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Mysterious illnesses have supernatural and ritualistic cures: Evidence from 3,655 century-old Irish folk cures.

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Abstract

Why and when do people draw upon religious and supernatural solutions to problems? Cognitive scientists and anthropologists have proposed a range of answers, stressing religion and ritual's capacity to alleviate anxiety, create a sense of order, or explain otherwise inexplicable events. Here we leverage a unique dataset of 3,655 folk cures for 35 diseases, collected in 1937/8 from a mostly rural Irish sample born roughly between 1850 and 1925. Since the diseases vary in theory-relevant ways and the cures vary in the degree to which they include religious and supernatural elements, this dataset facilitates a unique test of these predictions in a pre-modern western population. In pre-registered tests, we find that disease judged by two doctors to have causes and mechanisms that would be unclear to the patients were more likely to have supernatural/religious treatments. The severity of the disease, and the anxiety it provoked, the disability it likely caused were unrelated to religious and supernatural cures, contra common predictions.

Significance Statement

Classical anthropological and cognitive theories propose that supernatural healing practices emerge when ordinary causal reasoning fails, yet direct quantitative tests remain scarce. Using 3,655 "local cures", collected as part of a national project to document folklore in Ireland in 1937–38, we quantitatively test a range of theories about the appeal of supernatural cures. Pre-registered mixed-effects models reveal that diseases whose causes or bodily mechanisms would have eluded lay observers were around 50% more likely to attract religious or magical treatments, whereas disease severity, pain, anxiety, and need for care showed no reliable

relationship with supernatural or religious cure content. These findings suggest epistemic uncertainty may be a key driver of supernatural thinking about health.

Main Text

Introduction

The causes and treatments of illness have been regularly linked to supernatural and religious beliefs across human cultures and throughout time (1). Illnesses everywhere are thought to be plausibly caused by spirits, the evil eye, and breaking social taboos, and believed to be treatable with prayers, amulets, rituals, and shamanic healing. These supernatural beliefs exist alongside more naturalistic frameworks emphasising, for example, contamination, herbal remedies, as well as more biomedically informed concepts (2). Within any given cultural group, there is typically substantial cross-disease variability in the extent to which people's explanatory models and responses draw upon supernatural versus naturalistic worldviews. Epilepsy, for example, is very often seen in supernatural terms (3) whereas cuts and stings more rarely acquire supernatural explanations. This variation provides a useful opportunity to test the explanatory power of theories about the function and role of supernatural and religious beliefs since different theories make distinct predictions about which kinds of contexts - and hence which diseases - are most likely to elicit supernatural responses. Careful comparison of supernatural and naturalistic responses to a range of different diseases may help researchers understand the role of religion in this important area– they reveal how people think and make decisions about illness, as well as shedding light on when we are prone to use supernatural and religious explanations more generally.

Why might people draw upon supernatural or religious concepts, rather than naturalistic ones, when attempting to explain and remedy ill health? Theories within the

cognitive, anthropological, and evolutionary literatures can be used to derive several testable hypotheses, premised on the concept that treatments will spread more readily if they satisfy some psychological or social need. In brief, this literature suggests that 1) diseases with no obvious cause or mechanism (i.e., higher causal opacity or uncertainty) should be more likely to be treated with supernatural or religious cures 2) diseases that are more severe – i.e., that have a higher case fatality rate – should be more likely to elicit religious treatments, 3) diseases that provoke anxiety should be more likely to elicit ritualistic treatments and 4) diseases that incapacitate the patient and, therefore, increase the need for care and support, should elicit more religious treatments. Though we acknowledge these factors are interconnected (e.g., uncertainty can increase anxiety, severity can increase uncertainty), we will discuss them separately to differentiate the theoretical basis of each.

Despite the prominence of these theories, little work has examined how different types of existential threats influence the expression of religious/spiritual belief and behaviour within a single domain such as illness, and even fewer have done so in a way that allows for comparison with the use of scientific/naturalistic explanations under similar circumstances. By looking at factors like uncertainty, severity, anxiety, and need for support together, we can differentiate between them, to draw more precise conclusions about if, when, and why different meaning-making systems are engaged.

Natural, Supernatural, and Religious

To be able to accomplish this, we will need to be able to distinguish between natural, supernatural and religious treatments. 'Supernatural' can be defined as things beyond scientifically verifiable natural laws, but this definition does little to help understand how people for much of human history might have thought about this category. For the 1930s Irish who

generated our dataset, 'verifiable and natural' are more likely to consist of simple causal processes like physical touch or consuming a substance than scientific principles. Supernatural beliefs as 'beyond' natural consist of more complex causal processes, like actions at a distance, or the ideas of similarity in sympathetic magic. Though people do seem to be able to think about both these categories as distinct and sometimes co-occurring causes of illness (4, 5), it is not straightforward to specify the exact characteristics that consistently differentiated one from the other. The belief that a disease is caused by an invisible spirit is in many ways like the belief that disease is caused by invisible bacteria, and researchers have emphasised supernatural and natural thinking draws on some similar patterns of cognitive processing (6, 7). Identifying what counts as 'religious' is not straightforward either. For our purposes, we are interested in religious beliefs as they appear in folk treatments. Although religious institutions encompass more than the supernatural, religious folk beliefs can be regarded as a subset of supernatural beliefs. Here, we focus on practices such as the use of holy water or religious sites within folk treatments—these represent a specific subset of the complex causal processes we classify as supernatural.

We recognise that people using these cures might not sharply distinguish natural vs. supernatural. Nevertheless, this distinction is useful for testing theories of the origins of supernatural concepts outlined below and provides a basis for drawing a line to separate two categories that likely blur together somewhat in most people's minds.

Diseases with no obvious cause or mechanism

Malinowski (8) argued that supernatural reasoning is more readily applied where the causal processes that determine outcomes are not observable, comprehensible, or obviously modifiable. For instance, people understand perfectly well the labour and skill needed to build

canoes or maintain a productive garden and understand that magic and ritual cannot substitute these quite non-magical investments. But they also recognise that good harvests and successful fishing expeditions are also a function of other less tractable processes. Supernatural rituals are directed towards these latter unpredictable activities. For example, deep sea fishing is more imbued with magic and ritual than low-risk fishing within the lagoon (8). More relevant to our current project, Malinowski noted that diseases with obvious explanations – obvious within a given medical framework that it is – tended to elicit materialistic explanations (e.g., eating too much, working too hard) whereas diseases with less obvious explanations were attributed to witchcraft. A straightforward prediction from this perspective is that diseases which are less comprehensible will find more magical and religious cures. This effect has been suggested as part of the origin of shamanistic practices (9), and more recently, similar effects of uncertainty around the causes of illness have been found experimentally in Mauritius (10). When causes of mystery diseases were portrayed as unclear, participants saw supernatural causes as more likely and diseases with supernatural causes as requiring supernatural cures.

But why might people find supernatural cures more compelling when the aetiology (causes of an illness) and pathology (behaviour or symptoms of an illness) are unclear? Hong (11) and others (12) have argued that people find it psychologically difficult to accept ignorance and ineffectiveness when faced with opaque processes like, presumably, some illnesses. Working under assumptions of determinism (everything has a cause) and cosmological holism (all events are interconnected and these webs of connection span natural and supernatural domains), people seek ways of changing important outcomes despite the apparent intractability (13). Contrast tuberculosis (TB), with no obvious cause and unobservable disease processes, with a cut that has an obvious cause. A bandage or a salve does not seem like a plausible treatment

for TB but does for a cut. Opaque illnesses like TB present fewer options for obvious naturalistic cures. When causes and processes of a disease are unclear, we might expect a greater reliance on more general-purpose supernatural cures. Cases where diseases are given both supernatural and natural causes show the same pattern (14). HIV can be believed to be caused by both a virus and witchcraft: the virus explains the disease process, while witchcraft explains why this particular person encountered the virus (see also 15). These are not competing explanations for the same level of causation. The natural cause accounts for the biomedical mechanism; the supernatural cause addresses the more opaque social or moral "why-me" question (10).

Religious cures may also help people recover from the destabilising effects of illness by providing them with a sense that these events, while disruptive, are under some form of external control and influence (12). The sense that one's illness is incoherent and unpredictable is associated with a reduced ability to cope and plan, as well as poorer survival, over and above the direct effects of the pathology (16). Cures framed in a religious/supernatural way may be particularly good in helping people gain a sense of control over their circumstances.

If these theories accurately characterise people's responses to illness, then we should see greater use of supernatural worldviews in response to illnesses with uncertain causes or which involve unfamiliar combinations of symptoms, relative to illnesses that are more coherent and predictable.

Severity

Religious and supernatural cures might be particularly important for severe illnesses as these illnesses may provoke existential concerns. According to some scholars, the religious and spiritual ideas have the capacity to alleviate mortality anxiety and other types of existential concerns (17, 18).

Religious and supernatural beliefs that suppose an afterlife or non-material spiritual world are argued to give solace to people whose material existence is threatened by illness and the reminders of death (18, 19), and can offer comfort in times of upheaval and misfortune (20). Indeed, some studies have found that reminding people of their own mortality led to stronger religious beliefs and a stronger belief in divine intervention (21). More ecologically valid studies have found increases in religiosity among terminally ill people (22) and people who experienced hardship due to a natural disaster (20). However, other studies have seen little effect (10, 23) and so there is a clear need for additional tests of the explanatory power of these theories.

Ritual and Anxiety

Anxiety has clear adaptive benefits in situations of potential danger when one's actions can have an immediate impact on the anxiety-causing stimuli such as fighting or fleeing a predator (24). When this is not the case, anxiety can become chronic and damaging. Repetitive and ritualistic behaviours may provide relief from such maladaptive anxiety. Why? At a cognitive level, ritual actions are argued to provide a period of high-prediction accuracy, enabling the person to recover a sense of control (25) and thus improving performance, decision making, and wellbeing (26). The capacity of ritualised behaviour to provide relief from anxiety may have deep evolutionary roots (27) with non-human animals also displaying repetitive ritualistic-like behaviours such as pacing in conditions of chronic anxiety (28).

In humans, the stress that comes from the ability to ruminate on existential questions provides additional scope for chronic anxiety, especially during periods of illness. According to theories of ritual, anxiety-provoking illnesses should therefore have more ritualistic components in their treatments (e.g., performing a set of steps several times unnecessarily) than more benign illnesses. Anxiety is likely one of the underlying mechanisms of the effects of severity and

uncertainty and can be present even in illnesses for which we see a tractable cause. Thus, the use of ritual should be prevalent across both supernatural/religious and naturalistic treatments.

Religious care

Some evolutionary theories suggest that religion has the adaptive benefits of helping humans cooperate in demanding situations (29, 30), solidifying social bonds, and redistributing material resources in the face of adversity (31, 32). Believers of some gods consider that gods reward people who carry out acts of charity and care for the sick. Theorists like Stark (1996) have argued that part of what made early Christianity spread was the mandate to look after the sick and needy. The higher survival rate of Christians during plagues, and general tendency to do better through their cooperative efforts, was noticed by others, seen as evidence of the power of their God, and caused more people to convert. Illness and injury can cause long periods of incapacity where the victim is unusually vulnerable and dependent on care from kith and kin. For example, Sugiyama (34) found that 90% of Shiwiar forager-horticulturalists spent a month or more incapacitated by illness or injury in their lives; without extensive social support, such a period of incapacity will be fatal. Rather than the treatments themselves helping people who are ill, the adaptive benefit may lie in their ability to encourage social support. They do so by signalling that the sufferer as a good cooperative partner and worthy of care by others in the community (35) to increase one's chance of surviving an illness (e.g., 36). The onset of illness may thus be a prudential moment to demonstrate a commitment to the relevant religious community via engaging in a faith-based treatment (36, 37). From this *material benefits* theory, we can suggest that religious treatments (as a subset of the broader category of supernatural treatments) will be more common when illness requires more care.

The Schools' Collection from the Irish National Folklore Collection

We examine supernatural/religious and naturalistic content in a large database of folk medical cures for a broad range of diseases collected in the 1930's in Ireland, when supernatural and natural folk cures were in wide usage (38). This newly digitalised dataset includes over 740,000 pages of folklore, including folk cures collected across the Irish Free State, soon after its formation. The cures were collected as part of a broader folklore project involving 50,000 children and 5,000 schools (39). The children interviewed parents, grandparents, and elders on local history, traditions, farming practices, as well as folk medical practices. Their records were transcribed and collected under the supervision of teachers to create a unique dataset which may illuminate, amongst other things, medical and religious culture in a sample of people born between 1850 (the likely birth year of the oldest informants) and 1925 (the data-collecting children).

The cures include a range of naturalistic cures (e.g., to cure a nosebleed, draw blood from the face by applying a cold object to the back of the neck), religious cures (e.g., holy water is poured into an aching ear while saying a prayer), and other supernatural cures (e.g., put a worm in a bottle and bury it where it cannot be found to cure a toothache). Since the diseases that these cure treat vary along theoretically relevant dimensions like seriousness and causal opacity, they provide a unique testing ground for theories which predict when religious and supernatural cures will dominate over more naturalistic treatments.

One might expect naturalistic treatments to outcompete supernatural and religious cures because they are more effective at alleviating symptoms or shortening illness. However, cross-culturally and historically, folk cures often rely on intuitive but implausible biological processes and, with some exceptions, are unlikely to benefit people directly (40, 41). A cursory

examination of the treatments in the corpus suggests that the vast majority have no direct beneficial effects.

Hypotheses

Based on the theories outlined above, we have formulated the following hypotheses. We were largely agnostic on which of these hypotheses would be supported but used them to structure our search for patterns in the uses of supernatural and naturalistic cures.

- **H1:** Illnesses with unclear causes and unclear underlying pathology will be more commonly treated with supernatural treatments (including religious treatments).
- **H2:** Severe illnesses will be more commonly treated with supernatural treatments (including religious treatments) than with naturalistic treatments.
- **H3**: Ritualistic treatments (both scientific/natural and religious/supernatural) will be more common when illnesses provoke high anxiety.
- **H4**: Explicitly religious treatments (as opposed to other types of supernatural content) will be more common when illness results in a need for care.

In addition to these preregistered hypotheses (https://osf.io/ed8v9), we performed some exploratory analyses. All confirmatory and exploratory tests are clearly labelled below. The dataset and the analysis code are also available on figshare (https://figshare.com/s/77c9c858581e5014feed).

Results

Descriptive Statistics

The most frequent diseases in the dataset were warts (N=576), followed by whooping cough (N=365), toothache (N=225), and burns (N=190). The diseases with the greatest proportion of supernatural non-religious treatment were whooping cough (72%), mumps (66%), and warts (53%). Religious treatments were represented in a greater proportion in treatments for sties (40%), erysipelas (28%), and rickets (25%). Corns (100%), cuts and wounds (95%), and

earache (94%) were treated with naturalistic treatments more than other diseases. Mumps (74%), sties (63%) and rickets (48%) were most often ritualistic while cuts and wounds (100%), broken bones (98%), and bleeding (97%) were most often not ritualistic. The tables in part 1 of the supplementary materials show the descriptive statistics for the predictor and outcome variables for each disease, respectively.

Uncertainty about the causes and mechanisms of illness

We predicted (H1) that treatments would be more likely to have supernatural and religious content if the illnesses had no clearly identifiable cause or mechanism. To test this, we used two proxies for uncertainty based on the ratings provided by two medical doctors: uncertainty about the cause and uncertainty about the mechanism. According to our medical experts, the antecedent causes of illnesses like rheumatism (rating = 9), rickets (rating = 9), and cancer (rating = 8.5) would be unclear to people without a medical education. In contrast, sprains, stings, and burns (all ratings = 1) have obvious causes and there is little uncertainty about the chain of events that led to the pathology. Uncertainty about the *biological mechanisms* underlying the pathology was judged to be high in, for example, rheumatism, rickets, and hiccups (all ratings = 9) whereas burns, broken bones, and thorns are diseases in which mechanisms are more obvious (all ratings = 2-2.5).

Mixed effects logistic regression models show that both proxies for uncertainty about the disease predict a higher proportion of religious/supernatural treatments in the diseases (Figure 1). In the exploratory split of dataset, both uncertainty about the mechanism underlying the illness (OR = 1.76, 89% CI[1.23, 2.52]) and the cause of the illness (OR = 1.63, 89% CI[1.17, 2.33]) predicted more religious/supernatural treatments. In the confirmatory spilt of the dataset, the effect sizes were similar for uncertainty about the mechanism (OR=1.66, 89% CI

[1.10, 2.50]) and cause uncertainty (OR = 1.45, 89% CI[0.96, 2.18]), though the confidence interval crosses 1 for cause uncertainty.

In the full dataset, which enables the most precise estimate of effect size, uncertainty about the mechanisms underlying the illness (OR = 1.74, 89% CI[1.22, 2.50]) and the cause of the illness (OR = 1.56, 89% CI[1.09, 2.24]) predicted more religious/supernatural treatments. We can interpret this to mean that 1-standard deviation increase in the uncertainty about the mechanism or the cause leads to a 74% and 56% increase respectively in the odds that a supernatural or religious element will be present in the treatment. Note that the full regression tables for these analyses are available in part 2 of the supplementary materials.

In the logistic regressions above, religious and supernatural treatments are combined and contrasted with naturalistic treatments. In an exploratory mixed effects multinomial logistic regression model, we investigated if religious and supernatural treatments might have distinct relationships with uncertainty. As the centre two panels in figure 1 show, we observed a consistent relationship only between uncertainty about the mechanism and supernatural content. The other results directionally suggest that both types of uncertainty may influence both religious and supernatural content, but the findings were not clear.

Although we had no theory-driven prediction, diseases with uncertain causes (OR = 1.60, 89% CI [1.23, 2.09] in the full dataset) and mechanisms (OR = 1.82, 89% CI [1.39, 2.38]) were more likely to have ritualistic treatments, see right panel in Figure 1.

Since religious/supernatural cures tend to be ritualistic (as confirmed in our data: OR = 2.77, 89% CI [2.28, 3.37]), we wondered if ritualistic content could explain the uncertainty-religious/supernatural relationship shown in Figure 1. To check this, we reran the mixed effect

logistic regression model predicting religious/supernatural vs naturalistic treatment adding ritualistic (vs non-ritualistic) treatment to the uncertainty predictors with the full dataset. This association between uncertainty about the mechanism and religious/supernatural treatment remained when adding ritualistic vs non-ritualistic treatment to the model (OR = 1.64, 89% CI [1.16, 2.30]), though the association was stronger for the ritualistic predictor (OR = 2.76, 89% CI [2.27, 3.35]) than for the uncertainty about the mechanism. Similarly, the association between uncertainty about the cause and religious/supernatural content remained of a similar magnitude when adding ritualistic treatment to the model (OR = 1.49, 89% CI [1.05, 2.09]). The association was again stronger for the ritualistic predictor (OR = 2.76, 89% CI [2.27, 3.36]).

Severity of the illness

To test H2, which predicted that severe illnesses are more commonly treated with supernatural/religious treatments than with naturalistic treatments, we used five proxies for severity: the proportion of patients expected to die of the disease in 1930s Ireland, the expected level of sickness of the typical patient seeking medical help, the proportion of patients who are very sick, the level of pain of the typical patient seeking medical help, the proportion of patients with severe pain. Diseases rated as severe on most of these metrics included tuberculosis, broken bones, cancer, and whooping cough whereas hiccups, ringworm, and warts were rated as more benign.

Mixed effects logistic regression models showed no robust relationships between the five proxies of severity and the content of the treatments: for brevity, we report the findings from the full dataset only. One proxy for severity was associated with somewhat higher religious/supernatural content: the sickness of the typical patient (OR = 1.29, 89% CI[0.86,

1.92]). The other four proxies for severity showed no positive or negative effects on supernatural/religious content. These included the proportion of patients expected to die of disease (OR = 1.04, 89% CI[0.79, 1.36]), the proportion of patients with severe pain (OR = 0.82, 89% CI[0.57, 1.19]), the pain of the typical patient (OR = 0.76, 89% CI[0.51, 1.13]) and the proportion of patients who are very sick (OR = 1.09, 89% CI[0.72, 1.63]), see Figure 2 left panel. Therefore, we did not find support for the prediction (H2) that severity would be more commonly associated with religious/supernatural treatments than naturalistic treatments.

In an exploratory analysis, we also examined if more severe diseases had more ritualistic content. Ritualistic treatments were no more common in diseases high in the various measures of severity, with the exception of pain, which predicted lower levels of ritual content. See Figure 2 top right panel.

Anxiety-inducing Diseases

To test H3, which predicted that ritualistic treatments (both scientific/natural and religious/supernatural) are more common when illnesses provoke high anxiety, we also asked the medical experts to estimate the typical anxiety levels of patients seeking care for this illness as well as the proportion of patients experiencing high anxiety.

The results show that the anxiety of the typical patient and the proportion of patients with high anxiety were unreliable predictors of ritualistic treatment in the exploratory, confirmatory, and full datasets. In the full dataset, the OR for the anxiety of the typical patient was 1.02 (89% CI[0.72, 1.43]), and the OR for the proportion of patients with high anxiety was 0.97 (89% CI[0.70, 1.34], Figure 2 bottom right). The prediction that (H3) anxiety-inducing

diseases would be more commonly associated with ritualistic than non-ritualistic treatments, was not supported.

A reviewer usefully suggested an alternative way to conceptualise anxiety: it stems from the perception that one's situation is both highly uncertain and highly consequential. While our measure of anxiety – asking doctors to estimate the anxiety levels of patients with illnesses – presumably captures this emotional state, a more direct approach may be to look at the interaction of uncertainty and severity. As a test case, we regressed uncertainty about the cause and sickness of the typical patient on the probability that a cure had supernatural content. We chose these measures of uncertainty and severity since they had stronger relationships with supernatural content in the aforementioned analyses. The interaction of cause uncertainty and sickness level did not predict more supernatural treatment (OR = 0.80, 89% CI[0.54, 1.18]) and neither did the interaction of other measures of uncertainty and severity.

Diseases Elicit Need for Care

We included measures of disability and need for care to test (H4) the *material benefits theory* described above, which predicted that explicitly religious treatments (as opposed to other types of supernatural content) will be more common than naturalistic treatments when illness results in a need for care. However, neither the disability of the typical patient nor the proportion of patients with severe disability had a robust relationship with religious treatment, with confidence intervals including 1 in call cases. In the full dataset the OR estimate for religious treatment versus naturalistic treatment was 0.26 (89% CI[0.05, 1.33]) for the disability of the typical patient and 0.82 (89% CI[0.62, 1.10]) for the proportion of patients with severe disability.

Discussion

Cognitive scientists and anthropologists have developed a range of theories about when and why people draw upon religious and supernatural solutions to problems: they bring predictability to uncertain situations, reduce anxiety, and encourage community support and cooperation. By testing this in a corpus of early 20th century Irish folk medicine we found that illnesses with unclear causes or biological mechanisms were more commonly treated with supernatural/religious and ritualistic treatments than disease with more obvious causes or pathologies. This finding is congruent with classical anthropological work from Malinowski and others pointing out the particular importance of supernatural intervention in situations of uncertainty.

Jackson et al. (42) recently found that people across time and societies were more inclined to use supernatural concepts to explain natural events like disease and famine than human-caused events like murder and theft. Illness was the domain most often explained in supernatural terms. Their argument – that the inexplicability of the phenomena is a key determinant of supernatural concepts – is well supported by our more focused exploration of the disease domain. The supernatural cues in our dataset did not appear tightly linked to supernatural entities that had caused the illness. Rather, it seemed that people were seeking practical solutions to problems and when the disease had no intuitive cure, people fell back upon more supernatural concepts.

Why should uncertainty about the mechanisms or causes elicit more supernatural content? It seems likely that people want to do *something* in the event of illness: accepting that a process is governed by unobservable and unmodifiable processes may be psychologically

372 unsatisfying, and in some circumstances, maladaptive. In biomedical contexts, people appear to
373 prefer aversive interventions like surgery over doing nothing (usually termed “watchful
374 waiting”), even when surgical outcomes are poorer (43). But when the causes and mechanisms
375 of a disease are a mystery, the illnesses present few affordances for action and folk models of
376 biology and healing fail to suggest plausible ways to intervene. Perhaps it is in these contexts
377 that people draw upon more supernatural treatments grounded in more diffuse and elastic
378 conceptual frameworks, such as sympathetic magic.

379 In our dataset, diseases with obvious causes and mechanisms like broken bones tended
380 to get natural treatments (though it should be noted that bone setting was probably one of the
381 few potentially effective treatments in our dataset). The mechanisms/causes of broken and
382 dislocated bones are obvious, and people who hunt or tend animals may well have encountered
383 additional examples of these pathologies. The solutions are intuitive: pull the limb along its axis
384 till the bone recovers its position for a dislocation and stabilise the bone so that it heals straight
385 for a fracture. In the dataset, specific local people with experience of these procedures were
386 mentioned, and unsurprisingly, there were few supernatural cures for broken bones.

387 Cuts, wounds and burns had similarly natural treatments, thought these were unlikely to
388 be effective: cobwebs for cuts and butter/vinegar/paraffin/lard/baking soda for burns. Sties and
389 oral thrush, on the other hand, were thought by the doctors to have causes and mechanisms
390 that would be opaque to the patient, and these tended to have supernatural cures like pointing
391 specific numbers of thorns at the stie or having a person born after the death of their father
392 breath down the thrush-afflicted mouth. If a lack of actionable intervention points is indeed
393 what drives individuals toward supernatural cures, this may clarify why uncertainty about

underlying mechanisms is a more reliable predictor of resorting to such remedies than mere ambiguity about what *caused* the disease.

Infectious diseases like mumps, whooping cough, erysipelas (a skin rash), scrofula (a neck swelling, often caused by TB) are more frequently associated with supernatural cures. This pattern could emerge because infectious agents—especially when poorly understood—offer limited points of direct intervention from a lay perspective. Historically, the invisible, dynamic, and often unpredictable nature of infectious agents confounded straightforward causal attributions and thwarted easy, mechanical remedies. Without a clear way to link what we do to preventing or treating these illnesses, ordinary explanations fail to offer practical steps for action. As a result, people may turn to broader, more flexible ideas—like supernatural forces or sympathetic magic—to explain and control diseases they cannot otherwise understand or manage.

Our study suggests a more robust relationship between uncertainty and supernatural treatments than between uncertainty and explicitly Christian treatments: It may be that the framing of the questions ("local cures") may have deterred people from including more orthodox religious solutions since, at the time, there was a tension between orthodox Catholicism and folk Christian/supernatural beliefs. Some, presumably common, religious responses to illness like praying for divine intercession, lighting a votive candle, consulting a priest, or requesting that a Mass be offered were notably absent from the corpus. For similar reasons, the question elicited relatively few orthodox medical solutions (e.g., 'seeing a pharmacist'). It is plausible that disease uncertainty and severity could have additional effects on people's willingness to draw upon orthodox medical or religious solutions that are not well represented in this dataset.

Uncertainty about the mechanism and the cause not only predicted supernatural treatments but also ritualistic treatments – or treatments with several repeated steps. A treatment for thrush, for example, was that “the father would put the bill of the gander in the child's mouth and then squeeze it so that the gander would breathe down the throat of the child. This should be done three mornings in succession.” Or for rickets: “they bathed the child in water taken from a south running stream and then put the child under an ass six times”. The most obvious explanation for this is that our operationalisation of ritual (having repeated steps) was more a proxy measure of supernaturalness.

In contrast, other characteristics of the illness such as their severity, anxiety, and need for support did not have a clear relationship with either supernatural/religious or ritualistic treatments, except their level of pain, which was more commonly treated with non-ritualistic treatments. Other previous research has found a relationship between repeated ritualised actions and anxiety reduction (25). Perhaps this suggests that the relationship does not extend to illness, or that we did not capture anxiety well in our measure. Either way, further research is needed here to draw strong conclusions. We are similarly cautious about overinterpreting the null effect for disease severity, though we have previously found similar null effects for this relationship in another study (10). It is quite possible that the data recording process – where children solicited cures from older members of their household – introduced biases that masked the effects of severity. Religious cures for TB or cancer might have seemed too heavy a topic for children, for some reason. As we note above, participants may not have considered orthodox religious responses when queried about “local cures”. It seems intuitive that people with a severe illness would be more willing to try a supernatural cure, but this may stem from a broader increase in the willingness to try anything (see 44) and this would not necessarily

increase the proportion of supernatural cures. This hypothesis is not easily testable in our dataset as many cures repeat or are likely to have a shared origin (for example, there are hundreds of cures for warts that involve snails).

The relationship between pain and a reduction in ritualised treatments was not predicted and we have no strong speculations about why this effect exists. We define treatments as ritualistic if they contained steps that were repeated several times over, which may just be difficult for people in pain, or perhaps people in pain would be more impatient with treatments that take time to implement.

Conclusion

This research can offer some insight into when we reach for supernatural beliefs and thus offer some insight into why we have these beliefs in the first place. We suggest that these beliefs may, in part, arise because of a need to make sense of otherwise confusing or uncertain processes. We focus on illness here, but this tendency may be broader than that and is worth further investigation. Here, we find that uncertainty surrounding an illness makes it more likely that people will reach for supernatural cures. Though we used historical data, these effects are potentially still relevant in how we think about disease today. Alternatives to evidence-based medicine, many of them supernatural in nature, are prevalent everywhere, including contemporary western culture. Uncertainty around an illness may increase the likelihood of people engaging in these types of treatments.

Materials and Methods

Data

464 The data for this study was based on the Schools Collection, described previous, hosted
465 by Dúchas.ie (https://www.duchas.ie/en/tpc). The Schools Collection corpus was chosen
466 because it offers unique insights into the distribution of supernatural, religious, and naturalistic
467 medical treatments in a religious, pre-industrialised population with relatively little access to
468 formal health care. At the time, child mortality was approximately 10% (45) and life expectancy
469 was 59-years (46). Ethical approval was not required for this study as the data are in the public
470 domain.

471 We initially included in the study the data from the treatments related to the
472 categorized diseases in the dataset, excluding the uncategorized data tagged with the 'folk
473 medicine' label. We included only transcribed cures recorded in English (i.e., excluding Irish
474 language entries) as the coding team did not have the linguistic proficiency in Irish. The
475 categorized diseases were backache, bleeding, boils, broken or dislocated bones, burns, cancer,
476 chilblains, colds, corns, cough, cuts and wounds, earache, erysipelas, fallen breastbone,
477 headache, hiccups, jaundice, measles, mumps, rheumatism, rickets, ringworm, sciatica, scrofula,
478 sore eyes, sore throat, sprains, sties, stings, thorns, thrush, toothache, tuberculosis, warts,
479 whitlow, whooping-cough. After web scraping the data, we found out that some of the
480 observations contained multiple cures. We manually separated these cures into different
481 observations. After this, the dataset contained a total of 3,452 cures for the abovementioned
482 diseases. However, some of the diseases contained very few cures (less than 50), which we
483 considered potentially problematic. Consequently, we decided to oversample for these diseases
484 until reaching 50 cures (or the maximum number of cures found on the dataset if this number
485 was below 50) from the uncategorized diseases tagged with the 'folk medicine' label. We
486 eliminated from the dataset fallen breastbone because of its difficulty finding additional cures

among the uncategorized treatments and its very low number of cures in the categorized dataset. After doing this, the final dataset contains 3,655 cures for 35 diseases. Seemingly distinct illness categories might, in some instances, reflect different names for the same underlying diseases. While the results below use the preregistered, dataset-derived categories, we reran all the analysis grouping the most similar clusters of illnesses: coughs, colds, and sore-throat were grouped into a respiratory tract infection category, and bleeding and cuts-and-wounds were grouped into a laceration category. The results, shown in part 3 of the supplementary materials, are very similar to what we report below.

Coding of Treatments

Supernatural and natural

The treatments were classified according to several characteristics. First, the treatments were classified into naturalistic or supernatural treatments. A treatment was considered supernatural if it contained elements that violate commonplace conceptions of causality. The supernatural cures included elements indicating sympathetic magic (i.e., similarity between the cure and the disease, for example, such as using a snail to cure warts); the disease being passed to an object, animal, or person, or acting at distance (e.g., passing warts to another person if they take a bag with stones); accidental events (e.g. finding a snail without looking for it); special categories of people (e.g. the seventh son cures a disease), places (e.g. a halter near the nearest south-running stream), actions (e.g. put a potato in your pocket), incantations (e.g. praying) or other religious elements. A cure was considered naturalistic if it involved none of these supernatural processes and if it included physical contact with the body via ingestion, application, inhalation, or similar. Naturalistic is distinct from *evidence-based* or *effective*: rather we coded these cures as naturalistic if there were plausible causal pathways whereby the

medical substance could feasibly contact the ailment. This dichotomous variable was the outcome variable to test the hypotheses that predicted that uncertainty and severity are more strongly associated with supernatural than with naturalistic treatments.

Religious and not religious

Treatments were classified into religious vs non-religious. Religious treatments included elements such as praying, blessing, crossing oneself, or other actions related to Christianity. This variable was later used in tandem with the supernatural vs naturalistic variable to classify the treatments into three categories: religious, supernatural non-religious, and naturalistic. We used this variable as the outcome variable to test the prediction that explicitly religious treatments (as opposed to other types of supernatural content) are more common when illness results in a need for care.

Ritualization

Treatments were coded for the presence or absence of ritualistic components. In our coding scheme, both naturalistic and supernatural treatments could include ritualistic components. The presence of repetitive elements (e.g., say three Hail Marys) was used as the proxy for presence of ritualistic component as ritualization is often defined as “the limitation of behavioural expressions to predictable stereotypic and repetitive motor patterns” (25). Initially, we coded the number of repetitions with 0 if there were no repetitions, a number if the specific number of repetitions was specified, and M if the number of repetitions was not specified. Because of the inconsistency with how repetition was recorded (i.e., many cures only specified that they action should be repeated until the cure worked), we transformed this variable into a dichotomous variable of “repetition” or “no repetition”. This transformed variable was used to

test the prediction that anxiety is more commonly associated to repetitive/ritualistic treatments than with non-ritualistic treatments.

Coding process

The classification of the treatments was done by two coders, authors AJ and NR. Initially, both coders coded 210 treatments (5.7%) together to come up with a consistent coding scheme. Then, the coders coded 337 treatments (9.2%) independently to check the consistency of the independent coding (intercoder reliability: Supernatural vs Naturalistic Cronbach's α = 0.98; Number of Repetitions Cronbach's α = 0.96; and Religious vs Non-religious Cronbach's α = 0.92). The coders independently coded the remaining treatments in the dataset. Following human coding, we developed large language model (LLM) prompts to categorise the cures again to ensure accuracy. Discrepancies between human and LLM codes were resolved by author MdB. Note that the LLM coding was not pre-registered as LMMs were not sufficiently advanced when we were developing the protocol. There were no substantive changes to the results as a result of adding this step. Additional details about the coding, including the LLM models and prompts used, are available in part 4 of the supplementary materials.

Coding of Diseases

Two medical doctors graded each of the diseases in the dataset. One was a general practitioner / family doctor with 18 years of post-qualification experience practicing medicine, largely in rural Irish surgeries. The other was a paediatric consultant with a similar duration of experience. The two doctors were first briefed on the broad goals of the project. The hypotheses were not described. They were then asked to answer the questions "assuming no treatment and public health standards of 1900 – 1930s Ireland" and were provided with information about infant mortality rates, public health infrastructure, and medical standards at

that time. The doctors were free to consult any resources they might find helpful. In answering questions about the illnesses, they were asked to imagine that the distribution of patients included quite minor as well as severe cases. The assessments of each disease by the doctors included 11 questions (see Table 1).

These questions were first answer by the doctors independently. The correlations coefficients are provided in Table 1. The doctors then met in person to examine each other's codes, explain their reasoning to one another and, if they wished, adjust their ratings. They were not encouraged to reach consensus, but to change rating if they found each other's arguments convincing. Discrepancies in the initial coding for some items stemmed from factors like unfamiliarity with the disease among one of the doctors or differing professional experience (as a consultant pediatrician, one doctor tended to see more severe cases). Following discussion, agreement was substantially higher; see table 1. We then averaged the estimates from the two doctors. Note that two questions about anxiety levels were introduced after the doctor's initial independent coding and was coded just once by each doctor during the consensus meeting. The pairwise correlations between the different disease questions are shown in part 5 of the supplementary materials.

Table 1

Rating of diseases by two medical doctors.

Question asked about each of 35 diseases	Inter-doctor Correlations	
	Pre-discussion	Post-discussion

Proportion of patients who die of disease assuming no treatment.	0.63***	0.98***
Sickness of typical patient seeking help (9-point Likert scale from 1 [no sickness] to 9 [close to death].)	0.50**	0.85***
Proportion of patients who are very sick (i.e., a rating of 7 or above on the scale for the previous question).	0.72***	0.80***
Typical Disability of patient seeking for help (9-point Likert scale from 1 [no reduction in capacities or assistance needed] to 9 [unable to perform basic functions, totally dependent on others]).	0.55***	0.81***
Proportion of patients with severe disability (i.e., 7 or above on the previous questions) for one month or more.	0.60***	0.75***
Pain of typical patient seeking for help (9-point Likert scale from 1 [no pain at all] to 9 [the worst pain possible]).	0.52**	0.86***
Proportion of patients with severe pain (i.e., 7 or above in the previous question on the day they seek help).	0.42*	0.68***
Uncertainty about the cause of the disease (9-point Likert scale from 1 [Likely to be very uncertain about the antecedent cause of the disease] to 9 [Likely to be very certain about the antecedent cause of the disease]).	0.65***	0.93***
Uncertainty about the mechanism of the disease (9-point Likert scale from 1 [Likely to be very uncertain about the biological problem causing their symptoms] to 9 [Likely to be very certain about the biological problem causing their symptoms]).	0.11	0.96***
Anxiety of typical patient seeking for help (9-point Likert scale from 1 [not anxious/distressed at all] to 9 [extremely anxious/distressed]).		0.88***
Proportion of patients with high anxiety (i.e., level 7 or above on the previous anxiety scale)		0.89***

Table 1. Correlation between the ratings of different characteristics of the disease given by two medical doctors. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Data Analysis

Statistical analyses were preregistered in two parts. In the first part of the preregistration (https://osf.io/ed8v9), we outlined the exploratory analyses, produced with 50%

of the dataset, on the relationship between disease characteristics and cure characteristics. The models derived from these exploratory analyses (including the R script) were preregistered in the second part of the preregistration (https://osf.io/rup2d) to be used as confirmatory analyses of the results with the second 50% of the dataset. As stated in the second part of the preregistration, we have also tested the hypotheses with the same models produced with 100% of the dataset to attain more reliable estimates of the effects.

All the statistical analyses were conducted with R 4.1.0. To control for the effects of the shared variation within diseases and schools, we used mixed effects regression modelling with disease and school as separate random effects. The outcome variables for testing if causal opacity or severity produced more supernatural treatments (hypothesis 1 and 2; supernatural vs naturalistic treatment) and ritualisation through repetition reduced anxiety (hypothesis 3; with repetition vs no repetition) were dichotomous. Therefore, we ran mixed effects logistic regression models with the *lme4* package (47) to test these hypotheses. The outcome to test if religious treatments were more common in diseases needing care (hypothesis 4) were three categories (religious, supernatural non-religious, or naturalistic treatment). Therefore, we ran mixed effects multinomial regression models with the *mclogit* package (48) to test this hypothesis.

Because we used proxies of the variables of interest in two different scales (i.e., proportion and Likert scale from 1 to 9), all the coefficients reported here are standardized. We used 89% confidence intervals (see McElreath, 2018) throughout as having only 35 diseases in our predictor variables restricted the variance in which our effects could be detected.

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Figure Legends

Figure 1. Supernatural / religious cures for uncertain illnesses. Left panel shows coefficient plot with standardized coefficients from a mixed effect logistic regression. This preregistered analysis supports the hypothesis that diseases that provoke uncertainty would have more religious and supernatural treatments. The centre two panels examine the effects of uncertainty on supernatural and religious separately using mixed effect multinomial logistic regression. The right panel shows the relationship between uncertainty and ritual: this relationship was not predicted. All coefficients are standardised, and models have only one fixed effect. The random effects are disease and school.

Figure 2. Cures for painful and severe illnesses. Left panel suggests that severe diseases are not treated with more supernatural/religious treatments. Top right panel suggests that painful diseases are less likely to be treated with ritualistic treatments; this was not a predicted association. The bottom right panel indicates no relationship between anxiety and ritualistic treatment. These standardized coefficients are derived from mixed effect logistic regression models with one fixed effect and two random effects, disease and school.

Table 1. *Correlation between the ratings of different characteristics of the disease given by two medical doctors.*

Question asked about each of 35 diseases	Inter-doctor Correlations	
	Pre-discussion	Post-discussion
Proportion of patients who die of disease assuming no treatment.	0.63***	0.98***
Sickness of typical patient seeking for help (9-point Likert scale from 1 [no sickness] to 9 [close to death].)	0.50**	0.85***
Proportion of patients who are very sick (i.e., a rating of 7 or above on the scale for the previous question).	0.72***	0.80***
Typical Disability of patient seeking for help (9-point Likert scale from 1 [no reduction in capacities or assistance needed] to 9 [unable to perform basic functions, totally dependent on others]).	0.55***	0.81***
Proportion of patients with severe disability (i.e., 7 or above on the previous questions) for one month or more.	0.60***	0.75***
Pain of typical patient seeking for help (9-point Likert scale from 1 [no pain at all] to 9 [the worst pain possible]).	0.52**	0.86***
Proportion of patients with severe pain (i.e., 7 or above in the previous question on the day they seek help).	0.42*	0.68***
Uncertainty about the cause of the disease (9-point Likert scale from 1 [Likely to be very uncertain about the antecedent cause of the disease] to 9 [Likely to be very certain about the antecedent cause of the disease]).	0.65***	0.93***
Uncertainty about the mechanism of the disease (9-point Likert scale from 1 [Likely to be very uncertain about the biological problem causing their symptoms] to 9 [Likely to be very certain about the biological problem causing their symptoms]).	0.11	0.96***
Anxiety of typical patient seeking for help (9-point Likert scale from 1 [not anxious/distressed at all] to 9 [extremely anxious/distressed]).		0.88***
Proportion of patients with high anxiety (i.e., level 7 or above on the previous anxiety scale)		0.89***

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

PNAS

Supporting Information for

Mysterious illnesses have supernatural and ritualistic cures: Evidence from 3,655 century-old Irish folk cures.

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This PDF file includes:

Part 1: Disease level descriptive statistics

Table S1. Number and proportion of cures that are naturalistic, religious, supernatural, ritualistic, supernatural but not religious.

disease	N	Naturalistic	Supernatural or religious	Supernatural not religious	Religious	Ritualistic
backache	48	30 (62%)	18 (38%)	11 (23%)	7 (15%)	6 (12%)
bleeding	87	60 (69%)	27 (31%)	7 (8%)	20 (23%)	3 (3%)
boils	84	78 (93%)	6 (7%)	5 (6%)	1 (1%)	5 (6%)
broken bones	46	40 (87%)	6 (13%)	5 (11%)	1 (2%)	1 (2%)
burns	190	147 (77%)	43 (23%)	34 (18%)	9 (5%)	24 (13%)
cancer	50	38 (76%)	12 (24%)	9 (18%)	3 (6%)	3 (6%)
chilblains	96	91 (95%)	5 (5%)	4 (4%)	1 (1%)	9 (9%)
colds	76	68 (89%)	8 (11%)	5 (7%)	3 (4%)	13 (17%)
corns	50	50 (100%)	0 (0%)	0 (0%)	0 (0%)	5 (10%)
cough	50	44 (88%)	6 (12%)	6 (12%)	0 (0%)	13 (26%)
cuts and wounds	82	78 (95%)	4 (5%)	2 (2%)	2 (2%)	0 (0%)
earache	50	47 (94%)	3 (6%)	0 (0%)	3 (6%)	3 (6%)
erysipelas	105	24 (23%)	81 (77%)	52 (50%)	29 (28%)	26 (25%)
headache	88	53 (60%)	35 (40%)	12 (14%)	23 (26%)	15 (17%)
hiccups	51	42 (82%)	9 (18%)	4 (8%)	5 (10%)	8 (16%)
jaundice	85	63 (74%)	22 (26%)	14 (16%)	8 (9%)	25 (29%)
measles	50	39 (78%)	11 (22%)	9 (18%)	2 (4%)	7 (14%)
mumps	80	7 (9%)	73 (91%)	53 (66%)	20 (25%)	59 (74%)
rheumatism	108	82 (76%)	26 (24%)	21 (19%)	5 (5%)	20 (19%)
rickets	48	7 (15%)	41 (85%)	29 (60%)	12 (25%)	23 (48%)

disease	N	Naturalistic	Supernatural or religious	Supernatural not religious	Religious	Ritualistic
ringworm	138	66 (48%)	72 (52%)	43 (31%)	29 (21%)	36 (26%)
sciatica	50	35 (70%)	15 (30%)	8 (16%)	7 (14%)	6 (12%)
scrofula	21	6 (29%)	15 (71%)	10 (48%)	5 (24%)	5 (24%)
sore eyes	127	71 (56%)	56 (44%)	22 (17%)	34 (27%)	21 (17%)
sore throat	120	96 (80%)	24 (20%)	16 (13%)	8 (7%)	6 (5%)
sprains	129	77 (60%)	52 (40%)	18 (14%)	34 (26%)	18 (14%)
sties	101	25 (25%)	75 (74%)	35 (35%)	40 (40%)	64 (63%)
stings	50	40 (80%)	10 (20%)	10 (20%)	0 (0%)	2 (4%)
thorns	49	39 (80%)	10 (20%)	4 (8%)	6 (12%)	2 (4%)
thrush	91	26 (29%)	65 (71%)	50 (55%)	15 (16%)	28 (31%)
toothache	225	116 (52%)	109 (48%)	48 (21%)	61 (27%)	19 (8%)
tuberculosis	48	40 (83%)	8 (17%)	8 (17%)	0 (0%)	4 (8%)
warts	576	179 (31%)	397 (69%)	305 (53%)	92 (16%)	135 (23%)
whitlow	50	41 (82%)	9 (18%)	4 (8%)	5 (10%)	7 (14%)
whooping	356	54 (15%)	300 (84%)	254 (71%)	46 (13%)	89 (25%)

Table S2. Classification of the diseases by two medical doctors

disease	Proportion of patients who die of disease	Sickness of Typical Patient	Proportion of patients who are very sick	Disability of typical patient	Proportion of patients with	Pain of typical patient	Proportion of patients with severe pain	Uncertainty about the cause	Uncertainty about the mechanism	Anxiety of typical patient	Proportion of patients with high anxiety
sties	0	1.5	0.01	1	0	1.5	0	7.5	8	4.5	0.1
warts	0	2	0.01	1	0	1.5	0.01	5.5	8.5	2	0.01
whitlow	0	1	0.06	1.5	0	3	0.08	7	8.5	4	0.08
ringworm	0	1	0.01	1	0.01	1	0.01	8.5	8.5	4	0.13
hiccups	0	1	0.01	1	0.01	1	0	6.5	9	1	0.01
stings	0.005	1.5	0.06	1	0.01	1.5	0.01	1	2.5	5	0.08
thrush	0.001	1.5	0.01	1.5	0.01	2	0.01	7.5	8	4.5	0.08
thorns	0.0005	1	0.06	1	0.02	2	0	1.5	2.5	2.5	0.05
toothache	0	2	0.03	2	0.02	4.5	0.18	7	8.5	5.5	0.23
corns	0	1	0.03	1.5	0.03	2	0.03	3	3.5	3.5	0.06
boils	0.005	1.5	0.03	2	0.03	2.5	0.08	8	9	3.5	0.1
colds	0.0015	3	0.13	2	0.03	1.5	0.03	7.5	8.5	3	0.14
chilblains	0.001	1	0.04	2	0.03	4	0.1	1.5	8.5	3	0.08
bleeding	0.0065	4.5	0.11	3	0.03	5	0.53	1.5	2	4.5	0.15
cutsandwounds	0.0125	2.5	0.08	3	0.03	4.5	0.2	1	2.5	4.5	0.15
earache	0.001	3	0.13	1.5	0.04	5.5	0.18	8	8	6	0.23
mumps	0.0075	5	0.25	5	0.05	3	0.1	4	8.5	4.5	0.15
whooping	0.0175	6.5	0.65	6	0.05	2.5	0.04	5.5	8.5	8	0.75
soreeyes	0	3	0.02	1.5	0.06	3	0.06	6.5	7	5.5	0.23
cough	0.0275	5	0.5	2	0.08	2.5	0.05	7	8.5	6.5	0.45
headache	0.0055	3	0.1	2.5	0.08	4	0.15	8	8	5	0.2

sprains	0	1.5	0	2.5	0.08	4.5	0.18	1	6	3	0.1
backache	0.001	4	0.04	3.5	0.08	4.5	0.23	5	8.5	5.5	0.2
measles	0.035	5.5	0.35	5	0.08	3.5	0.06	4	8	7.5	0.6
sorethroat	0.0025	3.5	0.45	3.5	0.1	4.5	0.18	6	9	4.5	0.15
erysipelas	0.15	4.5	0.4	3	0.15	4	0.15	8.5	8.5	7	0.6
rheumatism	0.0025	2.5	0.23	4	0.15	5.5	0.35	9	9	6.5	0.43
burns	0.0105	4.5	0.3	5	0.18	6.5	0.55	1	2	7.5	0.75
sciatica	0.0005	2.5	0.05	4	0.23	6	0.35	8	7.5	5	0.2
rickets	0.0225	3	0.15	4	0.48	2.5	0.1	9	9	6	0.35
scrofula	0.55	7	0.63	5	0.48	7	0.63	4	8	8.5	0.9
cancer	0.325	6	0.85	5	0.5	4.5	0.3	8.5	9	7	0.83
jaundice	0.027	4.5	0.65	6	0.55	4.5	0.23	6.5	7.5	7.5	0.6
brokenbones	0.02	5.5	0.11	7.5	0.7	7.5	0.85	1	2	8	0.88
tuberculosis	0.625	7	0.88	8	0.8	3	0.13	5.5	8.5	7	0.35

Part 2: Full regression tables

Table S3. Predicting supernatural/religious v natural from uncertainty. Note predictors are mean-centered and scaled by 1 S.D. See figure 1, left panel for visualisation.

	Exploratory	**Confirmatory**	**Full**	**Exploratory**	**Confirmatory**	**Full**
Predictors	*OR (89% CI)*	*OR (89% CI)*	*OR (89% CI)*	*OR (89% CI)*	*OR (89% CI)*	*OR (89% CI)*
Intercept	0.56 (0.38 – 0.83)	0.56 (0.36 – 0.89)	0.62 (0.41 – 0.92)	0.53 (0.36 – 0.79)	0.53 (0.33 – 0.84)	0.58 (0.39 – 0.87)
Mechanism uncertainty	1.76 (1.23 – 2.52)	1.66 (1.10 – 2.51)	1.74 (1.22 – 2.50)			
Cause uncertainty				1.62 (1.14 – 2.31)	1.45 (0.96 – 2.20)	1.56 (1.09 – 2.24)
Random Effects						
σ^2	3.29	3.29	3.29	3.29	3.29	3.29
τ_{00}	0.80 $_{school\_ID}$	1.34 $_{school\_ID}$	1.10 $_{school\_ID}$	0.80 $_{school\_ID}$	1.34 $_{school\_ID}$	1.10 $_{school\_ID}$
	1.74 $_{disease}$	2.38 $_{disease}$	1.90 $_{disease}$	1.80 $_{disease}$	2.50 $_{disease}$	2.00 $_{disease}$
ICC	0.44	0.53	0.48	0.44	0.54	0.49
N	35 $_{disease}$	35 $_{disease}$	35 $_{disease}$	35 $_{disease}$	35 $_{disease}$	35 $_{disease}$
	443 $_{school\_ID}$	442 $_{school\_ID}$	608 $_{school\_ID}$	443 $_{school\_ID}$	442 $_{school\_ID}$	608 $_{school\_ID}$
Observations	1826	1829	3655	1826	1829	3655

Table S4. Predicting ritualistic v non-ritualistic from uncertainty. Note predictors are mean-centered and scaled by 1 S.D.

	Exploratory	**Confirmatory**	**Full**	**Exploratory**	**Confirmatory**	**Full**
Predictors	*OR (89% CI)*	*OR (89% CI)*	*OR (89% CI)*	*OR (89% CI)*	*OR (89% CI)*	*OR (89% CI)*
Intercept	0.19 (0.14 – 0.26)	0.16 (0.12 – 0.22)	0.17 (0.12 – 0.22)	0.17 (0.12 – 0.23)	0.17 (0.13 – 0.23)	0.18 (0.13 – 0.23)
Cause uncertainty	1.53 (1.17 – 2.00)	1.56 (1.17 – 2.08)	1.60 (1.23 – 2.09)			
Mechanism uncertainty				1.78 (1.32 – 2.38)	1.81 (1.34 – 2.43)	1.82 (1.39 – 2.38)
Random Effects						
σ^2	3.29	3.29	3.29	3.29	3.29	3.29
τ_{00}	0.59 $_{\text{school\_ID}}$	0.31 $_{\text{school\_ID}}$	0.44 $_{\text{school\_ID}}$	0.60 $_{\text{school\_ID}}$	0.31 $_{\text{school\_ID}}$	0.44 $_{\text{school\_ID}}$
	0.82 $_{\text{disease}}$	0.97 $_{\text{disease}}$	0.94 $_{\text{disease}}$	0.77 $_{\text{disease}}$	0.87 $_{\text{disease}}$	0.85 $_{\text{disease}}$
ICC	0.30	0.28	0.29	0.29	0.26	0.28
N	35 $_{\text{disease}}$	35 $_{\text{disease}}$	35 $_{\text{disease}}$	35 $_{\text{disease}}$	35 $_{\text{disease}}$	35 $_{\text{disease}}$
	443 $_{\text{school\_ID}}$	442 $_{\text{school\_ID}}$	608 $_{\text{school\_ID}}$	443 $_{\text{school\_ID}}$	442 $_{\text{school\_ID}}$	608 $_{\text{school\_ID}}$
Observations	1826	1829	3655	1826	1829	3655

Table S5. Predicting supernatural/religious v natural from uncertainty while controlling for ritualistic. Note predictors are mean-centered and scaled by 1 S.D. Only results for the full dataset are shown here.

	Full dataset	**Full dataset**
Predictors	*OR (89% CI)*	*OR (89% CI)*
Intercept	0.47 (0.32 – 0.69)	0.50 (0.34 – 0.73)
Cause uncertainty	1.49 (1.05 – 2.09)	
Mechanism uncertainty		1.64 (1.16 – 2.30)
Ritualistic	2.76 (2.27 – 3.36)	2.76 (2.27 – 3.35)
Random Effects		
σ^2	3.29	3.29
τ_{00}	1.01 $_{school\_ID}$	1.01 $_{school\_ID}$
	1.77 $_{disease}$	1.70 $_{disease}$
ICC	0.46	0.45
N	35 $_{disease}$	35 $_{disease}$
	608 $_{school\_ID}$	608 $_{school\_ID}$
Observations	3655	3655

Table S6. Predicting supernatural/religious v natural from severity. Note predictors are mean-centered and scaled by 1 S.D. Note only results for the full dataset are shown here.

	Full dataset	**Full dataset**	**Full dataset**	**Full dataset**	**Full dataset**
Predictors	*OR (89% CI)*	*OR (89% CI)*	*OR (89% CI)*	*OR (89% CI)*	*OR (89% CI)*
Intercept	0.57 (0.37 – 0.88)	0.57 (0.37 – 0.86)	0.57 (0.37 – 0.88)	0.60 (0.39 – 0.91)	0.61 (0.40 – 0.93)
Death rate	1.04 (0.79 – 1.36)				
Typical sickness		1.29 (0.86 – 1.92)			
Prop. very sick			1.09 (0.72 – 1.63)		
Prop. in severe pain				0.82 (0.57 – 1.19)	
Typical pain					0.76 (0.51 – 1.13)
Random Effects					
σ^2	3.29	3.29	3.29	3.29	3.29
τ_{00}	1.10 $_{school\_ID}$	1.10 $_{school\_ID}$	1.10 $_{school\_ID}$	1.10 $_{school\_ID}$	1.10 $_{school\_ID}$
	2.23 $_{disease}$	2.18 $_{disease}$	2.23 $_{disease}$	2.17 $_{disease}$	2.13 $_{disease}$
ICC	0.50	0.50	0.50	0.50	0.50
N	35 $_{disease}$	35 $_{disease}$	35 $_{disease}$	35 $_{disease}$	35 $_{disease}$
	608 $_{school\_ID}$	608 $_{school\_ID}$	608 $_{school\_ID}$	608 $_{school\_ID}$	608 $_{school\_ID}$
Observations	3655	3655	3655	3655	3655

Table S7. Predicting ritualistic v non-ritualistic from pain. Note predictors are mean-centered and scaled by 1 S.D.

	Exploratory	**Confirmatory**	**Full**	**Exploratory**	**Confirmatory**	**Full**
Predictors	*OR (89% CI)*	*OR (89% CI)*	*OR (89% CI)*	*OR (89% CI)*	*OR (89% CI)*	*OR (89% CI)*
Intercept	0.41 (0.21 – 0.81)	0.46 (0.23 – 0.93)	0.42 (0.22 – 0.83)	0.23 (0.15 – 0.34)	0.26 (0.17 – 0.39)	0.25 (0.17 – 0.36)
Typical pain	0.81 (0.68 – 0.96)	0.75 (0.63 – 0.90)	0.77 (0.65 – 0.92)			
Proportion in severe pain				0.14 (0.03 – 0.70)	0.07 (0.01 – 0.41)	0.11 (0.02 – 0.51)
Random Effects						
σ^2	3.29	3.29	3.29	3.29	3.29	3.29
τ_{00}	0.59 $_{school\_ID}$	0.32 $_{school\_ID}$	0.44 $_{school\_ID}$	0.61 $_{school\_ID}$	0.32 $_{school\_ID}$	0.44 $_{school\_ID}$
	0.83 $_{disease}$	0.90 $_{disease}$	0.95 $_{disease}$	0.86 $_{disease}$	0.94 $_{disease}$	0.98 $_{disease}$
ICC	0.30	0.27	0.30	0.31	0.28	0.30
N	35 $_{disease}$	35 $_{disease}$	35 $_{disease}$	35 $_{disease}$	35 $_{disease}$	35 $_{disease}$
	443 $_{school\_ID}$	442 $_{school\_ID}$	608 $_{school\_ID}$	443 $_{school\_ID}$	442 $_{school\_ID}$	608 $_{school\_ID}$
Observations	1826	1829	3655	1826	1829	3655

Table S8. Predicting ritualistic v non-ritualistic from anxiety. Note predictors are mean-centered and scaled by 1 S.D. Results for the full dataset only are shown for these null results.

	Full dataset	**Full dataset**
Predictors	*OR (89% CI)*	*OR (89% CI)*
Intercept	0.17 (0.12 – 0.23)	0.17 (0.12 – 0.23)
Typical anxiety	1.02 (0.72 – 1.43)	
Proportion severely anxious		0.97 (0.70 – 1.34)
Random Effects		
σ^2	3.29	3.29
τ_{00}	0.44 $_{\text{school\_ID}}$	0.44 $_{\text{school\_ID}}$
	1.15 $_{\text{disease}}$	1.15 $_{\text{disease}}$
ICC	0.33	0.33
N	35 $_{\text{disease}}$	35 $_{\text{disease}}$
	608 $_{\text{school\_ID}}$	608 $_{\text{school\_ID}}$
Observations	3655	3655

Part 3: Reanalysis after clustering several disease categories

Some of the illnesses in the dataset are quite similar. Here we recalculated the main results after lumping coughs, colds, and sore throat into a respiratory tract infection category, and 'cuts and wounds' and bleeding into a laceration category. There were therefore 32 rather than 35 diseases. The key findings are similar, see figures S1 and S2. Readers interesting in alternative clustering can modify the code on lines 60 to 68 of the .r file.

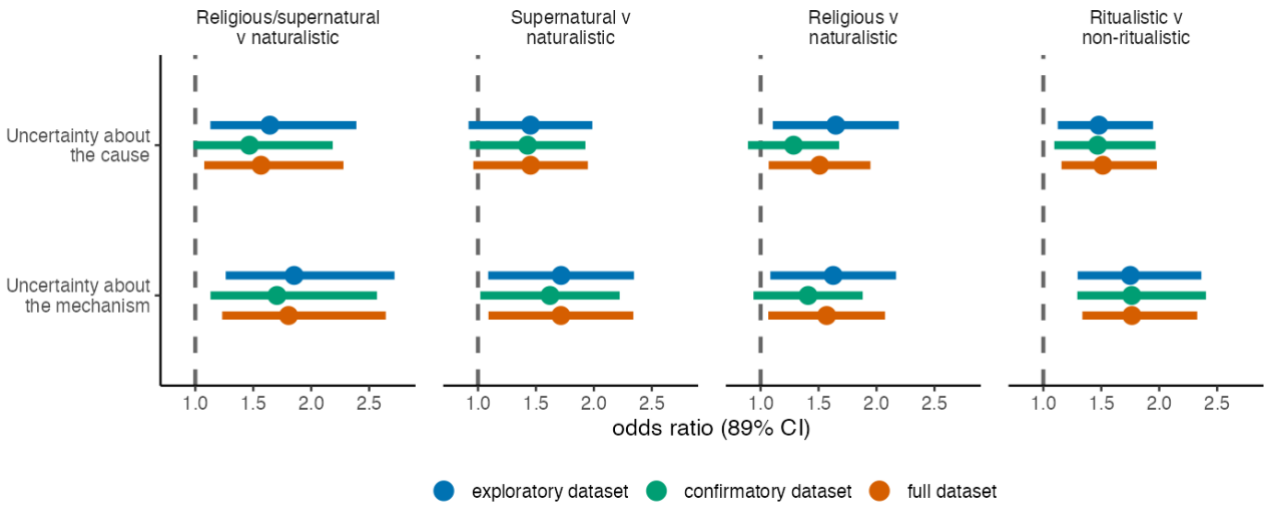

Figure S1. Are illnesses with uncertain causes and mechanisms more frequently treated with supernatural and religious treatments? Here we reanalyse the data after clustering similar diseases – see main supplementary text. Left panel shows coefficient plot with standardized coefficients from a mixed effect logistic regression. This supplementary analysis supports the hypothesis that diseases that provoke uncertainty have more religious and supernatural treatments. The centre two panels examine the effects of uncertainty on supernatural and religious separately using mixed effect multinomial logistic regression. The right panel shows the relationship between uncertainty and ritual: this relationship was not predicted. All coefficients are standardised, and models have only one fixed effect. The random effects are disease and school.

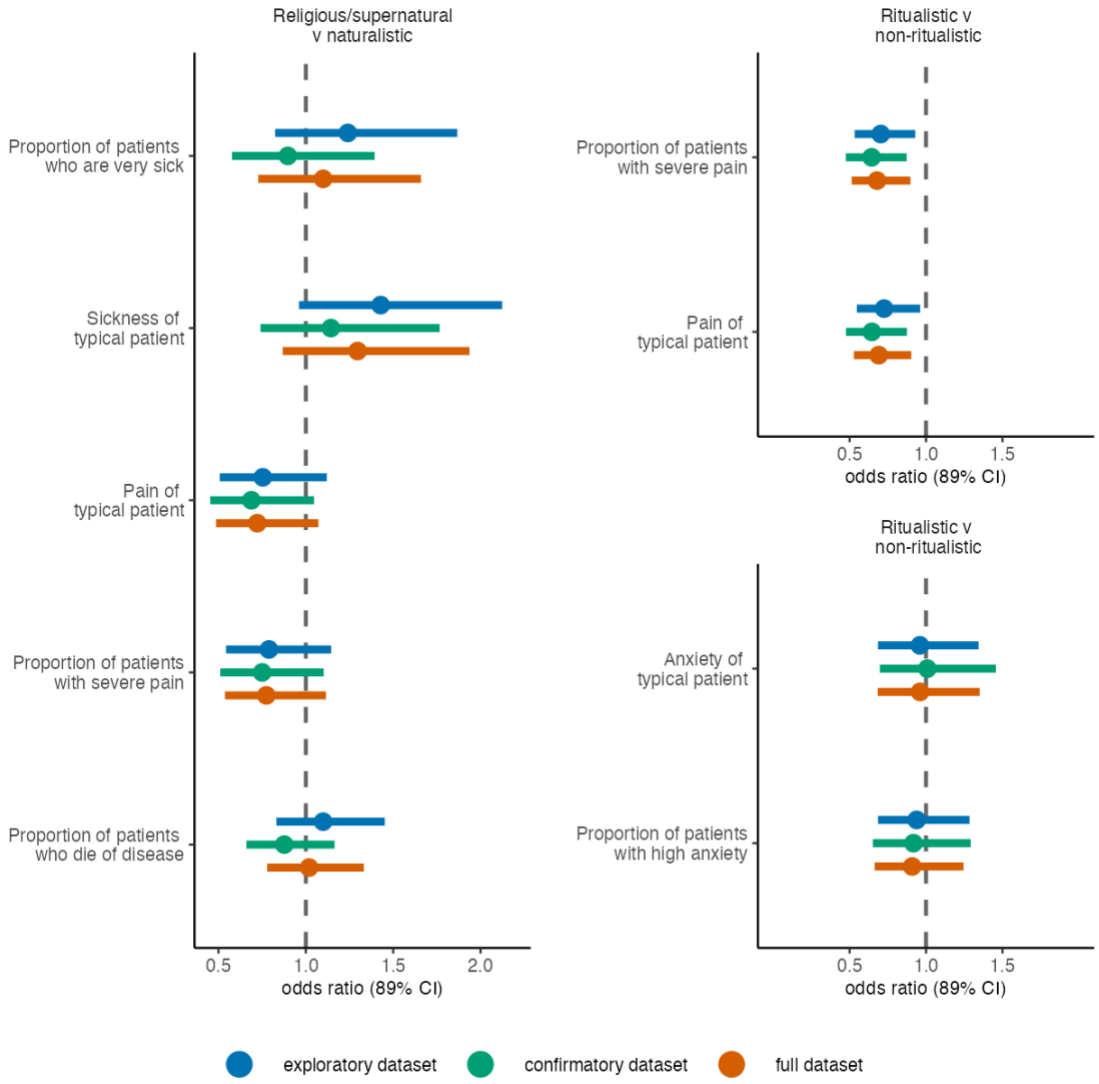

Figure S2. Left panel suggests that severe diseases are not treated with more supernatural/religious treatments. Here reanalyse the data after clustering similar diseases – see main supplementary text. Top right panel suggests that painful diseases are less likely to be treated with ritualistic treatments; this was not a predicted association. The bottom right panel indicates no relationship between anxiety and ritualistic treatment. These standardized coefficients are derived from mixed effect logistic regression models with one fixed effect and two random effects, disease and school.

Part 4: Additional information on disease coding including LLM prompts.

Note that the AI coding was not pre-registered as AI was not sufficiently advanced when we were developing the protocol. There were no substantive changes to the results as a result of adding this step. The supernatural versus naturalistic categorisation was executed using Open AI's gtp-4o, version 2024-04-09 with the below prompt. Discrepancies between the AI and the initial coding team were resolved by another author, MdB. In 90% of cases the LLM and the human coder agreed. The discrepancies were largely due to the LLM coding being over-inclusive with supernatural coding (49% were coded as supernatural by the LLM versus 44% by the researchers). The independent human coder resolved the discrepancies in favour of the LLM in 144 (40%) cases and in favour of the human in favour of the researcher's coder in 212 (60%) of cases.

Religious cures were also coded in duplicate by the research team and then by OpenAI's gtp-4o-mini, version 24-07-18. A 175-word prompt, similar to the instructions to human coders and including several examples was provided to the LLM, along with the cures. There were 236 disagreements (6.5%) between the researchers and the LLM across the 3,655 cures. The lead authors reviewed these and resolved 148 to the LLMs categorisation (63%). These generally involved references to prayers, rites, or saints that had been missed by the human coders. The LLM sometimes overperceived religion, with, for example, many ordinary Marys being perceived as the Virgin Mary.

Natural versus supernatural prompt.

=gpt(I'm going to give you a cure for a disease that was collected from an Irish school child in 1937. I want you to decide if the cure is SUPERNATURAL or NATURAL. A treatment is SUPERNATURAL if it contains elements that violate commonplace conceptions of causality. The SUPERNATURAL cures includes

Sympathetic magic: A perceived similarity between the cure and the disease (e.g., using a snail to cure warts).
Disease transfer: Belief that the ailment is transferred to another object, animal, or person, or cured at a distance (e.g., passing warts by giving someone a bag of stones).
Accidental events: Events with no causal connection to the ailment but seen as integral to the cure (e.g., finding a snail without looking).
Special agents: A reliance on special people (e.g., seventh sons), places (e.g., south-running streams), or incantations (e.g., praying).
Post-treatment actions affecting causality: Belief that the effectiveness of the cure depends on changes to the materials or objects after their direct interaction with the body (e.g., burning a cloth used in the treatment or releasing an animal involved in the cure).
Religious practices: Anything that draws upon religious themes. These will typically be folk/vernacular catholic practices including holy water, consecration, the trinity, prayers to saints, references to religious figures etc.

A cure is NATURAL if it involves none of these supernatural processes and if it includes physical contact with the body via ingestion, application, inhalation, or similar. NATURAL is distinct from evidence based or effective: rather, you should code these cures as naturalistic if there are plausible causal pathways whereby the medical substance could feasibly contact the ailment or where some naturalistic medical processes can be inferred (e.g., bone setting).

Here is how you would code the following cures:

Cure: 'A cure for whooping cough is to put a frog into a bottle and then to cork it. It is said that when the frog dies the whooping cough will be cured.'

Response: Code this cure as SUPERNATURAL since the effectiveness of the cure depends on events that happen after the cure is applied. This violates physical laws that cause precede effects.

Cure: 'To drink the water in which young nettles is boiled';

Response: NATURAL, since this cure involves drinking a herbal remedy, it is consistent with natural processes.

Cure: 'Get some garlic, chop it up very fine, and stew it slowly for hours in water. When cold bottle it, and drink some of it whenever an attack of coughing comes on.'

Response: NATURAL, since this cure involves only consumption of foods and no magical or religious processes.

Cure: 'an old cure for chilblains is to get a piece of raw turnip make a hole in it -fill the hole with salt and when the salt dissolves to water apply it to chilblains'

Response: NATURAL, this cure is strange, with references to holes in turnips. However, there are no obvious magical processes we can classify as magical.

Cure: 'In the name of Him who was truly born and was baptized in the River Jordanslacken the blood and strengthen the water of --------- Amen'

Response: Code this cure as SUPERNATURAL since it involves a magical prayer.

Cure: 'eat food left behind by a ferret'

Response: Code this cure as SUPERNATURAL since the curative effects of the treatment depend events that cannot physically alter the cures, ie, not being touched/eaten by an animal.

Cure: 'the smith family can cure broken bones'.
Response: NATURAL since this implies that Smith family have expertise in bonesetting, a natural cure.

If you are uncertain or the cure is ambiguous, classify it as NATURAL.

If SUPERNATURAL, return '1',
If NATURAL, return '0'
Return no other text.

Here is the cure:
",
Y2)

Religious versus not religious prompt.

=GPT("I'm going to give you a cure for a disease that was collected from an Irish school child in 1937. I want you to decide if the cure is RELIGIOUS or NOT RELIGIOUS

Religion refers to any reference to Christian elements such as prayer, bible, saints, religious objects, blessed objects or people, holy places, holy wells, the holy trinity, the virgin mary etc.

Here is how you would code the following cures.

Cure: 'The Sign of the Cross made with a Marriage Ring (Gold) will also cure'
Response: RELIGIOUS. Rationale: This has clear references to catholic rituals like making the sign of the cross.

Cure: 'Some people cure a sprain with woollen thread and by saying some prayers.'
Response: RELIGIOUS. Rationale: This mentions prayer.

Cure: '3. A person that licks a Man Creeper frog has a cure of a burn by blowing their breath on the burn'

Response: NOT RELIGIOUS. Rationale: Although supernatural, this cure does not include any Christian elements.
If RELIGIOUS, return ‘Y’,
If NOT RELIGIOUS, return ‘N’

Do not justify your decision.", Y2)

Part 5: Correlations between predictor variables

Figure S3. Pairwise Pearson correlations between all variables coded by the doctors, which were used as predictors in the subsequent analyses.