	14.77			
5: Disfluency Supernatural agents (3–21)	Control: sample font	88	12.16	5.99	2.06	0.04	0.31
	Analytic: <i>sample font</i>	91	10.40	5.44			

disbelief [$t(55) = 2.24$, $P = 0.03$, Cohen's $d = 0.60$; Table 2]. In sum, a novel visual prime that triggers analytic thinking also encouraged disbelief in God. Although participants showed no awareness of the hypothesis or the influence of the primes, study 2 nonetheless relied on a fairly overt task to induce analytic processing. To further reduce potential experimental demand, studies 3 to 5 relied on even subtler manipulations to trigger analytic thinking outside of participants' explicit awareness.

In studies 3 and 4, participants rated their religious belief after completing a modified verbal fluency task priming procedure (22) previously used to activate analytic thinking without explicit awareness (23). In this task, participants received 10 different sets of five randomly arranged words (e.g., "high winds the flies plane"). For each set of five words, participants dropped one word and rearranged the others to form a meaningful phrase (e.g., "the plane flies high"). The analytic condition included five-word sets containing target analytic thinking words (analyze, reason, ponder, think, rational), and the control condition included thematically unrelated words (e.g., hammer, shoes, jump, retrace, brown, etc.). Because these exact words have not been used in previous research relating implicit primes to analytic thinking, we performed a pilot test with another group of participants ($N = 79$), which indicated that the analytic thinking primes did, as expected, improve performance on a subsequent analytic thinking task (20).

Study 3 included a sample of Canadian undergraduates who were randomly assigned to either the Analytic ($N = 50$) or the Control ($N = 43$) prime before completing the belief in supernatural agents measure used in study 1 (Table 1). As hypothesized, implicitly primed analytic thinking concepts significantly increased religious disbelief [$t(91) = 2.11$, $P = 0.04$, Cohen's $d = 0.44$; Table 2]. In addition, we obtained a measure of pre-experiment religious belief several weeks before the experimental session

to test whether pre-experiment individual differences in religious belief moderated any effects of analytic thinking on religious belief. Premeasured religious belief did not significantly moderate the effects of the analytic thinking prime on religious belief ($F = 0.42$, $P = 0.66$) (20).

Study 4 replicated the main result of study 3 with a broad nationwide (though nonrepresentative) sample of American adults recruited online, reflecting a wide range in age, income, and education (20, 24). Participants were again randomly assigned to complete either the Analytic ($N = 71$) or the Control ($N = 77$) implicit prime before completing the intrinsic religiosity measure used in study 1 (Table 1). Implicitly primed analytic thinking concepts again increased religious disbelief [$t(143) = 2.20$, $P = 0.03$, Cohen's $d = 0.36$; Table 2]. Combined, studies 3 and 4 demonstrated that even implicitly primed analytic thinking promotes religious disbelief. Nonetheless, experimental manipulations in studies 2 to 4 elicited analytic thinking by having participants perform one task or another (looking at pictures or unscrambling sentences) before rating their religious beliefs. Although unlikely, it is conceivable that the act of performing any task—not just tasks known to elicit analytic cognitive tendencies—may decrease religious belief.

In study 5, we used a still more subtle experimental manipulation that did not even require participants to perform an initial task to activate analytic thinking. We relied on cognitive disfluency, which is known to trigger analytic thinking strategies (18, 19). For example, in previous research, merely presenting information in a difficult-to-read font improves performance on multiple standard tasks used to evaluate analytic thinking in dual-process research, including syllogistic reasoning and the analytic thinking task used in study 1 (18, 19). We capitalized on these established findings by having participants rate their religious beliefs on a questionnaire presented in fonts pre-rated by a separate

group of participants (20) as either typical ($N = 91$; **sample**) or difficult-to-read ($N = 91$; *sample*). As hypothesized, analytic thinking activated via disfluency significantly increased religious disbelief [$t(177) = 2.06$, $P = 0.04$, Cohen's $d = 0.31$; Table 2]. As in study 4, individual differences in pre-experiment religious belief did not moderate the effect of analytic thinking on religious belief ($F < 0.05$, $P = 0.96$) (20). Additional alternative explanations focusing on experimental artifacts introduced by the disfluent font did not receive empirical support (20).

All of the manipulations used in studies 2 to 5 plausibly produce multiple effects, and any specific finding in a given study may be open to alternative explanations and should be interpreted with caution. However, across all studies, it is difficult to think of a broad alternative explanation that could parsimoniously explain why analytically overriding intuitive answers, visual exposure to a thinking pose, implicit priming of analytic thinking concepts, and perceptual disfluency all converge on promoting religious disbelief. By contrast, the hypothesis that analytic processing—which empirically underlies all experimental manipulations—promotes religious disbelief explains all of these findings in a single framework that is well supported by existing theory regarding the cognitive foundations of religious belief and disbelief.

These findings provoke the question of exactly at which stage of processing analytic strategies influence religious belief. We suggest three possibilities for future research. First, analytic processing may directly inhibit the low-level intuitions that presumably support religious beliefs, rather than acting specifically on higher-order religious cognitions. In support of this possibility, manipulations known to interfere with analytic thinking also increase the tendency to engage in teleological thinking (25). Second, engagement with analytic thinking may leave such low-level intuitions operational, yet inhibit the development of higher-order religious beliefs as they begin to arise in appropriate cultural contexts.

That is, people may still draw, for example, on teleological or dualistic intuitions, yet analytically override theistic beliefs. Third, rather than inhibiting low-level intuitions directly, or inhibiting theistic tendencies resulting from intuitive processes, analytic thinking might allow people to reflectively override existing religious beliefs. All three of these possibilities are broadly consistent with the present results, and may be complementary accounts rather than alternatives. We leave these intriguing possibilities for future research.

In closing, we urge caution in interpreting three key implications of the present results. First, although these findings were robust to variation in ethnic and religious backgrounds in the current samples, and in study 4, to variation in other demographic characteristics (20), it is important to examine the generalizability of our findings further across a more diverse range of populations and cultural contexts in future research (26). Second, although these results indicate that analytic processing promotes religious disbelief, we again emphasize that analytic processing is almost certainly not the sole cause of religious disbelief. Disbelief likely also emerges from selective deficits in the intuitive cognitive processes that enable the mental representation of religious concepts such as supernatural agent beliefs (10, 11, 13, 27), from secular cultural contexts lacking cues that one should adopt specific religious beliefs (1, 28, 29), and in societies that effectively guarantee the existential security of their citizens (30). The present results suggest one possible cognitive source of religious disbelief, and join a growing literature using experimental techniques to test hypotheses regarding

the cognitive, motivational, and cultural origins of religious beliefs (31). Finally, we caution that the present studies are silent on long-standing debates about the intrinsic value or rationality of religious beliefs (32, 33), or about the relative merits of analytic and intuitive thinking in promoting optimal decision making (34). Instead, these results illuminate, through empirical research, one cognitive stage on which such debates are played (35).

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Supplementary Materials

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Supplementary Text
Table S1
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