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Supernatural explanations across 114 societies are more common for natural than social phenomena

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Joshua Conrad Jackson[1]✉, **Danica Dillion**[2]✉, **Brock Bastian**[3], **Joseph Watts**[4,5], **William Buckner**[6], **Nicholas DiMaggio**[2] & **Kurt Gray**[2]

Humans across the globe use supernatural beliefs to explain the world around them. This article explores whether cultural groups invoke the supernatural more to explain natural phenomena (for example, storms, disease outbreaks) or social phenomena (for example, murder, warfare). Quantitative analysis of ethnographic text across 114 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 socially 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 versus 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 change[1], and Egyptians, Aztecs, Celtic and Tiv people used the will of gods to explain celestial cycles[2]. In the modern world, 90% of Muslim Tunisians believe that the evil eye can cause physical harm[3], and many American Christians perceived the COVID-19 pandemic as a form of apocalyptic divine punishment[4]. In these examples, humans make supernatural explanations by claiming that a supernatural agent (for example, a god, ancestor spirit or witch) or supernatural force (for example, karma, evil eye) is responsible for some earthly event.

Since the nineteenth century, scientists, philosophers and theologians have interpreted supernatural explanations using a 'god of the gaps' hypothesis—people infer supernatural agency behind phenomena that 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 (for example, 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. Although 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 agent[8]. 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

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[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, Victoria, 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. ✉e-mail: joshua.jackson@kellogg.northwestern.edu; danicaw@email.unc.edu

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 (the hand of God) when the dam broke spontaneously compared with if a dam worker had released the water[8]. This theory suggests that there is a basic human tendency to develop supernatural explanations for events that have absent or ambiguous causal agents[8].

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 that can be traced to Tylor[12], Frazer[13], Muller[14] and Hume[15]. These scholars wrote about animistic religions that 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 focused mostly 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 age[25], suggesting that humans may also develop religious beliefs that explain social behaviour. 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 conflicts[30], 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 analysing 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 (for example, gods, ancestor spirits, human magical practitioners such as witches or shamans) or supernatural force (for example, 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.

Analysing the ethnographic record also makes it possible for us to incorporate socio-political 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 practise hunting and gathering to large and urbanized societies that often practise 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 interactions[38], weak ties[39], social uncertainty[40] 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 behaviours 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 behaviour (for example, 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 neighbouring 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 allows 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 a 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 Fig. 1 for the global distribution of the sample and Fig. 2 for a visualization of the text most commonly associated with each of the six phenomena in our dataset). The Methods give 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.

Our approach was designed to appropriately: (1) model the interdependence of data-points (Galton's problem) and (2) avoid conflating missing data with the absence of supernatural explanations. To model the interdependence of data-points, we conducted phylogenetically adjusted analyses in which we nested our data-points within a global language phylogeny[45] (Methods). Although the cross-cultural distribution of supernatural explanations showed little evidence of phylogenetic patterning (Methods), we nevertheless used phylogenetically nested regressions and t-tests to reduce the risk of Galton's problem. Our main text analyses also excluded seven large-scale societies that had high levels of borrowing—a source of interdependence that is not modelled by our language phylogenies. The 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 coded for supernatural explanations only when an ethnography explicitly discussed that phenomenon (for example, 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 analysing 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 versus socially focused supernatural explanations. These steps mitigated the risk of missing data biasing our analyses.

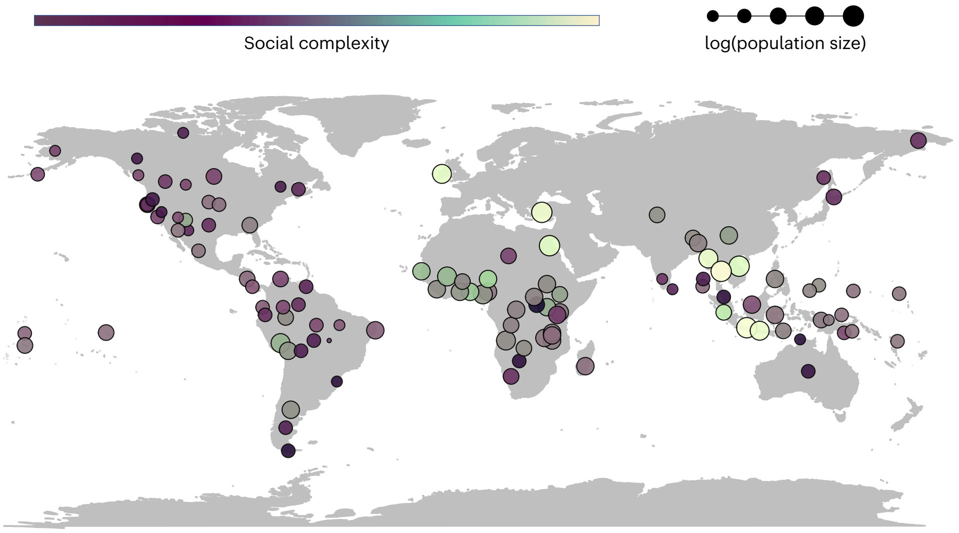

Fig. 1 | The geographic location of the 114 societies in our sample. Each node represents a society. Node colour indicates Murdock and Provost's[72] social complexity index. Node size indicates the logarithm of the population size as indexed by Murdock and White[63]. This map was generated in R using the geom_polygon, geom_point and map_data functions in the ggplot2 package.

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 that were not documented by the ethnographer. The median society in our sample had common supernatural explanations for four of the six phenomena that we coded. Table 1 provides examples of supernatural explanations—and text that was not coded as featuring a supernatural explanation—for each phenomenon.

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 versus social phenomena. In supplemental analyses, we dissect the various themes in these supernatural explanations using methods of text analysis. These text analyses identify the relative frequency of supernatural agents (for example, gods, spirits), human practitioners of magic (for example, shamans, witches) and disembodied supernatural forces (for example, karma, fate) in the qualitative supernatural explanation text (Supplementary Table 3).

Prevalence of supernatural explanations across domains

Supernatural explanations were more prevalent for natural phenomena compared with 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. By 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 versus social phenomena ($t(104) = 10.20$, $P < 0.001$, $Mean_{\text{difference}} = 0.32$, 95% confidence intervals (CI), 0.26 to 0.38). Societies were also more likely to have at least one supernatural explanation of a natural versus a social phenomenon ($t(104) = 2.18$, $P = 0.03$, $Mean_{\text{difference}} = 0.05$, 95% CI, 0.01 to 0.10). Figure 3 shows each society's documented supernatural explanations of natural and social phenomena on a language-based phylogeny.

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 ($b = 0.03$, $\beta = 0.06$, $P = 0.59$, s.e. = 0.06, $z = 0.54$, odds ratio (OR) = 1.03, 95% CI, 0.92 to 1.15), natural hazards ($b = -0.10$, $\beta = -0.13$, $P = 0.80$, s.e. = 0.42, $z = -0.25$, OR = 0.90, 95% CI, 0.40 to 2.03), food scarcity ($b = -0.13$, $\beta = -0.12$, $P = 0.79$, s.e. = 0.48, $z = -0.27$, OR = .88, 95% CI, 0.34 to 2.25) and warfare between polities ($b = 0.44$, $\beta = 0.55$, $P = 0.08$, s.e. = 0.25, $z = 1.77$, OR = 1.55, 95% CI, 0.95 to 2.53), or within polities ($b = 0.15$, $\beta = 0.19$, $P = 0.55$, s.e. = 0.25, $z = 0.59$, OR = 1.16, 95% CI, 0.71 to 1.92). In sum, there was no significant evidence that frequency of occurrence was associated with likelihood of supernatural explanation for any domain.

Social complexity and supernatural explanation prevalence

We next tested whether the gap in prevalence between supernatural explanations of natural versus 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 ($b = 0.17$, $\beta = 0.32$, $P = 0.01$, s.e. = 0.07, $t = 2.62$, 95% CI, 0.04 to 0.30), but negatively associated with supernatural explanations of natural phenomena ($b = -0.09$, $\beta = -0.29$, $P = 0.02$, s.e. = 0.04, $t = -2.42$, 95% CI, −0.17 to −0.02). Societies with low (1 s.d. below the sample mean) social complexity had a far greater proportion of supernatural explanations of natural versus social phenomena ($M_{\text{natural}} = 0.95$, 95% CI 0.86 to 1.04 versus $M_{\text{social}} = 0.52$, 95% CI, 0.37 to 0.67). This gap persisted in societies with high social complexity (1 s.d. above the sample mean), but it was considerably smaller ($M_{\text{natural}} = 0.85$, 95% CI, 0.75 to 0.94 versus $M_{\text{social}} = 0.71$, 95% CI, 0.55 to 0.88). Figure 4b displays the prevalence of each kind of supernatural explanation at different levels of social complexity. Our supplemental results show that the positive association with supernatural explanations of social phenomena was more robust to different model specifications than the negative association

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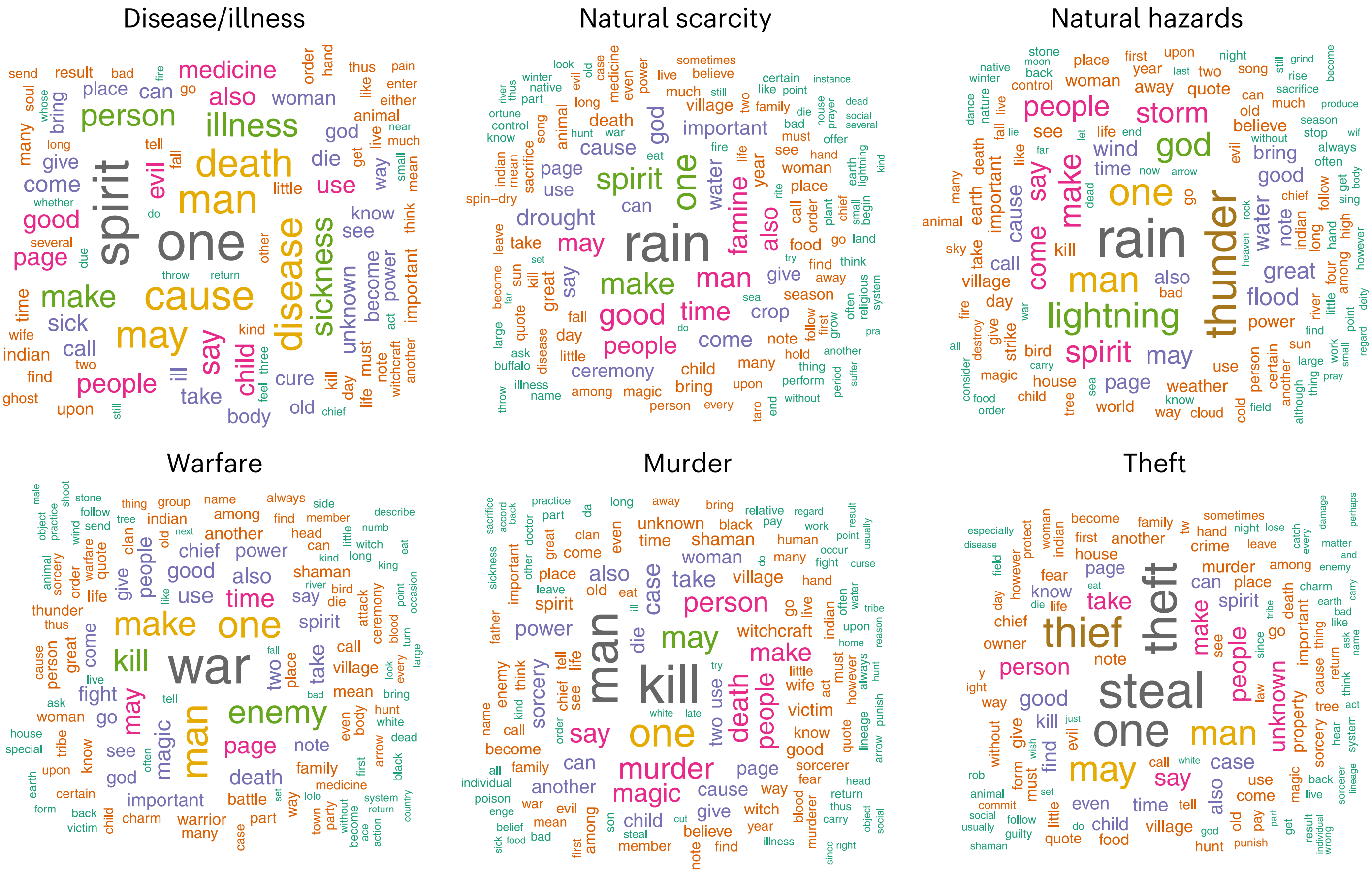

Fig. 2 | Word clouds for each domain. Word clouds produced with the Wordcloud package in R, after the text from our coding documents had been preprocessed. Preprocessing steps are summarized in the 'text analysis' section of the Supplementary Results. This word cloud includes text that was coded as featuring a supernatural explanation as well as text that was not coded as featuring a supernatural explanation.

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 ($\beta = 0.39$, $P = 0.004$, $t = 2.97$, 95% CI, 0.13 to 0.64). Population size implies larger and less familiar social networks. Supernatural explanations of social phenomena were also more common in societies with money ($\beta = 0.21$, $P = 0.04$, $t = 2.03$, 95% CI, 0.007 to 0.41), land transport ($\beta = 0.22$, $P = 0.03$, $t = 2.19$, 95% CI, 0.02 to 0.42) and technological specialization ($\beta = 0.27$, $P = 0.02$, $t = 2.28$, 95% CI, 0.04 to 0.49). By contrast, indicators of social inequality such as social stratification and political integration had near-zero standardized associations with supernatural explanations of social phenomena. These models shed some light on the forms of social complexity that 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 4a displays the estimates and standard errors from each of these models. See Supplementary Table 2 for full statistics associated with each indicator.

The Supplementary Results provide multiple robustness checks and exploratory analyses that support our conclusions. These include replications of key analyses while: (1) using the full sample of 114 societies (Supplementary Results); (2) using alternative language phylogenies (Supplementary Results and Supplementary Tables 4–6); (3) using regression weights based on our research team's confidence in the quantitative codes (Supplementary Results); and (4) using Quasi-Poisson estimation, which makes fewer distributional assumptions than our Gaussian Maximum Likelihood models (Supplementary Results). We also describe alternative coding schemes (Supplementary Methods) and analyse 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 a 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, suggesting that this effect is less robust. We provide comprehensive statistics and tables for these analyses in our supplementary materials.

Discussion

Religious beliefs are prevalent in virtually every human society[46], and may even predate anatomically modern humans[47,48]. People in many societies use their religious beliefs to explain natural and social phenomena[5,12,13,15,48]. 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

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 nggïyúdn 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 nggïyúdn wanted him for a sex companion.’ Aweikoma People Henry[80]	‘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 People Hoernlé[81]
Natural hazard	‘Lightning, kū′īdya 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[82]	‘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.’ Azande People Baxter and Butt[83]
Scarcity	‘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.’ Ainu People Batchelor[84]	‘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.’ Kapauku People Pospisil[85]
Warfare	‘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.’ Comanche People Wallace and Hoebel[86]	‘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.’ Alorese People Du Bois et al.[87]
Murder	‘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.’ Papago People Underhill[88]	‘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.’ Marshallese People Kramer et al.[89]
Theft	‘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.’ Toradja People Adriani and Kruijt[90]	‘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 behaviour.’ Garo People Burling[91]

Examples of ethnographic text evidence which 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.

principles compared with social events such as warfare and murder. This difference could not be explained by the frequency of phenomena (that disease outbreaks occurred more frequently than warfare).

Our findings suggest humans around the world may be most likely to apply religious beliefs to explain phenomena that 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 (for example, 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 in which 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[12,15,49], and more recent cognitive science claims that this anthropomorphism may have played a role in the evolution of religious beliefs[16]. We also show that, among natural phenomena, supernatural explanations were especially prevalent for illness and disease. This pattern supports theories that claim pathogen outbreaks encourage beliefs in ‘moral vitalism’—invisible forces of good and evil[50,51]—that can manifest through beliefs in evil spirits (for example, 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 that was

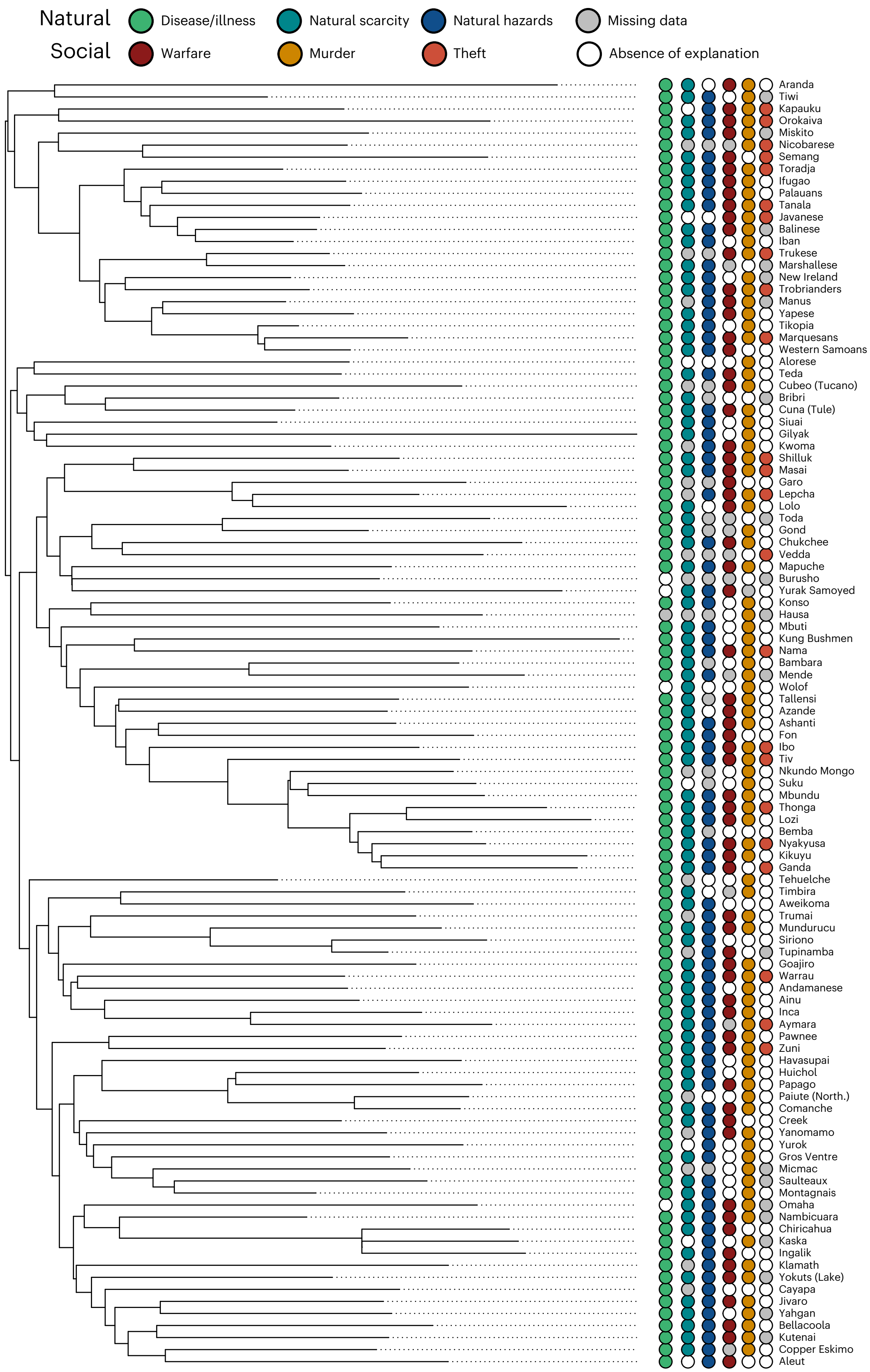

Fig. 3 | Documented supernatural explanations of natural and social phenomena of 107 societies on a language-based phylogeny. Supernatural explanations colour-coded by phenomena and organized according to the Automated Similarity Judgment Program global language phylogeny[45]. Tips have been aligned (dotted lines) for ease of viewing and interpretation. Supernatural explanations for natural phenomena (disease, scarcity, hazards) are represented by cool colours and supernatural explanations for social phenomena (warfare, murder, theft) are represented by warm colours.

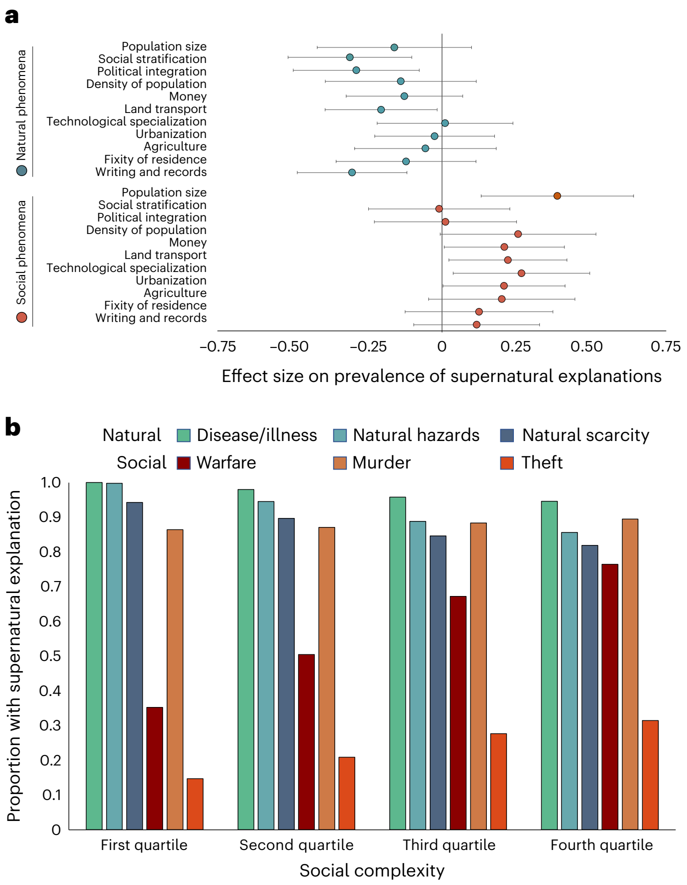

Fig. 4 | Relations between social complexity and supernatural explanation frequency. a, Standardized associations—derived from phylogenetically adjusted regressions—between indicators of social complexity and the frequency of supernatural explanations of natural and social phenomena from phylogenetically nested regressions ($n = 107$). Error bars represent 95% CI and centres represent beta values. **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 colours and supernatural explanations for social phenomena (warfare, murder, theft) are represented by warm colours. All analyses are two-tailed.

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 ties[38], social uncertainty[40] and distrust[41], all factors that increase uncertainty about people's behaviour and the underlying reasons for that behaviour. 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[44,51]. 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 with other social phenomena. One possible reason for this difference was that theft was the only phenomenon we examined that 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 suffering[8], consistent with early scholars such as Malinowski[43] and Freud[52] noting a cross-cultural connection between religion and death, and contemporary studies have found that death anxiety makes religious beliefs salient[53]. 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 that inspire supernatural explanation.

We also note two limitations to this study. First, our data are based on ethnographic texts, which are often written from an eighteenth or nineteenth century Western perspective. Although we excluded ethnographies and content that showed clear problematic biases (for example, overt racist agendas), our findings may still be impacted by subtler biases (for example, theoretical schools of authors), and we encourage future research to scrutinize and re-analyse 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 in which 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 that were based on distinct text. Nevertheless, it is sometimes impossible to fully disentangle 'social' and 'natural' phenomena based on ethnographic descriptions.

We see two main future directions for this work. The first of these 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 that are more positively valenced because dyadic completion appears stronger for negatively valenced phenomena compared with positively valenced phenomena[8].

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[54–56] and practices[57,58] 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 versus discourage social cohesion. We encourage future research that 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[59,60], and studies have found that beliefs in moralizing gods and spirits correlate with both social complexity and prosociality[54,61]. 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.

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.

Methods

Sampling process

We developed our codes using ethnographic data retrieved from the electronic Human Relations Area Files (eHRAF)[35,62]. 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 Fig. 1 for the distribution of our sample)[63]. 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 the '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 'the Burmese', 'Fellahin' and 'Turks' can show high levels of non-indigenous religious ideas. For example, Scott[64] 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 Fig. 1 for the full distribution of complexity). However, we excluded seven socially complex societies with high levels of borrowing in our main text analyses because of 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 was harmful, which allowed us to avoid confounding natural versus social phenomena with negative versus positive phenomena. This is important because negative phenomena were more likely to be explained with supernatural principles than positive phenomena in previous psychological studies[8]. 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 that 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 versus not reported[65]. 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 coded supernatural explanations as absent only 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 in which 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 (Results) in which we used exogenous data on frequency of occurrence to test whether ethnographies with frequent mentions of warfare, natural hazards and so on, 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 intercoder reliability and confirming that each society had a sufficient volume and quality of source material (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. Figure 2 displays a word cloud with the most common words contained in these direct source material quotes (which includes both supernatural and non-supernatural explanations). We write more about the text analysis procedures that generated this word cloud in our Supplementary Results.

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: (1) read through the complete ethnographic material for all societies, (2) added any paragraphs that they felt we had neglected in our original survey, and (3) 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' that 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.

Of the 678 total phenomena across the 114 societies, 600 had sufficient data for us to develop codes. Of these 600 phenomena, 468 were 'common'. Because 'uncommon' explanations were rare, and typically held by a single person in a society or were tied to a single instance (for example, 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) versus 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 metadata on geographical (continent, latitude, longitude) and linguistic (language, language family) characteristics from D-Place[66]. Second, we collected data on the frequency of features in our supernatural explanations coding manual. We measured pathogen prevalence using an index developed by Low[67] 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 and Ember[68], who measured the frequency of natural disasters such as floods, storms and droughts. We measured natural causes of scarcity using Jackson et al.'s[69] food scarcity composite measure adapted from Dirks[70] and Ember and Ember[68]. We measured prevalence of warfare between polities (independent political groups), and within polities using data from Ross[71] 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. Ross[71] 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 because they could refer to many social conflicts.

We measured social complexity by using the 10-indicator social complexity index developed by Murdock and Provost[72] (writing and records, fixity of residence, agriculture, urbanization, technological specialization, land transport, money, density of population, political integration, social stratification), and also included Murdock and White's[63] 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 et al.[69] 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'; and 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); and 4, 'Intensive Agriculture' (original code 5). The resulting social complexity scale was highly reliable ($alpha = 0.92$).

Phylogenetic structure

To test for the effects of common ancestry on our inferences, we paired societies with languages on a global language phylogeny. Language-based phylogenies can provide a general proxy for common cultural ancestry[73] and have previously been used to test evolutionary hypotheses about religion and society[74,75]. Our primary phylogeny (Fig. 3) was developed by the Automated Similarity Judgment Program, which collected vocabulary lists from world languages and dialects[45]. Because the authors relied on automated similarity judgements of vocabulary items rather than expert cognate judgements, they were able to build a vastly more comprehensive tree that spans multiple language families. This made the phylogeny useful for analysing 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 languages[76]. The approach to tree construction and the results of these analyses are provided in the Supplementary Methods (Supplementary Table 7). We note that the results of these additional phylogenetic analyses are highly consistent with those presented here (Supplementary Tables 4–6).

Before testing our hypotheses, we evaluated phylogenetic patterning of supernatural explanations. Using the Fritz and Purvis D statistic to estimate phylogenetic patterning of a binary trait[77], 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 ($D = 1.58$, $P = 0.77$), natural hazards ($D = 0.18$, $P = 0.12$), warfare ($D = 0.83$, $P = 0.32$), murder ($D = 1.04$, $P = 0.52$) or theft ($D = 0.29$, $P = 0.07$). We found significant patterning for explanations of disease ($D = -2.19$, $P = 0.008$), 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 research[78].

Despite the lack of significant evidence for phylogenetic patterning, we used phylogenetically nested regressions as a safeguard. The modelling 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 and 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 Discrete[79]. 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 (Supplementary Fig. 2).

Reporting summary

Further information on research design is available in the Nature Portfolio Reporting Summary linked to this article.

Data availability

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

All code is available from https://osf.io/jsk4t/. All analyses were performed in R studio v.1.1.383 with the following packages: dplyr, ggplot2, ape, caper, phytools, MASS, phylolm, reshape2, rstudioapi and interactions.

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Author contributions

J.C.J., B.B. and K.G. conceptualized the study. J.C.J., D.D., W.B. and N.D. conducted the research. J.C.J., D.D. and J.W. analysed the data. J.C.J. and D.D. wrote the paper. All authors contributed to revising the paper.

Competing interests

The authors declare no competing interests.

Additional information

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Correspondence and requests for materials should be addressed to Joshua Conrad Jackson or Danica Dillion.

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Corresponding author(s): Joshua Conrad Jackson
Danica Wilbanks

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Software and code

Policy information about availability of computer code

Data collection	No special software or code was used in data extraction in this study
Data analysis	All analyses were performed in R studio version 1.1.383 with the following packages: dplyr, ggplot2, ape, caper, phytools, MASS, phylolm, reshape2, rstudioapi, interactions

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- A list of figures that have associated raw data
- A description of any restrictions on data availability

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/.

Field-specific reporting

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Behavioural & social sciences study design

All studies must disclose on these points even when the disclosure is negative.

Study description

Analysis of the content of supernatural explanations in societies from across the globe. This is a mixed methods study. We developed quantitative variables using coding procedures designed for ethnographic qualitative text.

Research sample

We developed our codes using ethnographic data from the electronic Human Relations Area Files (eHRAF). We retrieved ethnographic data 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. Since our analysis focuses on ethnographic text focusing on societies, we do not have demographic information about our subjects.

Sampling strategy

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.

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's 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. There are no procedures in this area of research for determining what a sufficiently large sample is, but our sample contains a mix of societies from all world regions and language families.

Data collection

We collected our ethnographic materials from a large anthropological database known as eHRAF World Cultures. 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. Figure 5 displays a word cloud with the most common words contained in these direct source material quotes (which includes both supernatural and non-supernatural explanations). We write more about the text analysis procedures that generated this word cloud in our supplementary results.

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.

Timing	Start date: August 2018. End Date: August 2022
Data exclusions	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.
Non-participation	NA - not human subject research
Randomization	NA - not human subject research, and there was no experimental design which could accommodate randomization.

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

Materials & experimental systems

n/a	Involved in the study	
☒	☐	Antibodies
☒	☐	Eukaryotic cell lines
☒	☐	Palaeontology
☒	☐	Animals and other organisms
☒	☐	Human research participants
☒	☐	Clinical data

Methods

n/a	Involved in the study	
☒	☐	ChIP-seq
☒	☐	Flow cytometry
☒	☐	MRI-based neuroimaging