Supernatural Explanations Across the Globe Are More Common for Natural Than Social Phenomena

Joshua Conrad Jackson^{1*}, Danica Wilbanks^{2*}, Brock Bastian³, Joseph Watts^{4,5}, William Buckner⁶, Nicholas DiMaggio², & Kurt Gray²

1. Kellogg School of Management, Northwestern University, Evanston, IL, USA
2. Department of Psychology and Neuroscience, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA
3. Department of Psychology, University of Melbourne, Melbourne, Australia
4. Religion Programme, University of Otago, Dunedin, New Zealand
5. Max Planck Institute for the Science of Human History, Max Planck Institute, Jena, Germany
6. Department of Anthropology, Boston University, Boston, MA, USA

*Correspondence should be addressed to joshua.jackson@kellogg.northwestern.edu or danicaw@email.unc.edu

Abstract

Humans across the globe use supernatural beliefs to explain the world around them. This paper explores whether cultural groups invoke the supernatural more to explain natural phenomena (e.g., storms, disease outbreaks) or social phenomena (e.g., murder, warfare). Quantitative analysis of ethnographies across geographically and culturally diverse societies found that supernatural explanations are more prevalent for natural than for social phenomena, consistent with theories that ground the origin of religious belief in a human tendency to perceive intent and agency in the natural world. Despite the dominance of supernatural explanations of natural phenomena, supernatural explanations of social phenomena were especially prevalent in urbanized societies with more complex and anonymous groups. Our results show how people use supernatural beliefs as explanatory tools in non-industrial societies, and how these applications vary across small-scale communities vs. large and urbanized groups.

Humans have long used religious beliefs to understand the world. Ancient Chinese and Korean societies used divine intervention to explain and justify dynastic change¹, and Egyptians, Aztecs, Celts, and Tiv people used the will of gods to explain celestial cycles². In the modern world, 90% of Muslim Tunisians believe that the evil eye can cause physical harm³, and many American Christians perceived the COVID-19 pandemic as a form of apocalyptic divine punishment⁴. In these examples, humans make supernatural explanations by claiming that a supernatural agent (e.g., a god, ancestor spirit, or witch) or supernatural force (e.g., karma, evil eye) is responsible for some earthly event.

Since the 19th century, scientists, philosophers, and theologians have explained supernatural explanations using a “god of the gaps” hypothesis—people infer supernatural agency behind phenomena which they do not understand^{5,6}. A narrow interpretation of this account could be that people use religion as a stopgap when a phenomenon has no clear scientific explanation (e.g., the origin of the universe)⁷. But a broader interpretation of “god of the gaps” is that people use supernatural agency to explain phenomena that have ambiguous causation. While this reasoning is popular, we still know little about the gaps that people use religion to fill. If people use religious beliefs to explain the world, what about the world do they seek to explain? We answer this question by surveying supernatural explanations in a global sample of societies.

We draw our hypotheses from the cognitive sciences, focusing especially on the theory of dyadic morality, which suggests that phenomena will gain supernatural explanations when they have an ambiguous causal agent⁸. According to this theory, humans intuitively perceive helpful or harmful phenomena through a “dyadic template” consisting of an agent and a patient^{9,10}. In many cases, both the agent and the patient are clear, like a child (the patient) who is abused by his parent (the agent). But in some cases, a patient seems to be helped or harmed without a clear agent, and people may be most likely to impute supernatural agency in these cases in a process of “dyadic completion.”¹¹ Consider a family who is killed by a flood while picnicking after a dam breaks. Past studies show that people are more likely to give a supernatural explanation for the family’s death (i.e., the hand of God) when the dam broke spontaneously compared to if a dam worker had released the water⁸. This theory suggests that there is a basic human tendency to develop supernatural explanations for events which have absent or ambiguous causal agents⁸.

Here we use this logic to test whether supernatural explanations are more common for “natural” phenomena such as droughts and storms—which often have no human causal agent—than for “social” phenomena such as murder and theft which are more likely to involve a responsible human agent. Our focus builds on a long legacy of studying religious belief and the natural world which can be traced to Tylor¹², Frazer¹³, Muller¹⁴, and Hume¹⁵. These scholars wrote about animistic religions which endowed animals, plants, and even rocks with souls and intentions. More recent psychological studies show that humans^{16–19}—and even some non-human animals^{20,21}—tend to attribute intentionality to phenomena in nature, and that natural disasters can increase religious conviction^{22–24}. These studies have mostly focused on smaller samples of Western and educated participants, but we suggest that a tendency to engage in dyadic completion should lead people from many different cultures to develop supernatural explanations for natural phenomena more commonly than for social phenomena.

However, we also acknowledge evidence that humans may be equally likely or more likely to develop supernatural explanations for “social” phenomena—in which one person or group acts on another person or group—as they are for natural phenomena. Humans are social animals and display an outsized interest in other humans from an early age²⁵, suggesting that humans may also develop religious beliefs that explain social behavior. Ethnographic studies describe many socially focused religious beliefs, including beliefs in religious specialists such as shamans and witches who can help or harm others through magical powers or special relationships with supernatural agents^{26–29}. Many groups also use prophecy and specialized rituals to predict and influence intergroup conflicts³⁰, and use theories of spiritual possession to explain social norm violations and justify punishments for these violations^{31–33}.

We test whether supernatural explanations are more prevalent for natural phenomena than social phenomena across a diverse sample of 114 societies within the ethnographic record, focusing on 107 of these societies in our main text and analyzing the full range of 114 in the supplementary results. We define supernatural explanations as the attribution of an event to supernatural processes, such as the actions of a supernatural agent (e.g., gods, ancestor spirits, human magical practitioners such as witches or shamans) or supernatural force (e.g., karma, evil eye). Using cross-cultural coding techniques from anthropology^{34,35}, we catalogue common supernatural explanations in each society based on qualitative ethnographic descriptions. We then compare the prevalence of naturally focused and socially focused supernatural explanations.

Analyzing the ethnographic record also makes it possible for us to incorporate sociopolitical and ecological variables into our analysis. In particular, we model the role of social structure. Societies have historically varied in social complexity, ranging from small kin-based nomadic groups that practice hunting and gathering to large and urbanized societies that often practice agriculture^{36,37}. We suggest that social complexity is unlikely to impact the prevalence of supernatural explanations of natural phenomena, because the lived elements of increased social complexity—anonymous interactions³⁸, weak ties³⁹, social uncertainty⁴⁰, and lower trust^{41,42}—do not obviously connect to how people make sense of the natural world.

On the other hand, increased social complexity could lead people to explain social phenomena through supernatural forces. Complexity brings uncertainty about predicting the behaviors of other people and groups, and studies find that humans develop religious beliefs in uncertain and unpredictable domains of life^{43,44}. When witnessing a stranger’s aberrant behavior (e.g., theft or murder), people may be more likely to infer supernatural possession or influence than if they were familiar with the perpetrator’s personality and motives. And when afflicted by a family member’s sudden death or a devastating raid by a neighboring group, people may be more likely to infer that the negative event was caused by witchcraft or sorcery if they live in a society full of strangers who could potentially be ill-intentioned magical practitioners. In a social information vacuum, people may be more likely to make socially focused supernatural explanations. This was not an a priori hypothesis in our project, but it is consistent with past research and theory.

Incorporating external variables also allow us to conduct several other key analyses. For example, we test whether frequently occurring events are more likely to gain supernatural explanations than infrequent events. For example, societies with frequent thunderstorms and floods may have more supernatural explanations of natural hazards than societies with more

stable climates. Furthermore, we use language-based phylogenies to control for ancestral relationships between societies in key analyses. In sum, our data offer a globally comprehensive view of how humans apply religious beliefs to explain natural and social phenomena, and how these explanations vary based on social structure.

Results

We developed an extensive, multi-stage coding process to quantitatively estimate whether supernatural explanations are common for three natural phenomena (disease, natural hazards, natural causes of food scarcity such as drought) and three social phenomena (warfare, murder, theft) across 114 societies (see Figure 1 for the global distribution of the sample). Our methods section gives an in-depth summary of how we selected our sample, developed our codes, and extracted exogenous data on language history, geography, and social complexity. We highlight some key points here so readers can interpret our analyses more easily.

Figure 1. The geographic location of the 114 societies in our sample. Each node represents a society. Node color indicates Murdock and Provost's⁴⁵ social complexity index. Node size indicates population size as indexed by White⁴⁵.

Our approach was designed to appropriately (a) model interdependence of datapoints (Galton's problem), and (b) avoid conflating missing data with the absence of supernatural explanations. To model the interdependence of datapoints, we conducted phylogenetically adjusted analyses in which we nested our datapoints within a global language phylogeny (described in the methods). Although the cross-cultural distribution of supernatural explanations showed little evidence of phylogenetic patterning (see methods section), we nevertheless used phylogenetically nested regressions and t-tests to reduce the risk of Galton's problem. Our main text analyses also excluded 7 large-scale societies which had high levels of borrowing—a source of

interdependence that is not modeled by our language phylogenies. Supplementary results show that results are highly similar when we include these societies in our analyses.

To avoid conflating the absence of supernatural explanations with missing data, we only coded for supernatural explanations when an ethnography explicitly discussed that phenomenon (e.g., a natural hazard, murder, theft), but people in the society did not make a supernatural explanation. When a phenomenon was not discussed, it was coded as missing. We omitted missing data when analyzing the percent of societies with supernatural explanations of each phenomenon, and we calculated the proportion of non-missing supernatural explanations coded as present—rather than the raw sum—when comparing the prevalence of naturally vs. socially focused supernatural explanations. These steps mitigated the risk of missing data biasing our analyses.

Initial analyses found that all but one society in our sample had evidence of at least one supernatural explanation. The Burusho people of modern-day Northern Pakistan was the only group with no documented supernatural explanations. However, we did not have sufficient data to code for four of the six supernatural explanations in this society, making it highly possible that the Burusho people had supernatural explanations which were not documented by the ethnographer. The median society in our sample had common supernatural explanations for 4 of the 6 phenomena which we coded. Table 1 provides examples of supernatural explanations—and text which was not coded as featuring a supernatural explanation—for each phenomenon.

Table 1.
Examples of Ethnographic Text Supporting Coding Decisions

	Supernatural Explanation Coded as Present	Supernatural Explanation Coded as Absent
Disease	“People fall sick and die because they are attacked by a nggüyúdn who wishes them ill or because they are seduced or ‘led off’ by one who wants them for company. Seduction is accomplished either through invitations to visit a “good country”, where the hunting is good and the honey plentiful, or through sexual stimulation. Klendó almost died because a female nggüyúdn wanted him for a sex companion.” Aweikoma People Henry, Benedict, & Kraus ⁴⁶	“When a man is sick, he is !nau, and must look after himself. He mustn’t touch anyone with his hands, he mustn’t touch cold water or the pots... He is taken to the well and has clay rubbed on his legs. He has also to take off all his old clothes.” Nama Hottentot People Hoernlé ⁴⁷
Natural Hazard	“Lightning, kū’idyā pīdya, which almost all people seem to recognize in one way or another as directly connected with thunder, is attributed by the Cayapa to the sword-like weapon carried by the Thunder spirit. It is maintained by some that Thunder strikes and kills people with his sword, or at any rate with the glint of it.” Cayapa People Barrett ⁴⁸	“The Azande call by the special name sangu (drizzle), distinct from mai, meaning any other rain. A sangu usually starts with a thunderstorm in the early morning. When the thunderstorm is over, the sky remains covered with a low grey sheet of clouds...these drizzles invariably produce a good crop of termites and a perfect sowing season for groundnuts. Later in July, a sangu is less welcome.”

Scarcity	<p>“They are a class who believe in the agency of good and evil spirits, and fancy they can, by the aid of their magic rites and verbal spells, bring good or evil upon people as they will. If...the rain fails so that there is a drought, or it rains too much and spoils the garden crops...these wizards lay it to the score of large numbers having become Christians, because, they say, by accepting Christianity they have forsaken their old gods and given up some of their ancient customs.”</p> <p>Ainu People Batchelor⁵⁰</p>	<p>Azande People Baxter⁴⁹</p> <p>“While, the weather never destroys the crops grown on the mountain slopes, as it can in the valley, a rare prolonged drought may affect the size of the tubers and thus reduce the harvest... Miss Doble in the Paniai region and I in the Kamu Valley have collected native legends which describe in vivid terms the period of prolonged drought and consequent widespread famine.”</p> <p>Kapauku People Pospisil⁵¹</p>
Warfare	<p>“Men who became especially noteworthy for their success in healing, procuring desired weather conditions, or ensuring a successful chase or war party, came to be singled out as medicine men.... Dreams about a successful raid were not deemed necessary as a sanction for starting a war party, but in most cases such dreams were the effective stimulus.”</p> <p>Comanche People Wallace & Hoebel⁵²</p>	<p>“This in turn often precipitates war. Once underway, a war can drag on for years in a series of retaliations, which are also given their financial colorings. The case of hard dealing in connection with a debt mentioned on page 67, which led to the theft of a child and from there to the taking of a head, is an illustration of such a situation.”</p> <p>Alorese People Du Bois, Kardiner, & Oberholzer⁵³</p>
Murder	<p>“The whole country is given over to witchcraft. Many fatal illnesses and sudden deaths are due to witchcraft. Witches even kill each other... If a sorcerer’s diagnosis or his treatment failed, he was open to the charge of murder by sorcery. Such an idea was never far from the Papago mind.”</p> <p>Papago People Underhill⁵⁴</p>	<p>“Moreover, the chiefs do not interfere in the quarrels between jealous persons, which at times are really bloody. Likewise blood vengeance (E.: irenwón) for murdered relatives is taken at the discretion of the individual.”</p> <p>Marshallese People Kramer & Nevermann⁵⁵</p>
Theft	<p>“In Parigi there is a great deal of stealing, and it therefore goes without saying that divining with maize kernels is also used in order to find out whether a theft planned beforehand will succeed or not. If the end figure of the kernels falls at 41 and 42, then either the thief or the person from whom he wants to steal will die in connection with it. 43 tells the thief that his deed will be successful, but that he must be careful, because the owner is vigilant. If the thief hits the number 44, then he can be sure that nothing will interfere with his undertaking, that he will find the occupants of the house fast asleep.”</p>	<p>“One of the most important obligations of members of a kinship group is to support each other in legal cases and to punish each other when guilty. In any serious quarrel which arises out of misbehaviour—such as divorce, theft, or false accusation—the two principals, each with their relatives, come together at a formal meeting such as that which considered Mingcheng’s behavior.”</p> <p>Garo People Burling⁵⁷</p>

Note. Examples of ethnographic text evidence that indicated that a supernatural explanation was present (left) or that a phenomenon was mentioned but did not include a supernatural explanation (right). See Supplementary Table 1 for more examples of supernatural explanations.

As Table 1 shows, our supernatural explanations were diverse in their content, length, and emotional tone. One goal of this analysis was indeed to broadly identify supernatural explanations in societies around the world and test whether, broadly speaking, these supernatural explanations were more common for natural vs. social phenomena. In supplemental analyses, we dissect the various themes in these supernatural explanations using methods of text analysis. In addition to visualizing themes in our text using word clouds (see Supplementary Figure 2), these text analyses identify the relative frequency of supernatural agents (e.g., gods, spirits), human practitioners of magic (e.g., shamans, witches) and disembodied supernatural forces (e.g., karma, fate) in the qualitative supernatural explanation text (see Supplementary Table 3).

Are Supernatural Explanations More Prevalent for Social or Natural Phenomena?

Supernatural explanations were more prevalent for natural phenomena compared to social phenomena. We found 96% of societies in our sample had common supernatural explanations for disease, 92% for natural causes of food scarcity, and 90% for natural hazards. In contrast, 67% of societies had common supernatural explanations of warfare, 82% for murder, and 26% for theft. Phylogenetically adjusted two-tailed paired samples t-tests showed that societies had significantly more supernatural explanations of natural vs. social phenomena, $t(104) = 10.20$, $p < .001$, $M_{diff} = .32$, 95% CI_s [.26, .38]. Societies were also more likely to have at least one supernatural explanation of a natural vs. a social phenomenon, $t(104) = 2.18$, $p = .03$, $M_{diff} = .05$, 95% CI_s [.01, .10]. Figure 2 shows each society's documented supernatural explanations of natural and social phenomena on a language-based phylogeny.

Figure 2. The documented supernatural explanations of natural and social phenomena of 107 societies on a language-based phylogeny. Supernatural explanations color-coded by phenomena

and organized according to the *Automated Similarity Judgment Program (ASJP)* global language phylogeny⁵⁸. Tips have been aligned (see dashed lines) for ease of viewing and interpretation. Supernatural explanations for natural phenomena (disease, scarcity, hazards) are represented by cool colors, and supernatural explanations for social phenomena (warfare, murder, theft) are represented by warm colors.

One reason for the gap between the frequency of socially focused and naturally focused supernatural explanations could simply be because disease outbreaks, natural hazards, and famine occur more frequently than murder, theft, and war. To evaluate this possibility, we ran two-tailed logistical regression models to test whether the frequency of infectious disease outbreaks, natural hazards, food scarcity, and warfare between and within polities predicted supernatural explanations of these phenomena. None of these models yielded significant results. Frequency of occurrence was not significantly related to the presence of supernatural explanation for infectious disease, $b = .03$, $\beta = .06$, $p = .59$, $SE = .06$, $z = .54$, $OR = 1.03$, 95% CI s [.92, 1.15], natural hazards, $b = -.10$, $\beta = -.13$, $p = .80$, $SE = .42$, $z = -.25$, $OR = .90$, 95% CI s [.40, 2.03], food scarcity, $b = -.13$, $\beta = -.12$, $p = .79$, $SE = .48$, $z = -.27$, $OR = .88$, 95% CI s [.34, 2.25], and warfare between polities, $b = .44$, $\beta = .55$, $p = .08$, $SE = .25$, $z = 1.77$, $OR = 1.55$, 95% CI s [.95, 2.53], or within polities, $b = .15$, $\beta = .19$, $p = .55$, $SE = .25$, $z = .59$, $OR = 1.16$, 95% CI s [.71, 1.92]. In sum, there was no significant evidence that frequency of occurrence was associated with likelihood of supernatural explanation for any domain

How is Social Complexity Associated with the Prevalence of Supernatural Explanations?

We next tested whether the gap in prevalence between supernatural explanations of natural vs. social phenomena varied as a function of social complexity (see methods for the details of this index). Phylogenetically controlled two-tailed regressions showed that social complexity was positively associated with supernatural explanations of social phenomena, $b = .17$, $\beta = .32$, $p = .01$, $SE = .07$, $t = 2.62$, 95% CI s [.04, .30], but negatively associated with supernatural explanations of natural phenomena, $b = -.09$, $\beta = -.29$, $p = .02$, $SE = .04$, $t = -2.42$, 95% CI s [-.17, -.02]. Societies with low (1 SD below the sample mean) social complexity had a far greater proportion of supernatural explanations of natural vs. social phenomena (M s = .95 vs. .52). This gap persisted in societies with high social complexity (1 SD above the sample mean), but it was considerably smaller (M s = .85 vs. .71). Figure 3 (Panel B) displays the prevalence of each kind of supernatural explanation at different levels of social complexity. In the supplementary results, we show that the positive association with supernatural explanations of social phenomena was more robust to different model specifications than the negative association with supernatural explanations of natural phenomena. This may be because naturally focused supernatural explanations were prevalent in nearly all societies, leaving little variance to explain.

We also ran exploratory models correlating the prevalence of supernatural explanations with individual indicators of social complexity, with particular focus on socially focused supernatural explanations. We found that supernatural explanations of social phenomena were most prominently associated with population size, $\beta = .39$, $p = .004$, $t = 2.97$, 95% CI s [.13, .64], and to a lesser extent with urbanization, $\beta = .21$, $p = .05$, $t = 1.99$, 95% CI s [.004, .41]. These indicators imply larger and less familiar social networks. Supernatural explanations of social phenomena were also more common in societies with money, $\beta = .21$, $p = .04$, $t = 2.03$, 95% CI s

[.007, .41], land transport, $\beta = .22$, $p = .03$, $t = 2.19$, 95% CIs [.02, .42], and technological specialization, $\beta = .27$, $p = .02$, $t = 2.28$, 95% CIs [.04, .49]. In contrast, indicators of social inequality such as social stratification and political integration had near-0 standardized associations with supernatural explanations of social phenomena. These models shed some light on the forms of social complexity which are most strongly tied to supernatural explanations of social phenomena. However, these are exploratory analyses, and we cannot claim that one indicator is significantly stronger than another. Figure 3 (Panel A) displays the estimates and standard errors from each of these models. See Supplementary Table 2 for full statistics associated with each indicator.

Figure 3. Relations between social complexity and supernatural explanation frequency. Panel A: Standardized associations between indicators of social complexity and the frequency of

supernatural explanations of natural and social phenomena from phylogenetically nested regressions. Error bars represent 95% confidence intervals. Panel B: Estimated rates of each supernatural explanation at different levels of social complexity. Supernatural explanations for natural phenomena (disease, scarcity, hazards) are represented by cool colors, and supernatural explanations for social phenomena (warfare, murder, theft) are represented by warm colors. All analyses are two-tailed.

Discussion

Religious beliefs are prevalent in virtually every human society⁵⁹, and may even predate anatomically modern humans^{60,61}. People in many societies use their religious beliefs to explain natural and social phenomena^{5,12,13,15,62}. Yet there has never been a worldwide survey of supernatural explanations, which has been a barrier to understanding the most common ways that people use religious belief as an epistemic tool. We conduct a large survey of societies in the ethnographic record to show that humans are more likely to use supernatural explanations to explain natural phenomena versus social phenomena. According to our analysis of the ethnographic record, societies were more likely to explain natural events like famine and disease using supernatural principles compared to social events such as warfare and murder. This difference could not be explained by the frequency of phenomena (i.e., that disease outbreaks occurred more frequently than warfare).

Supplementary results provide a host of robustness checks and exploratory analyses which support our conclusions. These include replications of key analyses while (a) using the full sample of 114 societies, (b) using alternative language phylogenies, (c) using regression weights based on our research team's confidence in the quantitative codes, and (d) using Quasi-Poisson estimation which makes fewer distributional assumptions than our Gaussian Maximum Likelihood models. We also describe alternative coding schemes in the supplementary methods and analyze our data using these coding schemes in the supplementary results. Across all models, supernatural explanations of natural phenomena are more common than supernatural explanations of social phenomena, and social complexity is linked to higher prevalence of supernatural explanations of social phenomena. The negative relationship between social complexity and the prevalence of naturally focused supernatural explanations does not reach significance in some models, however, demonstrating that this effect is less robust.

Our findings suggest humans around the world may be most likely to apply religious beliefs to explain phenomena which have no clearly responsible human agent. In other words, humans may use supernatural explanations to engage in “dyadic completion”: intuiting a causal agent behind natural phenomena where agency is ambiguous because there is no clearly responsible human cause^{8,11}. Dyadic completion was even consistent with some supernatural explanations of social phenomena (e.g., a person's sudden death attributed to murder through supernatural means). Our study therefore provides cross-cultural evidence that humans commonly infer supernatural agency in cases where there is no clearly responsible human agent.

This study also builds on longstanding philosophical claims that humans have a tendency to imbue spiritual anthropomorphism to the natural world^{12,15}, and more recent cognitive science claims that this anthropomorphism may have played a role in the evolution of religious beliefs¹⁶.

We also show that, among natural phenomena, supernatural explanations were especially prevalent for illness and disease. This pattern supports theories which claim that pathogen outbreaks encourage beliefs in “moral vitalism”—invisible forces of good and evil^{63,64}—that can manifest through beliefs in evil spirits (e.g., demons) and forces such as the evil eye.

An advantage of our global sample is that we could estimate why supernatural explanations vary across societies. In particular, we found that social complexity correlated positively with the prevalence of socially focused supernatural explanations, an association which was driven partly by population size and urbanization. There could be many complementary mechanisms underlying this association. For example, larger and more complex groups involve more anonymity than smaller groups, with a greater share of weak ties³⁸, social uncertainty⁴⁰, and distrust⁴¹, all factors that increase uncertainty about people’s behavior and the underlying reasons for their behavior. This uncertainty about social causes could increase people’s likelihood of explaining negative social events using supernatural forces such as witchcraft, possession, and evil eye^{44,65}. Another possible reason is that people are particularly concerned about social phenomena such as conflict and theft in complex societies, which would explain why these supernatural explanations were particularly correlated with social complexity. Although we did not find an association between frequency of warfare and frequency of warfare-focused supernatural explanations, concern about warfare is a more subjective factor and it is plausible that people living in large nation-states are more concerned about conflict than people living in smaller-scale societies. One final possibility is that religious elites become a larger occupational niche in socially complex societies, and people are more likely to solicit them to predict and explain social phenomena such as warfare, murder, and theft.

A secondary finding from this study was that supernatural explanations were especially rare for theft, even compared to other social phenomena. One possible reason for this difference was that theft was the only phenomenon we examined which did not directly involve mortality. Even though theft is harmful for society, it is less life-threatening than warfare, illness, or drought. Research finds that dyadic completion is tied to the experience of suffering⁸, consistent with early scholars such as Malinowski⁴³ and Freud⁶⁶ noting a cross-cultural connection between religion and death, and contemporary studies have found that death anxiety makes religious beliefs salient⁶⁷. An alternative mechanism is that theft is extremely rare in some societies because there is no private property, but this explanation is unlikely because we only coded for supernatural explanations in ethnographies which described theft. A third explanation is that thieves’ intentions are clear, whereas the causal agent responsible for warfare, natural hazards, or disease may have more ambiguous intentions which inspire supernatural explanation.

We see two main future directions for this work. The first of these future directions will involve broadening the focus of our survey to include a wider range of phenomena. Although the six phenomena that we documented were very broad and were extensively discussed in ethnography, we highly encourage future research to replicate our findings using different phenomena, especially phenomena which are more positively valenced since dyadic completion appears stronger for negatively valenced phenomena compared to positively valenced phenomena⁸.

A potential second future direction involves testing whether supernatural explanations can be adaptive for social life. Converging lines of research show that many religious beliefs^{68–70} and

practices^{71,72} can increase prosociality and parochial cooperation. In the supplementary results, we present some initial analyses of supernatural explanations and social cohesion, and discuss how different properties of supernatural explanations may encourage vs. discourage social cohesion. We encourage future research which empirically tests whether any features of supernatural explanations may be positively associated with social cohesion or cooperation. One of these features may be supernatural punishment beliefs. Individuals in a society may believe that an earthquake was caused by widespread theft in a community, or that a disease outbreak was caused by a lack of ritual participation. These examples are common in both large-scale and small-scale societies^{73,74}, and studies have found that beliefs in moralizing gods and spirits correlate with both social complexity and prosociality^{68,75}. Testing whether “moralistic” supernatural explanations correlate with greater social cohesion and social complexity would involve coding supernatural explanations for theories of causation rather than just coding which phenomena societies explain using supernatural principles. This would be an important area of future study.

We also note two limitations to this study. First, our data are based on ethnographic texts, which are often written from a 18th or 19th century Western perspective. Although we excluded ethnographies and content that showed clear problematic biases (e.g. overt racist agendas), our findings may still be impacted by subtler biases (e.g. theoretical schools of authors), and we encourage future research to scrutinize and re-analyze our publicly accessible codes. The second limitation is that the natural and social phenomena in our study may not always be completely independent. For example, some ethnographies described cases where a sudden illness and death led to accusations of murder by witchcraft, and these descriptions were coded as supernatural explanations of both murder and disease. To mitigate this limitation, we used multiple regression to control for the covariance between natural and social explanations and phenomena in all our analyses, and we replicated our findings in supplementary analyses using revised “disease” and “murder” codes which were based on distinct text. Nevertheless, it is sometimes impossible to fully disentangle “social” and “natural” phenomena based on ethnographic descriptions.

This study provides a quantitative window into how people apply supernatural beliefs to understand the world. We document systematic patterns in how people use religion as an explanatory tool across human groups. Natural phenomena are frequently explained via supernatural principles in societies across the globe, whereas social phenomena become more frequently explained via supernatural forces within socially complex societies. These findings suggest that supernatural explanations may evolve to address gaps in human knowledge, and that variation in supernatural beliefs across human groups may in part reflect differences in what humans find ambiguous or important across different social structures.

Method

Sampling Process. We developed our codes using ethnographic data retrieved from the electronic Human Relations Area Files (eHRAF)^{35,76}. We retrieved ethnographic data and variables from societies in the Standard Cross-Cultural Sample (SCCS), a diverse and distantly related sample of societies designed to minimize Galton’s Problem in cross-cultural research (see Figure 1 for the distribution of our sample)⁷⁷. Other coding projects have used the Ethnographic Atlas, which is an expansion of the SCCS. However, the societies in the Ethnographic Atlas have

greater cross-cultural contact with one another, fewer variables available on features of their social systems, and tend to be less thoroughly documented than societies in the SCCS.

Our aim was to develop codes for a large and diverse sample of societies spanning different geographies, cultural ancestries, and levels of social complexity. We also sought to avoid coding societies with high levels of globalization, a form of horizontal transmission that can violate statistical assumptions of independence even in phylogenetically controlled regressions. One challenge with these aims was that many of the most socially complex societies in the SCCS are highly globalized groups. SCCS time-matched ethnographies for “Russians,” “Japanese,” and “Chinese” were all conducted shortly after or before the second world war. Other complex societies in the SCCS such as the “Aztecs” and “Romans” were described by historians rather than ethnographers and their source materials are more speculative. Even socially complex societies with good ethnographic documentation such as “Burmese,” “Fellahin,” and “Turks” can show high levels of non-indigenous religious ideas. For example, Scott⁷⁸ points out that the 10 Christian commandments was a central Burmese religious code in his ethnography.

We ultimately sampled 114 societies with high-quality ethnographic documentation and a range of social complexity, with a small skew towards smaller-scale societies (see Supplementary Figure 1 for the full distribution of complexity). However, we excluded 7 socially complex societies with high levels of borrowing in our main text analyses due to concerns about non-independent data-points. In our supplementary results, we summarize our results without these exclusions to show that our findings replicate in the full set of societies.

Coding Process. We developed codes for supernatural explanations of three natural and three social phenomena. The three natural phenomena were infectious diseases (pathogens), natural hazards, and naturally caused food scarcity (drought or famine). The three social phenomena were warfare, murder, and theft. We chose these categories because they were feasible to classify as naturally caused or socially caused events, but they were similar in other ways. For example, each of these phenomena were harmful, which allowed us to avoid confounding natural vs. social phenomena with negative vs. positive phenomena. This is important because negative phenomena were more likely to be explained with supernatural principles than positive phenomena in previous psychological studies⁸. These phenomena were also commonly and equally discussed within ethnographies. In some cases, the same ethnographic information would apply to multiple codes, which happened most commonly when death due to illness (a natural phenomenon) was interpreted as murder through witchcraft (a social phenomenon). These cases of overlap show how the categories of “natural” and “social” can often be blurred, and to some extent overlap is unavoidable. However, we developed a supplementary set of disease codes and murder codes which excluded these cross-over paragraphs and helped empirically distinguish the categories. We present results using these additional codes in our supplementary results.

Our coding process was designed to address recent concerns about the difference between coding an event as absent vs. not reported⁷⁹. We were particularly concerned with mistakenly coding supernatural explanations as absent simply because the focal event (natural hazard, theft, murder) had not occurred in recent memory. To help address this possible confound, we only coded supernatural explanations as absent when there was evidence of the phenomenon, but people in a society had not made a supernatural explanation. For example, we only coded supernatural

explanations of theft as absent in cases where theft was described with no attribution to the supernatural. Infectious diseases were recorded in 99% of societies, naturally occurring food scarcity in 81%, natural hazards were recorded in 84%, warfare in 88%, murder in 98%, and theft in 81%. We also performed a further check (see results section) in which we used exogenous data on frequency of occurrence to test whether ethnographies with frequent mentions of warfare, natural hazards, etc., described more supernatural explanations of these phenomena.

Our coding procedure followed two key steps. The first step involved developing an initial set of quantitative codes and justifications. Two research assistants conducted an initial coding of the qualitative ethnographic data. After establishing inter-coder reliability and confirming that each society had a sufficient volume and quality of source material (see supplementary methods), research assistants coded sources based on whether supernatural explanations were absent (no evidence of supernatural explanation), uncommon (supernatural explanations were held by single people or small groups and were not widely acknowledged in a society), or common (supernatural explanations were widely acknowledged in the society). Every code was justified with direct quotes from ethnographic source material.

The second step involved scrutinizing and amending the initial set of codes. The second author first completed a quality check of the research assistant's decisions based on the source material that they identified and then the fifth author—who had not previously participated in our coding scheme—performed an external audit in which they (a) read through the complete ethnographic material for all societies, (b) added any paragraphs which they felt that we had neglected in our original survey, and (c) suggested a revision to the code where appropriate. After this external audit, a hypothesis-blind research assistant reviewed the original code and the fifth author's suggestions, and—blind to which code was the original and which code was the suggestion—chose the more appropriate code based on the source material. We also assigned a final set of “confidence codes” which indicated our team's confidence in the accuracy of each code based on the volume and clarity of supporting text. This two-step process yielded a high-quality set of quantitative codes as well as comprehensive ethnographic text that we used to develop these codes. We have uploaded documents containing our quantitative codes, confidence codes, and supporting qualitative text to our OSF page at <https://osf.io/jsk4t/> where they can be downloaded and potentially adapted into new codes by future researchers.

Out of the 678 total phenomena across the 114 societies, 600 phenomena had sufficient data for us to develop codes. Of these 600 phenomena, 468 were “common.” Since “uncommon” explanations were rare, and typically held by a single person in a society or were tied to a single instance (e.g., a single description of a man in the Tehuelche society declaring that the redness of the setting sun was an omen of war), we focused on commonly held explanations in our analysis and created dummy variables representing whether a supernatural explanation of a particular explanation was absent or uncommon (0) vs. common (1). The supplementary results replicate our results while recoding uncommon explanations as present rather than absent.

Exogenous Variables. We also collected exogenous data on our sample of societies from several sources. First, we collected basic meta-data on geographical (continent, latitude, longitude) and linguistic (language, language family) characteristics from D-Place⁸⁰. Second, we collected data on the frequency of features in our supernatural explanations coding manual. We measured pathogen prevalence using an index developed by Low⁸¹ in which seven pathogens were coded

on a 1 (absent) to 3 (widespread or endemic) scale. We dummy-coded this scale such that 0 represented societies with absent pathogens and 1 represented reported pathogens, and then summed across the seven pathogens to create a 1-7 scale. We measured natural disasters using data from Ember & Ember⁸², who measured the frequency of natural disasters such as floods, storms, and droughts. We measured natural causes of scarcity using Jackson, Gelfand, and Ember's⁸³ food scarcity composite measure adapted from Dirks⁸⁴ and Ember & Ember⁸². We measured prevalence of warfare between polities (independent political groups), and within polities using data from Ross⁸⁵ that used scales from 1 (rare or never) to 4 (occurring at least yearly). We could not find previous studies that had developed cross-cultural codes for the frequency of murder or theft across societies. Ross⁸⁵ coded for conflict in local community and resort to physical force by disputants in settling disputes. We considered these variables too general to approximate frequency of murder since they could refer to many social conflicts.

We measured social complexity by using the 10-indicator social complexity index developed by Murdock and Provost (writing and records, fixity of residence, agriculture, urbanization, technological specialization, land transport, money, density of population, political integration, social stratification), and also included White's⁴⁵ population size variable. We included population size within the social complexity index because population size had a higher item-total correlation than any other complexity indicator and it had high theoretical significance to our hypotheses. All significant effects replicate with or without including the population size variable. We recoded three of the Murdock and Provost variables using the same strategy as Jackson, Gelfand, & Ember⁸³ because some values of the original scale were not incremental. For example, the original "Agriculture" codes were 1 = "None"; 2 = "10% Food Supply"; 3 = "10% Secondary"; 4 = "Primary, Not Intensive"; 5 = "Primary, Intensive." We recoded the variable to 1 = "No Agriculture" (original code 1); 2 = "Supplementary Agriculture" (original codes 2-3); 3 = "Subsistence Agriculture" (original code 4); 4 = "Intensive Agriculture" (original code 5). The resulting social complexity scale was highly reliable ($\alpha = .92$).

Phylogenetic Structure. To test for the effects of common ancestry on our inferences, we paired societies to languages on a global language phylogeny. Language-based phylogenies can provide a general proxy for common cultural ancestry⁸⁶ and have previously been used to test evolutionary hypotheses about religion and society^{87,88}. Our primary phylogeny (Figure 2) was developed by the Automated Similarity Judgment Program, which collected vocabulary lists from world languages and dialects⁵⁸. Since the authors relied on automated similarity judgements of vocabulary items rather than expert cognate judgments, they were able to build a vastly more comprehensive tree that spans multiple language families. This made the phylogeny useful for analyzing our global sample of societies. To evaluate the robustness of phylogenetic analyses across different methods of tree construction, we also built a series of trees using data from the Glottolog catalogue of world languages⁸⁹. The approach to tree construction and the results of these analyses are provided in the supplementary methods (see also Supplementary Table 7). We note that the results of these additional phylogenetic analyses are highly consistent with those presented here (see Supplementary Tables 4-6).

Prior to testing our hypotheses, we evaluated phylogenetic patterning of supernatural explanations. Using the Fritz and Purvis D statistic to estimate phylogenetic patterning of a binary trait⁹⁰, we tested the null hypotheses that distributions of natural and social supernatural

explanations were randomly patterned. We found no significant patterning for explanations of food scarcity ($D = 1.58, p = .77$), natural hazards ($D = .18, p = .12$), warfare ($D = .83, p = .32$), murder ($D = 1.04, p = .52$), or theft ($D = .29, p = .07$). We found significant patterning for explanations of disease ($D = -2.19, p = .008$), but only four societies were coded as having no supernatural explanation of disease, which means that the analysis had a severe restriction of range and may have been biased by individual data-points. At best, these results suggest limited phylogenetic patterning of supernatural explanations, and we do not find significant evidence that associations involving supernatural explanations are likely to be confounded by shared ancestry, which is a concern in cross-cultural comparative research⁹¹.

Despite the lack of significant evidence for phylogenetic patterning, we used phylogenetically nested regressions as a safeguard. The modeling functions for the phylogenetically nested regressions do not return information on degrees of freedom, so we provide the number of societies involved in each analysis within Supplementary Tables 8-9 (many analyses did not involve our full sample of societies because of missing data in exogenous variables). The lack of phylogenetic patterning in our data and the potential for horizontal transmission between societies means that it would be inappropriate to use phylogenetic methods based on strong assumptions of vertical inheritance, such as Pagel's Discrete⁹². Our phylogenetically nested regressions assumed normal distributions of residuals. We also replicated key results using generalized linear models with Quasi-Poisson estimation which do not assume normally distributed residuals as a safeguard since our dependent variables were skewed (see Supplementary Figure 2).

Data Availability Statement. All data are available from <https://osf.io/jsk4t/>. We sourced many of our variables from the standard cross-cultural sample, and these variables are available from D-Place at <https://d-place.org/>. We sourced ethnographic records from eHRAF World Cultures. The eHRAF World Cultures database can be found at <https://ehrafworldcultures.yale.edu/>.

Code Availability Statement. All code is available from <https://osf.io/jsk4t/>.

References

1. Zhao, D. The mandate of heaven and performance legitimation in historical and contemporary China. *Am. Behav. Sci.* **53**, 416–433 (2009).
2. Hawkins, G. S. Sun, moon, men, and stones. *Am. Sci.* **53**, 460A–408 (1965).
3. Bell, J. et al. The world's Muslims: unity and diversity. *Pew Research Center*. <https://www.pewresearch.org/religion/2012/08/09/the-worlds-muslims-unity-and-diversity-executive-summary/> (2012).
4. Dein, S. Covid-19 and the apocalypse: religious and secular perspectives. *J. Relig. Health* **60**, 5–15 (2021).
5. Nietzsche, F. W. *Thus Spoke Zarathustra: A Book for Everyone and Nobody*. (Oxford Univ. Press, 2005).
6. Drummond, H. *The Lowell Lectures on the Ascent of Man*. (J. Pott & Company, 1898).
7. Preston, J. & Epley, N. Science and God: an automatic opposition between ultimate explanations. *J. Exp. Soc. Psychol.* **45**, 238–241 (2009).

8. Gray, K. & Wegner, D. M. Blaming God for our pain: human suffering and the divine mind. *Personal. Soc. Psychol. Rev.* **14**, 7–16 (2010).
9. Gray, K., Young, L. & Waytz, A. Mind perception is the essence of morality. *Psychol. Inq.* **23**, 101–124 (2012).
10. Schein, C. & Gray, K. The theory of dyadic morality: reinventing moral judgment by redefining harm. *Personal. Soc. Psychol. Rev.* **22**, 32–70 (2018).
11. Gray, K., Schein, C. & Ward, A. F. The myth of harmless wrongs in moral cognition: automatic dyadic completion from sin to suffering. *J. Exp. Psychol. Gen.* **143**, 1600 (2014).
12. Tylor, E. B. *Primitive Culture: Researches Into the Development of Mythology, Philosophy, Religion, Art, and Custom.* (J. Murray, 1871).
13. Frazer, S. J. G. *Golden Bough: A Study in Magic and Religion.* (Macmillan, 1959).
14. Müller, F. M. *Natural Religion: The Gifford Lectures Delivered Before the University of Glasgow in 1888.* (Longmans, Green, and Company, 1889).
15. Hume, D. *The Natural History of Religion.* (A. and H. Bradlaugh Bonner, 1757).
16. Barrett, J. L. Exploring the natural foundations of religion. *Trends Cogn. Sci.* **4**, 29–34 (2000).
17. Barrett, J. L. *Why Would Anyone Believe in God?* (AltaMira Press, 2004).
18. Boyer, P. *Religion Explained: The Evolutionary Origins of Religious Thought.* (Basic books, 2007).
19. Epley, N., Waytz, A. & Cacioppo, J. T. On seeing human: a three-factor theory of anthropomorphism. *Psychol. Rev.* **114**, 864 (2007).
20. Goodall, J. *In the Shadow of Man.* (Houghton Mifflin Harcourt, 2000).
21. Cheney, D. L. & Seyfarth, R. M. Assessment of meaning and the detection of unreliable signals by vervet monkeys. *Anim. Behav.* **36**, 477–486 (1988).
22. Bentzen, J.S. Acts of God? Religiosity and natural disasters across subnational world districts. *Econ. J.* **129**, 2295–2321 (2019).
23. Zapata, O. Turning to God in tough times? Human versus material losses from climate disasters in Canada. *Econ. Disasters Clim. Change* **2**, 1–23 (2018).
24. Sibley, C. G. & Bulbulia, J. Faith after an earthquake: a longitudinal study of religion and perceived health before and after the 2011 Christchurch New Zealand earthquake. *PLoS One* **7**, e49648 (2012).
25. Leppänen, J. M. Using eye tracking to understand infants' attentional bias for faces. *Child Dev. Perspect.* **10**, 161–165 (2016).
26. Singh, M. Magic, explanations, and evil: on the origins and design of witches and sorcerers. *Curr. Anthropol.* **62**, 2–29 (2018).
27. Winkelman, M. J. *Shamanism: The Neural Ecology of Consciousness and Healing.* (Greenwood Publishing Group, 2000).
28. Winkelman, M. J. A cross-cultural study of the elementary forms of religious life: shamanistic healers, priests, and witches. *Relig. Brain Behav.* **11**, 27–45 (2021).
29. Singh, M. The cultural evolution of shamanism. *Behav. Brain Sci.* **41**, (2018).
30. Sosis, R., Kress, H. C. & Boster, J. S. Scars for war: evaluating alternative signaling explanations for cross-cultural variance in ritual costs. *Evol. Hum. Behav.* **28**, 234–247 (2007).
31. Cohen, E. *The Mind Possessed: The Cognition of Spirit Possession in an Afro-Brazilian Religious Tradition.* (Oxford University Press, 2007).

32. Keener, C. S. Spirit possession as a cross-cultural experience. *Bull. Biblic. Res.* **20**, 215–235 (2010).
33. Cohen, E. & Barrett, J. L. Conceptualizing spirit possession: ethnographic and experimental evidence. *Ethos* **36**, 246–267 (2008).
34. Slingerland, E. *et al.* Coding culture: challenges and recommendations for comparative cultural databases. *Evol. Hum. Sci.* **2**, (2020).
35. Ember, C. R. *Cross-Cultural Research Methods*. (Rowman Altamira, 2009).
36. Fry, D. P., Keith, C. A. & Söderberg, P. *Social Complexity, Inequality and War Before Farming: Congruence of Comparative Forager and Archaeological Data*. (McDonald Institute for Archaeological Research, 2020).
37. Turchin, P. *et al.* Quantitative historical analysis uncovers a single dimension of complexity that structures global variation in human social organization. *Proc. Natl. Acad. Sci.* **115**, E144–E151 (2018).
38. Dunbar, R. I. The social brain hypothesis and its implications for social evolution. *Ann. Hum. Biol.* **36**, 562–572 (2009).
39. Wang, C., Lizardo, O. & Hachen, D. S. Using big data to examine the effect of urbanism on social networks. *J. Urban Aff.* **43**, 40–56 (2021).
40. Zeiderman, A., Kaker, S. A., Silver, J. & Wood, A. Uncertainty and urban life. *Public Cult.* **27**, 281–304 (2015).
41. Malinowski, B. *Argonauts of the Western Pacific: An account of Native Enterprise and Adventure in the Archipelagoes of Melanesian New Guinea*. (Routledge, 2013).
42. Hogg, M. A., Adelman, J. R. & Blagg, R. D. Religion in the face of uncertainty: an uncertainty-identity theory account of religiousness. *Personal. Soc. Psychol. Rev.* **14**, 72–83 (2010).
43. Gershman, B. Witchcraft beliefs as a cultural legacy of the Atlantic slave trade: evidence from two continents. *Eur. Econ. Rev.* **122**, 103362 (2020).
44. Fischer, C. S. On urban alienations and anomie: powerlessness and social isolation. *Am. Sociol. Rev.* 311–326 (1973).
45. Yang, G. & Zeng, S. The comparison of trust structure between urban and rural residents in China. *Am. J. Ind. Bus. Manag.* **6**, 665–673 (2016).
46. Murdock, G. P. & Provost, C. Measurement of cultural complexity. *Ethnology* **12**, 379–392 (1973).
47. Henry, J., Benedict, R. & Kraus, H. F. *Jungle People: A Kaingang Tribe of the Highlands of Brazil*. (Psychoanalytic Quarterly, 1944).
48. Hoernlé, W. Certain rites of transition and the conception of! nau among the Hottentots. *Harv. Afr. Stud.* **2**, 65–82 (1918).
49. Barrett, S. A. *The Cayapa Indians of Ecuador*. (Heye Foundation, 1925).
50. Baxter, P. T. W. & Butt, A. *The Azande and Related Peoples of the Anglo-Egyptian Sudan and Belgian Congo: East Central Africa Part IX*. (Routledge, 2017).
51. Batchelor, J. *Ainu Life and Lore: Echoes of a Departing Race*. (Kyobunkwan, 1927).
52. Pospisil, L. J. *Kapauku Papuan Economy*. (Yale University, 1963).
53. Wallace, E. & Hoebel, E. A. *The Comanches: Lords of the South Plains*. (University of Oklahoma Press, 2013).
54. Du Bois, C.A., Kardiner, A., & Oberholzer, E. *The People of Alor: A Social-Psychological Study of an East Indian Island*. (The University of Minnesota Press, 1944).
55. Underhill, R. *Social Organization of the Papago Indians*. (Columbia University Press, 1939).

56. Krämer, A., Nevermann, H., Brant, C. & Armstrong, J. M. *Ralik-Ratak (Marshall Islands)*. (Friederichsen, De Gruyter and Co., 1938).
57. Adriani, N. & Kruijt, A. C. *The Bare'e-speaking Toradja of Central Celebes (the East Toradja)*. (Noord-Hollandsche Uitgevers Maatschappij, 1951).
58. Burling, R. *Rengsanggri: Family and Kinship in a Garo Village*. (University of Pennsylvania Press, 1963).
59. Jäger, G. & Wichmann, S. Inferring the world tree of languages from word lists. *Evolang*. <http://evolang.org/neworleans/papers/147.html> (2016).
60. Brown, D. E. Human universals, human nature & human culture. *Daedalus* **133**, 47–54 (2004).
61. Mithen, S. *The Singing Neanderthals: The Origins of Music, Language, Mind and Body*. (Harvard University Press, 2006).
62. Insoll, T. *Archaeology, Ritual, Religion*. (Psychology Press, 2004).
63. Darwin, C. *The Descent of Man, and Selection in Relation to Sex*. (Princeton University Press, 2008).
64. Bastian, B. et al. Explaining illness with evil: pathogen prevalence fosters moral vitalism. *Proc. R. Soc. B* **286**, 20191576 (2019).
65. Bever, E. Witchcraft fears and psychosocial factors in disease. *J. Interdiscip. Hist.* **30**, 573–590 (2000).
66. Freud, S. *The Future of an Illusion*. (Broadview Press, 2012).
67. Jong, J. & Halberstadt, J. *Death Anxiety and Religious Belief: An Existential Psychology of Religion*. (Bloomsbury Publishing, 2018).
68. Watts, J. et al. Broad supernatural punishment but not moralizing high gods precede the evolution of political complexity in Austronesia. *Proc. R. Soc. B Biol. Sci.* **282**, 20142556 (2015).
69. Norenzayan, A. et al. The cultural evolution of prosocial religions. *Behav. Brain Sci.* **39**, (2016).
70. Jackson, J. C. et al. Tight cultures and vengeful gods: how culture shapes religious belief. *J. Exp. Psychol. Gen.* **150**, 2057–2077 (2021).
71. Whitehouse, H. et al. The ties that bind us: ritual, fusion, and identification. *Curr. Anthropol.* **55**, 000–000 (2014).
72. Gelfand, M. J., Caluori, N., Jackson, J. C. & Taylor, M. K. The cultural evolutionary trade-off of ritualistic synchrony. *Philos. Trans. R. Soc. B* **375**, 20190432 (2020).
73. Lightner, A., Bendixen, T. & Purzycki, B. G. Cross-cultural datasets systematically underestimate the presence of moralizing gods in small-scale societies. Preprint at <https://doi.org/10.31235/osf.io/29at3> (2022).
74. Rossano, M. J. Supernaturalizing social life. *Hum. Nat.* **18**, 272–294 (2007).
75. Shariff, A. F. & Norenzayan, A. Mean gods make good people: different views of God predict cheating behavior. *Int. J. Psychol. Relig.* **21**, 85–96 (2011).
76. Skoggard, I., Ember, C. R., Pitek, E., Jackson, J. C. & Carolus, C. Resource stress predicts changes in religious belief and increases in sharing behavior. *Hum. Nat.* **31**, 249–271 (2020).
77. Murdock, G. P. & White, D. R. Standard cross-cultural sample. *Ethnology* **8**, 329–369 (1969).
78. Scott, J. G. *The Burman, His Life and Notions*. (Ravenio Books, 2014).
79. Beheim, B. et al. Treatment of missing data determines conclusions regarding moralizing gods. *Nature* **595**, E29–E34 (2021).

80. Kirby, K. R. et al. D-PLACE: A global database of cultural, linguistic and environmental diversity. *PLoS One* **11**, e0158391 (2016).
81. Low, B. S. Pathogen stress and polygyny in humans. in *Human Reproductive Behaviour: A Darwinian Perspective* 115–127 (Cambridge University Press, 1987).
82. Ember, C. R. & Ember, M. War, socialization, and interpersonal violence: a cross-cultural study. *J. Confl. Resolut.* **38**, 620–646 (1994).
83. Jackson, J. C., Gelfand, M. & Ember, C. R. A global analysis of cultural tightness in non-industrial societies. *Proc. R. Soc. B* **287**, 20201036 (2020).
84. Dirks, R. Starvation and famine: cross-cultural codes and some hypothesis tests. *Cross-Cult. Res.* **27**, 28–69 (1993).
85. Ross, M. H. Political decision making and conflict: additional cross-cultural codes and scales. *Ethnology* **22**, 169–192 (1983).
86. Evans, C. L. et al. The uses and abuses of tree thinking in cultural evolution. *Philos. Trans. R. Soc. B Biol. Sci.* **376**, 20200056 (2021).
87. Watts, J., Sheehan, O., Atkinson, Q. D., Bulbulia, J. & Gray, R. D. Ritual human sacrifice promoted and sustained the evolution of stratified societies. *Nature* **532**, 228 (2016).
88. Basava, K., Zhang, H. & Mace, R. A phylogenetic analysis of revolution and afterlife beliefs. *Nat. Hum. Behav.* **5**, 604–611 (2021).
89. Hammarström, H., Forkel, R., Haspelmath, M. & Bank, S. *Glottolog 4.3*. (Glottolog) doi:10.5281/zenodo.4061162 (2020).
90. Fritz, S. A. & Purvis, A. Selectivity in mammalian extinction risk and threat types: a new measure of phylogenetic signal strength in binary traits. *Conserv. Biol.* **24**, 1042–1051 (2010).
91. Bromham, L., Hua, X., Cardillo, M., Schneemann, H. & Greenhill, S. J. Parasites and politics: why cross-cultural studies must control for relatedness, proximity and covariation. *R. Soc. Open Sci.* **5**, 181100 (2018).
92. Pagel, M. Detecting correlated evolution on phylogenies: a general method for the comparative analysis of discrete characters. *Proc. R. Soc. Lond. B Biol. Sci.* **255**, 37–45 (1994).

Acknowledgements. This study was supported by a grant from the John Templeton Foundation and the Issachar Fund to JCJ, BB, JW, and KG. Neither funding source was involved in the conceptualization, design, data collection, writing, or decision to publish this work. We are grateful for the research assistance of Michael Doucette, Hadden LaGarde, Vishal Easwar, and Susie Webb.

Author contributions. JCJ, BB, and KG conceptualized the study. JCJ, DW, WB, and ND conducted the research. JCJ, DW, and JW analyzed the data. JCJ and DW wrote the paper. All authors contributed to revising the paper.

Competing interests. The authors declare no competing interests.

Supplementary Information

Supplementary Figures

Supplementary Figure 1. Distribution of Social Complexity. Distributions of social complexity across our full sample (left) and the sample we used for our main text analyses (center) and the entire Standard Cross-Cultural Sample (right).

Supernatural Explanations for Natural Phenomena Supernatural Explanations for Social Phenomena

Supplementary Figure 2. Distribution of Supernatural Explanations for Natural and Social Phenomena. Distributions of supernatural explanations of natural phenomena (left) and social phenomena (right). We used composite proportion variables in the primary analyses to adjust for missingness. These composites are the number of social/natural supernatural explanations divided by the number of social/natural phenomena that were discussed in the ethnographies.

Disease/Illness

Natural Scarcity

Natural Hazards

Warfare

Murder

Theft

Supplementary Figure 3. Word Clouds for Each Domain. Word clouds produced with the “Wordcloud” package in R, after the text from our coding documents had been preprocessed. Preprocessing steps are summarized in the “text analysis” section of the supplementary results. This wordcloud includes text which was coded as featuring a supernatural explanation as well as text which was not coded as featuring a supernatural explanation.

Supplementary Tables

Supplementary Table 1. Further Examples of Supernatural Explanations	
Phenomenon	Supernatural Explanation
Disease	<p>“Prosperity does not depend upon the activities of an individual, but upon his supernatural possessions, spirit, tally post, and a third to be described later. If the tally post tilts far from the perpendicular, its owner becomes ill, and can be cured only by straightening it.”</p> <p>Bellacoola People Boas¹</p>
Natural Hazard	<p>“The Kapauku make use of these spirits to explain natural phenomena. Thus [Page 19] clouds, although clearly recognized as vapor, are believed to be a spirit’s special habitat. Rain is said to be caused by the female Abeguwo, a spirit who urinates down on the people. Stars are the lighted ends of cigarettes smoked by the spirits in the blue sky. Thunder is the flatus of a spirit. And earthquakes are caused by a mythical beast Awega, who beats the earth with its tail.”</p> <p>Kapauku People Pospisil²</p>
Scarcity	<p>“The serious ailments discussed in the previous chapter, paludism, dysentery, catarrh, syphilis, ancylostomiasis, with all of their effects, have no significance for the Guaraúno, since they do not recognize them as such or as of solely natural origin, dependent on fragile, weak, and corrupt nature. They attribute any serious illness, great plagues and epidemics, death itself, to the arrow, sorcery, witchcraft.”</p> <p>Warrau People Moreno & Muirden³</p>
Warfare	<p>“A hole has been made in the upper horn and the drug is introduced through this. It is a great means of divination. When war is imminent, the nyokwekulu begins to ferment, and exudes through the hole: “It knows all about war.” So the country can prepare for it. No wonder that this powerful medicine is preserved with superstitious awe and the greatest care.”</p> <p>Thonga People Junod⁴</p>
Murder	<p>“In general it is recognized that a shaman may use his power in one or more ways. Perhaps most significant, and certainly most feared, is the use of shamanistic power for sorcery. This is characteristic of a bad shaman who is impelled to kill people and particularly those of whom he is jealous.”</p> <p>Ingalik People Osgood⁵</p>
Theft	<p>“A certain wizard painted his body red, and the scalp knot was painted in white on his breasts and knees. He placed wreathes of yucca around his wrists and ankles, and then entered the whirlwind, which is the friend of witches, headforemost. He traveled to the great river of the west and returned to Zuñi in one day. He went to the great river to steal the plume offerings deposited by</p>

the rain priests near Zuñi and carried by the butterflies attached to the plume
sticks to the great river.”

Zuni People
Stevenson⁶

Supplementary Table 2.

Associations between Supernatural Explanations and Social Complexity Indicators

Predictor	<i>b</i> (<i>SE</i>)	β	<i>t</i>	<i>p</i>	95% <i>CI</i>s
Natural Phenomena					
Population Size	-.02 (.02)	-.16	-1.21	.23	-0.42, 0.10
Social Stratification	-.05 (.02)	-.31	-2.91	.004	-0.51, -.01
Political Integration	-.05 (.02)	-.29	-2.66	.009	-0.50, -.08
Density of Population	-.02 (.03)	-.14	-1.07	.29	-0.39, 0.11
Money	-.03 (.02)	-.13	-1.26	.21	-0.32, 0.07
Land Transport	-.04 (.02)	-.20	-2.13	.04	-0.39, -.02
Technological Specialization	.003 (.04)	.01	.09	.92	-0.22, 0.24
Urbanization	-.009 (.02)	-.02	-.24	.81	-0.22, 0.18
Agriculture	-.06 (.02)	-.05	-.46	.65	-0.29, 0.18
Fixity of Residence	-.01 (.01)	-.12	-1.01	.32	-0.35, 0.11
Writing and Records	-.05 (.02)	-.30	-3.21	.002	-0.48, -.01
Social Phenomena					
Population Size	.01 (.04)	.39	2.97	.004	0.13, 0.64
Social Stratification	-.002 (.03)	-.009	-.08	.94	-0.25, 0.23
Political Integration	.003 (.03)	.08	.10	.92	-0.23, 0.25
Density of Population	.05 (.03)	.25	1.91	.06	-0.006, 0.51
Money	.07 (.04)	.21	2.03	.04	0.007, 0.41
Land Transport	.07 (.03)	.22	2.19	.03	0.02, 0.42
Technological Specialization	.14 (.06)	.27	2.28	.02	0.04, 0.49
Urbanization	.05 (.03)	.21	1.99	.05	0.003, 0.41
Agriculture	.06 (.04)	.20	1.60	.11	-0.04, 0.44
Fixity of Residence	.02 (.02)	.12	.98	.34	-0.12, 0.37
Writing and Records	.03 (.03)	.12	1.08	.28	-0.09, 0.33

Note. All statistical tests are two-tailed.

Supplementary Table 3.

Percentage of Supernatural Explanations Referencing Key Terms

Word	Disease	Natural Scarcity	Natural Hazard	Warfare	Murder	Theft	Total
Supernatural Agents							
Spirit	58.72%	43.02%	43.02%	35.82%	46.74%	34.62%	45.92%
God	21.10%	33.72%	40.70%	23.88%	14.13%	3.85%	25.11%
Demon	13.76%	3.49%	10.47%	5.97%	8.70%	7.69%	8.80%
Ghost	10.09%	3.49%	3.49%	2.99%	9.78%	3.85%	6.22%
Human Practitioner of Magic							
witch	19.27%	5.81%	3.49%	16.42%	44.57%	15.38%	18.24%
shaman	17.43%	11.63%	15.12%	19.40%	20.65%	0.00%	15.88%
sorcerer	24.77%	13.95%	9.30%	19.40%	36.96%	30.77%	21.89%
Disembodied Supernatural Force							
karma	0.92%	0.00%	1.16%	0.00%	2.17%	0.00%	0.86%
luck	8.26%	6.98%	4.65%	8.96%	6.52%	3.85%	6.87%
fate	6.42%	1.16%	3.49%	4.48%	3.26%	3.85%	3.86%
Broader Categories							
Sup. Agents	72.48%	62.79%	72.09%	55.22%	58.70%	42.31%	63.73%
Hum. Magic	46.79%	29.07%	24.42%	41.79%	71.74%	46.15%	43.56%
Dis. Forces	13.76%	8.14%	8.14%	13.43%	11.96%	7.69%	10.94%

Supplementary Table 4.

Replicating Analyses of Naturally vs. Socially Focused Supernatural Explanation Frequency
(Sum of Explanations) Across Alternative Language Phylogenies

Tree	<i>t</i>	<i>p</i>
Glottolog Tree 1	10.49	<.001
Glottolog Tree 2	10.49	<.001
Glottolog Tree 3	10.49	<.001

Supplementary Table 5.

Replicating Association Between Social Complexity and Frequency of Socially Focused Supernatural Explanations Across Alternative Language Phylogenies

Tree	<i>b (SE)</i>	<i>β</i>	<i>t</i>	<i>p</i>	<i>95% CIs</i>
Glottolog Tree 1	.19 (.06)	.36	3.07	.003	0.07, 0.32
Glottolog Tree 2	.23 (.07)	.44	3.45	.001	0.10, 0.37
Glottolog Tree 3	.17 (.06)	.32	2.89	.005	0.06, 0.29

Supplementary Table 6.

Replicating Association Between Social Complexity and Frequency of Naturally Focused Supernatural Explanations Across Alternative Language Phylogenies

Tree	<i>b</i> (<i>SE</i>)	β	<i>t</i>	<i>p</i>	<i>95% CIs</i>
Glottolog Tree 1	-.09 (.04)	-.27	-2.47	.02	-0.16, -0.02
Glottolog Tree 2	-.08 (.04)	-.25	-2.31	.02	-0.15, -0.01
Glottolog Tree 3	-.09 (.03)	-.26	-2.44	.02	-0.15, -0.02

Supplementary Table 7.

Original and Replaced Glottocodes in the ASJP Language Tree

Original Code in ASJP Tree	Replaced Code
aleu1260	east2533
bemb1257	town1238
west2618	copp1244
gilb1244	bana1287
haus1257	araw1280
hava1248	hava1249
amga1235	tuwa1243
koyu1237	dege1248
beav1236	kask1239
mars1254	rata1243
lese1243	bila1255
nama1264	nama1265
lihi1237	nots1237
mong1338	nkun1238
nyak1260	nyak1261
omah1247	omah1248
baru1269	orok1269
nort2954	nort1551
toho1245	toho1246
chip1241	alba1270
fare1241	taln1239
plat1254	tana1285
yoku1256	vall1251
mina1268	nege1240

Supplementary Table 8.

Number of Societies with Data on Key Variables

Variable	Societies (Main Text)	Societies (Full Sample)
Supernatural Explanation Codes		
Pathogens	106	113
Scarcity	88	93
Natural hazards	91	96
Warfare	97	100
Murder	106	112
Theft	87	92
Exogenous Variables		
Social complexity	107	114
Pathogen prevalence	107	114
Natural hazard prevalence	46	50
Famine prevalence	101	108
Internal war prevalence	61	63
External war prevalence	62	63

Supplementary Table 9.

Number of Societies Included in Key Analyses

Name of Analysis	Societies (Main Text)	Societies (Full Sample)
T-Test: Proportion of Natural vs. Social Explanations	107	114
T-Test: At Least One Natural vs. Social Explanation	107	114
Frequency of Occurrence Regression: Disease	106	113
Frequency of Occurrence Regression: Scarcity	84	89
Frequency of Occurrence Regression: Natural Hazards	40	43
Frequency of Occurrence Regression: Warfare	53	54
Social Complexity Regression: Social Phenomena	107	114
Social Complexity Regression: Natural Phenomena	107	114

Supplementary Methods

Further Information about the Coding Process

Here we summarize additional details about how we coded supernatural explanations in the ethnographic record.

Reliability Process. Our initial coding of the ethnographic materials required training two research assistants to access, read, and interpret text from the ethnographic record. To ensure that their coding decisions were reliable, we initially instructed the research assistants to code the same batches of 10 societies and then evaluated whether they made the same coding decisions. For the first batch of 10 societies, coders' decisions had low reliability (Krippendorff's $\bar{\alpha} = .53$), so they met as a pair, discussed their different decisions, and reached a consensus. For their second batch of 10 societies, inter-coder reliability reached an average Krippendorff's α value of .75 across the 6 codes, which we deemed sufficiently reliable. After this second 10-society batch, research assistants split the remaining sample of societies and independently coded their half of the sample.

Excluding Societies with Insufficient Volume or Quality of Ethnographic Text. In our methods section, we report a sample size of 114 societies. This figure does not include eight societies that we included in the very early stages of coding but dropped from the study because of absent or poor-quality data. Five societies (Mao, Lapps, Gilbertese, Amahuaca, Cayua) had insufficient data because their ethnographies were not hosted on eHRAF or did not feature discussions of supernatural beliefs. We excluded a further two societies (the Abipon people and Kaffa people) because their ethnographic material was strongly biased by racism from Christian missionaries. Research assistants judged ethnographer bias subjectively, but their decisions were supported by the co-author team. For example, Dobrizhoffer's⁷ account of the Abipón people of Argentina's Gran Chaco region contains the claim "I said that the Abipón were commendable for their wit and strength of mind; but, ashamed of my hasty praise, I retract my words, and pronounce them fools, idiots, and madmen. Lo! This is proof of their insanity! They are unacquainted with God, and the very name of God" (p. 64). The research assistants were blind to our research questions, which mitigated the possibility of research assistants recommending exclusions in a biased manner.

Matching Societies to Language Trees

We identified the languages spoken by societies in our sample based on the Glottolog entries associated with their SCCS identities in the D-Place database of world cultures⁸. Languages in the *Automated Similarity Judgment Program (ASJP)* global phylogeny are identified based on language names rather than standardized language codes. Whenever possible we matched the Glottolog language names associated with societies in our sample with entries in the ASJP tree. When the exact language matches were not apparent, we matched based on known alternative language names, or by assigning the nearest language on the ASJP tree. This approach does not assume that language groups are interchangeable; it is simply a pragmatic step to approximate ancestral heritage for groups that were not represented in Glottolog (see Supplementary Table 8

for the full list of original and matched Glottocodes). For our supplementary Glottolog based language trees we were able to assign exact language matches for all societies in our sample.

Supplementary Results

Text Analysis

In addition to our quantitative codes, we also conducted an exploratory analysis of our qualitative text using standard dictionary methods⁹. The goal of this text analysis was to better understand the content of our supernatural explanations through key words which identified whether supernatural explanations involved (a) supernatural agents (e.g., gods, spirits, ghosts), (b) human practitioners of magic (e.g., shamans, sorcerers, witches), or disembodied supernatural forces (e.g., such as luck, karma, or fate).

Prior to this analysis, we pre-processed the qualitative source text from our coding documents through a two-step process. First, we tokenized the text, which involves converting the raw text to a series of “tokens” that represent meaningful words. Our tokenization process removed punctuation, symbols, numbers, urls, stop-words, and converted all text to lower-case. We also lemmatized tokens so that words with the same meaning but different forms (e.g., steal, stole) would be combined. Second, we converted the tokenized text to a “document-feature matrix” in which texts represent words, tokens represent columns, and values represent the number of times that a token is detected in a text. These processes are standard best-practice steps in cleaning text prior to performing dictionary analyses⁹. Supplementary Figure 3 displays word clouds which were fit to this preprocessed data for each domain of supernatural explanation. These word clouds were fit to all text in each domain, which included text describing supernatural explanations but also text that did not describe supernatural explanations.

After this preprocessing was complete, we searched for the presence or absence of 10 key terms representing supernatural agents (“spirit*,” “god*,” “demon*,” “ghost*”), human practitioners of magic (“witch*,” “shaman*,” “sorcer*”) and disembodied supernatural forces (“karma*,” “luck*,” “fate*,”). We selected these categories subjectively based on key terms that the coders had observed during the coding process. The star notation following each word allowed us to include multiple forms of the word which may not have been coerced during lemmatization (e.g., sorcerer and sorceress). We left out two key terms— “magic” and “evil eye”—because these terms were used in different contexts across supernatural explanations. They sometimes were used in the context of human magical practitioners, sometimes in the context of supernatural agents, and sometimes in the context of disembodied supernatural forces.

We only searched for the prevalence of these terms in text coded as featuring supernatural explanations since our goal was to understand supernatural explanation content in particular. This search resulted in presence-absence dummy-variables for each term. Supplementary Table 3 summarizes the prevalence of each term across supernatural explanations, organized in terms of domain of explanation. As displayed in Supplementary Table 3, the two most common terms were “spirit” and “god,” followed by each of the human practitioner terms.

We also grouped these terms into dummy-variables representing the overarching categories (e.g., the “supernatural agents” dummy-variable took values of one if supernatural explanations cited any of the supernatural agent terms). Analyzing these broader variables showed that approximately 64% of supernatural explanations across all domains featured at least one supernatural agent, 44% of supernatural explanations featured at least one human magical practitioner, and 11% of supernatural explanations featured at least one disembodied force. These variables were essentially uncorrelated at the level of the supernatural explanation. Supernatural explanations featuring supernatural agents were not significantly more or less likely to feature human practitioners of magic, $r(464) = -.01, p = .79$, or disembodied supernatural forces, $r(464) = .05, p = .28$, and supernatural explanations featuring human practitioners of magic were not significantly more or less likely to feature supernatural forces, $r(464) = .01, p = .82$.

In sum, this text analysis found that supernatural explanations feature supernatural agents, human practitioners of magic, and disembodied forces. However, disembodied forces appear to be more rarely featured than supernatural agents or human magical practitioners. These different kinds of supernatural explanations are also not mutually exclusive: supernatural explanations do not *either* appear to feature supernatural agents or human magical practitioners.

We note that this text analysis is not a thorough content analysis of our supernatural explanations, and our list of key terms is not comprehensive. Our text analysis is merely intended to give a broad survey of the relative prevalence of different supernatural themes across these supernatural explanations.

Robustness Tests

We conducted a number of robustness tests which we present below. These tests focused on our central two analyses: (a) comparing the prevalence of supernatural explanations of natural phenomena with the prevalence of supernatural explanations of social phenomena and (b) estimating the association between social complexity and each kind of supernatural explanation.

Replicating Key Results with the Full Sample of Societies. We replicated our key analyses using the full sample of societies that included seven societies which we excluded due to high levels of borrowing from large-scale religions. Even in the full sample of societies, supernatural explanations were still more prevalent for natural phenomena compared to social phenomena. We found 96% of societies in our sample had common supernatural explanations for disease, 92% for natural causes of food scarcity, and 90% for natural hazards. In contrast, 67% of societies had common supernatural explanations of warfare, 82% for murder, and 28% for theft. Phylogenetically adjusted paired samples t-tests showed that societies had significantly more supernatural explanations of natural vs. social phenomena, $t(111) = 10.38, p < .001$.

Phylogenetically controlled regressions showed that social complexity was positively associated with the prevalence of supernatural explanations of social phenomena, $b = .13, \beta = .29, SE = .05, t = 2.46, p = .02, 95\% \text{ CIs } [.03, .23]$, but was not significantly associated with supernatural explanations of natural phenomena, $b = -.06, \beta = -.20, SE = .03, t = -1.78, p = .08, 95\% \text{ CIs } [-.12, .005]$.

Replicating Key Results with Distinct Disease and Murder Codes. We replicated our main findings using revised “disease” and “murder” codes which were based on distinct descriptions of the two phenomena. In other words, we re-coded for supernatural explanations of disease and murder while excluding all ethnographic text which reflected simultaneous supernatural explanations of these two phenomena (e.g., attributing a family member’s illness and death to murder through sorcery). This produced revised supernatural explanation codes of murder and disease which were independent.

With these distinct codes, supernatural explanations were still more prevalent for natural phenomena compared to social phenomena. We found 94% of societies in our sample had common supernatural explanations for disease, 92% for natural causes of food scarcity, and 90% for natural hazards. In contrast, 67% of societies had common supernatural explanations of warfare, 76% for murder, and 28% for theft. Phylogenetically adjusted paired samples t-tests showed that societies had significantly more supernatural explanations of natural vs. social phenomena, $t(111) = 9.77, p < .001$.

Phylogenetically controlled regressions showed that social complexity was positively associated with the prevalence of supernatural explanations of social phenomena, $b = .12, \beta = .26, SE = .05, t = 2.25, p = .03$, 95% CIs [.02, .22], but the negative association with supernatural explanations of natural phenomena did not reach significance with these revised codes, $b = -.05, \beta = -.16, SE = .03, t = -1.45, p = .15$, 95% CIs [-.11, .02].

Replicating Key Results while Including Uncommon Supernatural Explanations. Next, we replicated our key analyses with codes that counted phenomena as being attributed to supernatural agents when any explanation was *present*, even if it was not a widespread belief across the society. Coding for present rather than common supernatural explanations, supernatural explanations were more prevalent for natural phenomena compared to social phenomena.

We found 99% of societies in our sample had supernatural explanations for disease, 97% for natural causes of food scarcity, and 97% for natural hazards. In contrast, 74% of societies had supernatural explanations of warfare, 94% for murder, and 36% for theft. Phylogenetically adjusted paired samples t-tests showed that societies had significantly more supernatural explanations of natural vs. social phenomena, $t(104) = 7.50, p < .001$.

Phylogenetically controlled regressions showed that social complexity was positively associated with the prevalence of supernatural explanations of social phenomena, $b = .17, \beta = .42, SE = .12, t = 2.39, p = .02$, 95% CIs [.05, .53], but it was not significantly associated with supernatural explanations of natural phenomena, $b = -.19, \beta = -.14, SE = .15, t = -1.24, p = .22$, 95% CIs [-.37, .08].

Replicating Key Results with Quasi-Poisson Estimation. We tested whether the relationships between social complexity and natural and social supernatural explanations replicated using Quasi-Poisson estimators in the social complexity regression analyses. These analyses only focused on the analyses using regression: the relationship between social complexity and

supernatural explanations. We found that social complexity was positively associated with the prevalence of supernatural explanations of social phenomena, $b = .25$, $SE = .08$, $t = 2.83$, $p = .006$, 95% CIs [.07, .40], and was positively associated with the prevalence of supernatural explanations of natural phenomena, $b = -.07$, $SE = .04$, $t = -1.99$, $p = .049$, 95% CIs [-.14, .001].

Replicating Key Results with Regression Weights Representing Coding Confidence.

Throughout our multi-stage coding process, we asked coders to generate 1-4 “confidence codes” in addition to their supernatural explanation codes. We updated these confidence codes throughout the coding process such that higher confidence codes (e.g., a score of “4”) indicated more confidence in our judgments that a supernatural explanation was present, absent, or missing, and lower confidence codes (e.g., a score of “1”) indicated low confidence in our present, absent, or missing code because of unclear source material or disagreement between coders. Here we present a set of analyses where we weighted our regression models according to these confidence codes, such that societies with higher average confidence codes were weighted above societies with lower average confidence codes. These analyses only focused on the analyses using regression: the relationship between social complexity and supernatural explanations.

With these weighted models, phylogenetically controlled regressions showed that social complexity was positively associated with the prevalence of supernatural explanations of social phenomena, $b = .14$, $\beta = .26$, $SE = .05$, $t = 2.77$, $p = .007$, 95% CIs [.04, .24], but the negative association with supernatural explanations of natural phenomena did not reach significance, $b = -.06$, $\beta = -.19$, $SE = .03$, $t = -1.97$, $p = .052$, 95% CIs [-.13, .001].

Evaluating Alternative Language Phylogenies. Our main text analyses controlled for ancestral interdependence using the *ASJP* phylogeny. We note that the historical relationships represented in global language phylogenies—even those developed using state-of-the-art methods—involve uncertainty, particularly in the deeper groupings and structures. To test how sensitive our results are to our choice of global language trees, we performed supplementary phylogenetic analyses using a custom set of global phylogenies build from data in the Glottolog database of world languages¹⁰. The Glottolog database contains comprehensive classification data for over 20,000 world languages and dialects based on expert judgements. This language classification data provides the underlying structure of language phylogenies but does not contain information on the scale of the branches. We developed a method for simplifying the classification scheme of Glottolog and scaling branches according to different potential distances between taxonomic classifications. This yielded three language phylogenies with the same structure, but the scaling of the branches varied to reflect different assumptions about the relationships between linguistic groupings and cultural similarity. Supplementary Tables 3-5 show that results are highly similar across these three alternative trees.

Supernatural Explanations and Social Cohesion

In secondary analyses, we examined how social cohesion and social inequality relate to the prevalence of supernatural explanations. Past research has connected both social cohesion and social inequality to specific religious beliefs and practices. Research on religious prosociality has found that synchronizing or highly arousing rituals can increase feelings of group bondedness^{11,12}

and that belief in supernatural punishment or moralizing gods can increase parochial cooperation^{13,14}. In contrast, research on the darker side of religion has found that human sacrifice rituals can increase and perpetuate social stratification¹⁵.

Supernatural explanations could relate to social cohesion and complexity in a number of interesting ways. Some supernatural explanations might reinforce social norms and group rituals. For example, the Lolo (or Yi) people of Southern China believe in divination rituals using wood or bones which forecast whether wars will have favorable or unfavorable outcomes. These rituals may lead to greater confidence and fortitude in battle because it alleviates soldiers' fear of defeat. Supernatural explanations which involve supernatural punishment could also lead to greater cooperation or prosociality because they imply that norm violations will be met with divine retribution. Finally, supernatural explanations which stigmatize individuals or family groups via witchcraft accusations may actually inhibit group cohesion and/or lead to persistent social inequality by leading to feuds or persecution. These different mechanisms are not mutually exclusive. For example, some supernatural explanations could increase group cohesion whereas others could decrease group cohesion.

As a first step towards testing these ideas, we collected data on social cohesion and social inequality across our sample of societies and estimated how these variables relate to the prevalence of supernatural explanations. Our measures of social cohesion and social inequality come from an analysis of six items from Ross's codes of conflict and social dynamics¹⁶. These were: (a) participation in the political process, (b) distribution of political power, (c) loyalty to the society, (d) loyalty to a local community, (e) compliance of individuals with community norms and decisions, and (f) modes of conflict management in the community. A maximum likelihood exploratory factor analysis suggested two factors based on eigenvalues, parallel analysis, and an acceleration factor approach. The first factor (Eigenvalue = 1.88) contained loadings from "participation in the political process" (.67) and "perceptions of political leaders' power" (.79). The second factor contained loadings from "loyalty to wider society" (.72), "modes of conflict management in a community" (.43), "compliance with community norms and decisions" (.46) "loyalty to local community" (.35). We coded the factors so that higher scores on the first factor represented greater inequality, and higher scores on the second factor represented greater group cohesion.

Phylogenetically controlled regressions showed no significant associations between social cohesion or inequality. Social inequality was not significantly associated with the prevalence of supernatural explanations of natural phenomena, $b = -.03$, $\beta = -.16$, $SE = .02$, $t = -1.48$, $p = .14$, 95% CIs [-.08, .01], or with supernatural explanations of social phenomena, $b = .01$, $\beta = .03$, $SE = .05$, $t = .21$, $p = .84$, 95% CIs [-.08, .10]. Similarly, social cohesion was not significantly associated with supernatural explanations of natural phenomena, $b = -.02$, $\beta = -.09$, $SE = .03$, $t = -.81$, $p = .42$, 95% CIs [-.08, .03] or with supernatural explanations of social phenomena, $b = -.02$, $\beta = .04$, $SE = .06$, $t = .37$, $p = .71$, 95% CIs [-.09, .14].

These regressions are a very preliminary analysis, and we encourage future research to explore more nuanced ways that supernatural explanations might be linked to social cohesion and social inequality. One possibility that we encourage would involve coding whether supernatural explanations include instances of moralistic supernatural punishment, and testing whether these

moralistic supernatural explanations are linked to higher levels of group cohesion or cooperation. Research teams can develop these codes using our pre-existing coding documents which we have made publicly accessible at <https://osf.io/jsk4t/>.

Supernatural Explanations in Pastoral Societies

Our main text focused on how the prevalence of supernatural explanations of social phenomena and supernatural explanations of natural phenomena varied based on societies' levels of social complexity. In secondary analyses, we also tested whether supernatural explanations—particularly explanations of theft—might be related to pastoralism. Past studies have described how there is a greater risk of theft in pastoral societies where livestock is mobile. Theft can also deplete a family's entire food-store^{17,18}. We reasoned that this might lead to a greater prevalence of supernatural explanations of theft in pastoral societies.

We used the “Subsistence Economy” code which classified all SCCS societies as primarily (1) Gathering, (2) Fishing, (3) Hunting, (4) Pastoral, or (5-7) Agricultural¹⁹. We recoded the variable into a binary variable in which “1” referred to pastoral groups and 0 referred to other subsistence strategies. With this variable, we found that pastoral subsistence style was not significantly associated with supernatural explanations of natural phenomena, $b = .05$, $\beta = .06$, $SE = .09$, $t = .50$, $p = .62$, 95% CIs $[-.14, .23]$, or with supernatural explanations of social phenomena, $b = .07$, $\beta = .05$, $SE = .16$, $t = .41$, $p = .68$, 95% CIs $[-.25, .38]$. Additionally, pastoral subsistence style was not significantly associated with supernatural explanations of theft, $b = .17$, $\beta = .09$, $SE = .24$, $t = .70$, $p = .49$, 95% CIs $[-.31, .65]$. While pastoral economies are associated with several forms of cultural variation, such as the prevalence of honor cultures¹⁸, pastoralism was not associated with the content of supernatural explanations in our dataset.

References

1. Boas, F. *Third Report on the Indians of British Columbia*. (Houghton, Mifflin & Company, 1891).
2. Pospisil, L. J. *Kapauku Papuan Economy*. (Yale University, 1963).
3. Turrado Moreno, A. & Muirden, S. *Ethnography of the Guarauno Indians*. (Lit. y Tip. Vargas, 1945).
4. Junod, H. A. *The Life of a South African Tribe*. (Attinger Frères, 1913).
5. Osgood, C. *Ingalik Social Culture*. (The Yale University Press, 1958).
6. Stevenson, M. C. E. *The Zuni Indians: Their Mythology, Esoteric Fraternities, and Ceremonies*. (U.S. Bureau of American Ethnology, 1904).
7. Dobrizhoffer, M. *An Account of the Abipones: An Equestrian People of Paraguay*. (J. Murray, 1822).
8. Kirby, K. R. et al. D-PLACE: A global database of cultural, linguistic and environmental diversity. *PLoS One* **11**, e0158391 (2016).
9. Jackson, J. C. et al. From text to thought: how analyzing language can advance psychological science. *Perspect. Psychol. Sci.* **17**, 805–826 (2022).
10. Hammarström, H., Forkel, R., Haspelmath, M. & Bank, S. *Glottolog 4.3*. (Glottolog) doi:10.5281/zenodo.4061162 (2020).
11. Whitehouse, H. et al. The ties that bind us: ritual, fusion, and identification. *Curr. Anthropol.* **55**, 000–000 (2014).
12. Jackson, J. C. et al. Synchrony and physiological arousal increase cohesion and cooperation in large naturalistic groups. *Sci. Rep.* **8**, 1–8 (2018).
13. Norenzayan, A. et al. The cultural evolution of prosocial religions. *Behav. Brain Sci.* **39**, (2016).
14. White, C. J., Kelly, J. M., Shariff, A. F. & Norenzayan, A. Supernatural norm enforcement: thinking about karma and God reduces selfishness among believers. *J. Exp. Soc. Psychol.* **84**, 103797 (2019).
15. Watts, J., Sheehan, O., Atkinson, Q. D., Bulbulia, J. & Gray, R. D. Ritual human sacrifice promoted and sustained the evolution of stratified societies. *Nature* **532**, 228 (2016).
16. Ross, M. H. Political decision making and conflict: additional cross-cultural codes and scales. *Ethnology* **22**, 169–192 (1983).
17. Moritz, M. A critical examination of honor cultures and herding societies in Africa. *Afr. Stud. Rev.* **51**, 99–117 (2008).
18. Nisbett, R. E. & Cohen, D. *Culture of Honor: The Psychology of Violence in the South*. (Routledge, 2018).
19. Murdock, G. P. Ethnographic atlas: a summary. *Ethnology* **6**, 109–236 (1967).