Magic and Empiricism in Early Chinese Rainmaking

A Cultural Evolutionary Analysis

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Ritual protocols aimed at rainmaking have been a recurrent sociocultural phenomenon across societies and throughout history. Given the fact that such protocols were likely entirely ineffective, why did they repeatedly emerge and persist, sometimes over millennia, even in populations with writing and recordkeeping? To address this puzzle, many scholars have argued that these protocols were not instrumental at all and that their practitioners were not really endeavoring to employ them to bring about rain. Here, taking advantage of the wealth of historical records available in China, we argue to the contrary: that rainmaking is best viewed as an instrumental, means-end activity and that people have always placed strong emphasis on the outcomes of such activities. To account for the persistence of rainmaking, we then present a set of cultural evolutionary explanations rooted in human psychology that can explain why people's adaptive learning processes did not result in the elimination of ineffective rainmaking methods. We suggest that a commitment to a supernatural worldview provides theoretical support for the plausibility of various rainmaking methods and that people often overestimate the efficacy of rainmaking technologies because of statistical artifacts (some methods appear effective simply by chance) and underreporting of disconfirmatory evidence (failures of rainmaking not reported or transmitted). The inclination to "do something" when a drought hits versus "do nothing" likely also plays a role and persists in the world today.

Online enhancement: appendix.

Introduction

Ever since the advent of agriculture, rainfall has played a crucial role in people's lives (Rockström, Barron, and Fox 2009; Wahlquist 2009). Historically, rainfall was often a matter of life and death in any society that relied on farming or pasture for subsistence. Thus, a lack of rain in seasons when crops needed water posed a serious threat to farmers regarding their survival; in societies with complex political hierarchies, the stability of the state hinged on rain (Chaney 2013; De Châtel 2014; Kebbede and Jacob 1988; Li et al. 2017). An influential hypothesis on Chinese dynastic change, for example, proposes that changes in Chinese dynastic powers may have been affected by a lack of precipitation mediated through popular unrest (Zhang et al. 2008).

Given the enormous importance of rainfall for subsistence, there have always been strong incentives to produce rain when it is needed. Societies across the world and throughout history attempted exactly this. In his masterpiece *The Golden Bough*, James Frazer (1890) devotes an entire chapter to the magical control of the weather: the rainmaking activities of the peasants in Russia, tribal farmers in New Guinea, the Omaha in North America, and many other traditional societies are all described in vivid detail. More recent ethnographic work further suggests the widespread nature of such efforts (Başgöz 1967; Ruppert 2002; Schoeman 2006).

The historical and cross-cultural recurrence of rainmaking itself is not puzzling. After all, when there is a problem, it is not surprising that people try to solve it. What is puzzling is that we as modern readers know that traditional rainmaking attempts were ineffective.[1] That is, assuming that modern science is to be trusted, the ancients' rainmaking efforts did not exert any influence on weather. The real question is thus this: Why did people engage in a costly and time-consuming activity that objectively did not achieve its explicit aims? Anthropologists have been keenly aware of this problem, and there has been a long-standing debate regarding such seemingly ineffective actions and the implications for human rationality (Horton 1993; Tambiah 1990). On the one hand, Tylor, Frazer, and their intellectual predecessors claim that magic shares the

1. To our knowledge, there was no rainmaking effort that was scientifically plausible until the nineteenth century.

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same fundamental goals as science: to explain, predict, and possibly control the natural world. On the other hand, many scholars have reacted against Tylor and Frazer's interpretation. Levy-Bruhl (1926), for example, suggests that "primitive" men have a fundamentally different thinking mode in which mental processes were powered by emotion rather than reason and ritual activities are best described as "mystical participation" rather than "rational action." Durkheim (2008) divides the world into two radically contrasted categories, the sacred and the profane, and posits that although the profane simply refers to the everyday ordinary, sacred objects and actions are characterized by a sense of awe and respect by virtue of their being symbols of societies. This distinction was later taken up by many thinkers, such as Radcliffe-Brown (1952) and Max Gluckman (1944), who suggest that the two categories require different kinds of interpretations: while the profane may be interpreted as "logical-empirical" through means-end decision calculus, the sacred requires a kind of sociological explanation. Malinowski similarly thinks that the indigenous people themselves recognize a distinction between the supernatural and rational (Malinowski 2002), and the great sociologist Talcott Parsons (1937) expanded this account by suggesting that there are certain actions that are "nonrational"; that is, they have no pragmatic end other than the performance of the acts themselves. In short, the reaction against the Tylor-Frazer reading of ineffective actions in traditional societies is that the actions are not really trying to achieve their alleged goals—they are not instrumental. These actions are driven by emotion, respect for tradition, power dynamics in the community, or other noninstrumental factors. Many anthropologists today still follow the reaction against Tylor and Frazer.

Let us step back and place rainmaking in this larger context. The Tylor-Frazer position on this would simply be that people engage in rainmaking activities to produce rain. For the symbolic-sociological proponents, the key issue is whether rainmaking may be viewed as a type of profane, instrumental activity. Wittgenstein (1967) famously thinks it may not be. For him, the Native rainmaker does not really think he can make rain. In other words, he does not act out of "opinion" but rather "instinct," and his actions serve not as genuine instrumental effort but as a kind of emotional discharge of anger and anxiety. Later authors also often emphasize the sociological and symbolic functions of rainmaking activities (Mbiti 1970; Ngara 2012) but rarely dismiss their instrumentality entirely. Surely, it would be very difficult to completely ignore the instrumental aspect of rainmaking; as will be shown, much historical evidence strongly suggests that various kinds of rainmaking were intended to be used as instruments to induce rain.

As a population with a long and continuous literary tradition, China provides an ideal case for a close examination of rainmaking. Because of the large amount of historical material, there have been many studies of Chinese rainmaking that focus on specific historical periods, and the recent advent of digitized databases of Chinese texts has enabled more quantitative assessment of elite history and culture (e.g., Sturgeon 2006). Here we take advantage of such resources and offer a detailed analysis of rainmaking in China.

Our paper is organized as follows: In part one ("Folk Theories of Rain and Rainmaking in Early China" and "Rainmaking as an Effort to Produce Rain"), we summarize major theories of rain in early China and the corresponding rain-inducing activities, arguing that the majority of rainmaking activities are best understood as instrumental efforts. In part two ("The Cultural Evolution of Rainmaking: All Magic and No Empiricism?"), we focus on the premodern period (in particular the Tang and the Song dynasties, 618–1276 CE) and offer a cultural evolutionary analysis of various rainmaking methods by focusing on their perceived efficacy. We argue that there has always been a great deal of empiricism in rainmaking despite a prevailing supernatural worldview that sustains the plausibility of many methods, and we propose a mechanism for how the same set of psychological learning mechanisms that produces adaptive cultural products and protocols nonetheless can generate and maintain maladaptive and costly actions like rainmaking. To preview, some methods will appear efficacious simply by chance even if one meticulously tracks their successes and failures, and underreporting of rainmaking failures further contributes to the overestimation of various rainmaking methods' efficacy. In the final section ("The Decline of Rainmaking: A Rejection Based on Theory"), we offer an account of the decline of traditional rainmaking in China by attributing it to a shift in people's background worldview.

Folk Theories of Rain and Rainmaking in Early China

Like many traditional societies, premodern China had elaborate theories about meteorological phenomena, such as precipitation and winds. For analytic convenience, we divide the theories into two large categories: "personal gods" and "impersonal forces." This distinction will help us better conceptually organize the myriad of theories and understand the associated actions to produce rain.

Personal Gods Theory of Rain

Various kinds of personal god theories prevailed in China during different periods of time. Generally, a personal god refers to an anthropomorphic, intentional agent that has humanlike dispositions and may respond to human desires and concerns (Bering 2012; Boyer 2001) as a result of our species' mentalizing capacity and other related cognitive intuitions, such as dualism (Chudek et al. 2018; Frith and Frith 2012). This means that these gods can be pleaded with, manipulated, bribed, and even coerced. Regarding rainmaking, the gods involved are often perceived to either be able to control weather phenomena or be the direct cause of rain. As such, to ask for rain is to negotiate with these gods. The corresponding rainmaking activities therefore become sensible if and only if we treat the underlying controlling or causative agents as

humanlike entities with the capacity to make rain. In traditional China, these agents could be deceased ancestors, local deities (deceased famous individuals who serve as "protectors" of a geographic region), or supernatural beings such as dragons (detailed descriptions of these personalized gods can be found in the appendix, available online).

The key takeaway here is that the way people interact with these gods closely resembles human-human interactions. The most striking example is perhaps threat or coercion, as can be seen in the following quote from Taizu (1328–1398 CE), the first emperor of the Ming dynasty: "The Deity lives off this soil, but it will not sympathize with my people. Now I make a covenant with the Deity that within three days it must rain. If it does not rain, then I will ruin the Deity's shrine" (Cohen 1978).[2] Here, the emperor is exercising his authority and treats the local deity as an inferior. Similar instances were recorded for lower officials as well; sometime between 1068 and 1083, a local magistrate brought an image of a deity to his office and vowed: "If it does not rain in three days, I will destroy your temple" (Huang 1914).[3] The recorded outcome of such threats varies; in the former case it was recorded that rain indeed came within three days (presumably because of the emperor's supreme authority), while in the latter the outcome was not specified. There were also occasions when the deities got angry at the threat and retaliated with natural disasters (Cohen 1978).

Impersonal Forces Theory of Rain

Alongside many beliefs about rain that involved humanlike agents, there was also theorizing on the impersonal forces that produce rain. Generally, these impersonal forces theories of rain rely on principles of sympathy and correspondence, and the literati—mostly Confucians—tended to prefer this type of explanation to those based on personal gods. Note that these forces are not purely mechanistic in the modern sense but often appear mysterious in nature and may respond to human actions in rather moralistic ways (Ding 2009; Wong 2011). Thus, the distinction between personal and impersonal rainmaking agents can get murky, although this is common with regard to cosmic forces (Willard et al. 2020).

Broadly, these rainmaking theories involving impersonal forces can be divided into "interactions between heaven and mankind," a Confucian view of the causal structures of the universe (Wong 2011), and various sympathetic magic techniques to produce rain. Interactions between heaven and mankind maintains that there is a resonance between heaven and the actions of people, especially the political leaders, as they are viewed as the representation of heaven.[4] When the leaders err (usually in the form of bad governance), heaven may send disasters or portents (灾异). Sympathetic magic theories of rain in traditional China, on the other hand, operate on the basis of the principle of "like stimulates like," as the early Han scholar Dong Zhongshu (179–104 BCE) explicitly theorizes:

> The beautiful invokes the beautiful, the evil invokes the evil; [this is because] things of the same kind respond to each other. A horse neighs and other horses neigh; a cow moos and other cows moo. When kings and emperors rule well, there will appear beautiful and auspicious things; when their rule is about to end, there will appear monstrous spirits and ghosts. Therefore things of the same kind stimulate each other: as such, dragons cause rain, fans get rid of heat. (Dong 2018:chap. 57)

We can see from the above quotation that the claim "dragon causes rain"[5] is situated in a larger sympathetic magical framework. More generally, Dong Zhongshu also discussed rainmaking vis-à-vis the yin-yang principle.[6] Because rain is considered yin, to induce it is to use its own kind—things that are also yin. He therefore recommended rainmaking efforts such as the following: (1) women should appear in public places, whereas men should remain in their houses;[7] (2) towns should close their southern gates and open those on the north;[8] and (3) the lighting of fires should be prohibited. As Bodde (1964) points out, the rainmaking efforts documented in *Chunqiu Fanlu* are more likely to be Dong's own scholastic formulation than an account of actual activities performed by the general populace. The core idea of employing sympathy to induce rain, however, persisted throughout imperial China till as late as the Qing dynasty (1644–1912; Liu 2013).

Interestingly, the concept of "sincerity" (诚) often played an important role in rainmaking: for heaven to grant rain, political leaders needed to be completely sincere when performing these rituals (Snyder-Reinke 2020). Consequently, rainmaking failures might be attributed to the insincerity of rainmakers. We suggest that this is an illustrative case of a more general phenomenon of "invoking an auxiliary hypothesis to protect core theories," in the language of the philosophy of science. It is common for people to invent reasons to explain (away) technological failures post hoc to prevent their theories from being falsified. However, there is ample historical and ethnographic evidence showing that people's subjective understanding of technological efficacy is probabilistic (Hong and Henrich 2021; Hong 2022*b*). That is to say, while people

2. 明外史.

3. 台州金石录 (a record of inscriptions from Taizhou).

4. Chinese emperors are often referred to as *tianzi* (天子), literally, son of heaven.

5. Of course, this depends on the belief that dragon and rain are of the same kind.

6. In traditional Chinese culture, yin and yang are a pair of complementary concepts and are perceived to be a fundamental attribute of any material object. Yin usually refers to the feminine, negative, moist, and cool, whereas yang refers to the masculine, positive, dry, and hot.

7. See *Chunqiu Fanlu*, chap. 74. Interestingly, Dong Zhongshu also talks about applying the same principle to stop rain, i.e., to release or expose things that are yang, e.g., men or fire. See *Chunqiu Fanlu*, chap. 75.

8. This very technique was used as late as 1892 (Snyder-Reinke 2020). In traditional Chinese culture, south is associated with yang, and north is associated with yin.

(under a particular worldview; see sections below) always believe that rainmaking can work when properly conducted, their estimation of the probability that the desired outcome (rain) would follow the technological action (rainmaking) will decrease in the face of empirical failures, regardless of the excuses invoked. In other words, while the lack of sincerity may be used as an auxiliary hypothesis to protect confidence in supernatural rainmaking techniques, people's confidence in any particular rainmaking protocol (all factors considered, including sincerity) is likely to be affected by observed failures. This is especially true when multiple methods are available, as in the case, for instance, when multiple deities were believed to be able to exert control over weather.

Rainmaking as an Effort to Produce Rain

The above description of theories of rain and rainmaking methods already hints at the instrumental nature of rainmaking in early China. For the sake of completeness, we offer a few additional notes to bolster this claim.

Problem-Solving-Style Instructions on Rainmaking

In most Chinese dynasties, rainmaking was performed on both a regular and ad hoc basis (Snyder-Reinke 2020); that is, in addition to the annual rituals in which the emperors and officials prayed for abundant harvest and good weather, rainmaking was also performed when there was a drought. This has resulted in a large corpus of transmitted "how-to" texts on rainmaking. These texts often have a distinctive problem-solving flavor: if it does not rain, do A; if it still does not rain, do B. For example, the following rainmaking instructions appear in the official dynastic record of Sui (隋书):

> If there is a drought after the fourth month of the year, then [one shall] pray for rain, and do the following seven things (policy issues such as improving criminal justice and reducing taxation): . . . make the local officials bathe and fast for three days and pray for the state (*sheji* 社稷); if it does not rain after seven days, one needs to pray all over again. If it still does not rain after the three procedures, then pray to the local deities that often bring cloud and rain. (Zheng 1973:126)

Such detailed instructions can also be found in popular rainmaking manuals such as *The Divine Farmer's Book of Praying for Rain* (*Shennong Qiuyu Shu* 神农求雨书), which specifies the relevant rain-inducing action based on dates. Plan A is usually some kind of rain dance; if it fails, then plan B (closing the southern gate of the town and placing water outside)[9] is carried out. If it still fails, then plan C (e.g., exposing shamans or spirit mediums under the sun) is carried out, and if plan C fails again, there is plan D (piling up firewood on the sacred mountain and burning it). The stepwise style of these instructions is reminiscent of how modern mechanics or IT technicians fix a car or a computer. Like traditional rainmakers, these specialists have certain causal theories of how things normally work and adopt a strategy of trying a series of potential solutions until the problem is fixed.

Willingness to Try Alternative Methods

In traditional China, both government officials and commoners were willing to try a variety of methods in hopes of bringing rain, and their attitude toward various methods of rainmaking was anything but dogmatic. If rain did not arrive after they prayed to deity A, they often switched to a different deity without hesitation (Hansen 2014). Such an attitude is exemplified by a phrase in *Classic of Poetry* (诗经, sec. Da Ya 大雅, song Yun Han 云汉; Legge 1876:331), compiled more than 2,000 years ago, saying that "To every Spirit I have vowed / The choicest victim's blood has flowed / As offerings I have freely paid" in the context of dealing with a lasting drought.

Although state Confucianism provided more abstract, moralistic theories about the causes of natural calamities (that drought and other disasters were intimately linked with the ruler's politics), government officials were often quite willing to incorporate local beliefs and practices, experiment with occult technologies, and sometimes employ traveling rainmakers. Indeed, the extensive records of rainmaking leave the overwhelming impression that these officials were willing to try anything to save their people (and their jobs). One particularly telling example occurred in the year 1004 CE,[10] when Emperor Zhenzong (真宗) invited a western monk (胡僧) who successfully used dragon images to summon rain during a drought. After the success, Zhenzong made the following comment: "Although [the method] is unconventional, yet for saving people from drought, it is not to be avoided."[11] Although classically educated and presumably sharing the philosophical views of most Confucian scholars, the emperor had an eminently practical view of rainmaking and was willing to try seemingly odd methods to obtain rain.

Lower officials were similarly likely to use a succession of different methods (including praying to different deities) until finally rain arrived. In the drought year of 1078, the famous essayist and historian Zeng Gong (曾巩), when serving as the governor of Fuzhou (福州), tried five different rainmaking methods, from sympathetic magic to praying to local deities, over a period of 20 days (Huang 2011). Ordinary people similarly asked a number of deities for rain, and the deities that "successfully"[12] produced rain were thanked, venerated, and sometimes brought to other geographic regions by their worshippers (Hansen 2014).

9. This is clearly reminiscent of Dong Zhongshu's method.

10. By that time Confucianism was firmly established as the state orthodox philosophy, and such sympathetic magic actions would certainly be deemed as illegitimate.

11. Original text: 虽不经， 然为民救旱, 亦无避也. See *Song Huiayo Jigao* 宋会要辑稿, chap. 18.

12. In this context, "success" simply refers to the temporal contiguity of prayer or offerings and rain.

Contemporaneous Skepticism toward Rainmaking

A central concern of any instrumental activity that claims to achieve specific goals is whether it indeed achieves those goals. For modern readers, we cannot help but wonder about the effectiveness of these exotic rainmaking methods: Is it really true that natural phenomena are linked with the emperor's rule or that an image of a dragon would attract a real dragon that brings rain? We suggest that the ancients had the same concerns, although skeptical comments were perhaps less likely to be recorded or transmitted in written texts.

The fact that people were willing to try many different rainmaking methods in a sequential fashion (as shown above) already indicates that some methods were trusted more than others. Naturally, one would try what one perceives to be the most effective methods first and then attempt alternative methods down the effectiveness scale while also taking costs into consideration. If a particular method repeatedly fails to bring rain, then skepticism naturally arises. Such skepticism, however, rarely leads to a complete rejection of the underlying theory, as one can easily explain away failures by attributing them to accidental ritual errors or the incompetent or insincere practitioner. On the other hand, skepticism can also arise from theoretical plausibility, even in the absence of empirical data.

More historical details of ancient skepticism toward rainmaking rituals can be found in the appendix, but for the sake of illustration, let us note the views of the most famous early Chinese skeptic of religious rituals, the Confucian scholar Xunzi (310–235 BCE). In a broader essay exploring the proper attitude to have toward "heaven" or "nature" (*tian*), Xunzi notes:

> If we sacrifice and it rains, what does it mean? I say: it does not mean anything. It is the same as not sacrificing and having it rain. When the sun is eaten by the moon [i.e., when there is an eclipse], we [perform a ritual to] save it; when heaven has a drought, we sacrifice; we engage in crackmaking and milfoil divination and only then decide a great event. But we do not thereby obtain what we seek—all of these practices are performed for their cultural (*wen* 文) value. Therefore, the gentleman sees these rituals as cultural practices, even as the common people take them as having supernatural (*shen* 神) causality. To see them as cultural is auspicious; to see them as supernatural is inauspicious.[13]

This is part of a larger argument that Xunzi makes for understanding religious ritual in a symbolic and functional sense, rather than as literally efficacious techniques for bringing about desired outcomes in the world (Campany 1992). For Xunzi, sacrifice and other divinatory rituals are best seen as serving a social function: they bring people together, create a sense of community, and allow individuals to better understand where they fit into the social hierarchy. The scholar or intellectual, Xunzi's intended reader, should understand that we perform rituals for this social reason, not because there is any causal connection between human action and natural phenomena.[14]

Xunzi's supernatural skepticism, however, is best seen as the exception that proves the rule. His agnostic or atheistic view of heaven as simply an impersonal, blind process independent of human control (Machle 1976) remained a minority position, even among the elite, and—as the evidence cited above indicates—appeared to have little or no effect on very practical and literal views of the efficacy of rain rituals. The fact that, even armed with a theoretical argument against rainmaking magic, the Chinese, from the elite down to the general populace, continued to enthusiastically embrace such rituals makes their continued appeal even more puzzling.

The Cultural Evolution of Rainmaking: All Magic and No Empiricism?

Like most other culturally transmitted practices, rainmaking protocols are subject to cultural selection processes that influence their differential spread (Fog 1999; Mesoudi 2005). The exact mechanism of this evolutionary process is still under some scholarly debate (Claidière, Scott-Phillips, and Sperber 2014; Claidière and Sperber 2007; Henrich and Boyd 2002), yet it is generally agreed that there are some basic principles that describe the transmission of cultural practices. For instrumental activities such as rainmaking, the probability of it being adopted by others in the community often depends on its perceived efficacy. Often, the focus of this literature is identifying recurrent features of ineffective instrumental practices that contribute to their plausibility. For example, repetition and the presence of religious icons are shown to increase the perceived efficacy of rituals (Legare and Souza 2012); the form of bloodletting (colocation of cure and symptom and the act of removing blood from the body) fits our folk physical and folk biological intuitions (Miton, Claidière, and Mercier 2015). More recently, Singh (2017) suggests that features like inhumanness—physical appearance or behavioral habits that differ from those of normal humans—contribute to the cultural success of many shamanistic practices. In sum, this line of research argues that certain practices are more likely to be adopted because they appear more plausible with regard to achieving people's goals, possibly because of some universal cognitive mechanisms. Many evolutionary-minded anthropologists take a similar approach and offer adaptive accounts of

13. Xunzi (2011:chap. *Tianlun*).

14. Xunzi's larger point that rainmaking rituals may have political and social efficacy has been extensively addressed in the literature. Our main focus in this paper, however, is the explicit instrumental nature of rainmaking: i.e., rainmaking to induce rain. As we have previously argued (Hong and Henrich 2021), a ritual's social, religious, and political functions depend on the public's belief that the ritual can indeed achieve its explicit purposes (bringing about rain, generating accurate information, etc.), which means that we still need to answer the question of why people believe in the explicit efficacy of rainmaking in the first place.

why the human mind finds particular cultural representations attractive (Boyer and Ramble 2001; Gervais et al. 2011; Henrich and Boyd 2002; Miton, Claidière, and Mercier 2015; Norenzayan et al. 2014).

This kind of explanation has been broadly applied to empirically ineffective technologies such as magic and divination. Indeed, one proposed defining feature of magic is that it is "nonempirical" (Levy 1966) or seriously empirically inadequate (Nadel 1954),[15] with the implication that people supposedly do not care much about whether the means employed really produce the desired ends. We suggest, however, that although it is certainly true that beliefs and cultural practices may spread successfully because they fit our psychological intuitions, there has always been a great deal of empiricism involved in any instrumental activity, and rainmaking is no exception. Specifically, outcomes of different rainmaking methods matter, and the same psychologies (e.g., payoff-biased cultural transmission, as well as trial and error learning) that enable the spread of adaptive cultural practices are still at work when people evaluate different rainmaking methods.

This empiricist attitude toward rainmaking methods, however, does not guarantee optimal behavioral outcomes. Specifically, why did people not realize that rainmaking does not actually work and instead adopt rational inaction, a "do-nothing" strategy, given that rainmaking rituals often incur significant time, effort, and material cost? Research in cognitive psychology has proposed several accounts based on faulty information processing, and we shall discuss two main ones that are most relevant for the present study. First, classic studies have demonstrated the phenomenon of the "illusion of control," where people erroneously attribute some observed outcome to their own actions (Langer 1975; Rudski 2004). Second, certain heuristics such as the availability heuristic (Schwarz et al. 1991; Tversky and Kahneman 1973, 2013) and the representativeness heuristic (Kahneman and Frederick 2012; Kahneman and Tversky 1972) may affect how we perceive frequency and probability. In the context of rainmaking, these biases mean that (1) we often subjectively feel that we have control over rainfall, especially when rain occasionally does occur after a ritual is performed, and (2) when we think about the frequency of rainmaking success, we tend to selectively recall cases when rain indeed fell after a ritual was performed—arguably, these cases are more cognitively salient than rainmaking failures.

We think that these accounts do fit the evidence, and they offer important explanatory insights on the persistence of rainmaking. However, these psychological accounts exclusively focus on individual cognition and largely ignore population-level processes in which beliefs are updated and transmitted over many generations. Previously, we have formally modeled how individuals' subjective perception (from the perspective of the individuals themselves) of technological efficacy may be influenced by various factors,[16] where objective efficacy (from the perspective of modern science) is an important input source (Hong and Henrich 2021). Here we offer two additional factors that contribute to the perceived efficacy of rainmaking from the empirical front by considering both how individuals form and update beliefs regarding the efficacy of rainmaking techniques and how these beliefs transmit to the population. Briefly, the efficacy of certain rainmaking methods may be overestimated because of (1) statistical artifacts (i.e., multiple culturally transmitted rainmaking methods being evaluated simultaneously causes some to appear efficacious by chance) and (2) underreporting of failed rainmaking attempts. Finally, we discuss the role of the background supernatural worldview that sustains the fundamental validity of traditional rainmaking and the eventual decline of rainmaking in China as a result of a shift in worldview.

Payoff-Biased Cultural Transmission in Rainmaking

The focus on the outcome of rainmaking, at both the individual level and state level, can be clearly seen in both primary historical records and secondary sources. Simply put, people paid serious attention to outcomes of rainmaking and preferentially adopted methods with more perceived success. This particular psychology is usually termed "payoff-biased cultural transmission," and it plays an important role in adaptive cultural evolution (Boyd and Richerson 2009; Kendal, Giraldeau, and Laland 2009). In the context of rainmaking in early China, three aspects are particularly illustrative.

First, there was often competition among various methods. In medieval China (Tang and Song dynasties, 618–1276 CE), where a myriad of Buddhist, Daoist, and other local popular religious practices and beliefs coexisted, neither government officials nor ordinary folk had strong commitments to any single deity or religious doctrine, especially on practical matters such as rainmaking (Wang 2006). As a result, there existed a wide range of possible methods to choose from in times of drought, and these methods were often in a "market competition" situation where the efficacy of different methods and the competence of different specialists were compared (Wang 2016).

Second, the evaluation criteria for judging good from bad methods strongly depend on their outcomes, which always serve as good evidence for efficacy. In his extensive treatment of medieval Chinese rainmaking, Capitanio (2008) describes a genre of literature known as "evidentiary miracles," which

15. Note that "magic" is an anthropologically problematic term that resists clear definition (Styers 2005). Here we are using it as a convenient shorthand to refer to cultural practices sustained by nonempirical components (primarily innate, evolved intuitions), as summarized above. Below we use "magic" or "magical practices" to collectively refer to Frazerian sympathetic magic and practices that involve interacting with humanlike entities.

16. Hereafter, by "perceived efficacy," "beliefs about efficacy," and "estimation of the efficacy of," we mean individuals' emic understandings (i.e., their subjective perceptions, beliefs, and estimates).

refers to a collection of successful rainmaking anecdotes. As the author suggests, these stories likely served as rhetorical devices to convince people of the power of respective practitioners or their methods. Hansen (2014) similarly emphasizes the importance of efficacy (*ling* 灵)[17] in individuals' decisions regarding which deity to offer prayers to. In evaluating the efficacy of various rainmaking methods, people focused not only on the eventual outcomes but also on the timing of the rain. In other words, temporal contiguity matters: a method that is followed by immediate rainfall would be deemed more efficacious and credible than one with delayed rain. Many famous historical cases emphasize the immediacy of rain after the ritual is conducted. In official Chinese dynastic records, entries that involve rainmaking frequently mention the timeliness of rain with words like "the very day" (是日) and occasionally more dramatic stories where rain fell during the ritual or immediately after the ritual. Sometimes explicit time limits were placed on specialists who claimed to have the power of inducing rain. For example, when Emperor Daizong of the Tang dynasty ordered the Buddhist monk Amoghavarjra to make rain, he made the timing requirement very explicit: "If it rains within three days it will be due to your magic power. If it rains after three days, the credit will not be yours" (Shi 2018).[18] In a sense, rainmakers were placing a dangerous bet when promising to induce rain because although success could bring fame and fortune, failure often meant severe punishment (sometimes death). During a drought in the Jin dynasty, a diviner reported to Emperor Zhangzong (1200 CE) that she had been informed by someone in her dream that sufficient rain would fall in three days. Unfortunately, no rain occurred after three days, and the diviner pleaded guilty to the emperor.[19]

Third, in some historical periods, the state was directly involved in spreading rainmaking methods that were seen as having been proved successful by their outcome, and the Song dynasty is a particularly illustrative example. During this time popular local deities were generally deemed illegitimate (淫祀) by the state, and people worshipping them could potentially be penalized; however, the government could also grant titles to these deities that then accorded them legitimate status (正祀), allowing them to receive official endorsement and sometimes funding (for repairing temples, etc.; Pi 2005). The criteria for granting titles to local deities seem to have been primarily based on efficacy in terms of realized positive outcomes. Emperor Shenzhong's order in the year 1074 CE was very explicit: "For all deities and temples that are efficacious and responsive to prayers, if they are famous and do not have official titles yet, titles will be granted. Those that already have titles but not publicly praised should also be advertised to the public."[20] Hansen's (2014) comprehensive study of Chinese medieval popular religion strongly supports this view with many historical details. What is particularly striking from Hansen's descriptions is that the title granting for local deities involved a lengthy verification process. Local people would request a particular deity to be officially recognized by making a request to the county magistrate, who checked the power of the deity by sending local leaders and their deputies to verify whether the claimed miracles really took place and examine the deity's history of responding to prayers. If the report on the deity's miracles was favorable, the magistrate would petition a fiscal intendant, who then reported to the central government and explained what steps had been taken to verify the deity's power. The final reports could be extremely detailed and sometimes even included the names of witnesses that the inspectors interviewed.

Aside from granting titles to deities with apparent records of success, the Song state also endorsed rainmaking approaches based on sympathetic relationships. A very popular method involved the use of lizards because of their physical resemblance to the mythological dragon. This "lizard rainmaking method" (蜥蜴祈雨法) was mentioned to the emperor by an administrator who emphasized its efficacy by invoking his personal experience with its successful application (Qi 2018). A few years later, when a drought occurred, the method was officially proposed. It was tried and "worked," and the government subsequently endorsed and promoted this method as an effective way to induce rain at local levels.[21] For some time this method was so popular that there was a shortage of regular lizards and people resorted to using geckos instead (Jiang 1981)—again relying on sympathetic relationships (geckos resemble lizards).

In other dynasties where rainmaking activities were less centrally organized, we observe instances of lower officials serving as disseminators of "effective" rainmaking methods. During the Qing dynasty, for example, local officials had a remarkable degree of freedom to choose from existing methods and revise them (Snyder-Reinke 2020). The rainmaking method invented by the mid-Qing scholar Ji Daqui serves as a typical example: Snyder-Reinke (2020) records multiple instances where local officials heard about the method and tried it, the method proved successful, and then they decided to disseminate the method through textual instructions.

From the above reviews, we can see that if some method within the possibility space was indeed effective (hypothetically speaking), it would almost certainly have been identified by the Chinese. Given that none of the methods were effective, why did people, including highly educated elites, mistakenly perceive efficacy in certain rain rituals and continue to pour significant material and temporal resources into pursuing such rituals? Why did individuals not adopt the obvious strategy of

17. *Ling* is sometimes translated as "supernatural efficacy." This is, however, imposing Western categories on Chinese concepts. Although *ling* is most often used to describe the efficacy of what we would categorize as supernatural entities and technologies, it is also used to describe fully natural methods such as herbal medicine.

18. 宋高僧传 (biographies of eminent monks of Song).

19. Tuo (2022:chap. 101).

20. Xu (2014:chap. 20).

21. Li (2004:chap. 281).

"doing nothing," which would have—as Xunzi pointed out in the third century BCE—provided the same results without the effort or expense? Granted, while doing nothing in the face of drought is not as cognitively salient as the elaborative rainmaking rituals, which were often performed and public, we have seen that scholars such as Xunzi did question the efficacy of these methods and certainly entertained the possibility that doing something was no better than doing nothing (see appendix). In the following sections we suggest two factors to help explain the persistence of ineffective rainmaking activities: some methods may have appeared effective purely by chance, and many rainmaking failures may have been underreported.

Empirically Successful Rainmaking Methods Arising Purely by Chance

Statistics as a discipline was formulated and mathematized rather late in history (MacKenzie 1988), and the concept of chance was poorly understood before the mid-seventeenth century (Hacking 2006). One aspect of rainmaking that many modern readers may fail to appreciate is that evaluating the efficacy of rainmaking methods is in fact a nontrivial statistical challenge that requires carefully controlled experimentation and analyses. Our scientific understanding of the world tells us that none of the ancient rainmaking methods work; people without such theoretical commitments, however, were faced with an inferential problem similar to what is now referred to as "multiple testing" (Miller 2012). Briefly, the problem is that when a large number of hypotheses were being considered simultaneously without control measures such as the Bonferroni correction (Armstrong 2014), some hypotheses may have appeared statistically significant simply by chance.

In the context of rainmaking, this means that some rainmaking methods may have appeared to be effective because many different methods were available on the market and some happened to obtain a successful track record by chance. Note that as a cultural species, people's ideas about what might work are mostly culturally transmitted. This fact, combined with individuals' idiosyncratic local environments, creates a large number of available methods.

A little formalization may be useful to demonstrate this phenomenon and provide some numerical intuitions. Suppose that there are N methods of rainmaking (identical in terms of their efficacy) under consideration. Each method is "experimented" n times, with the probability of "success" being P. The probability density distribution of the total number of successes of each method is a binomial distribution with parameters P and n. The expected number of methods with k out of n successes (a success rate of k/n) is thus

$$\binom{n}{k} \cdot P^k \cdot (1 - P)^{(n-k)} \cdot N. \quad (1)$$

Figure 1 provides a graphical illustration of the above equation. If the probability of success of each method, P, is set to be the same as chance (as we would expect from a modern perspective when it comes to rainmaking rituals), we observe that although most methods have a success rate lower than or close to chance, there will be quite a few methods with success rates significantly higher than chance. For example, if the chance of rain is 0.3, among the 100 rainmaking methods, we expect 10 with a 50% success rate, four with a 60% success rate, and one with a 70% success rate merely as a result of randomness. Therefore, some rainmaking methods may appear very efficacious, not because they actually influence weather but merely because of chance. Of course, keep in mind that if a method with a solid track record suddenly fails, there are many potential explanations, such as the incompetence or insincerity of a particular rainmaker.

Underreporting of Disconfirmatory Instances

A second reason why the efficacy of rainmaking protocols may be perceived to be higher than it actually is (chance) is that many of the rainmaking failures are not reported and thus not transmitted over time. There is evidence that some people may have been aware of such underreporting issues. For example, the Song historian and philosopher Lü Zuqian (1137–1181 CE) made the following statement when commenting on the Confucian text *Zuo Zhuan* (~500 BCE):

> Some people ask: "Zuo's record of crackmaking and milfoil divination cases were so amazing and spectacular; given such predictive accuracy, why are there so few [records] of them?" The answer: "From the Lord Yin till Lord Ai was a total of two hundred and twenty-two years. Kings, lords, dukes, the literati and the commoner perhaps made tens of thousands of divinations, and only tens of the efficacious cases were recorded in Zuo's book. These tens of the cases were collected in Zuo's book and therefore feel like a lot; if they were dispersed into the two hundred and twenty-two years it would feel extremely rare. If divination cases were of deceptive nature or had failed predictions, they would not have transmitted during their time and would not be recorded in the book. I do not know how many tens of thousands of them were missed. If we had all of them [recorded], they would not be so rare. (Lü 1988)[22]

Similarly, the famous Ming politician Zhang Juzheng (1525–1582 CE) commented on the then-popular practice of geomancy:

> Some people say: "Geomancers' words (predictions) often turn out to be true. If [they do] not [possess real abilities], how could they foresee what is going to happen in the future?" This statement is not true. . . . Suppose there is a place here, let three geomancers predict [whether it is suitable for placing a tomb]; one says it is auspicious, one says it is inauspicious, and the third says it is first auspicious followed by inauspiciousness. . . . If it turns out auspicious people will say the first geomancer made accurate predictions;

22. 东莱左氏博议.

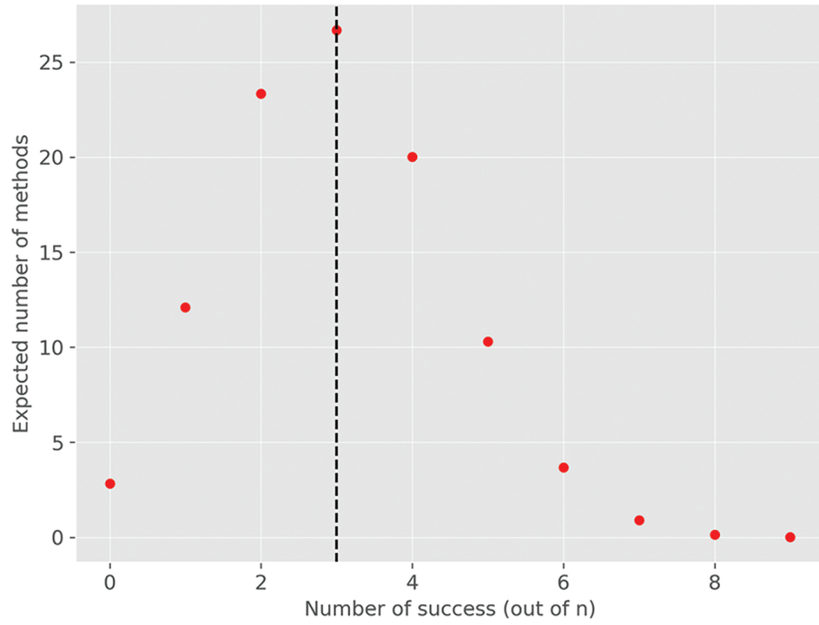

Figure 1. Graphical representation of equation (1) with illustrative parameter values: $n = 10$; $P = 0.3$; $N = 100$. The expected number of successes purely by chance ($x = 3$) is denoted by the dashed line.

> if it turns out inauspicious they will say the second geomancer made accurate predictions, and auspiciousness followed by inauspiciousness will be said to be predicted by the third geomancer. People transmit cases of accurate predictions and not cases of inaccurate predictions. That's why [predictive] failures are not heard and successes by chance stay/exist [in our society]. (Zhang 1935)[23]

Although Lü Zuqian and Zhang Juzheng are talking about divination and geomancy, the same argument can be easily applied to other instrumental activities, such as rainmaking. To obtain some quantitative information on the possible underreporting of rainmaking failures,[24] we compiled a data set using the digitized official Chinese dynastic records (*Twenty-Four Histories* plus *Draft History of Qing*),[25] which are systematic records of important people and events of the previous dynasty written by professional historians of the later dynasty (Wilkinson 2012) from the Chinese Text Project (ctext.org). Specifically, we searched for the keywords "to pray or request" (祈) and "to pray" (祷), collected all instances involving the prayer for rain or snow to occur or stop, and recorded whether an outcome was specified as well as the number of days it took between performing the ritual and the occurrence of the desired effect (e.g., rain, snow, or clear sky).

Table 1 summarizes the results. One clear trend here is that there are very few recorded failures and as a result many more successes, relatively speaking. What is particularly conspicuous is that a substantial proportion of the rainmaking outcomes are not reported. While we do not necessarily need to know the details of every rainmaking attempt, we are interested in whether failures are more likely to go unreported than successes, and there are a few reasons to think that this was the case. First, successful rainmaking was often viewed as a kind of achievement, and many rainmakers took pride in it (Snyder-Reinke 2020). These rainmakers were thus more likely to advertise their own success. Second, a suspicious pattern can be observed when we consider the days it took for an outcome to occur: there are many more rainmaking successes that occur shortly after (zero to one days) the rainmaking ritual than those with a longer delay. The phrase "on this very day" (是日) is often used, which gives an impression of an immediate weather response. In the Qing dynasty, where we have rather detailed records of the time it took for rainmaking efforts to take effect, 42.2% of the rainmaking successes occurred on the same day the ritual was performed, and the distribution has a rather long tail, with the number of days before rain, snow, or clear sky ranging from 1 to 30

23. 葬地论.

24. Note that these recorded rainmaking instances are quite special in that they come from the official dynastic records, which carry a certain authority. We suggest, however, that this sense of authority carried by transmitted texts is not unique to China: the authority of Aristotle in the West, e.g., has shaped our understanding of the causal structures of the world for thousands of years, and it was only rather recently (the scientific revolution in the seventeenth century) when we observed a profound shift in epistemology in Europe (Wootton 2016). Galenic medical theory similarly shaped subsequent medical practices in Europe well until early modern times (Hankinson 2009; Nutton 1972).

25. Books used for keyword search: *Shiji* (史记), *Han Shu* (汉书), *Houhan Shu* (后汉书), *Sanguozhi* (三国志), *Jin Shu* (晋书), *Nan Shi* (南史), *Bei Shi* (北史), *Sui Shu* (隋书), *Jiu Tangshu* (旧唐书), *Xin Tangshu* (新唐书), *Jiu Wudaishi* (旧五代史), *Xin Wudaishi* (新五代史), *Song Shi* (宋史), *Jin Shi* (金史), *Yuan Shi* (元史), *Ming Shi* (明史), *Qing Shigao* (清史稿).

Table 1. Outcome and accuracy of rainmaking data from Chinese dynastic records

Dynasty	Date (CE)	Total ritual attempts	Rain ritual success	Rain ritual failure	Success rate (%)	Outcome unreported (%)
Han (汉) and before Han	Before 220	17	15	0	88.2	11.8
Jin (晋)	266–420	2	2	0	100	0
N and S (南北朝)	420–589	23	18	3	85.7	13.8
Sui (隋)	581–619	2	0	0	NA	100
Tang (唐)	618–907	32	13	5	72.2	43.8
Five dynasties (五代)	907–960	38	8	2	80.0	73.7
Liao (辽)	907–1125	10	3	0	100	70
Song (宋)	960–1279	179	37	2	94.9	78.2
Jin (金)	1115–1234	59	11	2	84.6	78.0
Yuan (元)	1271–1368	25	18	1	94.7	24
Ming (明)	1368–1644	54	11	5	68.8	70.4
Qing (清)	1636–1912	146	54	2	96.4	61.6
Total		497	144	17	89.4	65.1

Note. N = northern; S = southern.

(fig. 2). This suggests that while cases of immediate success were unambiguously reported, the lack of immediate success was not interpreted and reported as failure; indeed, there is quite some room in attributing later rain to earlier rainmaking. On the extreme end, we see that a delay of as much as 30 days could still be said to be due to previous rainmaking efforts.

Such underreporting may have arisen for a number of reasons, including confirmation bias (Johnson 2017; Nickerson 1998) and the aforementioned availability and representativeness heuristics. Regardless of the initial cause, the consequence of underreporting is that naive individuals (readers of the dynastic histories) may erroneously conclude that rainmaking was highly effective even if they do not possess the cognitive biases. In other words, the tendency to underreport disconfirmatory instances creates a feedback loop in which the belief in the perceived efficacy of rainmaking (or any other technology) may be recursively boosted.

In the Background: A Supernatural Worldview

We should keep in mind that despite the sporadic skeptics (whose views were never very popular), most ordinary people in premodern China held a worldview in which spiritual agencies could respond to human requests and objects may stimulate one another on the basis of sympathetic principles. This meta-understanding of the world created strong content bias (Henrich and McElreath 2003) regarding the a priori plausibility of various kinds of rainmaking protocols. With the

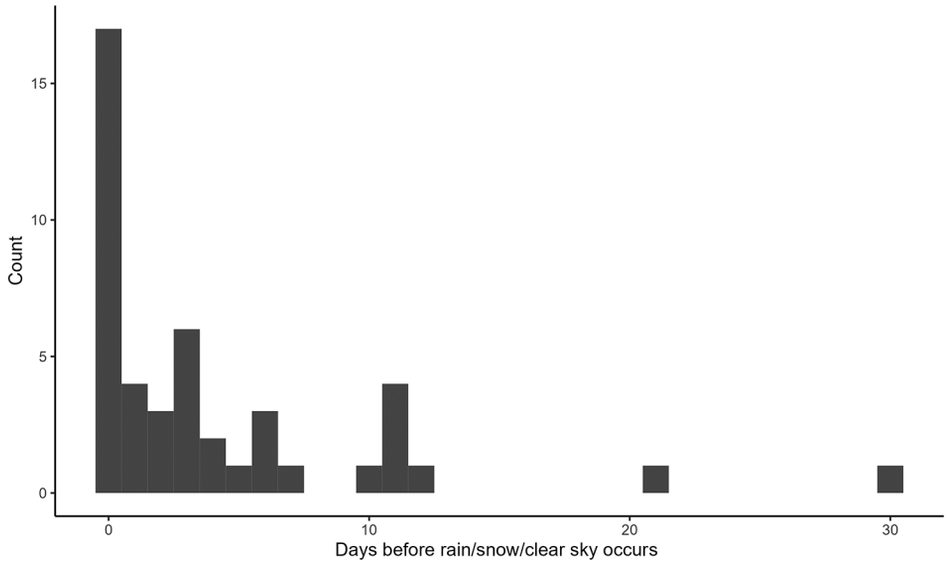

Figure 2. Number of days it took before the desired weather occurred, as recorded in the *Draft History of Qing*.

theoretical commitment of the existence of humanlike agencies, failures to bring about rain are more likely to be attributed to unpersuasive negotiations with the divine or to too much attention to the wrong deity.

This supernatural worldview is closely related to the literature that focuses on the intrinsic plausibility of cultural practices discussed in the beginning of the section "The Cultural Evolution of Rainmaking: All Magic and No Empiricism?" To reiterate, this literature within evolutionary psychology and anthropology has treated the content-specific biases regarding why we find particular cultural practices plausible as largely a result of genetically evolved causal intuitions (Boyer 2020; Miton, Claidière, and Mercier 2015; Singh 2017). We would like to point out that although such a supernatural worldview is certainly supported by innate intuitions, it is also subject to systematic cultural input and may change as a result of cultural influence. As we will show, this was exactly what happened during the turn of the twentieth century: the replacement of the supernatural worldview with the scientific-mechanistic finally led to the full rejection of ineffective rainmaking rituals. It was not the case that the Chinese suddenly had good data to distinguish ineffective from effective rainmaking methods. Rather, a mechanistic understanding of the world that categorically denied their plausibility increasingly supplanted earlier worldviews.

The Decline of Rainmaking: A Rejection Based on Theory

The persistence of various rainmaking methods throughout Chinese history and across the world is remarkable and has been extensively studied. Yet their relatively sudden decline has received much less scholarly attention.[26] This is unfortunate since the conditions under which many people came to no longer believe in these objectively ineffective methods provide crucial insights into the psychological and sociological mechanisms that had sustained them for millennia (e.g., table 1). On the surface, the dramatic decline of ancient rainmaking and other magical practices took place in the late nineteenth and early twentieth centuries, as China gradually modernized under Western cultural influences. Rainmaking, along with many other ancient practices, was deemed "superstitious" and replaced with modern technologies that, unlike magic and divination, often had both materialist theoretical explanations and systematic empirical grounding.

This account is largely accurate, but it misses some key information regarding the social dynamics during this cultural transition. How did China modernize, and what exactly happened to the ancient beliefs and practices? We suggest that the decline of traditional rainmaking was ultimately due to the rejection of traditional theories of rain at the elite level, and then modern scientific theories of weather phenomena were disseminated through institutional channels such as mass education. In other words, it was not the case that people somehow realized that various traditional rainmaking efforts did not perform any better than chance on the basis of data, but rather that the imposition of a different worldview made the traditional theories behind these rainmaking efforts seem implausible.

From the late Qing to the early nationalist era, Western scientific ideas spread quite rapidly, as people were impressed by the superiority of Western technological and scientific achievements (Cheng 1960). During the same era, students were sent to the United States and Europe to study science and applied technology (Deng 1995; Xiu-li 2008); most of them returned to China, and many held important positions in the subsequent nationalist government (Wei 2008). Regarding rainmaking, many Western-educated Chinese scholars either publicly or anonymously voiced their criticism by emphasizing the implausibility of weather being controlled by gods and deities and often offered alternative, more naturalistic theories of rain. For example, in 1908, the influential early modern intellectual Hu Shi made the following comment on traditional rainmaking methods:

> When there is a drought, people want to pray for rain; but who do they pray to? Maybe praying to Heaven and Earth 天地? Yet heaven is but a puff of air, and earth is but a globe. Maybe to the Jade Emperor? To the Dragon King? Yet, the Jade Emperor and Dragon King are made of wood and mud and they know nothing [about weather]. (Hu 1908)

Others explicitly articulated alternative, scientific theories of rain. In 1926, Harvard-educated geologist and meteorologist Zhu Kezhen published an article repudiating the traditional rainmaking practices and explaining the natural causes of rain—that is, the current scientific take on rain:

> Rain comes from the water vapor in the air. All air that is close to the Earth contains water vapor; not only air above the sea, but also air above the desert. Whether it rains or not depends on the condensation of water vapor into water. The lower the temperature of the air is, the less it contains water vapor. . . . Therefore low air temperature is the necessary condition for rain. (Zhu 1926)

26. Note that, strictly speaking, traditional rainmaking still exists in both China and elsewhere in the world, just as astrology and other "superstitious" practices still have their market. In any society with a sufficiently large population and complex social structures, there are going to be people who commit to different epistemologies and practice nonmainstream practices. In the United States, e.g., a small yet often vocal minority holds beliefs to the contrary of scientific consensus (e.g., anti-vaccination beliefs) despite the spectacular scientific and technological advances the United States has experienced during the past few centuries. However, if we look at the larger picture, there is a genuine, qualitative difference in the public understanding and practice of rainmaking between traditional China and modern China precisely because of a worldview shift. Even in the case of Taiwan, where traditional rainmaking (praying to deities) is more frequent and is sometimes attended by public officials, surveys show that only a minority expects the rainmaking ritual to be "efficacious," and there is often public pressure from intellectuals that discourages high-level government officials from attending these "superstitious" rituals (Wu 2021).

A particularly telling example occurred during a severe drought in southeastern China in 1934. The long-lasting drought caused much desperation, and many traditional rainmaking practices were conducted in various localities (Ai 2010). In Shanghai, philanthropists, entrepreneurs, and some local activists organized a fundraising event and invited the "Heaven's Master Zhang"(张天师) to perform a rainmaking ritual. The ritual was in fact a "success": rain indeed came afterward (Hu 2017*b*). In traditional China, this would no doubt have been touted as proof of the rainmaker's capacity to induce rain and the effectiveness of the rainmaking method. The reaction from many Western-educated intellectuals at the time, however, was one of criticism, ridicule, and sarcasm (Hu 2017*a*). The following derisive comment in the leading newspaper at the time, *Shun Pao*, exemplified a common attitude:

> During the drought this year, the Soviet Union spent such time and money to invent artificial rainmaking; our 63rd generation Heaven's Master just needed to step onto the podium and exercise his magical power, didn't heavy rain fall as well? But it is told that Heaven's Master Zhang for some reason has attempted suicide five times; I hope that he passes all his magical apparatus to the 64th generation before he dies. (Sanduo 1934)

By this time, although uneducated laypeople still maintained some of the traditional beliefs, the educated elites had rejected them on theoretical grounds. Therefore, any observed success could be only incidental and not due to the causal influence of rainmakers. A keyword search of "praying for rain" (求雨) in the Shanghai Library Chinese Periodical Full-Text Database shows that in the year 1934, 44% of the articles expressed obvious negative attitudes toward traditional rainmaking activities out of a total of 66 occurrences, and among the disapproving articles, the vast majority (90%) did not mention any actual rainmaking failures. Rather, many of the articles explicitly labeled traditional rainmaking as "superstition" (迷信) and those peasants who believed in it "stupid people" (愚民). How was the elite-level skepticism during this time different from the sporadic skepticism of earlier eras? We suggest two key differences. First, the shock of Western superiority that hit China was so profound that it fundamentally rattled many people's faith in traditional Chinese culture in general. Thus, many intellectual elites adopted entire sets of cultural beliefs and value systems from the West, which led to a total rejection of the theoretical core of traditional Chinese divination, rainmaking, and other magical practices (Spence 1982)—a case of prestige-biased transmission (Henrich and Gil-White 2001). Second, these elites—given the power of the Chinese state—were in a position to quickly and efficiently spread new worldviews through institutions such as modern schools, universities, and government agencies.

The elimination of ineffective rainmaking methods and the realization of the superiority of the do-nothing strategy, therefore, should be viewed as the result of a group-level process. That is, it was caused by the spread of the materialistic and scientific worldview from western Europe to other parts of the world. Within-group cultural evolutionary forces such as payoff-biased transmission often fail to pick up the do-nothing among many do-something strategies. This is because the do-nothing strategy does not benefit from the underreporting of disconfirmatory evidence (in fact, in this case positive instances are likely to go underreported, as they are less likely to be noticed), and as a single strategy with low salience, it is unlikely to appear efficacious by chance. Again, people do care about outcomes, but the empiricism in traditional societies works better when the optimal variant is of a do-something nature.

One of the prominent features of modern science, we argue, is that it denies the causal relevance of magical action and alleged outcomes, thus making the do-nothing strategy the only scientifically defensible alternative. However, it is worth noting that the do-something bias is so powerful that we can still see it skewing behavior in modern societies: as a recent newspaper article notes, the modern version of rainmaking, seeding clouds with chemicals to induce precipitation,[27] is practiced quite widely across modern China. This is despite evidence that it is efficacious only in, at best, very specific circumstances and that overall the costs of the practice appear to greatly outweigh the benefits (*Economist* 2021). If an ineffective do-something strategy can prevail in modern China, even with the benefit of detailed data gathering and modern scientific models, the longevity of traditional rainmaking practices is not at all surprising.

In fact, rejection of a set of previously accepted practices due to a shift in worldview was likely a general feature in the evolution of ineffective instrumental practices. In his most celebrated book, *Religion and the Decline of Magic*, Keith Thomas penetratingly concludes that

> once their initial premises are accepted, no subsequent discovery will shake the believer's faith, for he can explain it away in terms of the existing system. Neither will his convictions be weakened by the failure of some accepted ritual to accomplish its desired end, for this too can be accounted for. . . . The reaction against magic could thus never come from the cumulative resentment of disappointed clients. It had to arise from outside of the system altogether. (Thomas 2003:767)

Subsequent work in the history of science largely corroborates this claim. It was suggested that astrology in seventeenth-century England, for example, be rejected on nonempirical grounds, as what it would take to test the core tenets of astrology was simply unavailable at the time (Kemp 2003). Similarly, the decline of alchemy was attributed to a change in the larger sociocultural context rather than to its empirical inadequacies (Clements 2017). As in the case of

27. In contrast with traditional rainmaking, which involves praying to deities or sympathetic magic, cloud seeding, whatever its actual efficacy, is distinct in being theoretically plausible within the modern scientific, mechanistic worldview.

rainmaking, a mechanistic worldview renders such traditional practices implausible.

Conclusion

In this paper, we focus on the nature of rainmaking rituals in traditional China and argue that they have always been understood as instrumental activities to induce rain, as strongly supported by the extensive historical records and the extant studies of Chinese rainmaking. We further argue that despite the existence of payoff-biased transmission, which usually produces adaptive cultural practices, certain psychological and social factors nonetheless can maintain such ineffective technologies as people fail to realize the superiority of the do-nothing strategy while under a supernatural worldview. Thus, the dramatic decline of ineffective rainmaking requires a rejection of the underlying theories of rain. In China, although antisupernatural, mechanistic theories of the world were available to elites as early as the third century BCE, widespread theoretical rejection had to wait more than two millennia, until contact with the West. It is worth exploring in more detail the economic, political, and cultural factors that finally allowed the successful diffusion of a mechanistic and materialistic worldview of natural phenomena at this point in Chinese history, but our view is that prestige-biased transmission played an important role.

Although we have exclusively focused on rainmaking in premodern China, our proposed cultural evolutionary explanations for the persistence of rainmaking rituals hold for ineffective technologies in general. Shang oracle bones, for example, contain many rain-related predictions (whether it will rain on a certain day) and sometimes have "verifications" (whether it indeed rained on that day), and the vast majority of the recorded outcomes are confirmatory (Keightley 1985). More generally, whenever there is a need to achieve some desirable outcome or to avoid an undesirable one, there will be an incentive to perform some (costly) technology or practice and potentially many technologies or practices deemed plausible under some larger worldview. Furthermore, when the outcome is probabilistic, people may overestimate the efficacy of these technologies either because of chance or because many of the disconformatory instances were omitted and lost during cultural transmission. Oneiromancy (Hong 2023), fetal sex prognostication (Hong and Zinin 2023),[28] traditional healing (appeasing ghosts or spirits to cure illness), and many other forms of magic prevail largely for these reasons. Note that the two proposed factors that bias efficacy perception—statistical artifacts and underreporting of failures—are but two features (among many others) of the underlying cultural evolutionary processes (Hong and Henrich 2021), and a complete understanding of ineffective technologies, past and present, would require an understanding of the evolved intuitions, the population dynamics of information transmission, and the larger social context in which such transmission occurs.

28. Gender-related divination was also common in China (Li 2015); once the gender of the baby is believed to be revealed, one can decide whether to keep it (in the case of a boy) or to abort it (in the case of a girl).

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Comments

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Most divination and magical procedures focus on inscrutable present states of affairs (e.g., Is this person a witch?), so they do not make predictions about future observable events. But the ones that do trigger the inevitable question of empirical refutation. Hong, Slingerland, and Henrich are quite right to reject the traditional anthropological hand-waving around that question. In the same way that people really want to know the true state of affairs about witchcraft (see, e.g., Boyer 2020; Holbraad 2012; Myhre 2006), they really want to affect the weather. So it makes sense to ask what psychological processes lead to sustained belief in the face of poor empirical support. The authors provide very clear evidence that the concern for empirical validation, far from being an outsider's preoccupation, was crucial for Chinese scholars who commented on rainmaking. The authors should also be commended for avoiding an easy way out—for example, stating that people are just swayed by confirmation bias or low rationality standards—and for providing a detailed account of the various statistical artifacts that can lead to an inflated estimate of the efficacy of rainmaking. This very lucid and important article raises questions to do with the sources and the cultural evolution processes.

One may wonder to what extent the sources examined here constitute a rather exceptional sample. These are not just written but also mostly scholarly sources, and they come from a cultural tradition in which systematicness and numeral patterns are highly valued. That is why the sources provide such rich material for Hong, Slingerland, and Henrich's detailed analysis. It is possible, even probable, that most rainmaking in peasant communities, away from such literate specialists, involved much cruder confirmation estimates. This is not to deny the relevance of such scholarly materials—quite

the opposite. Precisely because of their focus on coherence and quantitative evidence, the scholars painted themselves into a corner, so to speak, and had to confront the question of efficacy instead of avoiding it. Still, these cultural operators were mainly commentators. That is, they were not engaged in actually prompting gods and natural forces to bring rain but commented on those who were so engaged. Does that make a difference? That is an empirical question that specialists of that literature should perhaps address.

Hong, Slingerland, and Henrich describe the process of cultural evolution, in this domain, in terms that need some elucidation. For one thing, they state that "although . . . practices may spread successfully because they fit our psychological intuitions, there has always been a great deal of empiricism . . . in any instrumental activity." This is puzzling and would require some elaboration. Most of our evolved psychological dispositions are geared to fitness maximization and by consequence would certainly overlap, to a large degree, with "empiricism," understood as the detection of actual causal regularities in our social and natural environments (Shepard 1994). The kind of payoff bias described by Boyd and Richerson is precisely a biological account of (some aspects of) that overlap, it would seem.

A more difficult question is that of the connection between cultural input and people's representations. Hong, Slingerland, and Henrich create a dichotomy where we may not need one when they argue that the supernatural worldview "is certainly supported by [evolved] intuitions, [but] it is also subject to systematic cultural input" ("In the Background: A Supernatural Worldview"). (I substituted the term "evolved" for "innate," which is misleading in so many ways.) It is not clear why this evolved and cultural distinction is necessary here. People certainly attend to "cultural input"—but they do that because of evolved dispositions to attend to such input, to attend to some of it preferentially, and to derive highly specific consequences from that input. That is a clear implication of dual-inheritance models (Boyd and Richerson 2005) or of epidemiological ones (Claidière, Scott-Phillips, and Sperber 2014; Claidière and Sperber 2007).

This is not (or not just) mere quibbling because this question of transmission is related to the authors' description of the relations between people's perception of efficacy in rainmaking, on the one hand, and more general commitment to what they call a supernatural worldview, which provides a meta-understanding of causal processes, on the other ("In the Background: A Supernatural Worldview"). In the perspective presented here, there is a quasi-deductive relation between very general commitments (people, e.g., believe in the existence and causal powers of gods or in the existence of natural impersonal forces), on the one hand, and more specific beliefs (e.g., that specific rainmaking procedures may well be efficacious). The more global beliefs are there to start with and support the more specific ones.

From a cognitive standpoint, that may seem puzzling. Most people engaged in rainmaking, it would seem, trust the procedure (to some extent) because they have socially transmitted information about its efficacy. It seems just as likely that such beliefs in local, specific causal processes in fact contribute to the general plausibility of beliefs in gods, impersonal forces, and so on. True, one may well say that all these are mutually supportive in some kind of feedback or circular justification. But the authors' materials would seem to indicate that the inductive route (actual, observed success in rainmaking adds support to the existence of gods, their powers, etc.) is more generally plausible. People's concern with actual, quantitative estimates of success would suggest that they provide the evidence. If a supernatural worldview sufficed, then concerns about empirical validation of the procedures would not occur or would be less salient.

One could raise the same question about the short discussion of the demise of traditional rainmaking. The authors point out, very convincingly, that the elites' role in that process may have been crucial ("The Decline of Rainmaking: A Rejection Based on Theory"). But again, the process may have been considerably boosted by the kind of "payoff sensitivity" bias described above. In that view, nonelite people were much less convinced of the powers of rainmakers because of the introduction of better technologies, and this (among many other factors) would contribute to the demise of the supernatural worldview in general. It is to the authors' credit that they present these rich materials in a way that directly raises and addresses crucial questions concerning the cultural evolution of symbolism and technology, some of which could not be mentioned in the space of this short commentary.

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Do the Skies Themselves Send Down Showers?

> TO ALL TO WHOM THESE PRESENTS SHALL COME:
> WHEREAS, the state is in the midst of an exceptional drought, with some parts of the state receiving no significant rainfall for almost three months, matching rainfall deficit records . . . and
> WHEREAS, a combination of higher-than-normal temperatures, low precipitation and low relative humidity has caused an extreme fire danger over most of the State, sparking more than 8,000 wildfires which have cost several lives, engulfed more than 1.8 million acres of land and destroyed almost 400 homes, causing me to issue an ongoing disaster declaration since December of last year; and

> WHEREAS, these dire conditions have caused agricultural crops to fail, lake and reservoir levels to fall and cattle and livestock to struggle under intense stress, imposing a tremendous financial and emotional toll on our land and our people; and
> WHEREAS, throughout our history, both as a state and as individuals, Texans have been strengthened, assured and lifted up through prayer; it seems right and fitting that the people should join together in prayer to humbly seek an end to this devastating drought and these dangerous wildfires;
> NOW, THEREFORE, I, . . . Governor of State, under the authority vested in me by the Constitution and Statutes of the State, do hereby proclaim the three-day period . . . as Days of Prayer for Rain in the State. I urge citizens of this State of all faiths and traditions to offer prayers on that day for the healing of our land, the rebuilding of our communities and the restoration of our normal way of life.
> IN TESTIMONY WHEREOF, I have hereunto signed my name and have officially caused the Seal of State to be affixed at my Office. (Wilonsky 2011)

After reading the important article by Hong, Slingerland, and Henrich, you might assume that this rainmaking ritual comes from a society that lacks a system of widespread formal education and access to modern scientific methods and technologies. But as it turns out, one does not need to rely on evidence from ancient China to test the hypothesis Hong, Slingerland, and Henrich convincingly argue for, namely, that a commitment to a supernatural worldview provides theoretical support for the plausibility of various rainmaking methods and that people overestimate the efficacy of rainmaking technologies because of statistical artifacts and the underreporting of disconfirmatory evidence. The rainmaking ritual above was sanctioned by Governor Rick Perry of Texas over a decade ago on April 21, 2011 (Wilonsky 2011). Texas has the ninth-largest GDP in the world and the second largest in the United States, made possible by heavy investment in cutting-edge technology. The event above had rainmaking as an explicit instrumental goal, making arguments that this was merely a symbolic activity implausible.[29]

Perry's rainmaking ritual has much in common with the rainmaking technologies described by Hong, Slingerland, and Henrich. It is based on a supernatural worldview, is time-consuming, is effortful, and gives people an opportunity to "do something."

In the case of Chinese rainmaking rituals, the authors propose an explanation based on a combination of errors or biases in information processing (e.g., the illusion of control, availability heuristics, and representativeness heuristics) and group-level processes: statistical artifacts (i.e., the number of simultaneous rain-promoting rituals that are practiced and evaluated) and underreported results. In the case of this Texan rainmaking ritual, similar biases and heuristics apply. The underreporting of disconfirmatory evidence certainly applies. There was precious little media coverage of the fact that it was many months after this event before the rains came to Texas.

A commitment to a supernatural, in this case Christian, worldview is widespread among the political leadership and citizenry of Texas. References to God as an agent with the capability of controlling the weather are pervasive in biblical scriptures: "When he thunders, the waters in the heavens roar; he makes clouds rise from the ends of the earth. He sends lightning with the rain and brings out the wind from his storehouses" (Jeremiah 10:13). "He provides rain for the earth; he sends water on the countryside" (Job 5:10). "He wraps up the waters in his clouds, yet the clouds do not burst under their weight. He covers the face of the full moon, spreading his clouds over it" (Job 26:8–9). "I will send you rain in its season, and the ground will yield its crops and the trees their fruit" (Leviticus 26:4).

One also does not need to rely on anecdotes from modern-day Texas to test the hypothesis that Hong, Slingerland, and Henrich propose. In previous research in a very different cultural, religious, and historical context, modern-day Brazil, we studied the cognition underlying perceptions of ritual efficacy. *Simpatias* are ritualistic remedies widely used in Brazil that are causally opaque; they lack obvious causal mechanisms. They are, however, very detailed in terms of procedure, timing, and artifacts. Our data from research on reasoning about the efficacy of simpatias are consistent with Hong, Slingerland, and Henrich's thesis. First, our intuitive causal reasoning explains why we overestimate the efficacy of ritualistic technologies (in our case, simpatias). Procedural specificity, rigidity, and repetition all increase the perception of the efficacy of rituals used to treat instrumental problems, as does the presence of a religious icon (Legare and Souza 2012, 2014). Note that simpatias exist exclusively to solve instrumental problems; people perform them because they think that, in principle, they might have a (causal) effect. There are also multiple ways people who use simpatias use to explain when they (often) do not produce the desired outcome. Lack of faith and the presence of doubt feature heavily in post hoc rationalizations for their lack of efficacy, as does a failure to adhere carefully enough to the precise ritual protocol. There is not always the expectation that they will work immediately, which contributes to the underreporting of disconfirmatory evidence (the second part of the Hong, Slingerland, and Henrich thesis).

In more recent work, we have studied instrumental rituals associated with the perinatal period in northern India. We have documented dozens of ritualistic practices that pregnant women and their families engage in with overtly instrumental goals. There is perhaps nothing with higher stakes than pregnancy and childbirth. Thus, the rituals of this period

29. Interestingly, Governor Perry was not the first to organize state-sanctioned rainmaking rituals in the United States. Georgia governor Sonny Perdue organized an event in 2007 to "very reverently and respectfully pray up a storm" (ABC News 2009; see also CBS News 2007).

overwhelmingly have overly instrumental goals, including preventing miscarriage, birth defects, and maternal and child mortality. Explaining these practices as purely symbolic is wildly improbable. Note that engaging in ritual practices associated with traditional medicine and religion does not dissuade mothers from engaging in biomedical practices using modern technology. Traditional medicine and biomedicine are both widely used in these communities to prevent negative outcomes and promote positive outcomes (Legare et al. 2020).

Just as traditional medical and biomedical technologies coexist in northern India, ritualistic practices that originate from religion and science coexist in all modern-day human cultures. Humans are pragmatists and deploy a suite of culturally sanctioned practices to treat their problems, both mundane and profound.

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The Sciences' Institutional Forms and Established Procedures Help to Guard against Confirmation Bias

Hong, Slingerland, and Henrich (HSH) examine the persistence of rainmaking across the history of China to illustrate how learning mechanisms that produce adaptive cultural products can sometimes also spawn and sustain maladaptive practices. The particular learning mechanism on which they focus is payoff-biased transmission, which favors arrangements that yield comparatively greater levels of "perceived success."

Since it concentrates on arrangements' outcomes, payoff-biased transmission, ceteris paribus, seems unproblematic. Difficulties for this "population-level" process arise, though, from discrepancies between what humans apprehend as successful and what is, in fact, advantageous. HSH demonstrate that even in a case as straightforward as assessing the relative merits of various rainmaking technologies, humans' cognitive predilections distorted their judgments about those technologies' efficaciousness. HSH emphasize two things. The first is humans' inattentiveness to the possibility of some effect occurring simply by chance. This is of a piece with Kahneman, Slovik, and Tversky's (1982) famous research on humans' woeful ability to handle probabilities. The second concerns humans' comparative inattentiveness to proposals' failures as opposed to their successes.

HSH illuminate one implication of that second penchant, identifying another hitherto unnamed cognitive bias in the bargain. They maintain that payoff-biased transmission, in combination with a bias to do something about prominent problems, results not just in people's disinclination to do nothing in such circumstances, but also in their failure to appreciate the merits of inactivity. They observe that doing nothing "does not benefit from the underreporting of disconfirmatory evidence" the way that programs for doing something do and that "positive instances are likely to go underreported, as they are less likely to be noticed." Since in the face of salient challenges people rarely do nothing, either consciously or deliberately, HSH may be underestimating the negative consequences of "positive instances" for doing nothing—that is, when notable problems (e.g., lack of rain) are resolved while doing nothing. Typically, when a salient problem is resolved even though people are doing nothing, they often begin searching either for what it is that they did unintentionally or for what happened that caused that result. In effect, they spontaneously start theorizing about what to do thereafter, in the event that that problem occurs again.

Neglecting disconfirming evidence is the flip side of confirmation bias. Confirmation bias is a preoccupation with findings that square with existing beliefs or support favored hypotheses at the expense of heeding contrary evidence. Bureaucratic recordkeepers across Chinese history did not have the corner on confirmation bias. Research in cognitive science indicates that the phenomenon is ubiquitous (Gilovich 1991; Nickerson 1998). That includes among scientists. That is not too surprising given the time, effort, and resources scientists invest in their research. They are reluctant to discard their preferred hypotheses on the basis of some negative findings. They have considerable incentive to explain negative outcomes away and numerous means for doing so, whether by pointing to flawed designs, untidy measurements, unreliable apparatuses, or problematic analyses.

Confirmation bias's ubiquity suggests that it may not be completely outlandish to wonder whether it too may be an evolved cognitive heuristic. If implementing a technique for dealing with some practical problem results in a positive outcome, especially in a domain where people recognize that they have little causal understanding, confirmation bias might just serve for dealing with the question "What to do?" (as opposed to the question "Why does it work?"). After all, the principal concern is with whether the technique works, not whether its accompanying conceptual framing gets the world right. Finally, though, it is susceptible to contributing to the evolution of maladaptive practices since, ultimately, answering correctly why things work nearly always yields the best technologies.

According to HSH, holding a "supernatural worldview" is as good for eliciting confirmation bias as explicitly recognizing lack of causal insight, if not better. (Notably, both are likely to elicit a more faithful normative—as opposed to instrumental—imitative stance in learners [Legare et al. 2015; Whitehouse 2021].) Supernatural worldviews lent plausibility to rainmaking techniques. Not only do supernatural agents stand behind the causal accounts that many rainmaking techniques presume, but also, supernatural worldviews provide two auxiliary hypotheses for explaining any failure away: (1) rainmakers have appealed to the wrong supernatural agent and (2) rainmakers or their sponsors have, because of some consideration (e.g.,

insincerity), inadequately petitioned the (proper) supernatural agent.

HSH assert that scholars have accorded less scrutiny to traditional rainmaking techniques' rapid decline. To explain that, HSH champion the pervasive influence of dominant worldviews. Appealing to prestige-biased transmission, they contend that Chinese elites rejected supernatural frameworks in favor of Western science's mechanistic account. Traditional rainmaking techniques were overthrown not by the more careful recording and analysis of data, but, instead, by the rise of a new worldview (a competing theory)[30] that the prestigious deemed superior.

How broadly do HSH wish to apply their explanatory strategy? Their assertion that "cultural evolutionary explanations for [their] persistence . . . hold for ineffective technologies in general" presumably also applies to those technologies' demise. But do those explanations also cover the persistence and (subsequent) decline of what the sciences come to construe as unsatisfactory theories? That HSH speak of "a rejection based on theory," that they compare the fate of traditional rainmaking to the fates of astrology and alchemy, and that scientists are also susceptible to confirmation bias might suggest so.

Two considerations recommend caution. First, the cases of astrology and alchemy (for different reasons) may be unrepresentative of modern science once it has achieved an institutional form and established procedures. On the basis of fine-grained analyses of eighteenth-century chemistry, Paul Thagard (1992) argues that Thomas Kuhn's (1970) depiction of revolutionary science as conflict between utterly incompatible paradigms is overblown and that theory succession occurs more rapidly and less sensationally than Kuhn proposed. Second, the continuing evolution of the scientific community's institutional forms and established procedures has yielded cultural arrangements that collectively work to guard against the biases that can taint individual scientists' and research groups' probabilistic and conditional reasoning (McCauley 2011).

Reply

We are grateful for the thoughtful commentaries, which not only offer critical and constructive feedback but also enrich our discussion with relevant insights. The commentators recognize the value of our cognitive approach and raise pertinent questions that merit further investigation.

Boyer importantly points out that our analyses rely entirely on written, scholarly sources and that the authors of these written records were mostly commentators rather than practitioners of rainmaking. We acknowledge the selectivity of our data and the potential differences in cultural transmission dynamics in oral, face-to-face situations. As such, our analysis should be taken as an illustrative historical example that complements existing work on cultural transmission and the adoption of technological practices. There are reasons, however, to suspect that some of the proposed mechanisms that bias people's efficacy perception may be quite general. Reporting bias, for example, has also been documented in traditional, small-scale (Hong 2022*b*), and contemporary modern societies (de Barra 2017).

As if responding to these concerns, Erut and Legare offer helpful illustrations in modern contexts. Indeed, Governor Rick Perry's official state proclamation calling everyone to pray for rain was widely covered in both the Texas and national press. However, what received much less coverage was the utter failure of this rainmaking ritual. In fact, four months after the presidential candidate's three-day call to prayer, Texas experienced the hottest July on record and remained completely drought stricken. Similarly, Georgia's governor Sonny Perdue led a crowd of 250 people in a rain prayer as his state faced the worst drought in a half century. About two weeks later some rain did arrive, but 2007 still finished as one of Georgia's driest. On cue, some observers, particularly those with a Christian worldview, felt that two weeks was "close enough" and declared victory for the prayer ritual.[31]

Erut and Legare also point to fascinating research on the efficacy of Brazilian simpatias (Legare and Souza 2012) and ongoing work on pregnancy-related rituals in India. These lines of research converge with our own (Hong 2022*b*; Hong and Henrich 2021) to suggest that many rituals are viewed instrumentally by participants but (on the basis of the best science available) represent persistently ineffective technologies. The scientific question we wish to highlight is why such rituals would persist given that, as Boyer emphasizes, "our evolved psychological mechanisms are geared" toward "empiricism."

In the case of American rainmaking rituals, we note that in societies where politicians need to appeal to the masses, there is often an incentive for them to act in ways that resonate with public beliefs, such as demonstrating concern for their needs, and this is why rainmaking as well as many other ritualistic practices has been suggested to serve political ends. The elite-mass dynamics suggest that the belief in the efficacy of rainmaking among the masses may drive political leaders to engage in such rituals, creating a feedback loop that reinforces these beliefs. After 2016, Perry and Perdue were appointed by the Trump administration to lead the Departments of Energy and Agriculture, despite their failed rainmaking efforts. We hope that future work will explore how such political entrepreneurship interacts to sustain or diminish such beliefs.

30. The subtitle of the section "The Decline of Rainmaking" is "A Rejection Based on Theory."

31. https://christianindex.org/stories/as-georgias-governor-sonny-perdue-once-led-a-prayer-service-for-rain-it-rained,1223.

Boyer raises concerns about the distinction we make between "empiricism" and "intuition." We are delighted that Boyer raised this issue, as it gives us a chance to clarify an ambiguity in our terminology. By "empiricism" we refers to the cognitive processes that rely on external sensory experience, which, in the rainmaking context, refer to the perceived successes and failures of rainmaking. This captures any of our learning mechanisms that can respond to success and failure information, either directly (e.g., observation) or indirectly (learning from successful farmers or rainmakers). By contrast, "evolved intuition" refers to people's evaluation of the plausibility of various kinds of rainmaking methods in the absence of success and failure input. Crucially, these mechanisms do take in external stimuli but do not use success and failure information. Cultural evolutionists have long argued that humans reliably develop intuitions that make some beliefs more likely or more believable than others (Boyer 1993; Henrich and McElreath 2003). Precise models have explored what happens when the output of our evolved intuitions is at odds with that of mechanisms tuned to the current empirical world (Henrich, Boyd, and Richerson 2008; Hong and Henrich 2021).

Regarding the epistemic relationship between general theoretical commitments (supernatural worldviews) and specific local beliefs (rainmaking rituals), Boyer suggests that the inductive route is more plausible. While it is true that specific rainmaking successes can serve as evidence for the existence of deities, rain producing is only one among the many duties that these deities are believed to be responsible for; therefore, no amount of rainmaking failure could definitively disprove the existence of deities. However, a supernatural worldview posits only that it is possible to induce rain by negotiating with the deities, and people are left to wonder what specific method would be the most effective to achieve this end—this is where empiricism comes in.[32] Crucially, as Perry demonstrates, rainmaking practices readily reassert themselves as soon as one believes that supernatural agents control the weather.

The commentary by McCauley makes two valuable points. First, he highlights people's inclination to do something rather than nothing in the face of practical problems that need to be resolved and rightly points out that this inclination also encourages individuals to retrospectively infer what they (unintentionally) did when problems solve themselves. Indeed, such retrospective inference may serve as a cognitive engine that produces cultural beliefs that are factually incorrect (Hong 2022*a*). We agree that this is an important factor to consider.

In affirming the ubiquity of confirmation bias (this might be a topic of productive conversation between McCauley and Boyer), McCauley suggests that modern science may possess unique attributes that help avoid confirmation bias and that astrology and alchemy may be unrepresentative of modern science. We would like to clarify that we certainly do not think of astrology and alchemy as "modern" for the reasons McCauley suggests and that there is indeed something special about how modern science organizes itself and generates reliable knowledge. In our previous work, we emphasize that modern science as an institution produces knowledge in a systematic manner (e.g., randomized, controlled trials and meta-analysis) that aims to avoid various biases as a community (Hong and Henrich 2021). Of course, this is not to say that science is completely free of confirmation biases and the like, merely that the epistemic ideal in modern science and the conscious effort by scientists to mitigate biases create a much more epistemically secure environment for knowledge production.

We are encouraged to see a recent econometric analysis of rainmaking (Espín-Sánchez, Gil-Guirado, and Ryan 2023) and hope that our paper can inspire more systematic empirical studies of this fascinating topic. Again, we thank the commentators for their contributions and look forward to continued scholarly dialogue on this topic.

—Ze Hong, Edward Slingerland, and Joseph Henrich

32. For similar epistemic dynamics in dream divination and fetal sex prognostication, see Hong (2022*a*) and Hong and Zinin (2023).

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