

From the Impossible to the Improbable: A Probabilistic Account of Magical Beliefs and Practices Across Development and Cultures

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Like scientists, children and lay people are eager to build theories in order to make sense of their surrounding environment (e.g., Furnham, 1988). The scholars studying such lay theories like to draw suggestive parallels between scientific and lay theories: although the latter and the former have some undeniable dissimilarities, it is often remarked that they also share a great deal of commonalities (for a discussion, see: Gopnik, Wellman, & Kuhl, 1999; Kuhn, 1989). Interestingly, the domain of magic seems to provide a nice counterexample. Lay people uniquely develop complex theories—with no significant scientific counterparts—aiming to explain special features of “supernatural” events and beings.

Previous studies have demonstrated that lay people often develop distinct competing theories to explain the world. These lay theories are variably distributed across individuals, contexts, occupations, social groups, and cultures (Dweck, 2006; Markus & Hamedani, 2007). This chapter focuses on the “building blocks” of lay theories of magic. Existing studies on supernatural thinking maintain that lay theories of magic stem from a single common mechanism triggered by impossible events. In contrast to this widespread view, in this chapter, we will argue that lay theories of magic stem from at least two very distinct mechanisms: one triggered by impossible events and another triggered by improbable ones. We will show that, as

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yet, the diversity of the “building blocks” of lay theories of magic, and, as a consequence, the diversity of these theories themselves, has been largely underestimated.

In order to better grasp the originality of our proposal, it will be useful to briefly introduce existing approaches to magic. Magical thinking has been extensively studied by developmental psychologists and anthropologists alike, but seldom have these two approaches been discussed together. This chapter precisely tries to fill this gap by bringing together recent findings in developmental psychology, cognitive psychology, cognitive science of religion, and anthropology. Our central claim is that psychological and anthropological studies account for magic in two very different ways. Psychological evidence shows that people resort to magical explanations when faced with *impossible* events whereas anthropological evidence suggests that magical explanations are usually triggered by *improbable* events (rather than impossible ones). In this chapter, we argue that these two approaches to magic are not two partial accounts of the same cognitive phenomenon but two independent lines of research concerning distinct cognitive mechanisms. If, as we think, two distinct concepts of magic are to be recognized—one being based on counterintuition and the other on probabilistic reasoning—then an important question arises: how are these two concepts of magic, respectively, distributed across development and cultures?

The first part of the chapter focuses on the psychological approach to magic. These studies show that starting at a young age children distinguish between events and entities that violate our intuitive notions of basic causal laws (e.g., gravity) and those that do not. Next, we introduce the anthropological debate about the boundaries of magic (how it differs from science and religion), and we examine a series of case studies (on witchcraft and shamanism) which nicely epitomize the anthropological understanding of magic. Drawing upon ethnographic evidence, we argue that the approach to magic in terms of impossible or counterintuitive events fails to account for people’s actual beliefs and practices. Part three is entirely dedicated to the formalization of anthropological data discussed in part two. We argue that algorithmic complexity provides the best tools to model the way magic—as described by anthropologists—works; it is thus proposed that magical explanations are typically triggered by *complexity drops*, i.e., by events and objects whose features are expected to be complex but turn out to be simple. Part four attempts to provide an answer as to how “counterintuitive-magic” and “probabilistic-magic” are distributed across development and cultures. We first explore the historical trajectory of magic by tackling the themes of secularization and explanatory coexistence. Next, we explain why the anthropological account of magic poses a real challenge to psychological approaches to magic. Finally, we put forward four hypotheses specifying how “counterintuitive-magic” and “probabilistic-magic” are likely to be combined across development and distributed across cultures; we examine the strengths and weaknesses of each of these hypotheses and discuss the future directions of the study of magic.

The Developmental Psychological Approach: The Counterintuitiveness of Magic

Children's Conception of Magic

A large number of empirical studies show that young children are able to differentiate between impossible and possible events (Johnson & Harris, 1994; Rosengren, Kalish, Hickling, & Gelman, 1994). These impossible events (e.g., a person flying in the air) contrary to possible events, involve some sorts of violations of natural physical laws. Thus, children's distinction between impossible and possible events demonstrates their understanding of ordinary causality, or how the world works. Moreover, young children understand that some events involve ordinary processes whereas others involve magical processes. The theoretical claim is that children evoke a notion of magic to explain the events that cannot be explained by ordinary forces or processes (Chandler & Lalonde, 1994; Phelps & Woolley, 1994). By implication, children's understanding of magic is intimately related to their understanding of ordinary and possible events.

Young children have a very strict sense of what is impossible and possible either due to their less advanced understanding of causality or lack of familiarity or other reasons (see below, "Factors in children's judgment of reality vs. magical status"). Shtulman and Carey (2007) demonstrated that children below the age of 8 categorized improbable events, those that are possible but highly unlikely to happen in the real world (e.g., "polka dots on an airplane"), as impossible. From this finding, they argued that children's understanding of a distinction between impossible and possible events, and of ordinary causality, still undergoes a development. Even when a plausible explanation of how an improbable event can happen was offered, children continued to treat it as impossible (Woolley & Ghossainy, 2013). However, it is not clear whether children think of these improbable events as requiring a magical process or something different. Children have some understanding that different types of constraints are involved in the violation of different types of laws (Kalish, 1998). For example, they understand violations in the domain of social norms (e.g., violating school rules) are different from those in the domain of physical laws (e.g., walking through the wall). Given this consideration, children in Shtulman and Carey's (2007) study could think that improbable events are impossible for a different reason; they may think that these events are more similar to those involving violations of regularity in their social experiences (e.g., "dots on an airplane is not possible because it is not how it is supposed to be") than violations of physical laws.

Children's understanding of 'magic' changes with age so that 4-year-old children tend to think of magic as involving special power or skills, whereas 5-year-old children tend to think of it as involving tricks (Rosengren & Hickling, 1994). Nevertheless, magical and non-magical thinking coexist within an individual

throughout development (Subbotsky, 1993, 2010). For example, children who are initially skeptical about magical events can become believers. In one study, for instance, children were skeptical about a magical process of turning a drawing into a real entity that was represented in the drawing; but after being told about a story of a girl who used a box to turn drawings into real entities, a majority of the children when left alone displayed performances that reflected their magical stance toward the box (Subbotsky, 1993). In another study, while children initially denied the reality status of an event that was verbally described, they became credulous about the event once the event was displayed live to them (Woolley, Boerger, & Markman, 2004). Moreover, children who were led to believe a supernatural being communicated to them via signs (e.g., a light flickering) were more prone to the communicative message than those who were not (Bering & Parker, 2006). In the study, half of the children aged 3–9 years were assigned to an experimental group and, the other half, a control group. Children in the experimental group were introduced to an invisible agent called Princess Alice who they were told would help them choose a correct answer option in a game. These children were not told explicitly how Princess Alice would help but simply instructed somehow they would be told. Then, whenever they made an inaccurate response choice, a light flickered, for example. Children in the control group did not receive such priming of the idea about an invisible agent. The children who were led to believe in the existence of an invisible agent were more likely than those who were not believed that the invisible agent communicated to them in order to help them with the game. Interestingly, the effect was observed among children older than 7 years old, not among younger children. This age difference may be because attribution of the communicative intention as well as epistemic states to the supernatural agents requires further theory of mind development, and an understanding of the symbolic nature of the communicative message may not be present in younger children. Finally, contrary to a theoretical view that with age and education magical thinking declines and is replaced by scientific thinking (e.g., Piaget, 1929), adults do not completely outgrow magical thinking. Subbotsky (1993) demonstrated that adults were quite credulous to the idea that an experimenter was capable of performing impossible events (e.g., making an object disappear) after they viewed the impossible events. He further demonstrated that a scientific mode of thinking did not replace magical thinking even with increasing age, but the two coexisted in people's minds; and magical orientation was observed in behaviors even when verbal responses reflect a scientific mode of thinking (Subbotsky, 2001). For example, seeing an object destroyed after being placed inside an empty box without any physical and spatial contact with the object, but accompanied by a magical spell, participants tended to deny in their verbal judgments the possibility that the magical spell had caused the event, and yet they refused to place another object inside the box when asked to.

Factors in Children's Judgment of Reality Versus Magical Status

Of course, whether and to what extent children treat a certain event as magical depends on various factors (see Woolley & Ghossainy, 2013, for a review). Here we highlight two: familiarity with an event and social and cultural contexts. Children's familiarity with an event affects their judgment of reality status of an event. Cook and Sobel (2011) tested 4- and 6-year-old children and adults' assignment of reality status of possible and impossible machines. They found that children as well as adults distinguished between machines that violated biological or physical casual laws and those that did not, but 4-year-old children were more likely to judge familiar possible machines as real than unfamiliar possible machines. In addition, social and cultural contexts such as children's religious education and background can modulate their judgment of reality status of certain events. Four- to six-year-old children from religious families were more likely to judge religious context stories (e.g., biblical stories from the Old Testament) as real than children from non-religious families (Vaden & Woolley, 2011).

Next, in the following two sections, we focus our discussion on a handful of studies on children's attribution of magical power to themselves and others.

Children's Attribution of Magical Power to Themselves

Children's Wishing and Imagination

Young children believe that their own imagination can change or create reality. Woolley and Wellman (1993) demonstrated that, after imagining something in an empty box, 3-year-olds responded affirmatively that the box contained the object imagined. Harris, Brown, Marriot, Whittall, and Harmer (1991) also showed that 4- to 6-year-olds behaved as if the imagined object was real. In the study, children were asked to pretend that a monster or a bunny was inside a box. When they were left alone in the room with the box, children peeked into the bunny box but not into the monster box. However, there is also evidence that children acknowledged the existence of an imagined object in a box, but did not act accordingly, so that when another person asked for the imagined object, children rarely offered the box to the person (Phelps & Woolley, 1994). Nevertheless, it is possible that children in this study may have believed in the event, but did not outwardly show this to another person who may not have endorsed their magical world.

Children's belief that imagination can change the state or course of a real event may be extended to another case; wishing for something. Vikan and Clausen (1993) showed that children of ages 4 and 6 believed that wishing has an effect on another person, in terms of changing another person's actions. Moreover, children see wishing as a magical process involving special power or magic, not an ordinary

process involving mental-physical causality (Woolley, Phelps, Davis, & Mandell, 1999). These studies show that, with increasing age, children's tendency to believe in the efficacy of wishing wanes, and older compared to younger children thought that an event realized via wishing was caused by a trick rather than real magic (see also Woolley, 2000). A more recent study, however, shows that older children and adults preserve a tendency to believe in the efficacy of wishing (Subbotsky, 2005). Different methodologies used in the aforementioned studies make it difficult to adjudicate their conflicting findings. However, speculatively, they do suggest at the very least that magical tendency may be susceptible to contexts and conditions in which it is measured.

Children's Attribution of Magical Power to Other Agents

Children's Understanding of Supernatural Agents

Children believe in various supernatural and fantastical characters such as Santa Claus or the Tooth Fairy. All these characters share a common feature of possessing supernatural abilities violating physical and biological causal laws. We know that children treat supernatural agents differently from ordinary agents, attributing some special power only to the former. However, what exact capabilities children attribute to novel as well as familiar fantastical characters asks for further investigation. One line of research as reviewed below starts to provide some information concerning what those capabilities might be.

Children assign special power or ability to God. Vaden and Woolley (2011) showed that, while 4- and 6-year-old children viewed impossible events as not real, they endorsed the reality status of those events when they were told that God was involved. Vaden and Woolley asked 4- to 6-year-old children to judge the reality status of an event or a character described in a story either in a religious (reference to God, e.g., the story of Moses parting the sea but replacing original characters with novel character names) or a nonreligious context (otherwise the same stories as the religious context stories without reference to God). With increasing age, children who heard the religious context stories were more likely to judge the characters and events described as real than those who heard nonreligious stories.

Lane and colleagues, in a series of studies, extensively investigated what types of knowledge and abilities children and adults attribute to omniscient agents such as God as opposed ordinary human beings (Lane, Wellman, & Evans, 2010, 2012, 2014). Lane et al. (2012) demonstrated that children around the age of 5 attributed special power of knowing (e.g., knowing hidden contents of a box without perceptual access) to God and a novel agent, Mr. Smart, who was introduced as: ("This is Mr. Smart. Mr. Smart has special powers. He knows everything"). Lane et al. (2014) further investigated to what extent children and adults attributed extraordinary knowledge to special beings. With increasing age, participants tended to attribute broader and deeper knowledge to omniscient beings. A younger group

(3.5- to 6.5-year-olds) only attributed generic knowledge (e.g., “where to find the tallest tree in the world”) to Ms. Smart, whereas an older group (6.5- to 12-year-olds) attributed also their personal knowledge (e.g., birthdays) to the agent. Only adults, however, attributed the knowledge of their own thoughts and future to omniscient beings (Ms. Smart). Participants were also asked to choose between Ms. Smart (who was introduced as someone “who knows everything about everything”) and an expert (e.g., a mechanic) when asked who knows more about certain topics. With increasing age, participants tended to attribute deeper knowledge to omniscient beings so that, for example, only adults attributed more expertise-related knowledge to Ms. Smart than an expert, whereas the youngest group attributed more expertise-related knowledge to an expert than to Ms. Smart. Moreover, children’s exposure to religion was related to their attribution of broader knowledge to Ms. Smart—but this relation was only specific to the age range of 4–6. The authors speculated that this age range coincides with children’s developing theory of mind, and social cultural contexts (e.g., religions) may facilitate children’s understanding of extraordinary minds during this period. In addition, children from religious backgrounds appreciated extraordinary minds more readily than those from nonreligious backgrounds (Lane et al., 2012). These studies suggest that already by preschool age children are capable of appreciating the kinds of special knowledge that omniscient beings have, and with increasing age they become better able to reason about the omniscient beings’ extraordinary knowledge. As will be demonstrated below, this ability is not limited to children’s reasoning but influences their daily interactions and learning.

Children’s Preferential Learning from a Magical Person

Children also attribute magical power to an ordinary person if the person displays actions that are beyond ordinary causality (e.g., moving an object without touching it). Those children who perceive the person as possessing magical power tend to preferentially learn from that person. In a study by Kim and Harris (2014a), children of ages 3–8 were presented with video clips in which a person performs magical actions (e.g., moving a box without touching it) whereas another person performs non-magical actions (e.g., moving a box with her hand). Then, children heard these two people offering conflicting pieces of novel information (e.g., a label for a novel object, “a fep” vs. “a tog”) and were asked to endorse one of the information pieces. With increasing age children were less likely to prefer the information supplied by the magical person. Notably, however, individual difference rather than age better predicted preferential learning tendency; those children who were credulous to the reality status of the magical events tended to preferentially learn from the person, as compared to skeptical children. This tendency to preferentially learn from a magical person was not limited to the magical power of actions, but observed in the magical power of reading others’ minds (Kim & Harris, 2014b). Children preferentially learned from a person who accurately guessed others’ thoughts over another person who figured out others’ thoughts via communication.

In sum, children are able to distinguish impossible events from possible events, and at the same time, they do not entirely disregard magical thinking. In particular, with the right amount of evidence and supporting environment, adults as well as children entertain the magical world they themselves or others created. Children, moreover, preferentially learn everyday knowledge from a person they view as possessing magical power. Notably, one key element of children's understanding of magical events and supernatural agents and power in developmental psychology as reviewed above is their understanding of violations of basic physical laws. However, this notion of magic as defined as a blanket term for an event that a child's naïve theories cannot explain—while it has provided the field with fruitful directions for empirical investigations—excludes a prevalently common notion of magic in our everyday lives, as will be discussed in the following sections.

The Anthropological Approach: The Ordinarity of Magic

Introducing the Anthropological Approach to Magic

The methods used by anthropologists to study magic, and, as a consequence, the models of magic that have emerged from anthropological findings, are somewhat different from those to be found in developmental psychology. In the field of anthropology, the very concept of magic originates itself in discussions sparked by evolutionary anthropologists—notably Edward Tylor and James Frazer. These authors were primarily interested in understanding how magic—more broadly how “primitive” religions and cults (animism, totemism, witchcraft, etc.)—have gradually developed into more “sophisticated” forms (such as monotheism) and finally into science. Evolutionary anthropologists were thus willing to specify the psychological mechanisms leading from one evolutionary step to the other.

A few decades later, the evolutionary perspective largely gave way to investigations into the intricate coexistence of ordinary knowledge and magical thinking and the relations between magic, science, and religion (Evans-Pritchard, 1976; Hubert & Mauss, 1903; Malinowski, 1948). Magical thinking was not considered necessarily primitive and irrational anymore. This line of research has further been explored in the second half of the twentieth century (Horton, 1967a, b; Nader, 1996; Tambiah, 1990). In a similar vein, some scholars have begun to address more epistemological and philosophical questions relating magic to the theme of apparent irrationality and that of the incommensurability between worldviews (Bonney & Laugier, 2003; Da Costa, Bueno, & French, 1998; Hollis & Lukes, 1982; Jarvie & Agassi, 1967; Sperber, 1985; Triplett, 1994).

One important distinction between psychological studies of magic reviewed earlier in the chapter and those in the field of anthropology concerns methodologies. Classically, anthropologists do not resort to experiments in order to investigate a

topic. The forerunners of the discipline (such as Tylor or Frazer) were strictly armchair anthropologists speculating on the basis of missionaries' and travelers' outlandish reports; yet, at least from Bronisław Malinowski on, anthropologists have fruitfully resorted to participant observation: they have studied other people's thinking by living with these people and putting themselves in the same life settings, and looking at how these settings affect them (both cognitively and emotionally) (Goulet & Miller, 2007). Some anthropologists whose work on magic and witchcraft has been much vaunted have endorsed this method of participant observation in a particularly radical fashion and have thus revealed that even a modern and secular academic mind can easily be affected by magical beliefs and practices (Favret-Saada, 1980, Chap. 2, 1990; Luhrmann, 1991, Chap. 21).

While psychologists are mainly concerned with studying how children and adults perform specific tasks within experimental settings, anthropologists are first and foremost interested in documenting how magical thinking unfolds in natural settings. Typically, psychologists present impossible stimuli to participants and then look at what participants' responses are, whereas anthropologists typically look at daily practices and rituals and from there infer what is deemed magical in a given culture. The psychological method could be characterized as top-down: it assumes that the concept of magic is unambiguous and uniform and it operationalizes this concept through experiments. On the other hand, the anthropological method is best described as bottom-up: no assumption is made as to what magic amounts to and it is only the collection of ethnographic data through participant observation which determines what is deemed magical by people in real life. This methodological distinction will prove important in the next sessions.

Magic, Science, and Religion: Debating the Boundaries of Magic

A good amount of research in Anthropology is devoted to the study of similarities and differences between magic on one side and science and religion on the other side. Examining the boundaries of magic will help us better understand its scope and mechanisms. The position Malinowski (1948) took in this heated debate is particularly interesting. On the one hand, Malinowski maintains that the Melanesians—and more generally people living in any culture in which magic is pervasive—do not live in a world utterly different from ours, nor do they use a logic different from ours. They do not inhabit an ethereal and mystical world. The Melanesians described by Malinowski prove to be expert and ingenious gardeners and fishermen, and while reading *The Argonauts of the Western Pacific*, one realizes how adept they are at solving practical and rational problems. Thus, it clearly appears that Malinowski strongly disagrees with scholars such as Lucien Lévy-Bruhl (1923, 1927, 1966), who have somewhat exaggerated the mystical

nature of indigenous thinking. On the other hand, Malinowski demurs at the view—notably held by Frazer (1922)—according to which magic can be conflated with science. Admittedly, Malinowski grants that magic, very much like science, has very concrete and down-to-earth ends; but he argues that the function of magic remains very different from that of science and that of profane practical knowledge.

In *Magic, science and religion and other essays*, the middle way between the Lévy-Bruhlian view and the Frazerian view is delimited by a central dichotomy: the *sacred* and the *profane*. Malinowski advances that “[i]n every primitive community [...] there have been found two clearly distinguishable domains, the Sacred and the Profane; in other words, the domain of Magic and Religion and that of Science” (1948, p. 1). When the Melanesians are gardening or fishing, their profane know-how is recruited; but when their extended knowledge meets some limit and when they realize that their practical knowledge is not sufficient to control a crucial parameter of gardening or fishing, they then resort to totally different kinds of tools: tools pertaining to the sacred domain. Magic is used to compensate the limited scope of daily and scientific knowledge. Malinowski evocatively illustrates this idea through the example of gardening: “there is a clear-cut division: there is first the well-known set of conditions, the natural course of growth, as well as the ordinary pests and dangers to be warded off by fencing and weeding. On the other hand, there is the domain of the unaccountable and adverse influences, as well as the great unearned increment of fortunate coincidence. The first conditions are coped with by knowledge and work, the second by magic” (1948, p. 12). By the same token, Malinowski points out that no magic is used when fishing is done in the inner lagoon whereas magical procedures are widely used in open-sea fishing (1948, p. 14). As it happens, the first type of fishing involves almost no uncertainty while this other type of fishing is replete with uncertainty. Very much like science and practical knowledge, magic targets practical ends (e.g., improving the outcome of fishing or the crop); but unlike science and daily know-how, magic governs a specific plane of reality—the unpredictable parameters targeted by magical rituals that cannot be targeted by profane knowledge whatsoever.

The domain of magic (of the sacred), we are told, cannot be conflated with that of science (of the profane). However, it is interesting to note that this dualism is somewhat challenged by some ethnographic findings. For example, Shipibo¹ hunters of the Peruvian Amazon have at their disposal an argosy of magical techniques to ensure luck and success in the forest. Among them are plant baths. Specific plants (e.g., *ochiti jana*) are purported to imbue one’s body with some magical smell or wind (*nihue*) thanks to which hunting expeditions will prove to be remarkably successful. This beneficial effect is taken to be mediated by the spirit (*yoshin*) of the plant used in the bath. Interestingly, this spirit is conceived as benevolently interfering in the hunting process both as an invisible intentional entity and as a perceptible smell. In such a case, it is notoriously difficult to

¹Data about Shipibo culture have been collected by one of us (MF) on his fieldwork located in the Peruvian Amazon. Magic in Shipibo culture will be further discussed below.

disentangle ordinary knowledge from magical stratagem. The smell of the plant obviously conceals the hunter's characteristic smell (which would otherwise frighten and drive away the game animals) and it also serves as an enticement (because, it seems, the game animals like this particular smell). From a Western point of view, there is nothing magical about the efficacy of plant baths; what we are presented with is only a very rational and astute manipulation and luring of the game animals' senses. But at the same time, Shipibo hunters maintain that a benevolent spirit is present in the smell and that it is this spirit that brings about good fortune in hunting activities. This kind of ethnographic finding challenges Malinowski's clear-cut dichotomy: when Shipibo hunters are playing with smells to attract good fortune and lure the game animals, it is not clear at all where the profane (i.e., practical knowledge) ends and where the sacred (i.e., magical beliefs and practices) starts.

To be sure, magic and science resort to different tools and use these tools to deal with different parameters, but it remains that both, in the end, target the same tangible outcome (e.g., a successful hunt). Magic is a kind of technology whose main purpose is to achieve practical efficiency; religion, on the other hand, is concerned with moral and soteriological purposes pertaining not to the mundane world but to what Nietzsche accurately dubbed a "backworld" (*Hinterwelt*).² For instance, magic is typically being used to ensure a plentiful hunt or crop while religion is used to ensure salvation or cosmological liberation. Stanley Tambiah reminds us that for Malinowski, "[r]eligious action was not like magic a means to an end, it was an end in itself and it celebrated ultimate values, such as Providence and Immortality" (1990, p. 69).

This relates to another important difference between magic and religion; magic, like science, envisions the world in a very mechanistic way, whereas religion claims that autonomous volitional beings can interfere within the mechanistic concatenations of the natural world. A miracle is thus defined as God's sovereign decision to temporarily suspend the mechanistic laws of nature. Clearly, there is no such a thing as a miracle in magic. When a magician performs some magical rituals, the summoned supernatural beings and forces are not at liberty to choose to please the magician or to rebuff her inquiry. By contrast, when one prays to God, one's wishes may perfectly be fulfilled *or not*. As Tambiah pleasingly remarks, the world of religion supposes a "sovereign God" while that of magic is replete with "manipulable divine beings" (Tambiah, 1990, p. 21). The classical view of anthropology, thus, is that "[i]n its quintessential form [...] magic is ritual action that is held to be automatically effective" (Tambiah, 1990, p. 7). Frazer has certainly been the most radical champion of this view. In the *Golden Bough*, he discusses at length the striking proximity between magic and science, i.e., the shared *mechanistic* view of the world and the commonly assumed idea that instrumental actions are

²For an evolutionary proposal as to how religion—with its otherworldly orientation—emerged, see: Baumard, Hyafil, Morris, & Boyer, (2015).

automatically effective.³ Evans-Pritchard—albeit more moderately than Frazer—does concur with the idea that magical rituals work to a large extent mechanistically. For example, he states that “[i]n asking a [magical] medicine to act on his behalf a man does not beseech it to do so. He is not entreating it to grant a favor. He tells it what it is to do, just as he would tell a boy were he dispatching him on an errand” (Evans-Pritchard, 1976, p. 177).

This concise review of some of the most important anthropological theories of magic has made clear that magic as practiced in real life is nothing mystical or irrational; it is an instrumental knowledge (although usually not evidence-based) and a technology involving the manipulation of supernatural entities in order to achieve very practical outcomes.

Magic in Practice: Three Case Studies

As reviewed earlier, the psychological approach holds that magic is mainly defined by its counterintuitiveness. Strangely enough, it is difficult to find this feature in the data on magic that anthropologists collect in the field (in natural settings). Cases typically discussed by anthropologists, in which some magic is at play, do not involve any impossible event or impossible being; on the contrary, such cases are strikingly ordinary. In order to illustrate this point, we will now present three cases which exquisitely epitomize the kind of phenomena anthropologists are concerned with when they speak of magic. Different mechanisms (i.e., different types of complexity drops) can trigger magical explanations. Each example provided in this section illustrates a specific type of complexity drop.

Case 1: Succession of Misfortunes

Let us start with an excerpt from Jeanne Favret-Saada’s captivating monograph depicting witchcraft in contemporary French countryside:

In the Bocage [...] ordinary misfortunes are accepted as “one-off”; so, a single illness, the loss of one animal, one bankruptcy, even one death, do not call for more than a single comment: “*the trouble with him is that he drinks too much*”; “*she had cancer of the kidneys*”; “*my cow was very old*”.

An onslaught by witchcraft, on the other hand, gives a pattern to misfortunes which are repeated and range over the persons and the belongings of a bewitched couple: in succession, a heifer dies, the wife has a miscarriage, the child is covered in spots, the car runs

³“[In both magic and science,] the succession of events is assumed to be perfectly regular and certain, being determined by immutable laws, the operation of which can be foreseen and calculated precisely; the elements of caprice, of chance, and of accident are banished from the course of nature.” (Frazer, 1922, p. 49). See also Ruth Benedict (1933, p. 40).

into a ditch, the butter won't churn, the bread won't rise, the geese bolt, or the daughter they want to marry off goes into a decline ... (Favret-Saada, 1980, p. 6)

The characteristics of magic identified by Favret-Saada are rather ordinary. People surmise that some witchcraft is involved not because they face an extraordinary event—e.g., an event violating some physical law—but rather because they detect an abnormal pattern in the way very ordinary events unfold. Occasional misfortune is not enough to suggest that some magical process is at work; persistent misfortune is required to infer that some witchcraft is involved. Magic characterizes the specific concatenations of events rather than the very content of events. In the case reported by Favret-Saada, the content of the events mentioned is in fact remarkably mundane and plainly natural.

Case 2: Unfortunate Relatives and Friends

The second case study is a classical and well-known anecdote provided by Evans-Pritchard in his monograph on Zande⁴ witchcraft:

In Zandeland sometimes an old granary collapses. There is nothing remarkable in this. Every Zande knows that termites eat the supports in course of time and that even the hardest woods decay after years of service. [...] it may happen that there are people sitting beneath the granary when it collapses and they are injured [...]. Now why should these particular people have been sitting under this particular granary at the particular moment when it collapsed? [...]. Through years it might have collapsed, so why should it fall just when certain people sought its kindly shelter? (Evans-Pritchard, 1976, p. 22)

In this passage, Evans-Pritchard pinpoints in a very concise manner several central features of witchcraft. First, magic unfolds in the world in a very ordinary way. The collapse of the granary does not violate any physical law. It is not an extraordinary event: real people believe in witchcraft not because they hallucinate witches flying on broomsticks but because they face in their life very ordinary facts which possess a specific structure (we will see below how this structure can be formally defined). Second, people who believe in magic do not live in a parallel outlandish and mystical world. They share with us exactly the same world and are very knowledgeable about the physical and biological processes governing the everyday world: they know that granaries usually collapse not because of supernatural powers but because of very mundane termites. What Evans-Pritchard finally shows us is that Azande people find it quite unbelievable that an unfortunate event—such as the collapse of the granary—could strike these very specific people at this very specific moment. Why them? Why then? If this unfortunate event harmed these very specific people, then, there must be a reason. In witchcraft logic, the reason is quite obvious: some ill-intentioned agent wanted to harm these very specific people.

⁴The Azande are an ethnic group of North Central Africa. In the 1920s and 1930s, Evans-Pritchard extensively studied Zande communities located in today's South Sudan.

The way the witch is thought to have interfered in the natural course of the world is certainly extraordinary (outstanding powers are required). However, Evans-Pritchard makes it clear that the specific mechanisms through which such witchcraft assaults are carried out remain largely opaque and Azande do not speculate about them. In fact, in their eyes, it is not of great importance to know how the witch did what he or she did. What matters is to be able to see this mundane event as the sign of some magical interference in the normal course of the world. And what is so remarkable is that this sign does not take the form of something extraordinary; it does not consist in the violation of physical laws. Only those who have learned how to read the ordinary unfolding of mundane events will be able to know that what happened has been partly brought about by some magical agency. Novices, on the other hand, will not even notice that this mundane event was magical in essence.

Case 3: Atypical Features Violating Factual Knowledge

The third case study differs from the two previous ones in several respects. To begin with, it concerns shamanism (in the Northern Asian area) rather than witchcraft. Moreover, this case illustrates how *beings* are identified as magical, as opposed to how *events* are identified as being such:

Tuvan hunters claim that there exist certain ‘special’ (*tuskai*) beasts in the taiga; these being rare, they are ‘sacred beasts’ (*ydyktyg aynar*) whom it is forbidden to kill. They can be recognized by distinct visible traits of very variable types: this could be a variegated deer or a white one (albinism); a stag with no antlers, or conversely with very large antlers; a doe with antlers; a bear with patches; or a white squirrel, sable or polecat; or a fish with just one eye. [...].

This particular treatment of singular animals is extremely widespread among the indigenous peoples of Northern Asia. [...]. ‘The Evenks and the Yakuts believe there to be in each animal species certain powerful specimens that have the qualities of a demi-god’ (Nikolaev 1961: 49). In this way, according to Yakut tradition, there exists among bears a ‘shaman bear’, which is marked out by its intelligence, its invulnerability, and by the patches on its fur (Kulakovskii 1979: 55). [...]. With ants there would also be a very large ‘mother ant’, while arctic foxes and hares also include shamans. According to the Nenets, the squirrel that keeps its red fur in winter is a shaman, and it is forbidden to kill it (Zelenin 1936: 208). (Stépanoff, 2015, pp. 172–173)

It seems that the cognitive mechanisms underpinning the detection of magical properties in this case are different from the ones at play in the two previous cases. In this passage, Charles Stépanoff points out that the ascription of magical powers to an entity does not always stem from the pattern of occurrence of a sequence of events (as in Case 1), or from the nature of the persons on which magical powers are exerted (as in Case 2), but it sometimes depends on the violation of some typical features (Case 3). In the examples discussed by Stépanoff, an external feature (color, size, shape, etc.) happens to be violating some ethological knowledge, and,

as a result, the bearer of the atypical feature is inferred to be endowed with some magical powers (as will be shown later, atypical features include not only atypical morphology but also atypical behaviors, smells, and sounds).

Magic and the Varieties of Counterintuitions

The relationship between magic and the violation of domain-specific and domain-general knowledge deserves to be further detailed. To begin, let us define a few key concepts. Cognitive scientists and psychologists often distinguish between domain-specific and domain-general knowledge. Domain-specific knowledge or intuitive ontology refers to a kind of intuitive knowledge concerned with a defined category of objects or processes. By “intuitive” we mean that this knowledge develops independently of any deliberate reflective effort (intuitive knowledge can thus be contrasted with reflective or scientific knowledge). By a “specific category” or an “ontology”, we mean that this knowledge does not apply to any thing. Importantly, intuitive domains, categories, or ontologies are parsed accordingly to our everyday use of cognition (and plausibly evolution) rather than by clear-cut folk or scientific categories: “the distinct cognitive domains [...] do not always correspond to real ontological categories [...]. For instance, the human mind does not draw the line between living and non-living things, or between agents and objects, in the same way as a scientist or a philosopher would do” (Boyer & Barrett, 2005, p. 98). An example of domain-specific knowledge would be the knowledge that living beings need to be fed in order to grow. This knowledge emerges early in childhood [when exactly it emerges is still a matter of debate (Atran & Medin, 2008; Carey, 1985)]; and this knowledge is “specific” to the extent that it strictly concerns biological objects and processes (as opposed to physical or psychological ones). In contrast, probabilistic knowledge applies to various kinds of objects or processes (Xu, 2007). For instance, it can be used both to infer the trajectory of a ball and to ascribe mental states to other people. It is hence domain general.

The definition of two additional concepts—core knowledge and modularity—is in order. Core knowledge refers to a set of cognitive mechanisms enabling young children (and sometimes even infants) to compute objects, persons, places, and numerosities in a quite sophisticated way. Each core knowledge system is domain-specific: it is dedicated to one specific category of objects and processes. Moreover, core knowledge is assumed to have a long evolutionary history (on core knowledge, see: Spelke, 2000). Modularity has been defined in several ways (Barrett & Kurzban, 2006; Fodor, 1983), but—to somewhat simplify the matter—it is a quasi-synonym of core knowledge: it refers to mechanisms enabling children to be innately endowed with some specific knowledge, or at least, to learn specific knowledge extremely quickly. Modules, it is argued, have been developed throughout evolution because they were, in some ancestral environment, adaptively

advantageous. As we can see, core knowledge systems and modules share many commonalities. The main difference between the theory of core knowledge (Spelke, 2000) and the theories of massive modularity (Barkow, Cosmides, & Tooby, 1992; Sperber, 1996) is that while the former considers that only about half-a-dozen core knowledge systems are to be identified, the latter claim that dozens of modules are to be recognized. Yet, in contrast to rational constructivism (Xu, 2007), both core knowledge and massive modularity agree that cognition is to a fair extent innate as well as domain-specific.

These clarifications can help us better understand the debate about the nature of magic. The three case studies just described suggest that magic does not tap into domain-specific mechanisms. This claim may seem disputable, though. Indeed, as we all know, magical explanations typically presuppose that mind can have an effect over matter, that diseases can be healed by thoughts, that vitality can be lowered by a spell, etc. Such explanations, it seems, blatantly violate domain-specific knowledge. Importantly, when we say that magic as studied by anthropologists is not based on the violation of domain-specific knowledge, we do not mean to deny that magical explanations often go against our domain-specific intuitions. The question we are addressing is different: we are interested in studying the *features* which lead people to interpret an event or a being as magical. Studying the *content* of magical explanations—rather than their *triggering conditions*—is vain as such explanations considerably vary within- and between-subjects. People recognize the magical character of events in a remarkably consistent way; by contrast, they do not invest much effort in speculating what are specific and detailed magical processes which brought about such events—or, when they do (for example, to please the ethnographer), they are remarkably inconsistent through time. In the remainder of this chapter, we will thus restrict our investigation to the cognitive mechanisms through which an event or a being is detected as magical—nothing more.

The common claim of developmental psychology is that features triggering magical explanations can be characteristically defined as violating some domain-specific knowledge or some intuitive ontology. It is thus claimed that people resort to magic when faced with events or entities which contradict intuitive expectations as to how physical, biological, or psychological beings should behave. This is clearly stated by the editors of the state-of-the-art book *Imagining the impossible*: Developmental psychologists, they notice, are mainly concerned with the study of thinking about violations of domain-specific constraints and thinking going beyond the ordinary (Rosengren, Johnson, & Harris, 2000, p. xiii). This type of magic contrasts with the type of magic that anthropologists have been documenting at length in their monographs. Strikingly enough, in the three case studies that we have examined, no obvious violation of physical, biological, or psychological laws is observed. In Case 1, magic stems from the occurrence of very mundane physical and biological events (e.g., a car accident or the death of an animal). Similarly, in Case 2, the event reported to be magical is the collapse of a granary. Clearly, as such, this collapse does not violate any domain-specific knowledge. Case 3 does feature a violation, but what is being violated is

domain-general knowledge as opposed to domain-specific knowledge.⁵ In the end, none of the three examined cases contradict our intuitive ontologies. It must be consequently acknowledged that in real life, people resort to magical explanations in front of mundane events, and not impossible ones.

It is worth elaborating a bit more on Case 3. Indeed, influential cognitive theories have advanced that entities and properties violating knowledge more or less massively are constitutive of supernatural thinking (Pyysiäinen, 2002). Therefore, it remains to be determined whether cases such as Case 3 can be best characterized as a *minimal* violation of domain-general knowledge or a *maximal* violation of knowledge. For the sake of clarity, let us define four types of counterintuitions:

- *Type 1. Minimal domain-specific counterintuitions* are triggered by objects or events which possess one or very few properties violating domain-specific knowledge (Barrett, 2004b; Boyer, 2001). A human able to fly or a mountain able to talk are good illustrations of what minimal domain-specific counterintuition amounts to.⁶
- *Type 2. Multiple domain-specific counterintuitions* are triggered by objects or events which possess many properties violating domain-specific knowledge. Here is an example: “a dog that was made in a factory gives birth to chicken, can talk to people, is invisible, can read minds, can walk through walls, and can never die” (Barrett, 2004b, p. 23). Unlike maximal violations (see Type 4), multiple domain-specific violations are not intrinsically contradictory or utterly abstruse.
- *Type 3. Minimal domain-general counterintuitions* (or *oddities*) are triggered by objects or events which possess one or very few properties violating domain-general knowledge (Gille, 2014). For example, a cat with one eye or a pink cat (as opposed to, say, a flying cat) minimally violates *domain-general* knowledge but does not violate *domain-specific* knowledge. Let us spell this out: a cat qua physical object is domain-specifically known to be subject to gravitation; a cat qua living being is also domain-specifically known to grow and die. Any violation of this kind of specific and theory-based knowledge (e.g., a flying cat or an immortal cat) falls under Type 1 described above. Now, in addition to this specific theory-based knowledge, people have domain-general prototype-based knowledge. For example, cats have typically two eyes and four legs. Importantly, this knowledge cannot be inferred from knowledge that cats are living beings or physical objects. It is learned through domain-general mechanisms rather than inferred from domain-specific knowledge. When this

⁵On the distinction between domain-general (or factual, or prototypical) knowledge and domain-specific (or ontological) knowledge, see: Barrett (2004a, b), Chap. 2, Gille (2014).

⁶Minimally counterintuitive concepts are created as follows: “First, take an ordinary concept, such as “tree”, “shoe”, or “dog”, that meets all of the naturally occurring assumptions of our categorizers and describers. Then *violate* one of the assumptions. For instance, as a bounded physical object, a tree activates the nonreflective beliefs governing physical objects, including being visible. So make the tree invisible [...], and you have an MCI [minimally counterintuitive concept]” (Barrett, 2004b, p. 22).

prototypical domain-general knowledge is violated (e.g., a cat with one eye or two legs), this results in Type 3 counterintuition.

- *Type 4. Maximal domain-general and/or domain-specific counterintuitions (or contradictions)* are triggered by objects or events which are intrinsically contradictory and utterly abstruse and/or whose properties massively violate domain-specific and/or domain-general knowledge (Atran, 2002; Sperber, 1975). A good example of a contradictory concept is the Christian God, who is purported to be both trine and one.

Clearly, Type 1 and 2 do not apply to any of the three cases under examination. What about type 4? Now that we have clearly contrasted Type 3 counterintuition with Type 4 counterintuition, it seems obvious that only the former accurately describes what is going on in Stépanoff's reports. Bears and squirrels purported to possess magical powers are not ascribed these powers because they are able to fly in the sky (minimal domain-specific counterintuitiveness); neither are they ascribed such powers because they are massively contradictory to the point that it is hard to conceptualize them (contradiction). What makes these animals magical is simply that their features include some unusual color or some congenital malformation (minimal domain-general counterintuitiveness or oddities).

In cases described by ethnographers, events or beings typically recognized as magic are either not counterintuitive whatsoever (think of the collapse of a granary, in Case 2) or are at most minimally and domain-generally counterintuitive (think of the albino squirrel, in Case 3). It is often claimed that the domain-specific or modular architecture of the mind is key to understand magic. In contrast to such claims, we are left with the suggestion that the central component of magic lies in the domain-general interpretation of ordinary events. Importantly, the modular view of the mind is of no avail when it comes to understanding such domain-general cognitive processes. On the other hand, probabilistic models of the mind (Griffiths, Chater, Kemp, Perfors, & Tenenbaum, 2010; Tenenbaum, Kemp, Griffiths, & Goodman, 2011; Xu, 2007) seem particularly well suited to do the job. This is not to say that the modularist view of the mind should be discarded and will never be able to help us understand anything about magic. The matter is more intricate. Indeed, as shown in the beginning of the chapter, psychological experiments demonstrate that people do explain in magical terms domain-specific counterintuitive events; that is, when presented with such events, almost all children and at least some adults do resort to magical explanations. On the other hand, when people are not presented with laboratory stimuli but are freely navigating in the real world, what they typically explain in magical terms are domain-general minimally counterintuitive events as well as perfectly intuitive events. Domain-general models of cognition, it seems, are thus better equipped to understand when and how magic is evoked. The apparent contradiction between the two strands of evidence just discussed will be explored and adjudicated later in the chapter. For now, some formalization work is required in order to better understand the meaning and significance of the anthropological data under scrutiny.

Formalizing Anthropological Data: The Probabilistic Model of Magic

Complexity Drop as a Cue to Agency

Anthropological evidence demonstrates that people resort to supernatural explanations in front of events or beings which do not violate any domain-specific intuition. Models of magic based on domain-specific mechanisms are thus of no avail to understand such anthropological data. What is therefore needed is a model of magic which explains how magical thinking is underlain by domain-general cognitive mechanisms. As we will see, Kolmogorov's concept of algorithmic⁷ complexity, or rather the revamped version of this concept (Chater & Vitanyi, 2003; Dessalles, 2013; Griffiths & Tenenbaum, 2003; Vitanyi & Li, 2000), will prove particularly useful. What follows is a brief summary of a general model of magic that one of us has developed at length elsewhere (for more details, see: Fortier, in preparation).

Kolmogorov's theory of complexity aims at understanding the nature of randomness. The proposal is that randomness amounts to maximal complexity. Complexity, in turn, is defined by size of the shortest program that generates a given string; the longer the program (the higher the number of instructions a program needs to generate a given string), the more complex the program. For example, more instructions will be needed by a program to generate this string: 4, 7, 3, 5; as compared to that string: 1, 2, 3, 4. A random string such as (4, 7, 3, 5) demands more instructions because it is not compressible. In Kolmogorov's terms, a compressible string is less complex than a noncompressible one.⁸

Admittedly, one apparent limit of Kolmogorov's theory of complexity is that it is not computable. However, as Jean-Louis Dessalles notices, as long as we are using complexity in the field of cognitive science, this theoretical limit is harmless since we are by definition dealing with specific and limited "computing machines" (i.e., human minds) (Dessalles, 2007). When applied to human cognitive systems, acknowledging that complexity is a relative concept is not a problem anymore. Concretely, this means that what is complex for a given cognitive system (for person A) will not necessarily be complex for another system (for person B). For instance, (1, 9, 7, 4) may look totally random (highly complex) to person A, but it may simultaneously look very simple (not random at all) to person B, because, say, person B was born in 1974. Similarly, the first ten digits of π may look totally random (highly complex) to a non-mathematician and yet they look very simple (not random at all) to a well-trained mathematician.

⁷Henceforth the concept of "algorithmicity" (and its adjective "algorithmic") will be only used in a Kolmogorovian sense. The term strictly refers to the algorithmic information theory and the calculation of the complexity of objects (such as strings).

⁸For details on the concept of compressibility, see: Li and Vitanyi (1997, p. 108 et sq.)

Complexity theory has been fruitfully applied to various domains of cognitive science. In particular, Dessalles has developed a wide-ranging theory of unexpectedness and relevance entirely based on Kolmogorov complexity (Dessalles, 2007, 2010, 2013; Saillenfest & Dessalles, 2015). The tenet of his theory is that unexpectedness can be defined as the ratio between expected complexity and observed complexity. More specifically, if an event which was expected to be complex turns out to be very easy to describe, it will be deemed highly unexpected. If, for instance, I am traveling in Patagonia, I expect people I meet during my trip to be complex people (i.e., to be strangers whose description cannot be simplified or compressed); now, if I happen to meet my neighbor or a university colleague or a celebrity (i.e., a person whose description can be easily compressed and whose description is therefore simple), I will certainly be baffled by the unexpectedness of the encounter: I was expecting to encounter someone complex to describe and I happened to encounter someone unexpectedly simple. Unexpectedness can thus be defined as follows:

$$U = C_{\text{exp}} > C_{\text{obs}}$$

(where U stands for unexpectedness; C_{exp} for expected complexity; and C_{obs} for observed complexity).

This simple but powerful equation interestingly echoes a recent line of research in developmental psychology exploring the relationship between nonrandomness (or simplicity) and agency (Keil & Newman, 2015; Kushnir, Xu, & Wellman, 2010; Ma & Xu, 2013; Newman, Keil, Kuhlmeier, & Wynn, 2010; Wellman, Kushnir, Xu, & Brink, 2016). These studies show that very early on, humans explain the absence of randomness (i.e., high simplicity) by postulating the interference of an agency. This inference is particularly strong, as 9-month-olds (Ma & Xu, 2013) seem already able to hypothesize that nonrandom outcomes are generated by human agents and random outcomes by mechanistic processes. It appears that abnormal order (violation of randomness) is heuristically used as a cue to agency. Such a relationship seems indeed quite intuitive. If I am walking in a meadow, in a remote location, and I see flowers randomly scattered around me, there is nothing surprising about it. But let us now imagine that I suddenly encounter a perfectly straight line of flowers right in the middle of a remote meadow. There is no doubt that I will be surprised and think: someone must have planted these flowers here this way, this cannot be the result of randomness alone! So, in such a case, I was expecting high complexity (disorder) and I observed low complexity (order); as a result, I inferred that an agent must have somehow interfered: an agent must be added to the picture in order to explain the complexity drop. Hence the idea that complexity drop functions as a cue to agency:

$$(C_{\text{exp}} > C_{\text{obs}}) \rightarrow AD$$

(where AD stands for agency detection).

A further nicety has to be added to this model of agency detection. In an ingenious study, Falk and Clifford Konold (1997) have shown that the difficulty to encode a sequence (i.e., the complexity of the sequence) is a very good predictor of judgments of apparent randomness. In other words, probabilistic judgments—judging whether a sequence was generated by a random or an intentional process—are based on the experienced ease (or difficulty) in encoding a sequence. This explains why people are sometimes biased in their probabilistic judgments: the most difficult sequence to encode is not always the most random one. Although subjective complexity is not always a good guide to objective randomness, it is heuristically used by subjects to guess what the nature of the underlying generating process is.⁹

To summarize, the merit of Dessalles's theory is to provide a rigorous computational framework making straightforward predictions as to which events (or entities) will be deemed unexpected. Moreover, the developmental literature just reviewed helps us understand how unexpected simplicity is used as a cue to agency from an early age. Finally, Falk and Konold's work, as well as studies on metacognitive feelings, specify the link between experienced ease (i.e., fluency) on the one hand, and simplicity and nonrandomness on the other; so doing, they enable us to grasp the detailed psychological mechanisms through which Dessalles's computational framework is likely to be implemented. The following thesis can now be put forth: *when an event (or an entity) is expected to be complex (i.e., to be disfluent or difficult to process) but when it turns out to be simple (i.e., to be fluent or easy to process), this event (or this entity) will be perceived as unexpected, and, if the observed complexity drop (the gap between expected disfluency and experienced fluency) is big enough, it will be inferred that an agent must have caused the observed reduction of complexity.*

The Complexity Drop Model of the Supernatural (CDMS)

The previous section explains how *human agency* is detected. However, understanding magic requires us to explain how *supernatural agency* is usually detected. In order to grasp the mechanisms of supernatural agency detection, let us go back to Case 1. As previously explained, Favret-Saada's book demonstrates that, in the Bocage, the magical nature of an event lies in the very structure of a sequence of events rather than in the intrinsic features of each single event. If a misfortune happens to someone (e.g., a heifer's death), it will be interpreted as plainly natural.

⁹It is worth noting that the experienced ease (or difficulty) in encoding Falk and Konold are referring to is closely related to (if not synonymous with) the *feeling of fluency* (Unkelback & Greifeneder, 2013). This concept, which has extensively been discussed in the field of metacognition, is usually defined as the ease of information processing. Feelings of fluency are notably characterized by their phenomenology (Reber, Fazendeiro, & Winkielman, 2002; Schwarz & Clore, 2007).

However, if this misfortune is preceded and followed by other unfortunate events, each of these events will then be understood not only as the result of a natural process (e.g., the heifer died because of illness) but also as the obvious manifestation of some bewitchment.

We can now easily make sense of Favret-Saada's case in the light of the model adumbrated above. People generally expect events, either fortunate or unfortunate, to occur randomly. Let us write "1" for any fortunate event and "0" for any unfortunate event. People's expectation, then, is that any sequence of their life will look more or less like this: 010010110100. But sometimes, as we all know, life looks more like that: 000000000000. This is precisely what happens in Case 1. In our own terms, bewitched peasants are reasonably expecting a fairly complex sequence of events to take place (010010110100), but what effectively takes place happens to be an abnormally simple pattern of events (000000000000). The detection of some supernatural agency usually coincides with a striking complexity drop. However, the precise reason why complexity drops lead to the detection of *supernatural* agency remains to be spelled out.

To understand this, let us suppose that we are playing with a die. We expect the outcome of throws of a die to be random (for example: 3, 6, 1, 4, 2). Now, let us imagine that the observed outcome happens to be the following: 6, 6, 6, 6, 6. According to our model, this leads to some agency detection: someone must have tampered with the die—the die is definitely not a fair one! In front of such a complexity drop, the abnormal simplicity of the sequence is explained by resorting to an agent, and importantly this agent is a human one (not a supernatural one) because we possess a *natural causal schema* specifying how humans can tamper with dice. Let us now return to Case 1. As with the loaded die, a complexity drop is observed (a random sequence was expected and a nonrandom one occurs). Unlike the case of the loaded die, however, in Favret-Saada's case, we do not have any *natural causal schema* at our disposal in order to explain how a human agent caused the complexity drop. We know very well that humans can tamper with a die whereas we know of no human-like being able to control the course of existence and able to turn fortune into misfortune (or the other way around). When facing a complexity drop such as the one discussed by Favret-Saada, we are thus inclined to explain the nonrandom sequence of misfortunes by postulating the existence of an agent, and because no natural agent can turn fortune into misfortune, this agent must be a supernatural one. Indeed, only a *supernatural causal schema* can do the job of explaining such a complexity drop. Two kinds of complexity drop should thus be distinguished: one which can be accounted for by *natural causal schemas* and another which can only be accounted for by *supernatural causal schemas*. Hence, the two criteria of the Complexity Drop Model of the Supernatural (CDMS): *an event or a being will be ascribed supernatural features, if (i) the complexity which defines it is much lower than what was expected, and if (ii) the observed complexity drop cannot be accounted for by some natural agency.*

The CDMS seems able to explain fairly well the supernatural agency detection at work in Case 1. But how well can it equally easily account for cases such as those discussed by Evans-Pritchard (Case 2) or Stépanoff (Case 3)? It is here that

Dessalles's theory proves particularly fruitful and powerful. Indeed, not only does Dessalles provide a mathematical framework defining complexity drop in a thoroughgoing manner, but he also identifies distinct types of complexity drop.¹⁰ As will be shown, each of the three case studies presented above illustrates one specific type of complexity drop. For the sake of clarity, let us define the three types of complexity drop:

- *Type 1. Complexity drop triggered by redundancy.* First, a complexity drop can stem from the simplicity (the redundancy) of a pattern of events: one is expecting a random (a complex) string (e.g., a string where 1s and 0s are instantiated randomly) but observes a redundant (a simple) string (e.g., a string consisting only of 1s or 0s).
- *Type 2. Complexity drop triggered by proximity/familiarity.* Second, complexity drop can stem from the abnormal simplicity of the place or the characters involved in an event. Famous places (e.g., the White House) or famous people (e.g., Barack Obama) are remarkably simple, because computational resources required to describe them are very limited. Similarly, familiar places (the place where one was born) or familiar people (one's relatives) are particularly simple (not for everyone, but for the person concerned).
- *Type 3. Complexity drop triggered by atypicality.* Third, complexity drop can stem from atypical features. Let us consider the following geometric shapes: 3 squares and 1 chiliagon. To be sure, a chiliagon is intrinsically much more complex than a square (describing it requires more computational resources). However, if we want to single one specific shape out of the four aforementioned, it will be simpler to single out the chiliagon than any of the three squares. Singling out the chiliagon requires the program to follow one single instruction—"pick up the shape which does not look like the others"—whereas singling out one of the squares requires our program to use an additional instruction—"pick up the shape which looks like the others" and "which is located on the left/right." This is why, from an algorithmic standpoint, atypical items are intrinsically more complex than typical ones but are paradoxically simpler to describe.

As demonstrated earlier, Favret-Saada's case illustrates how Type 1 complexity drop can lead to the detection of supernatural agency. It is worth emphasizing that Type 1 complexity drop can result from either an abnormal succession of unfortunate events (Favret-Saada, 1980) or an abnormal succession of fortunate events (such as being abnormally successful at hunting or in love affairs) (Brown, 1986). We now turn to the two other cases.

Evans-Pritchard insists that when Azande resort to magical explanations, they do not mean to deny the reality of physical or biological processes at work (e.g., the

¹⁰See: Dessalles (2007, 2010). As a matter of fact, Dessalles identifies about a dozen of types of complexity drops. In this chapter, we discuss only three of them. However, several types of complexity drops singled out by Dessalles share commonalities and could therefore arguably be grouped together.

termites eating the wood of the granary) but they want to explain why is it that these “particular people”—these close friends and these relatives—have been injured and killed (Evans-Pritchard, 1976, p. 22). Clearly, what puzzles the Azande is not that a granary can fall—they know that, in virtue of the laws of nature, such a thing can very well occur—but rather that the granary can fall at the very wrong time and on the very wrong people. This is too big a coincidence! According to the CDMS, there is nothing incomprehensible in the Azande’s puzzlement. The event they interpreted in magical terms is indeed puzzling because the people concerned were very “particular people” (relatives and close friends); these people were, in algorithmic terms, abnormally simple people. So some (supernatural) agency had to be held accountable for this complexity drop. Evans-Pritchard’s case thus illustrates how a Type 2 complexity drop can lead to the detection of supernatural agency.

In Stépanoff’s case, we are dealing with entities (mostly animals, but also plants and rocks) whose features are remarkably atypical (because of their color, size or shape). This schema fits very well with what we have defined as Type 3 complexity drop. Atypical entities (such as an albino squirrel) are algorithmically simpler to describe than entities sharing many features with the other surrounding entities. It is worthy to note that Type 3 complexity drop can be brought about by an atypical *physiological* feature but also by an atypical *behavioral* feature. Anthropologists have extensively documented how, in certain regions of the world, animals behaving abnormally are suspected to be not real animals but spirits momentarily inhabiting an animal or taking the deceiving shape of an animal (e.g., Keifenheim, 1999).

Let us take stock: when an event or a being is processed with fluency (when it is algorithmically simple) while it was expected to be processed with difficulty (expected to be algorithmically complex), the unexpected fluency (the complexity drop) is explained by inferring that some agency has interfered at some point in the generating process; when, furthermore, the kind of agency required to cause such an unexpected fluency (such a complexity drop) does not fit with ordinary causal schemas, an extraordinary (or supernatural) causal schema is then posited or used. It must also be remembered that unexpected fluency (complexity drop) can be caused by distinct mechanisms (for a summary, see: Table 2).

Comparing the CDMS with Other Cognitive Models of Magic

In recent years, several models of magic have been developed by cognitive scientists of religion.¹¹ Spelling out how our proposal distinguishes itself from other well-established models will enable us to better understand the originality and scope of the CDMS.

¹¹Note that cognitive science of religion is not restricted to the study of religion *stricto sensu*. Many researchers working in this field are investigating shamanism, magic, witchcraft, etc.

Epidemiological Versus Doxastic Models of Magic

Among the most influential models of magic, those accounting for the epidemiology of supernatural representations deserve a special mention (Atran, 2002; Barrett, 2004b; Boyer, 2001; Sperber, 1996). Even though they differ in the details, all these models share the core thesis that owing to their counterintuitiveness, supernatural representations prove particularly catchy and can thus spread very successfully across space and time. The cognitive science of religion thus seems to corroborate the psychological approach to magic: recognizing that magical representations are essentially counterintuitive is apparently quite consistent with saying that counterintuitive stimuli tend to trigger magical explanations. Nevertheless, there is good reason to resist conflating these two lines of research and to maintain that the counterintuitive models of magic developed by the proponents of the epidemiological approach do not accord well with those put forward by developmental psychologists.

What psychologists demonstrate is that children (and, in some cases, adults) are inclined to postulate the existence of magical processes or magical beings in order to explain the occurrence of impossible events. That is, the need for an explanation leads people to be *committed to the existence* of magical entities and to *believe* in magical entities. In this regard, psychological models of magic attempt to explain the *doxastic* dimension of magic. By contrast, epidemiological models of magic are impervious to doxastic and ontological issues. Their aim is not to explain why or even whether people believe in or are ontologically committed to certain entities. Epidemiological models modestly aim at explaining why certain representations are very memorable and easily transmitted and why others are less so. Now, *pace* Boyer, remembering is not believing.¹² For example, we may all very well remember the concept of Santa Claus; the concept of Santa Claus may be very catchy; still, most of us do not believe in the existence of Santa Claus. The folklore is replete with myths, legends, and tales depicting counterintuitive entities. Fair enough. But this does not mean that representing (remembering, narrating, painting, etc.) these entities amounts to being committed to their existence—some people believe in some of these entities and others do not. Epidemiological models attempt to understand how representations spread in space and time but they have nothing to tell us as to why people might believe (or not believe) in them. Epidemiological models remain silent about the doxastic dimension of magic; in this regard, they are very different from the models of magic that developmental psychologists advocate.

Epidemiological models tend to equate supernaturalness with counterintuitiveness. Yet, as just mentioned, people can very well represent counterintuitive entities and still not believe in them. The set of counterintuitive representations is therefore bigger than that of supernatural beliefs. Moreover, as demonstrated earlier, people often believe in magic in situations in which no counterintuitive event or entity is

¹²Cf. Boyer (2001, pp. 302–304). For a critical discussion of Boyer's assumptions, see Fortier (in press).

involved (think of Favret-Saada's or Evans-Pritchard's case). It is important to understand why people interpret certain events (e.g., a sequence of misfortunes) or certain beings (e.g., an albino squirrel) as magical and why they are committed to the reality of these representations. Remarkably, the CDMS meets all these challenges.

The Hypersensitive Agency Detection Device and the CDMS

Some proponents of the epidemiological account of magic have attempted to meet the doxastic challenge by developing a model which explains why people are sometimes inclined to be committed to the existence supernatural entities. This is notably the case of Justin Barrett, who endorses the epidemiological program, but who has also developed the Hypersensitive Agency Detection Device (HADD) model in order to explain why people *believe* in some of the representations that they entertain (Barrett, 2004b). The HADD model is based on a wealth of studies showing that humans (and, to a certain extent, primates) are very adept at detecting agency (see: Rutherford & Kuhlmeier, 2013). By and large, the HADD assumes that it is evolutionarily advantageous to overdetect danger and agency in the world: it is better to trigger false positives (to detect a predator when there is none) rather than omitting actual signals (missing to detect a predator which is there). According to this view, humans have acquired a special ability to detect agency in their environment, and as a result, they are now prone to see agents everywhere (to see faces in the clouds, to attribute intentions to beings devoid of mental states, etc.). The HADD model is wide ranging. It includes three distinct versions of the same general claim:

- *From misperception to agency detection.* This line of research has been mainly explored by Stewart Guthrie (1993). Pareidolia is a striking instance of the kind of agency detection. Humans are prone to see anthropomorphic patterns (typically, a face) where there is no such pattern. Arcimboldo's paintings exemplify this bias fairly well. If one sees a face in a rock, one may subsequently infer that this rock is a living being and possess some kind of agency.
- *From motion to agency detection.* Another type of agency detection is based on motion. Heider and Simmel's (1944) famous study provides a good illustration of this phenomenon. When one sees a plain shape (such as a triangle) moving in a certain way, one cannot help attributing mental states to this triangle (e.g., this triangle is attacking or protecting someone). Motion is used as a cue to agency; as a result, agency can be ascribed to objects which are known for not possessing any agency.
- *From etiological gaps to agency detection.* Barrett (2004b) has extensively discussed cases where an event occurs while no visible agent is present. A door closing by itself generates an etiological gap: it is known that doors don't close by themselves, if it seems to do so, it must be because of an invisible agent. In

such a case, the existence of an invisible agent will be postulated to elucidate why the door closed itself and to fill the etiological gap.

Can these three versions of the HADD account for the three case studies introduced earlier? Does the HADD differ from the CDMS? Let us first focus on the two first versions of the HADD (misperception and motion). The weakness of these two models is that at most they explain how *natural agency* is ascribed but they do not say a word as to how *supernatural agency* is ascribed. By contrast, the CDMS readily explains how, for example, supernatural agency is inferred from a sequence of unfortunate events (only an agent with supernatural powers is able to turn fortune into misfortune). How could supernatural agency be inferred from pareidolia or motion? Besides, these two versions of the HADD wrongly assume that agency detection can only occur if the agent is *visible*. Yet, in many cases, supernatural agency detection occurs while the agent is not visible whatsoever (in Bocage witchcraft, for instance, misfortunes are visible but the causes of these unfortunate events—the supernatural agents—are not).

The third version of the HADD is a little more promising. *Inter alia*, it manages to explain how detection of *supernatural agency* occurs.¹³ The main drawback of this model, however, lies in the fact it takes agency detection to follow from the violation of physical laws. In the example of the door, an etiological gap needs to be filled only because some domain-specific counterintuition occurs. This is a serious problem because, as explained earlier, most of the cases provided by ethnographers do not involve the violation of any domain-specific knowledge. The HADD fails to account for this crucial fact. The CDMS, on the other hand, perfectly meets this challenge.

Probabilistic Models of Magic and the CDMS

Finally, it has been proposed that probabilistic models could help us understand the main mechanisms of magic (Bronner, 2003, 2007; Clément, 2003). Building upon previous research on probabilistic reasoning, it has been suggested that a cognitive bias such as the *gambler's fallacy* could explain why people have a distorted perception of probabilities and randomness, and thereby, why they resort to magical explanations. As Bronner (2003, 2007) remarks, people wrongly assume that the usual random course of nature is not compatible with homogeneity¹⁴; if a

¹³It is worth remarking that the supernaturalness of the agency at hand is still quite limited: admittedly, no natural agent can invisibly close a door, but it remains that closing a door, unlike turning fortune into misfortune, is not an outstanding feat.

¹⁴This is Bronner's own term. It must be pointed out that what is meant exactly by "homogeneity" remains rather vague. The term clearly seems to overlap with the concept of simplicity. The problem, however, is that Bronner does not provide any formal mathematical definition of homogeneity. As a consequence, no straightforward prediction can be made. By contrast, Dessalles' theory and the CDMS are grounded on neat formalism.

succession of fortunes (or misfortunes) occurs in a row, people will be puzzled and will look for a special (a supernatural) explanation, because they will reason that such a succession cannot be brought about by nature alone. This probabilistic approach to magic has many ideas in common with the CDMS.

Despite their valuable strengths, however, Clément's and Bronner's models remain limited for at least two reasons. First, they account very well for people's tendency to misrepresent randomness and probabilistic processes in general, but they do not spell out the link between probabilistic reasoning and agency detection. The link between cognitive biases and supernatural agency detection remains unexplained. The merit of Kushnir, Wellman, Xu, and colleagues is precisely to have discovered what the missing link was. Drawing upon these studies, the CDMS clearly spells out how supernatural agency detection stems from probabilistic reasoning. This is an important difference with Clément's and Bronner's models.

The second limit of existing probabilistic models of magic is that not any improbable event is liable to be interpreted as magical. Admittedly, in the three case studies we have examined something highly improbable is happening (i.e., an uninterrupted sequence of misfortunes is improbable; having relatives killed by the collapse of a granary is improbable; meeting an atypical animal or plant or rock is improbable); yet, there are plenty of improbable events which will never be interpreted in magical terms. Improbability is a necessary but not a sufficient condition of magic. Unlike strictly probabilistic models of magic, the CDMS does not predict that any improbable event triggers magical explanations; more specifically, it states that only *complexity drops* are likely to trigger magical explanations. *Complexity surges* (i.e., encountering randomness when order was expected) are very often highly improbable but they are not interpreted in magical terms. Think of the case mentioned earlier: I am walking in a meadow in which flowers are scattered randomly, and when I face an abnormally straight line of flowers I infer that a human agent must have intentionally planted the flowers this way. Now, let us consider the reverse case: I am walking in a *jardin à la française* and I am expecting to encounter only straight lines of flowers around me, but then, suddenly, I encounter flowers randomly distributed. Would I infer from this complexity surge that some human agent has intentionally planted these flowers randomly? This is very doubtful. Hence, the idea that agency detection is specifically a matter of complexity drop and not a matter of statistical improbability. The CDMS is more parsimonious and specific than existing probabilistic models of magic and it is able to make predictions which better fit with actual anthropological data.

Toward a Big Picture: Putting Counterintuitive-Magic and Probabilistic-Magic Together

Secularization and Explanatory Coexistence: The Persistence of Magic Through History

Before examining how the types of magic identified so far are combined and employed through development and cultures, it will be useful to look at the historical trajectory of magic. In particular, did the advent of modernity and secularization take place to the detriment of magic? It is often claimed that modernity and magic are antagonistic. For example, Weber (2003) and Thomas (1971) have both championed the view that religion and science have considerably contributed to the elimination of magic. Thomas notably maintained that the advance and development of science has gradually confuted magical beliefs; similarly, Weber famously contended that the world is now disenchanted (*entzaubert*) and there is no room in the secular cosmos for magic anymore. The accuracy of such assertions obviously depends on which definition of magic is adopted. If magic is defined in counterintuitive terms, then there is perhaps a grain of truth in Weber and Thomas' claim. For instance, the ingenuousness that people showed in front of counterintuitive feats a few centuries ago (Le Bouyer de Fontenelle, 1687) has arguably largely vanished; it might be that now more than before, adults see impossible events as being the result of trickery rather than real magic (but see Subbotsky, 2004, 2014). If magic is defined in terms of complexity drops rather than impossible events, however, Weber and Thomas' thesis might be proved wrong. In the remainder of this section, we will show that magic (as defined by the CDMS) is still widespread in the modern world. We will also suggest that two types of explanatory coexistence should be distinguished: *forced coexistence* (when two competitive explanatory frameworks coexist) and *easy coexistence* (when two non-competitive and complementary explanatory frameworks coexist).

It must first be acknowledged that the so-called wane of magic has never properly taken place. Human activities in which a great deal of uncertainty is involved are still, even in the modern world, replete with magical beliefs and practices (Bersabé & Martínez Arias, 2000; Blumberg, 1963; Keinan, 1994; Rudski & Edwards, 2007; Vyse, 1997). A plethora of anecdotes demonstrate that politicians and sportsmen (two domains in which uncertainty is prominent) often resort to the service of magicians (Bleak & Frederick, 1998; Blumberg, 1963; Pégard, 2000). Moreover, secularization processes are often only illusory. For example, one rather convincing idea that Favret-Saada (1986) has put forward is that the rise of witchcraft observed in the Bocage was a direct consequence of the demagification of the Catholic Church. Following the demands of clerical authorities, the priests stopped indulging in magical rituals, and as a result, Bocage peasants felt the pressing need of dealing with their existential misfortunes and they thus turned to witchcraft. The secularization of religion (in this case of the Catholic Church) was

not a sign of the secularization of the world; it simply amounted to a transfer of magical beliefs and practices from one side (the Catholic Church) to another (witchcraft).

It has been shown above that magic is to be distinguished from religion. While the latter is mainly concerned with otherworldly matters and big questions, the former is remarkably pragmatic, utilitarian, and down-to-earth. It is a pity that recent research on explanatory coexistence—i.e., on the simultaneous use of natural and supernatural explanations—does not subdivide the broad category of the supernatural into to subcategories: magic and religion (Legare, Evans, Rosengren, & Harris, 2012; Shtulman & Lombrozo, 2016). In itself, explanatory coexistence challenges the secularization story; if people explain the world in both natural and supernatural terms, this implies that, after all, supernatural beliefs have not entirely disappeared. It is worth emphasizing, however, that the thesis of the disenchantment of the world concerns chiefly magic. Modernity and secularization are claimed to be antagonistic with magic but not necessarily with religion (Weber, 2003). For instance, the coexistence of evolutionary and creationist explanations in accounts of the origin of man does not directly contradict the secularization story (Evans, 2001), whereas the coexistence of biological and witchcraft explanations in accounts of illness clearly does (Legare & Gelman, 2008).

Only tangible efficiency and material well-being matter in magic; there is no room for morality or otherworldly speculations. Science and religion, on the other hand, do address speculative issues such as the origin of man, of the universe, or the fundamental nature of things. Science shares with magic its instrumental and mechanistic image of the world, but it shares with religion its taste for abstract theorizing and big questions. In science and religion, a great amount of reflective effort is put in refining theories and grasping truth. By contrast, magic does not exhibit any kind of craving for truth; theoretical refinement is not seen as intrinsically valuable and worth pursuing; magic invests efforts in theorizing only to the extent that it will bring tangible outcomes.

On issues such as the origin of the universe, the earth, and man, religion used to hold theories directly competing with those of science. For example, the Roman Catholic Church has been forced to gradually update its theories in response to numerous challenges sparked by science (Hess & Allen, 2008). By contrast, magic is seldom in competition with science. Scientific explanations are not meant to elucidate why, for example, a complexity drop takes place when a granary collapses (Case 2). Magical explanations, on the other hand, are chiefly concerned with complexity drops. Magical theories are unlikely to be defeated by science because science does not intend to build any competitive theory accounting for complexity drops.¹⁵ The coexistence of magical and scientific explanations seems to be very

¹⁵It could be objected that sometimes science does produce theories liable to be competitive with magic and to demystify it. For example, when Gilovich, Vallone, and Tversky (1985) attempt to demonstrate that the “hot hand” phenomenon is a sheer fallacy, it seems that their scope indeed overlaps that of magic. But two remarks are in order: first, it is important to underline that scientific investigations demystifying magic are much rarer than those demystifying religion; second,

natural: each has a specific and an exclusive explanatory scope. No strenuous theoretical work is required to make them compatible. By contrast, the coexistence of religious and scientific explanations requires a great amount of theoretical refinement and hybridization. Making science and religion compatible is hard work because their explanations are competing.

The two distinct patterns of coexistence that we are trying to excavate become particularly salient when we look at fundamentalism. It appears that *religious* fundamentalism undermines explanatory coexistence while *magical* fundamentalism does not. There is little doubt that a Christian fundamentalist will embrace creationism and reject evolution wholeheartedly. On the other hand, the Zande “witchcraft fundamentalist” who believes in spells and witches beyond doubt will still acknowledge without demur that when a granary collapses it is not only because of the witch’s agency but also because of termites and physical laws. The non-competitiveness of magic and science seems to be bidirectional: it is hard to conceive of a system of magic in which supernatural explanations have entirely ruled out natural ones; and conversely, it is hard to conceive of a secularization process which would have undermined every magical belief.

Legare et al. (2012) have proposed that three types of explanatory coexistence should be identified.¹⁶ Following the previous remarks, we suggest that two additional types of coexistence should be recognized: *forced coexistence* and *easy coexistence*. Cases where magical explanations coexist with scientific ones illustrate what we have in mind when we speak of easy coexistence. In situations such as those described by Case 1 (Bocage witchcraft) and Case 2 (Zande witchcraft), beliefs in magic on the one hand and in biology and physics on the other are combined rather smoothly. Religious explanations and scientific ones, on the other hand, are more difficult to put together. As illustrated by the attempts of progressive popes to make biblical accounts of the world compatible with those of the most

(Footnote 15 continued)

demystification attempts against magic do not seem to be as successful as those against religion. In this regard, it is worth noting that a series of recent studies seem to invalidate Gilovich et al.’s analysis and to demonstrate that the hot hand phenomenon is in fact real (Bocskocsky, Ezekowitz, & Stein, 2014; Raab, Gula, & Gigerenzer, 2012; Sun & Wang, 2010). By and large, when a cognitive psychologist objects to believers in magic that their beliefs are demystified by such and such bias in probabilistic reasoning, believers can still reply: “the existence of a cognitive bias in general does not prove that the very specific complexity drop which happened to me was the result of that bias rather than the manifestation of a genuine non-random (i.e., intentional) process.” Magic aims to explain singular events (not events in general), and science can hardly challenge it in this regard.

¹⁶The first type of coexistence involves an explanatory pluralism across situations or contexts (it is a case of explanatory coexistence only *lato sensu* because coexistence is not considered under the same conditions). Namely, depending on context, people are likely to explain the same phenomenon (e.g., death) either in natural or in supernatural terms. The second type of coexistence consists in explaining the same phenomenon by resorting to two distinct explanatory frameworks and letting it rather vague as to how the two frameworks are exactly working together. In the third type of coexistence, two frameworks are used to explain distinct aspects of the phenomenon at hand; the explanatory function of each framework is thus clearly specified.

advanced science, a lot of amendments and hybridizations are required to ensure explanatory coexistence between science and religion.

Shtulman and Lombrozo (2016) have thoroughly examined the different ways in which explanatory coexistence can be accounted for. They find it rather unconvincing to argue that supernatural explanations persist—and coexist with natural ones—because people still lack proper scientific knowledge or because intuitive ontologies (core knowledge) make them think unscientifically, or because system 1 (fast unreflective thinking) is not able to comply with the reflective products of system 2 (slow reflective thinking). Shtulman and Lombrozo reject all these accounts and advocate a fourth explanation contending that supernatural thinking is still there simply because of its utility (2016, pp. 59–60). They further suggest that understanding the roots of explanatory coexistence probably requires a multifarious account. Here again, it seems that clearly distinguishing between magic and religion could help us better solve the challenge at hand. We have argued that humans have a craving for accounts that can explain complexity drops. Magic is extremely good at fulfilling this craving. So, as far as the coexistence of magical and natural explanations is concerned, Shtulman and Lombrozo's thesis that coexistence is underlain by utility seems quite convincing. However, it might be argued that some other account of explanatory coexistence is to be found when it comes to the coexistence of religion and science.

Notwithstanding all this, it is important to acknowledge that not any magical account of complexity drop is equally immune to scientific findings. Specifically, it seems that in the three case studies we have examined, only two clearly remain independent from science: namely, when magical explanations are triggered by an abnormally simple sequence (Type 1 complexity drop) or by abnormally simple characters and locations (Type 2 complexity drop). By contrast, it appears that when magical explanations are triggered by an atypical morphology or behavior (Type 3 complexity drop), science remains liable to undermine such explanations. In this case, magical explanations and natural explanations seem to be in competition and the coexistence between the two will be forced rather than easy. Let us consider the example of an albino squirrel which is purported to have supernatural powers because of its atypical features. If Siberian shamans were taught about genetics and about the biological underpinnings of albinism, it is likely that they would discard their belief about the supernaturalness of albino squirrels; at least, hard work would be needed in order to make natural explanations (the genetic account of albinism) and supernatural explanations (the shamanistic account of albinism) coexist. While scientific explanations cannot easily demystify magic based on Type 1 and Type 2 complexity drops, it appears that they can readily do so with magic based on Type 3 complexity drops. When assessing the impact of science and secularization on magic, one should therefore always pay close attention to the type of complexity drop at work.

Developmental Psychology and the Anthropological Challenge

Throughout this chapter, we have introduced a new model of magic in which probabilistic reasoning plays a key role. This model contrasts with existing psychological accounts of children's concepts of magic in which the violation of domain-specific intuitions has been the main focus. However, it must be emphasized that the apparent conflict between these two models of magic should not be understood as the conflict between two distinct scientific camps trying to model a single cognitive mechanism but rather as two complementary approaches researching two distinct cognitive mechanisms.

The first part of this chapter reviewed empirical studies investigating the "counterintuitive" model of magic. Children seem to perceive and understand the occurrence of events violating their domain-specific knowledge as magic. By contrast, anthropological reports about magic better fit with the "probabilistic" (or "algorithmic") model of magic. It appears that humans are liable to deploy distinct concepts of magic and therefore that magical beliefs and practices stem from two different sets of cognitive mechanisms.

It could be tempting to have a developmental story as to how "counterintuitive-magic" gradually transmutes into "probabilistic-magic", as people grow older. Such a story would allow developmental psychologists to take the anthropological challenge not too seriously: the relevance of the probabilistic model of magic would be restricted to adulthood. Until proven otherwise, however, there is no evidence to borne out such a developmental story. Hence the first challenge: *as yet, developmental psychologists have been exclusively studying magic through the lenses of the counterintuitive model of magic and they have disregarded the possibility that magical beliefs and practices are extensively underpinned by probabilistic mechanisms, not only among adults, but also among children.*

Admittedly, a few psychologists have already paid some attention to the relationship between impossibility, improbability, and magic. Such is the case of Shtulman and Carey (2007). One significant finding reported in this study is that children have it that an impossible event can occur in the real world only thanks to some magical interference, whereas an improbable event can naturally occur in the real world (2007, pp. 1026–1027). At first sight, this seems to provide evidence against the first challenge just outlined: as far as children are concerned, it is wrong to claim that improbable events trigger magical explanations. It is worth looking at the definition of "improbability" Shtulman and Carey operationalize in their experiment, though. The kind of event they have in mind when speaking of "improbable events" are events such as "finding an alligator under the bed," importantly, in their experiment, they explicitly rule out any "statistical" definition of improbable events (2007, pp. 1017–1018). As we have seen throughout the chapter, the probabilistic model of magic predicts that only events involving some kind of complexity drop are likely to trigger magical explanations. While statistical improbability does generate such complexity drops, on the other hand, "conceptual

improbability” (e.g., finding an alligator under the bed) notably fails to do so. As a consequence, Shtulman and Carey’s study does not bear on the definition of probabilistic-magic that we are proposing here. To our knowledge, psychologists have never studied the link between complexity drops and magical explanation. The challenge anthropology is posing to psychology thus seems to remain unaddressed.

In order to properly address this challenge, psychologists should introduce new experimental paradigms in their toolbox. Experimental paradigms usually used by psychologists involve children who are typically presented with events violating intuitive ontologies (e.g., a flying physical object) and a character who is shown to be able to bring about such counterintuitive events. By contrast, the kind of paradigm satisfactorily operationalizing the probabilistic definition of magic advocated here would feature the occurrence of striking complexity drops (e.g., drawing a white ball from an urn containing mostly black balls) and a character shown to be able to bring about such counterintuitive events. Indeed, from our probabilistic standpoint, a supernatural agent (or a human endowed with supernatural powers) is nothing more than an agent able to bring about complexity drops left unexplained by ordinary models of causation.

Not only does the complexity drop model suggest that psychologists may have forgotten to take into consideration the probabilistic mechanisms underlying magical explanations, but, what is more, it may be that these probabilistic mechanisms are in fact much more used and widespread than the domain-specific ones on which psychologists are focusing. Classical experimental paradigms of magic consist in presenting children with events violating intuitive ontologies. It is undeniable that children tend to resort to magical explanations when faced with such counterintuitive stimuli. Such stimuli are massively produced by psychologists in laboratories or conjurers on stages in theaters, but it is worth noting that these stimuli are very rare in the natural world. If one endorses a naturalistic approach and rejects the existence of miracles, one must conclude that counterintuitive stimuli exist only to the extent that humans use their tricks and ingenuity to produce them. On the other hand, stimuli characterized by a complexity drop do not always require the interference of human agency. A succession of unfortunate events sometimes occurs naturally whereas a miracle always requires the interference of some kind of trickery.

Contrary to what authors such as Le Bouyer de Fontenelle (1687) mistakenly asserted, a modicum of anthropological knowledge suffices to realize that agents supposedly endowed with supernatural powers (witches, sorcerers, shamans, etc.) are not claiming to be able to bring about impossible events but rather to bring about complexity drops. As a consequence, being exposed to a culture where magical practices are pervasive does not amount to being exposed to numerous counterintuitive events. It seems fair to say, then, that both children and adults are presented in their daily existence with a substantial amount of naturally occurring complexity drops while counterintuitive events remain rather rare. Therefore, the worry is that, when presenting children with counterintuitive events, psychologists do target a cognitive faculty children have (that of interpreting such events magically) but they may fail to specifically target the cognitive mechanisms children are

tapping into when they are faced with complexity drops in their daily existence. Hence, the second challenge that anthropology poses to psychology: *as yet, psychologists have been exclusively studying magical explanations triggered by counterintuitive stimuli and it may be that such magical explanations remain in fact rarely employed in the real world because of the lack of naturally occurring counterintuitive stimuli; conversely, it may be that magical explanations triggered by complexity drops are the only ones massively employed in the real world—indeed, the natural environment is replete with complexity drops while counterintuitive events are to be encountered mainly in psychology laboratories and on stages.*

Counterintuitive-Magic and Probabilistic-Magic Across Development

The comparative examination of psychological and anthropological studies on magic led us to single out two types of magic: (1) *counterintuitive-magic* (for short, *CT-magic*) is characteristically triggered by counterintuitive stimuli and is underpinned by domain-specific cognitive mechanisms; (2) *probabilistic-magic* (for short, *PR-magic*) is characteristically triggered by complexity drops and is underpinned by probabilistic (or algorithmic) cognitive mechanisms. Different hypotheses can be put forward as to how these two types of magic coexist together, or replace each other, or prevail over the other across development.

Four Hypotheses About the Developmental Trajectory of Counterintuitive-Magic and Probabilistic-Magic

In what follows, we will consider four potential hypotheses about the developmental trajectory of CT-magic and PR-magic (see summary in Table 1):

Let us spell out the content of Table 1:

Hypothesis 1. Replacement of CT-magic by PR-magic throughout development. The first hypothesis has it that CT-magic is the only kind of magic to be found

Table 1 “Counterintuitive-magic” and “probabilistic-magic” across development

	Childhood	Adulthood
Hypothesis 1	CT-magic	PR-magic
Hypothesis 2	CT-magic + PR-magic	PR-magic
Hypothesis 3	PR-magic	PR-magic
Hypothesis 4	CT-magic + PR-magic	PR-magic + CT-magic

among children while PR-magic is the only kind of magic to be found among adults.

Hypothesis 2. Decrease of CT-magic after short coexistence of PR- and CT-magic. The second hypothesis advances that children are capable both CT- and PR-magic, but that, as they grow older, they eventually discard CT-magic and keep exclusively PR-magic.

Hypothesis 3. Exclusivity of PR-magic throughout development. The third view claims that both children and adults exert exclusively PR-magic.

Hypothesis 4. The coexistence of CT-magic and PR-magic throughout development. The fourth hypothesis states that CT-magic and PR-magic coexist both among children and adults.

Hypothesis 1: Replacement of Counterintuitive-Magic by Probabilistic-Magic Throughout Development

The strongest evidence in favor of Hypothesis 1 is that, on the one hand, plenty of findings from developmental psychology support the existence of CT-magic, and that, on the other hand, plenty of data from anthropology support the existence of PR-magic. Clearly, the most straightforward way to solve these two sets of findings is to advance that developmental psychologists accurately account for magic at work *in children's minds* while anthropologists accurately account for magic at work *in adults' minds*.

There are some reasons to reject Hypothesis 1, though. As it happens, we have recently designed an experiment operationalizing the probabilistic definition of magic developed in this chapter,¹⁷ and one of us (MF) has conducted this experiment in the Peruvian Amazon, with children aged from 5 to 9. Interestingly, the preliminary data suggest that at least some children are able to discriminate between

¹⁷In this experiment, the supernatural agent (the shaman, the witch, the medicine man) was defined as an agent able to control complexity drops occurring in the world. Children were presented with videos featuring a character drawing balls from three urns located in front of him. These urns contained black balls and only one single white ball. Importantly, white balls were the only balls containing a reward inside: thus, drawing a white ball was tantamount to being lucky and drawing a black ball tantamount to being unlucky. If the character was drawing a black ball, he was being *expectedly* “unlucky” (expectedly, because most of the balls were black in the box); if, on the other hand, he was drawing a white ball, he was being *unexpectedly* “lucky” (unexpectedly, because only a single ball was white in the box). Because urns contained mostly black balls and because balls were being drawn randomly, the character was expected to be most of the time expectedly “unlucky”. This is precisely what was happening in the first phase of the experiment (no improbable outcome occurred). But, in the second phase, the character started to draw balls with a very special glove or performing a special ritual before drawing the balls. Thanks to this “magical” glove or to this “magical” ritual, the character was now drawing only white balls from the urns. The character was thus being unexpectedly lucky; he was somehow able to control the probabilistic unfolding of the events of the world and to make happen only fortunate events (i.e., to make happen only drawings whose outcomes were white balls).

random complexity drops and complexity drops seemingly resulting from the interference of an agent endowed with magical powers. Furthermore, when asked about the occurrence of a complexity drop, a few children explicitly reported that the complexity drop they had observed in the video had been caused by magic. This demonstrates that at least some children do resort to magical explanations when no ordinary model of causation can satisfactorily account for the occurrence of a complexity drop. In other words, PR-magic is already at work among children (at the very least, among some children). This is no big surprise given that very young children are known to be good probabilists (Denison, Reed, & Xu, 2013) and good at inferring agency from complexity drops (Kushnir et al., 2010; Ma & Xu, 2013; Wellman et al., 2016). Taken together, these results tend to invalidate Hypothesis 1.

All this being said, the claim that PR-magic is to be found already among children may need to be a bit qualified. One possibility is that children already possess PR-magic but that this kind of magic is not as widespread among children as it is among adults. A long time ago, Mead (1932) had noticed that supernatural thinking could not be boiled down to some kind of intellectual immaturity; by the same token, some experimental studies have recently showed that supernatural explanations increase with adulthood. This has been clearly demonstrated in Legare's study on supernatural explanations of illness in South Africa (Legare & Gelman, 2008). Such findings nicely echo thorough ethnographic work revealing the importance of training in the development of magical thinking (e.g., Luhrmann 1991). To put it in our own terms, detecting complexity drops in the environment may be a universal ability but it certainly requires intense training to properly develop. These remarks strongly suggest that although PR-magic is most likely already at work in young children's mind, it is not yet fully developed.

On a related note, one could surmise that some types of complexity drops (e.g., Type 1) are readily detected by everyone, including children, while other types of complexity drops (e.g., Type 2 or Type 3) require a great deal of enculturation. It is also worth emphasizing that magical inferences are amply guided by background knowledge. Explaining an abnormal complexity drop requires the possession of a theoretical framework specifying what kind of supernatural entity usually causes such and such complexity drop. Cultures in which complex cosmologies are available explain different types of complexity drops by resorting to different types of supernatural entities. For example, depending on whether the illness is short and sudden or gradual and long-lasting, it will be inferred that a witch rather than a sorcerer or a spirit rather than God, has caused the illness. Such inferences seem to require a cognitive sophistication that children may not have. Thus, even though PR-magic may already be at work among children, it remains unlikely that children are able to employ magic with as much sophistication as adults.

Hypothesis 1 and Hypothesis 2: Decrease of Counterintuitive-Magic Throughout Development

Both Hypothesis 1 and Hypothesis 2 advance that CT-magic decreases as children grow older. While younger children and older children are both able to detect the specialness of impossible events (Johnson & Harris, 1994), only the former judge that such events can still occur in real life through the interference of magic (e.g., Phelps & Woolley, 1994). A recent neuroimaging study shows that the recognition of impossible events and the subsequent reflective effort to make sense of the causal incongruity of such events coincide with an increased activity in the dorsolateral prefrontal cortex (DLPFC) and in the anterior cingulate cortex (ACC) (Parris, Kuhn, Mizon, Benattayallah, & Hodgson, 2009). This finding interestingly echoes other studies showing that prefrontal areas—and particularly the DLPFC—are notoriously deactivated in dreaming (Hobson, Pace-Schott, & Stickgold, 2000; Maquet et al., 1996; Schwartz & Maquet, 2002). It is well known that impossible events occurring in dreaming are almost never recognized as incongruous—presumably because of the deactivation of the DLPFC. Contrariwise, in lucid dreaming, where the activity of the DLPFC resembles that of waking states, impossible events are easily recognized as incongruous (Dresler et al., 2012; Schmitz, Kawahara-Baccus, & Johnson, 2004; Voss, Holzmann, Tuin, & Hobson, 2009). More to the point, neuroanatomical studies on the development of the prefrontal cortex among children allow us to speculate that the reason why children are able to recognize the specialness of impossible events and yet unable to demystify such events (to treat them as mere trickery) is that their prefrontal cortex (and in particular their DLPFC) remains largely underdeveloped (Diamond, 2002; Giedd et al., 1999). However, this hypothesis should be cautiously considered, because, first, the DLPFC seems also to be recruited when improbable (but possible) stimuli are processed, and second, the distinction between improbable and impossible stimuli may simply be a question of degree of activation (Fletcher et al., 2001; Fugelsang & Dunbar, 2005; Parris et al., 2009).

It could consequently be argued that psychological and neuroscientific findings support to a certain extent the claim (common to Hypotheses 1 and 2) that CT-magic significantly decreases throughout development. As humans grow older (as, presumably, their DLPFC and ACC develop), they become more and more skeptical about impossible events and they come to demystify impossible stimuli they are presented with. Unlike impossible events, complexity drops appear to remain unaffected by the development of prefrontal critical faculties. Indeed, complexity drops do not entail the occurrence of events violating basic causal laws. The existence of CT-magic depends on the absence of prefrontal scrutinizing of the world; on the other hand, PR-magic depends only on the ability to use complexity drops as a cue to agency (Griffiths & Tenenbaum, 2001; Kushnir et al., 2010; Ma & Xu, 2013; Wellman et al., 2016). Hypotheses 1, 2, and 3 all reason that if the development of prefrontal critical faculties coincides with the decrease of CT-magic, then, the only type of magic to be found in adulthood will be PR-magic.

Hypothesis 3: Exclusivity of Probabilistic-Magic Throughout Development

Hypothesis 3 goes even further than simply saying that only PR-magic is to be found among adults. It additionally contends that PR-magic is the only type of magic children are capable of. One motivation for endorsing this hypothesis is that, as argued earlier, it might be that CT-magic is after all nothing more than an experimental artefact to be encountered only in psychology laboratories where children are presented with stimuli violating their intuitive ontologies; in the real world, where no such naturally occurring stimuli are encountered, children would never have the chance to exert CT-magic. Therefore, in natural settings, the only kind of magic to be encountered among humans (regardless of their age) would be PR-magic.

The soundness of this Hypothesis depends on what is meant by saying that only PR-magic is *present* among children. This can be interpreted in two ways: (1) in the everyday world, children use only PR-magic; (2) children resort to magic only when they are presented with improbable stimuli and not when they are presented with impossible ones (regardless of whether this is done in a laboratory or in the everyday world). While (1) is concerned with how children think in natural settings, (2) is interested in studying children's cognitive dispositions and doing so may include the use of stimuli rarely (or even never) occurring in natural settings. By and large, it seems, anthropologists tend to find question (1) more significant and interesting than question (2), and conversely, psychologists tend to find (2) more significant than (1). We do not want to enter into this debate here, but let us simply point out that if Hypothesis 3 is understood to mean (2) it is then clearly untenable for, as we have seen, plenty of evidence demonstrates that when presented with the right stimuli children do use CT-magic. By contrast, if what is meant is no more than (1), then further investigations should be carried out in order to assess whether this hypothesis is accurate or not.

Hypothesis 4: The Coexistence of Counterintuitive-Magic and Probabilistic-Magic Throughout Development

Hypothesis 4 denies the main claim of Hypothesis 3 regardless of whether this claim is understood as meaning (1) or (2). To be sure, no naturally occurring impossible stimuli can be observed in the real world but it remains that advanced technology or illusions do generate such stimuli; consequently, it seems disputable to claim that no counterintuitive event is ever encountered outside of psychology laboratories and theater stages. As we have seen, children do not always possess the critical tools to demystify counterintuitive events (to recognize them as being no more than the product of trickery or technoscience). For this reason, like Hypotheses 1 and 2, Hypothesis 4 predicts that children often use CT-magic both

inside and outside of laboratories: counterintuitive stimuli brought about by tricks and technological achievements are seen as real magic. Hypothesis 4 is bolder than Hypotheses 1 and 2 as it claims that CT-magic is widespread no less among adults than among children. To be sure, adults have the ability to demystify impossible events; yet, Hypothesis 4 insists that even though adults are able to demystify impossible events, it does not mean that they always do so. Experimental evidence supports the view that, at an implicit level, adults to behave as if they were believing in CT-magic (Subbotsky, 2014). Moreover, it seems that when one's image of the world allows for some miracles to occur, not all impossible events are being demystified (Luhmann, 1991, 2012).

Hypothesis 4 has probably some grain of truth. What is more doubtful, however, is whether CT-magic is as important as PR-magic in adult cognition. Cultural differences seem to matter, here. While it is very hard to find examples of impossible events interpreted in magical terms in witchcraft or shamanism, it is undeniable that such examples can readily be pointed out in the Christian tradition. Let us now turn to the question of knowing how the types of magic are instantiated across cultures.

Types of Magic Across Cultures

Types and Subtypes of Magic

Different types (and subtypes) of magic have been identified throughout the chapter. The two types of magic are: PR-magic and CT-magic. Furthermore, it has been shown that CT-magic can be further divided into two subtypes of magic depending on whether the violation at work is minimal or maximal. Likewise, it has been shown that PR-magic can be further divided into three subtypes, which correspond to the three mechanisms by which complexity drops can occur. All these types and subtypes of magic are summarized in Table 2.

A few remarks are in order. As previously explained, entities exhibiting atypical features do violate knowledge, but only domain-general knowledge, not domain-specific one. Atypicalities trigger counterintuitions but not in the modular sense of the term. Here, when we speak of CT-magic, we specifically refer to counterintuitions violating domain-specific knowledge. This is why violations of domain-general knowledge coinciding with complexity drops are classified as PR-magic rather than CT-magic. When discussing the different types of counterintuitions, we identified three types of counterintuitions as well as a fourth type that we called a contradiction (e.g., “God is trine and one”). This fourth type of counterintuition is not featured in Table 2. The reason is that while counterintuitive beings and events are talked about both in magic and religion, contradictory beings and events, on the other hand, seem to belong only to religion.

The important question we now want to tackle is that of knowing whether the types and subtypes of magic summarized in Table 2 are liable to be more developed

Table 2 The types and subtypes of magic

Types of magic	Probabilistic-magic (PR-magic)			Counterintuitive-magic (CT-magic)	
Cognitive mechanisms involved	Tapping into probabilistic/algorithmic mechanisms			Tapping into modular mechanisms	
Subtypes of magic	<ul style="list-style-type: none"> • Type 1 complexity drop (simplicity stemming from redundancy) 	<ul style="list-style-type: none"> • Type 2 complexity drop (simplicity stemming from familiarity/proximity) 	<ul style="list-style-type: none"> • Type 3 complexity drop (simplicity stemming from atypicality) • Minimal violation of domain-general knowledge 	<ul style="list-style-type: none"> • Minimal violation of domain-specific knowledge 	<ul style="list-style-type: none"> • Maximal violation of domain-specific knowledge
Examples	Favret-Saada (1980) Brown (1986)	Evans-Pritchard (1976)	Stépanoff (2015) Keifenheim (1999)	Boyer (2001)	Atran (2002)

in certain cultures than others. Specifically, two proposals are worth examining: (1) CT-magic may be more developed in Christian cultures and less so in shamanistic or witchcraft ones; (2) PR-magic based on Type 3 complexity drop seems to be rarely encountered in modern and Western cultures, whereas it seems to be widespread in indigenous and more traditional cultures.

Counterintuitive-Magic in Christian Tradition

Owing to the importance it attaches to miracles, Christian tradition differs from numerous other supernatural systems. One first answer, then, would be to say that CT-magic is virtually absent in witchcraft or shamanism but is relatively widespread in Christian cultures. As we know, the Epistles describe many miracles that Jesus is purported to have accomplished (Jesus walking on water, feeding the multitude or changing water into wine, etc.) (Pyysiäinen, 2008). Such narratives are often discussed and commented on among Christians. It is hence plausible that the view that magic is first and foremost a matter of counterintuition originates itself in the Christian concept of magic as the power to make miracles. Scholars who are not familiar with magic in non-Christian contexts should therefore be careful not to project the Christian framework onto other cultures where such a framework is irrelevant.

Probabilistic-Magic in Christian Tradition

It must be emphasized that the importance of CT-magic in Christian culture is not necessarily incompatible with the pervasiveness of PR-magic. What anthropologists of Christianity have precisely shown is that, in their daily life, Christian believers use mostly PR-magic (Wilson, 1983). It is worthy to point out that most of Christian believers have never experienced miracles. Complexity drops, on the contrary, are part of everybody's existence. Qua humans, Christians believers are like everybody else: they mainly have to monitor and control complexity drops (improbable events), and in this respect, miracles (impossible events) do not matter greatly. There is no much difference between an animistic Shipibo singing to the spirit of *toé* (*Brugmansia*) to recover a lost item and a Roman Catholic believer praying Saint Anthony to recover a lost item. Such daily practices are all about managing complexity drops and have not much to do with impossible events. Finally, it must be noted that the term "miracle" is sometimes used in Christian contexts to refer to improbable rather impossible events (Mosse, 2006).

Counterintuitive-Magic and Probabilistic-Magic in Shipibo Culture

Participant observation is particularly useful to assess the distribution and pervasiveness of distinct (sub)types of magic within a culture. During our stay in Shipibo

communities of the Middle Ucayali, we noticed daily talks about PR-magic. This type of magic is typically used to explain why a man is unusually lucky (or unlucky) in hunting (or fishing), why an animal behaves atypically, why a child is ill, etc. In all these cases a complexity drop is taking place and Shipibo people make sense of such a drop by resorting to the world of spirits, shamanism, and sorcery. By contrast, very rarely did we notice any talk about CT-magic. Only one clear such case has been reported to us. Leonardo (now an elder) told us that one day, while he was still a child, a mestizo magician able to transform humans into animals arrived in the village and threatened Leonardo's father to turn him into a nag if he was not to give away a pig. This story is clearly based on CT-magic; but such stories are very rare in communities of the Middle Ucayali.

On the other hand, some aspects of Shipibo thinking suggest that CT-magic may be more present in indigenous communities of the Middle Ucayali than in Western countries. Although CT-magic seems very rarely used by Shipibo people, it is not unlikely that, when presented with counterintuitive stimuli (impossible events), Shipibo adults will be more inclined than Western adults to interpret these stimuli in magical terms. Indeed, ethnographic anecdotes suggest that the reality/fantasy distinction and the ascription of unreality to impossible events (i.e., recognizing them as the mere product of trickery) greatly varies across cultures. For example, Shipibo adults do not seem to grasp the difference between present-day real beings, real beings of the past, and fictional beings.

Television has recently arrived in the indigenous communities of the Middle Ucayali, and as a result, more and more Shipibo adults have occasionally the opportunity to watch documentary films and movies. To our surprise, we were once asked the following by a Shipibo adult: "Martin, tell me, are there dinosaurs living in your country?" As it happens, our informant had recently watched *Jurassic Park*. Because he did not have the background knowledge that we have about special effects, it seems that he understood the entire movie as a nonfictional film: he reasoned that people who recorded this video had traveled somewhere on earth where these astonishing animals called dinosaurs are actually living. If you do not know about special effects, such a line of reasoning is indeed very rational. Similarly, a colleague reported us that he has had the opportunity to watch *Avatar* with his Shipibo friends; they were all fascinated and bewildered and kept asking him during the entirety of the movie what kind of animal or human Na'vi were.

On another occasion, we were trying to impress our Shipibo informant by telling him that, in Western countries, some people jump from high cliffs and fly in the sky thanks to wingsuits. To which our informant responded at once that he was already knowledgeable about it and even knew the name of the man accomplishing such feats: Superman. Indeed, not long ago, he had had the opportunity to watch *Superman* and manifestly understood Superman's feats as nonfictional facts. Taken together, this ethnographic evidence implies that the ascription of reality or unreality to fictional beings and impossible events varies across cultures.

Subtypes of Probabilistic-Magic Across Cultures

It appears that subtypes of magic are also unevenly distributed across cultures. For example, while Type 3 complexity drops are encountered in Siberian and Amerindian indigenous cultures (Keifenheim, 1999; Stépanoff, 2015), it is hard to find any instance of it in modern magic (Blumberg, 1963; Favret-Saada, 1980). This may be related to the point we made earlier to the effect that Type 1 and Type 2 complexity drops, unlike Type 3, are hard to demystify and can thereby overcome secularization. Another potential cultural specificity must be pointed out. It has been mentioned that Type 3 complexity drop can take at least two forms: morphological and behavioral. Now, an interesting hypothesis worth exploring is that in cultures in which livestock farming prevails atypical features interpreted in magical terms are chiefly the color, shape, and size of animals whereas in cultures in which hunting prevails atypical features interpreted in magical terms are chiefly the behavior, smell and sound of animals. The comparison of Southern Siberia on the one hand (Stépanoff, 2015) and Northern Siberia and Amazonia on the other (Déléage, 2005; Gutierrez Choquevilca, 2010; Keifenheim, 1999; Willerslev, 2007) is in this regard very enlightening.

Conclusion

We have first presented the widely adopted view in psychology according to which magic is underpinned by domain-specific mechanisms: when faced with impossible events, young children—and some old children and adults—are inclined to resort to magical explanations. By contrast, anthropological data suggest that, in the wild, magic (i.e., shamanism, witchcraft, sorcery, etc.) is usually underpinned by domain-general mechanisms: when faced with complexity drops, adults—and, most likely, children—are inclined to resort to magical explanations. We have argued that these two models of magic are not to be understood as two accounts of the same phenomenon but rather as two accounts of distinct cognitive mechanisms.

One could object that anthropological findings fall out of the scope of psychology: what matters is not how people think in their everyday life but how they perform if asked to carry out an experimental task. When comparing the psychological and the anthropological approach to magic, it is therefore always important to bear in mind the distinction between *cognitive dispositions* (psychology's scope) and *actual cognitive performances* (anthropology's scope). Nevertheless, we have argued that anthropological data do pose a challenge to the psychological model of magic. First, psychologists have not empirically tested how children react to the occurrence of complexity drops. In particular, the question of knowing whether magical explanations are more easily triggered by complexity drops or by impossible events remains to be investigated. Second, psychologists have shown that magical explanations (triggered by impossible events) tend to decrease as children grow older and as impossible events are gradually construed as trickery rather than

real magic. This piece of evidence suggests that if any kind of magical thinking is to be found among old children and adults, it will be PR-magic (i.e., magic triggered by complexity drops). It is indeed much harder to demystify magical interpretations of complexity drops than magical interpretations of impossible events. Likewise, secularization seems to undermine mostly the CT-magic and not so much the PR-magic. Magic based on probabilistic reasoning is largely compatible with science and is probably here to stay.

We hope that this new probabilistic model of magic will lead psychologists, anthropologists, cognitive scientists of religion, and historians of religion alike to investigate many of the questions and challenges which have been raised in this chapter but which will remain in abeyance until more research is carried out.

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