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The role for simulations in theory construction for the social sciences: Case studies concerning Divergent Modes of Religiosity

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Abstract

Religion is, at the very least, a highly complex social phenomenon. The theories we use to understand religion – and the social sciences more generally – are often so complex that even experts in the field may not be able to see all their consequences. Social simulations can help us understand and communicate the consequences of a theory, provided we can describe the theory sufficiently precisely and comprehensively to run it on a computer. In this article we demonstrate the benefits of simulating the predictions of a well-known theory in the Cognitive Science of Religion, the theory of Divergent Modes of Religiosity. Many of these predictions have already been tested against contemporary and longitudinal evidence, using the methods of both qualitative case study and large-scale survey, and some of the mechanisms responsible for the patterns observed have been investigated by means of controlled experiments. Nevertheless, in simulating the patterns of religious transmission and transformation predicted by the modes theory we discovered numerous aspects that were underspecified, generating new hypotheses for investigation in future empirical research. This back-and-forth between simulation and theory testing has the potential to accelerate progress in the scientific study of religion.

Introduction: Simulation as a Scientific Tool for the Study of Religion

Since its introduction to the social sciences by Axelrod and Hamilton (1981), social simulation has been widely viewed as a powerful tool with obvious applicability to the full range of social sciences, including the study of religion. Nevertheless the history of social simulation has been variable. There have been outstanding recent examples of social science informed by simulations such as the Powell et al. (2009) anthropological account of the Paleolithic transition, or the work done by Laver (2005) to test the fit between theories of political party policy making and real party behavior. Yet the vast majority of social simulation papers languish in specialist conferences and journals. While such venues may help advance the technological state of the art for simulation, the substance-area contributions of these works are often overlooked. Indeed given review processes that take place outside of the mainstream for their substance areas, in the worst case the substantial social science contributions of these papers may not even be fully tested. This process may account for the suspicion with which some academics view work done in social simulation.

All new research methodologies, whether quantitative or qualitative, deservedly meet scrutiny before they are considered to have proved their utility. In this article we both argue and demonstrate that social simulation has by now proved its utility at least in some contexts. We hope also to help make those contexts more apparent — not only to those who do not yet include social simulation as part of their research tool set, but also to those modelers who have had difficulty publishing in or otherwise engaging with the mainstream literature of their chosen application field.

Although there has been some debate and discussion about the exact role of simulation in not only the study of religion but science more generally, there is increasing consensus that a simulation simply *is* a theory (Bryson et al., 2007; Kokko, 2007). Like any other theory, a simulation must be tested against data derived from observations of the world, pertaining to the target system that the theory seeks to explain. What makes simulation special as a methodology is that, in order to be simulated, a theory must be specified so completely that its consequences can be demonstrated by executing it on a computer. This allows the

discovery of emergent outcomes not originally anticipated, which may serve as additional evidence for or against the theory.

A critical aspect of the scientific process is that theories can change. They may be extended, generalized, or specified to create more or better explanations. Science itself can be viewed as an evolutionary process, where peer review and other forms of expert opinion (e.g. choices made for teaching curricula or studies to replicate) continually narrow the field of available theories by selecting between them, but then subsequently broaden the field by varying the surviving theories – applying a variety of enhancements to these theories in order to increase their validity or predictive value. Simulation can perform several key roles in this process. Simulations not only allow better understanding of theories, they allow theories to be communicated with unprecedented precision as the actual code of the simulation can be transmitted from researcher to researcher over the Internet.

The simulation process therefore holds promise to improve and accelerate the process of the scientific understanding of religion. But it also carries with it risks. Theories represented as computer simulations might become so complex that they could not be truly understood by any one mind. This could result in a situation where our ability to predict religious behavior could continue to improve, but without an associated increase in individual-human understanding. Besides potentially decreasing the pleasure or accessibility of scientific reasoning, such circumstances might also result in a reduction of scientific innovation where that innovation is based on human insight. On the other hand, many doubt that phenomena so complex as religion could ever be represented in the crude digital, quantitative ways that computational approaches typify.

In this article we attempt to address both of these concerns by demonstrating the value of simulation to theory construction. We detail progress we have made in extending the development of a well-known and well-established theory in the Cognitive Science of Religion, the Divergent Modes of Religiosity theory, via the use of two different social simulations. We begin with a recapitulation of the Modes theory itself, and of a case study of a religious system that inspired it, the birth and death of religious splinter groups in the Kivung. We then present qualitative descriptions of two models, the full details of which (including code) can be found in an electronic supplement to this article. The first simulation replicates the doctrinal-imagistic oscillations seen in the Kivung, while the second, more abstract simulation looks at processes underlying cycles in religious conservatism and ritualism more generally. Following from these we enumerate changes we have made to the Modes theory as a result of these simulations, before concluding with a brief discussion of the general value of simulation in the religious context.

Modes of Religiosity

The theory of 'Divergent Modes of Religiosity' (hereafter DMR) makes a series of testable predictions about the effects of ritual frequency and arousal on group size, structure, and patterns of transformation in a religion over time (Whitehouse 1995, 2000, 2004). The theory seeks to explain the striking differences we see between two broadly contrasting patterns of religious organization and transmission: the doctrinal mode exemplified by the many varieties of world religions embracing vast followings and promulgating a body of standardized teachings; and the imagistic mode uniting much smaller communities cultivating somewhat personal and esoteric revelations. The doctrinal mode is relatively recent, with origins around 8,000 years ago associated with agriculture and urbanization. The imagistic

mode is older. It currently often takes the form of localized traditions within a larger doctrinal system but it may still occur independently, as it does in many of the world's remaining small-scale stateless societies.

The doctrinal mode entails frequently repeated teachings and rituals. Much of the religious knowledge is codified in language and transmitted primarily via recognized leaders and authoritative texts. High-frequency ritual performances allow complex networks of ideas to be transmitted and stored in semantic memory. At the same time, routinization tends to suppress certain kinds of creative thinking about the meanings of the rituals. For both reasons, routinization is probably a necessary condition for the establishment of religious orthodoxies. The emphasis on verbal transmission facilitates highly efficient and rapid spread, through processes of evangelism and missionization. The emphasis on oratory and learning also facilitates the emergence of venerable leaders and teachers: gurus, prophets, and priests. These features taken together favor the emergence of centralized ecclesiastic hierarchies, which exert influence over the content and organization of authoritative religious knowledge.

By contrast, the imagistic mode of religiosity is based on infrequent, dysphoric rituals – for instance, the traumatic ordeals of initiation cults, millenarian sects, vision quests, and so on – typically involving extreme forms of deprivation, bodily mutilation and flagellation, or participation in shocking acts. Such practices trigger enduring and vivid episodic memories for ritual ordeals, encouraging long-term rumination on the mystical significance of the acts and artefacts involved. Imagistic practices are much harder to spread than doctrinal traditions. A major reason for this is that the religious knowledge is created through collective participation in costly rituals rather than being summed up in speech or text. Traumatic rituals create strong bonds among those who experience them together, establishing in people's episodic memories exactly who was present when a particular cycle of rituals took place. This tends to generate localized cults based on direct transmission through following by example, and so we never find the same kind of scale, uniformity, centralization, or hierarchical structure that typifies the doctrinal mode.

The DMR theory has been used to explain a number of long-standing puzzles in the study of religion. For instance, historians and biologists have used this theory to explain why routinized religions sometimes break up into splinter-groups or sects and why reformations occur (Gragg 2004; Hinde 2005; Pyysiainen 2004). Archaeologists have used the theory to account for the great transition from small-scale Neolithic societies to the vast and complex civilizations of the Near East, Mediterranean, and North Africa (Mithen 2004, Johnson 2004, Whitehouse and Hodder 2010). The modes theory has now been tested against over a hundred case studies based on ethnography (papers in Whitehouse and Laidlaw 2004, 2007), history, classics, and archaeology (papers in Whitehouse and Martin 2004, Martin and Whitehouse 2005, Pachis and Martin 2009), and the cognitive sciences (papers in Whitehouse and McCauley 2005, McCauley and Whitehouse 2005). Some of the evidence needed to test the modes theory was not available from established scholarship and so a number of new field research projects have been undertaken, targeting data collection towards areas where evidential needs of the theory were especially great (Barrett 2005, Ketola 2005, Xygalatas 2007). To obviate potential problems of researcher and selection bias, additional strategies have been adopted, including experimental research (Richert, Whitehouse, and Stewart 2005), and the construction of large-scale comparative datasets coding selected features of ethnographic descriptions of hundreds of rituals from a large sample of religious traditions (Atkinson and Whitehouse 2010).

Case study: mainstream Kivung movement and splinter groups

The DMR theory was first applied to a religious tradition in East New Britain Province, Papua New Guinea known as the Kivung (Whitehouse 1995). In *Tok Pisin* (the lingua franca of PNG), the word 'Kivung' means 'a meeting' or 'to meet' but for several ethnic groups in New Britain it also designates a large religious movement exemplifying all the main features of the Doctrinal Mode of Religiosity. Established in the early 1960s and spreading to encompass scores of villages in some of the more remote regions of the island, the movement has a centralized leadership, based at the coastal settlement of Malmal, from which regular patrols to outlying villages are sent: bringing news, collecting taxes, and policing the orthodoxy. Each Kivung village has its designated orators, trained at Malmal, charged with the responsibility of preaching a standard body of doctrines and overseeing a wide range of authorized rituals. At the heart of Kivung teachings is the idea that the ancestors of followers will one day return from the dead, bringing with them all the wonders of Western technology. It is said that the returning ancestors will take the physical appearance of white men and women, describing themselves as British or American financial investors and scientists. They will establish factories and shops where all the goods on display will be freely available to members of the Kivung. After this era of plenty, known as 'Taim Bilong Kampani' (the period of the companies), there will be a great Day of Judgment, presided over by God and the ancestors. Those who use their riches wisely will be saved but those who are greedy and debauched will be cast into Hell. The saved will then enjoy eternal Paradise on earth, known as Taim Bilong Gavman (period of the government) during which there will be no aging, no illness, no hunger, no childbirth, and no pain.

In order to persuade the ancestors to return from the dead and fulfill this eschatology, Kivung followers are required to perform a great variety of rituals and to obey various religious laws. Kivung rituals fall into four main categories: temple offerings, spiritual cleansing, sermonizing, and garden/cemetery rites. There are three categories of temple in each Kivung village: a cemetery temple, a temple dedicated to one of the movement's spiritual leaders (now deceased), and family temples. All have basically the same function – providing a suitable setting to lay out offerings to the ancestors of food, water and (if available) money. Each village has only one cemetery temple where offerings are presented twice a week. After the tables are laden, one man described as a 'witness' remains behind in the temple sitting on a rough bench in the corner listening for signs that the ancestors are present (such as a creaking door, or sounds of chewing or drinking). Sometimes the food is found to have been disturbed (for instance a morsel mysteriously removed) also taken as evidence of ancestral presence. At an appointed time, the witness emerges into the daylight to find the whole village assembled, eager to learn what has been seen or heard within the temple. The witness whispers into the ear of an orator who solemnly conveys the news. If evidence of ancestral presence is lacking this is a cause for concern, suggesting that somebody in the community has offended the dead.

Kivung ancestors are quite easily offended. The most common affront is to break one of the ten sacred laws, based loosely on the Decalogue of the Old Testament (as taught originally by Catholic missionaries in the region). Although invisible, the ancestors are thought to be present at any given time and take a keen interest in people's comings and goings. They are pleased when people obey the ten laws and offended by sinful behavior. Only when the living have eliminated sin will the ancestors return from the dead. The observations of the witness in the cemetery temple provide a way of gauging levels of sinfulness and the offerings when received are thought to strengthen the resolve of the ancestors to return. The sins of

individuals, families, and whole communities are regularly absolved through special rituals designed to restore harmonious relations with the ancestors.

Other regular communal activities that take place in the Kivung are special tasks and rituals associated with the village cemetery (where the dead are said to be 'planted' rather than 'buried') and communal gardens. An important site in any Kivung village is the 'Paradise Garden', representing the environment of Adam and Eve prior to the original sin. In Kivung accounts of the fall, offense was caused not by the eating of forbidden fruit but by Eve climbing a betel palm in which Adam had implanted a sharpened stone. As Eve slithered down she cut herself between her legs producing a strong flow of blood, the origin of her childbearing capacities (and those of her female descendants). For this reason Kivung followers distinguish themselves from most other New Guinea peoples by abstaining from the chewing of betel nut. They say that the red substance spat out by chewers is like menstrual blood, regarded as a dangerous pollutant in many indigenous cultures of PNG. One of the laws of the Kivung is that menstruating women cannot help to prepare offerings for the ancestors.

Such beliefs and practices are common to all Kivung villages, expressed regularly in public acts and pronouncements. Routinized transmission of Kivung beliefs and practices produces a high level of standardization of the mainstream orthodoxy, with even minor innovations and infractions being easy to identify and collectively policed. As noted above, in terms of DMR theory the mainstream Kivung has all the features of the 'doctrinal mode' (Whitehouse 1992, 1995, 2000). The resulting shared tradition comprises a shared meaning system roughly depicted in Figure 1 as a 'semantic network' (Carley and Kaufer 1993) of related ideas. Semantic networks are an analytic tool useful for evaluating theories like the DMR. The nodes in Figure 1 represent publicly transmitted concepts, framed in everyday discourse, in ritual and in the speeches of Kivung leaders and orators. The links between nodes represent especially close thematic or implicational associations, such that discourse pertaining to any given node has a high probability of referring also to those nodes to which it is directly linked. The strength of links between nodes, as represented here, is a function of how directly they are linked. In this simple network some nodes (e.g. God) are directly linked to most of the others but a few are more distantly connected and so more weakly linked to most other nodes (e.g. the ban on betel chewing is directly linked to only two other nodes). This also means that God is a more central node in the network than certain others, such as the ban on betel chewing.
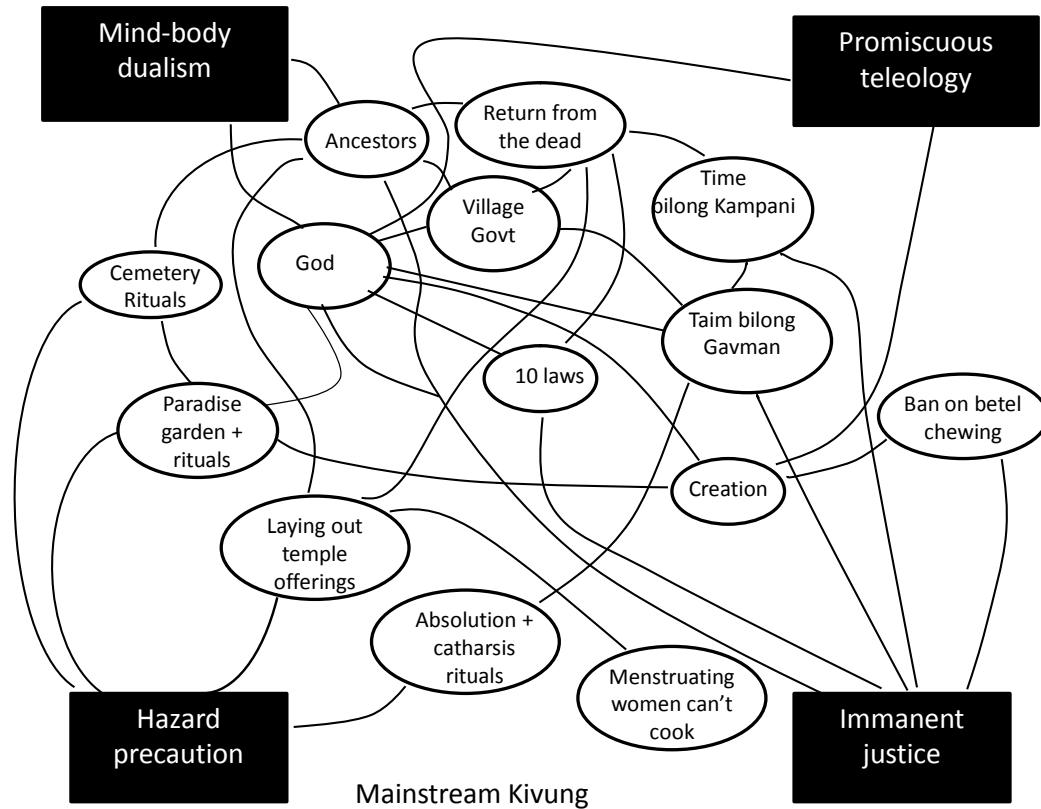
Figure 1: Mapping the mainstream meaning system

However exotic the Kivung may seem to Western observers, the mainstream semantic network is grounded in at least four implicit beliefs that are shared by all human populations (Boyer 2001; Barrett 2004). These implicit beliefs or 'intuitive anchor points' are depicted as black rectangles in the four corners of Figure 1. The intuitive anchors in our model are common to all religious traditions: (1) mind-body dualism delivers the ubiquitous intuition that higher level cognitive capacities such as beliefs, memories and desires can occur outside bodies e.g. in incorporeal beings such as ghosts, ancestors, and gods (Bloom 2004); (2) promiscuous teleology supports the recurrent belief that features of the natural world were designed with a purpose e.g. as proposed by creation myths (Kelemen and DiYanni 2005); (3) hazard precaution helps to explain the obligatory character of ritual, accounting also for the exaggerated concern in many rituals with symmetry and exactness, threshold and entrance, redundant repetition, etc. (Boyer and Lienard 2006); (4) immanent justice is the ubiquitous intuition that bad deeds lead to punishment and prosocial behavior leads to rewards (Callen, Ellard and Nicol 2006). As is typical of religions generally, most Kivung teachings and practices are directly rooted in one or more of these anchoring implicit beliefs. The more distantly a belief is connected to an anchor point the more mnemonic support and cultural scaffolding it requires to be preserved intact, for instance in the form of regular repetition in sermons or sacred texts. In the absence of such pedagogic aids religious beliefs over time tend to be converted into more intuitive expressions, a process that has been described as the Cognitive Optimum Effect (Whitehouse 2004). Our model incorporates four anchor points; a more complete model would require several more (Whitehouse 2008).

The mainstream orthodoxy of the Kivung depicted in Figure 1 is occasionally eclipsed by small splinter groups comprising no more than a few villages at most, who break away

temporarily from the larger religious movement claiming that they have a new plan for bringing the ancestors back from the dead. Outbursts of this kind occur in most Kivung villages roughly every five years. Each time a splinter group occurs, its prophesies fail and followers typically return to the fold, resuming their daily rounds of mainstream Kivung rituals more or less as if nothing had happened. Splinter groups are usually inspired by some extraordinary event, interpreted as a sign that the ancestors are ready to return. It is quite common for individuals to claim to have witnessed such a sign but generally the consensus is skeptical. When motivation levels are high among mainstream followers, skepticism is strong. But after years of unremitting commitment to routinized practices, people grow weary and impatient,[1] becoming more credulous of claims that now, at last, the longed-for miracle is due. Splinter group activities invariably whip up high levels of excitement, in stark contrast to the dullness of everyday ritual life. Once hopes are some followers defect. But a more common pattern is for followers to return to the mainstream movement with renewed vigor and conviction, listing any number of rationalizations for the failure of prophesy. In effect, splinter groups typically rejuvenate commitment to Kivung orthodoxy. Similar patterns have been observed in millenarian movements and 'activist' religions more generally (Whitehouse 2000). Splinter groups predicting impossible events such as the return of a messiah or of the ancestors tend not to endure, whereas those with less falsifiable prophesies may turn into more lasting mainstream traditions in their own right (Stark and Bainbridge 1979). But either way, group morale following a splintering event tends to be raised considerably.

Figure 2 shows the semantic network generated by one instance of a splinter group documented during a two-year period of fieldwork in the late 1980s (Whitehouse 1995). The trigger for this particular splintering event was the alleged possession of a young man, Tanotka, by a local ancestor. During his spirit possession, Tanotka uttered various cryptic statements such as 'I am a post'. This was interpreted as a reference to the construction of traditional round houses, where the rafters of the roof converge upon a central post. For many, this meant that the possessing ancestor (post) would support the community (multiple rafters) in its efforts to be reunited with the village government. As this idea gained currency a series of new rituals were invented, involving the symbolism of circles and posts (for instance dancing in a circle or creating rings of human bodies with Tanotka in the center). Other novel ideas rapidly caught on. For instance, it was suggested that people should discard all Western style clothes such as shorts and T-shirts and go virtually naked as their ancestors had once done. Since the sudden appearance of naked bodies prompted widespread erotic excitement the leaders of the splinter group decided to organize a mass marriage to pair off those at greatest risk of temptation to fornicate (especially young bachelors). Witnesses in the temples who had previously only heard noises attributable to the visiting spirits now claimed to be hearing fully articulated statements from the ancestors which became known as 'reports' (reminiscent of the authority of government reports). Great feasts were held to celebrate the imminent return of the ancestors. New teachings became widely accepted, for instance that when the ancestors returned the living would peel away their black skins to reveal a fresh white skin underneath, free of blemishes and sores. The forest would be flattened and a concrete 'paradise' of high-rise buildings would replace it. The dominant ethnic group in the region, the Tolai (who had long ridiculed the Kivung), would receive a share of the riches brought by the ancestors. But this would be their undoing, because they would squander their wealth and be cast into Hell. In preparation for these much-desired events, splinter group members constructed a traditional round house where they held nightly vigils to await the returning ancestors. Feasting continued until all local food stocks had been depleted but there

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[1]   This impatience has been described as the 'tedium effect' (Whitehouse 2004)

was no sign of the returning ancestors. A government patrol ordered everyone back to their homes and gardens. Most people claimed that the Devil had blocked them but next time they would succeed.
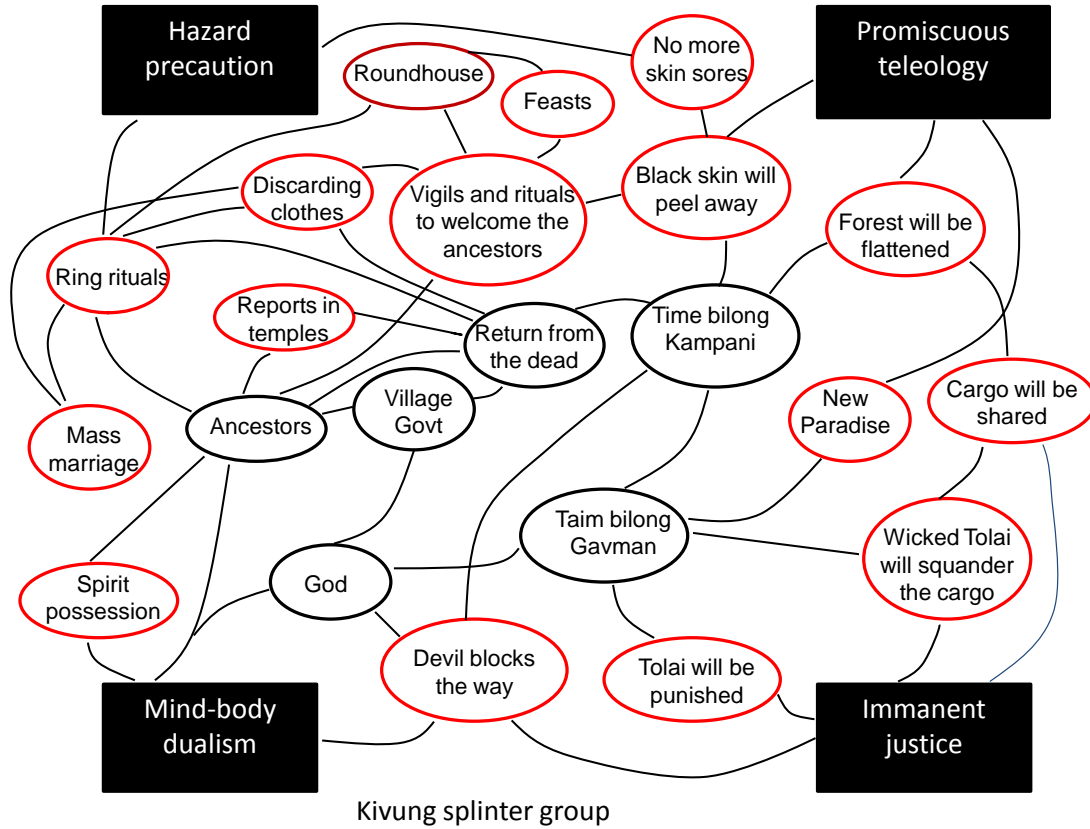

Figure 2: The meaning system of a Kivung splinter group

The splinter group lasted only a matter of months. During this period it produced a novel belief system consisting primarily of new nodes, which we depict in Figure 2 with red circles. This system overlaps the core elements of the mainstream movement, depicted with black circles in Figure 2. At its height this short-lived semantic network gained general acceptance in two villages but never spread more widely than that. In terms of DMR theory, the splinter group exemplifies the 'imagistic mode' (Whitehouse 1995, 2000). A diagnostic feature of this shift from the doctrinal to the imagistic is the appearance of low-frequency, highly-arousing rituals.

Model 1: Simulating doctrinal-imagistic oscillations in the Kivung

For the purpose of modeling the oscillation between a doctrinal mainstream movement and an imagistic splinter group in the Kivung, we broke the process into two parts: (1) a tool kit consisting of a set of high-level domain-specific behaviors, and (2) specific Kivung models built from the tool kit by composing and parameterizing behaviors (Kahn and Noble 2010). Dividing the simulation task in this way facilitates the construction of multiple related models. It also facilitates understanding, because it clarifies which aspects of a model are unique to the specific target system, and which are general to the theory under which the

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model is constructed. Finally, the tool kit permits researchers lacking the technical expertise to build computer models from scratch to still modify and refine models by recombining or reparametrizing established theoretical components by using the abstractions provided by the tool kit.

Here we implemented about one hundred simulation action components which can be used to give behaviors to people including leaders and followers, anchor points, belief nodes, links, homes, temples and any other entities relevant to a religious practice. We co-developed this tool kit along with the model of the Kivung and their splinter group as described above. The tool kit includes action components we developed to support the visualization of the state of the model and the semantic network of the simulated agents. Other components are used to make observations of the simulation e.g. to plot the mean motivational level of religious participants. The models we implemented within this tool kit are a small semantic network for the Kivung religion consisting of 18 nodes and a splinter group consisting of 26 nodes.

Modeling the Kivung required beginning with a series of assumptions about the memorability and motivational force of various nodes in the mainstream network. A starting assumption is that the more distant a given belief or practice is from an intuitive anchor point, the more rapidly it will be forgotten or garbled if not encountered regularly. We also assume that different nodes in the network have variable motivational force or emotional salience, ranging from low (e.g. the Kivung dogma of original sin) to high (the expectation of returning ancestors or the fear of eternal damnation). We assume further that the frequency of exposure to a given node in the network will impact both memory and motivation: as frequency increases the risk of forgetting is reduced but so too is emotional salience; as frequency decreases, garbling and forgetting become more likely but emotional intensity is enhanced. Motivation is maximal when a belief is first acquired or refreshed. Motivation drops with time and with repetition. When mean motivational levels drop below a threshold, agents will be open to novel ideas.

Our models of Kivung followers currently include two kinds of agents with artificial minds: expert orators and lay adherents. Orators are ascribed the semantic network portrayed in Figure 1. They transmit the contents of this network to the laity in accordance with standard Kivung schedules e.g. following a five-week cycle of twice-weekly speeches about the ten laws. Followers update their semantic networks based on what the orators tell them. Agents forget nodes in the network that are not repeated frequently and the rate of forgetting is partly determined by the distance of a given node from an intuitive anchor point – the further away from an anchor point, the more easily the node decays. Each node has a maximum level of motivation, represented in the visualization tools and the figures below by a color. Colors towards the red end of the spectrum represent high motivation; those towards the blue end low motivation. Levels of motivation diminish over time and with repetition.[2] When motivation levels drop below a threshold, tedium sets in, the orthodoxy loses its authority, and more appealing innovations begin to enjoy a selective advantage. Figure 3 is a snapshot taken from one of our simulations of the semantic network of a typical member of the Kivung splinter group around the mid-point of its existence.

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[2]   We assume that a religious practice (such as gospel singing), just like any cultural practice (such as going to a rock concert) is always higher impact when first experienced than after many years of having similar experiences.
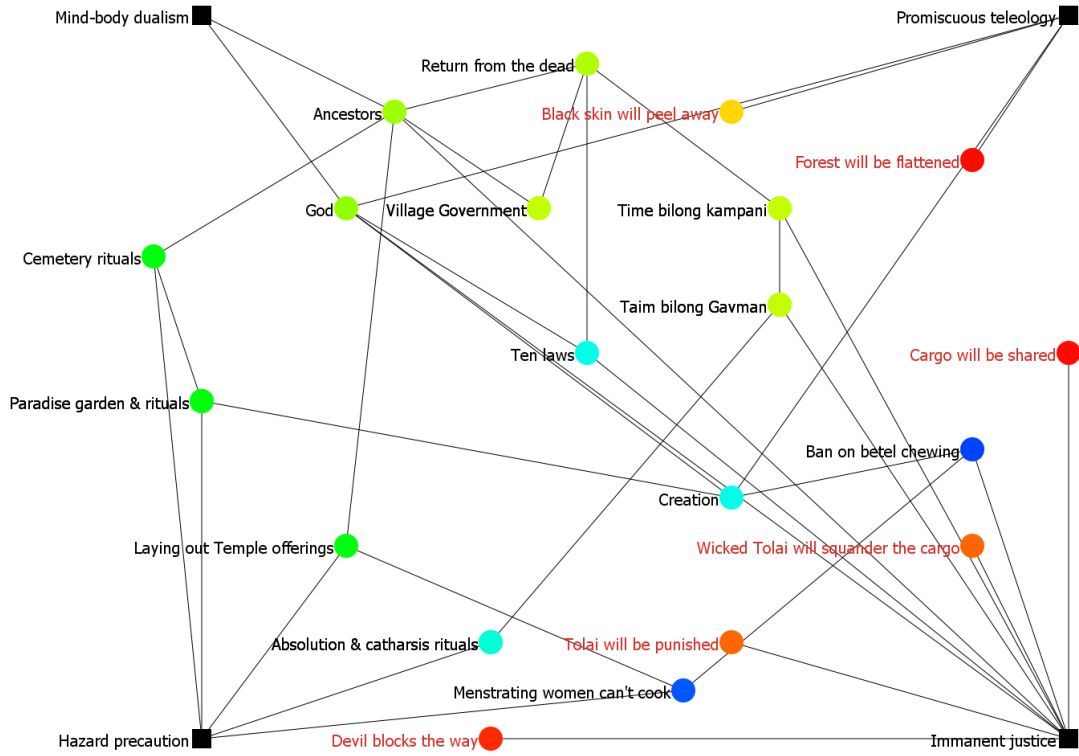
Figure 3: Snapshot of semantic network for typical Kivung splinter group member

Our model executes by simulating the individuals in the population. Some are religious leaders and regularly transmit parts of the doctrine. Others when receiving those transmissions add nodes (practices and beliefs), add links between nodes, and strengthen existing links. Nodes and links in each individual's semantic network have some probability of being forgotten. The motivational levels of the population are derived from the properties of the nodes representing practices and beliefs. These levels decay with repetition.

Followers in the model are periodically exposed to novel religious ideas. As long as most agents are regularly exposed to mainstream orthodoxy they notice unauthorized innovations, and as long as motivation levels are sufficiently high they will reject these ideas as erroneous or heretical. Once motivational levels have dropped to the threshold of the tedium effect (noted above) followers become open to adopting mutant beliefs and practices. Thus, in the case of the splinter group described earlier, we can simulate the process by which agents came to accept the possession of Tanotka, the veracity of reports from the temples, the need for ring rituals, the mass marriage, and so on. This general pattern is captured in Figure 4 which depicts changes in motivation levels over time. We observe a steady decline of motivational level as the mainstream doctrine is frequently repeated until levels become low enough for followers to begin to accept novel beliefs necessary for splinter-group formation. Under the influence of the new nodes, the motivation level increases although older nodes contribute less to motivational levels due to repetition.
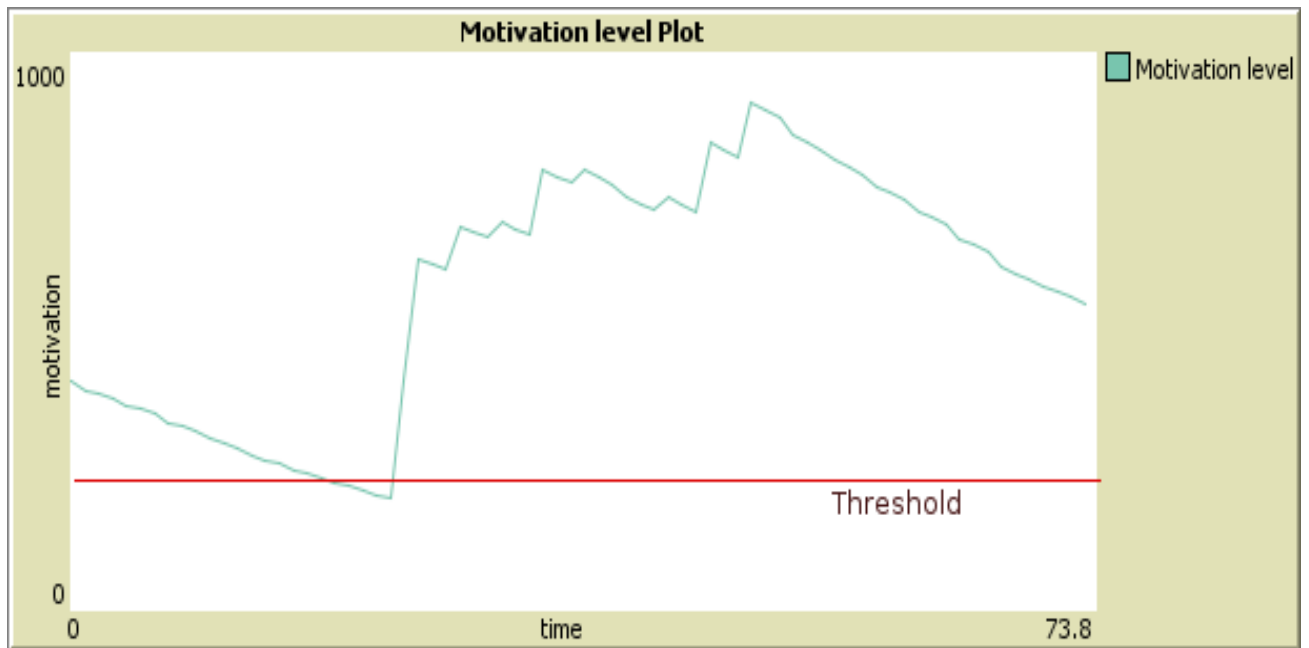
Figure 4: Dynamics of mean motivational level for the population plotted against time

While we believe there is much to learn from this coarse modeling of the Kivung, the tool kit we used to implement these models can accommodate much larger and more detailed networks. The tool kit supporting the model will be extended so that we can model transmissions and motivational changes caused by followers interacting with kin, in-laws, neighbors, and others. We have begun extending the tool kit to model multiple villages and a hierarchy of leadership. Several behaviors could be added to enable the modeling of long-term dynamics including birth, death, migration, and interactions between generations. As we extend and enhance the construction kit models can be constructed to explore new issues. Potentially, these might include group cohesion, the creation and role of social networks, nested groups within wider organization and different levels of jurisdictional hierarchy, competition between groups, and multi-generational dynamics. The Kivung is our first case study, a means of establishing 'proof of concept'. Nevertheless, the tool kit presented here would only need a few additional components to be capable of modelling a wide range of substantially different religious traditions from around the world.

Model 2: Expanding the explanatory reach of the DMR theory through simulations

Model 1 was designed to explore the mechanisms by which intuitive, mnemonic, and motivational constraints impact the reproduction and transformation of religious systems. Viewed in an evolutionary framework, these are problems of *proximate causation*. But modes of religiosity are also adaptations to varying ecological conditions, often including competition with other cultural groups for scarce resources. To explain how and why modes of religiosity emerge and spread is thus also a question of *ultimate causation*.

Population and evolutionary processes can be modeled in a variety of ways. The level of detail for a model and the values estimated for its parameters depend on both our level of knowledge about the target system we are trying to understand and also our objectives in describing the system. In the models reported here we take a joint population dynamic /

cultural evolution approach by modeling religious groups as units that can change in membership and in behaviors. Depending on our objectives, we could investigate short- or long-term dynamics, the birth, evolution and extinction of groups, or we could model behavioral trait evolution.

Model 2 is based on hypothesized patterns of recruitment and defection in a pluralistic religious environment comprising traditions operating in the doctrinal mode, where opportunities to move between traditions are motivated by incentives or 'carrots' or impeded by sanctions or 'sticks'. If we imagine, for instance, a bustling American city with numerous Christian churches vying for members, then it seems reasonable to assume that euphoric practices such as gospel singing, speaking in tongues, miraculous healings, and so on will be highly visible to potential recruits. Such practices in our model function as 'carrots', enticing potential converts as well as maintaining high motivation levels among existing members. But traditions also commonly impose sanctions on defection, ranging from the withdrawal of social support networks through to the threat of terrible forms of supernatural punishment such as eternal damnation. These sanctions or 'sticks' serve to reduce the rate at which members of a tradition defect, even when incentives to do so are present.

The survival of a religious tradition depends not only on its capacity to attract and maintain a following but also by its capacity to achieve cultural stability over time. Beliefs and practices that are frequently and publicly repeated, for instance daily or weekly, come to be somewhat fixed in procedural and semantic memory and widely shared in the participating population (Whitehouse 1992). When the frequency of participation is reduced, however, innovations are less readily noted (Whitehouse 2004) and there is a tendency to favor innovations that are pleasing (thereby functioning as 'carrots'). In this way a doctrinal orthodoxy can be reconfigured as (or augmented by) more popular expressions of religiosity, such as local festivals, cults, and related customs, typically occurring less frequently than the mainstream tradition (e.g. according to seasonal or annual cycles). Where a doctrinal orthodoxy is substantially displaced by more colorful 'little traditions' (Redfield 1955), the stage is set for reformations (Whitehouse 2000; cf. Weber 1947). Typically reforming ambitions seek to restore the basics or 'fundamentals' of the original doctrinal orthodoxy and the more routinized forms of worship needed to reproduce these elements (Pyssiainen 2005). By contrast, when the frequency of worship increases, even the most euphoric practices gradually lose their charm. Excessive routinization of a tradition can produce the 'tedium effect' (see above), a state of affairs in which openness to major innovations, and thus splintering from the mainstream tradition, becomes increasingly likely. In some cases splinter groups return to the fold, their motivation levels rejuvenated (as in the Kivung case study described above). Such a scenario is especially common where the goals of the splinter group are unachievable, as in most 'activist' religions such as millenarian movements and cargo cults (Worsley 1957). Other splinter groups, however, may present teachings and prophesies capable of sustaining their credibility indefinitely and so can form more or less stable buds, offshoots from the mainstream religion that in some cases spread widely, even displacing the more ancient tradition. Our present question is whether the same patterns would emerge from a computational simulation based on quite parsimonious assumptions.

Model 2, although conceptually simple, requires a surprising number of rules to achieve even this essential level of realism. The model is simulated numerically through an iterative process (c.f. details in this article's electronic appendix). The model can follow any specified number of religious groups from year to year, and deploys a set of rules governing practices, ritual frequencies, splintering and reformation, and between-group migration. In *practices*,

depending on ritual frequency, groups change in their ability to attract new followers or maintain existing followers. For low frequencies, groups tend to become more attractive to outsiders, whereas for high ritual frequencies, they tend to maintain their population through fear. In *frequencies*, a group may increase or decrease its ritual frequency, based on recent tendencies to become more repressive towards existing members (in which case ritual frequencies increase), no net change in practices (ritual frequency is lowered), or more attractive to outsiders (no change occurs in frequency). *Splintering events and reformations* may occur, when groups become polarized in their practices. For groups that can no longer attract outsiders, there is a chance that the group splinters, in which case its ritual frequency decreases and it becomes more directed at attracting new members from the outside. In contrast, a group that is no longer able to maintain its following may experience a reformation, in which case it increases its ritual frequency and adopts techniques to increase group cohesion. Finally, individuals may *migrate* from group to group, and tend to do so when other groups are more attractive than their own, and their own group has weak cohesion mechanisms.

To examine the typical behavior of our model and to illustrate possibilities for future development and research, we conducted a number of numerical experiments. We present two of these briefly here (for details of the experiments and additional results please see the electronic appendix). In the first, we let a single religious group evolve to see how it may or may not change in isolation. In the second, we introduced 10 identical religious groups into the system, and explored how their characteristics changed through time.

Figure 5 shows the case where a single religious group evolves in isolation. We see that rituals alternate between periods of high and low frequency, that the transients at low frequency tend to last longer than those at high, and that intermediate frequencies are also very transient (Figure 5 (i)). A characteristic feature of this group is that repressive practices tend to exceed those capable of attracting new recruits (Figure 5 (ii)), and peaks in repressiveness tend to correlate with high ritual frequency. Given the condition that repression/ attraction capacities must go to very low frequencies in order for a splintering/ reformation to occur, Figure 5 shows that splintering is fairly frequent (about every 200 simulated years), whereas reformation is never observed. Figure 6 starts with the same conditions as the experiment in Figure 5, except that 10 identical groups are initially present. We see that many groups rapidly go extinct, due to competition for group members. Only two groups remain after 800 simulated years. Note that the prevailing groups possessed high ratios of attractiveness to repressiveness at the beginning of the simulation (Figure 6 (iii)), and were thus able to recruit members of competing groups. After year 800, the two persisting groups cycle in apposition to one another (Figure 6 (i)) and show cycles in ritual frequency (Figure 6 (ii)) and repression to attraction ratios (Figure 6 (iii)) that are similar to those for the single group in Figure 5.

i. Ritual frequency

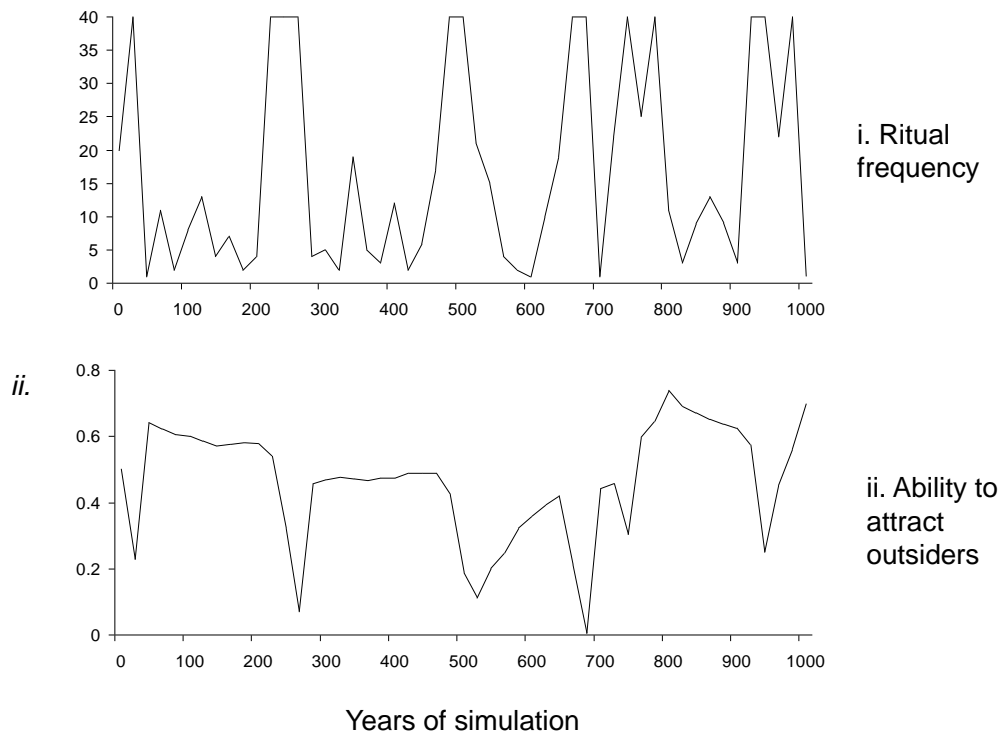ii. Ability to attract outsiders

Years of simulation

Figure 5: Dynamics of (i) ritual frequency and (ii) relative ability to attract outsiders compared to repress insiders in a single group over 1000 years of simulation
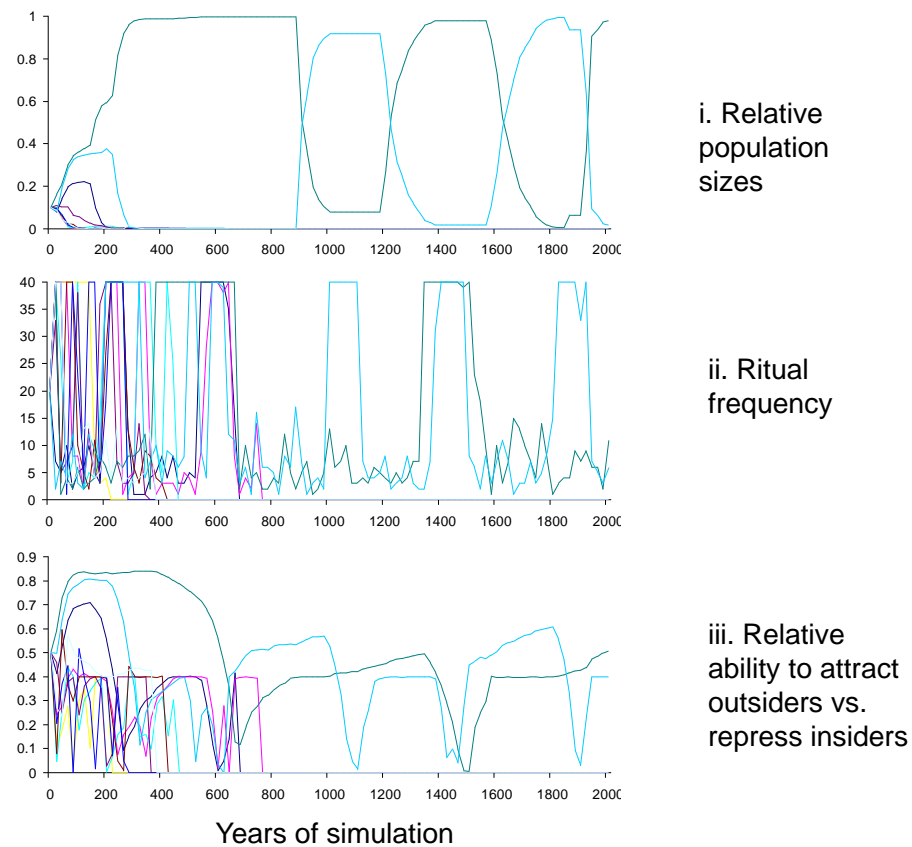

i. Relative population sizes

ii. Ritual frequency

iii. Relative ability to attract outsiders vs. repress insiders

Years of simulation

Figure 6: Competition between 10 religious groups over 2000 simulated years

The goal of the competition model is to increase our understanding of long-term changes in religious group behaviors. We need to identify the main processes that influence behaviors and how these impact the relative success or failure of groups. As shown in the simulations, these changes may be rapid, and seemingly doomed groups may rebound and come to dominate what once were successful groups.

It is important to note that this is a highly abstract, descriptive, exploratory model. The parameters described as constants in the outline of the algorithm and held constant in the simulations could all be altered. Doing this systematically and observing the results is called *sensitivity analysis*, which is an important part of model development. A comprehensive sensitivity analysis will both highlight the model parameters that require accurate estimation and also identify those that are pivotal to explaining variance in religious group behavior.

The flexibility of the algorithm allows for many possible lines of investigation, including the origin of successful religious groups, their characteristics, and how changing social landscapes may affect the persistence of endangered groups. To achieve greater rigor, however, several notable modifications to the current model will be necessary. First, changes in ritual procedures and frequencies will need to be integrated into a framework that allows for emulation of surrounding, more successful groups. Second, the model will need to be spatial, such that groups in proximity to one another interact more often than those that are more distant. A spatially explicit model must also address the question of religious spread: is it via local transmission or long distance colonization? Third, the theory will need to be modified to include more demographic variables, including different birth rates resulting from varied religious doctrines and practices. And fourth, future models should include defining cultural markers, allowing us to assess how the cultural landscape changes under variable competitive scenarios.

Discussion: Recalibrating the DMR theory

The process of building a simulation leads to theory refinement, an absolutely critical aspect of science. Establishing a plausible, coherent explanation for the phenomena we see around us is after all the primary goal of scientific research. Where there has been no previous theory or the previous theory was unnecessarily complex, then the simple demonstration that a model could possibly serve as an explanation is already a major contribution. Detailed validation against data is a way to improve existing theories, or to determine which of two variant theories is better at predicting and explaining the world. But establishing in the first place that an explanation could account for the data on a qualitative level is not only a contribution, it is a necessary first step before the iterative improvement of a theory can take place.

For the DMR theory in particular, many of its predictions are motivated by postulated causal links between ritual frequency, emotional arousal, memory, intuitive ontology, codification, transmission, group cohesion, group structure and scale, and social identity. In attempting to model this theory, the precise nature of these causal links has had to be specified more closely than ever before. As a result we have produced a raft of new hypotheses warranting further empirical investigation. Thus we demonstrate a significant benefit of modeling – that it enables us to expand and refine our repertoire of research questions. Here we detail just five examples.

First, building models has led to more fine-grained predictions concerning the effects of ritual frequency and systemic rigidity. In earlier formulations, the DMR theory proposed that high-frequency ('routinized') rituals and associated doctrinal transmission would serve to rigidify both orthodoxy and orthopraxy by making unintended innovation more discernible (and therefore more readily sanctioned) than in lower-frequency traditions. As frequency drops, so the potential for alterations to the system of beliefs and practices to occur undetected would increase. Our simulation of Kivung dynamics in Model 1 entailed the construction of an explicit network of concepts and practices for a particular high-frequency religious tradition, represented as nodes in changing semantic networks. This demonstrated the need for more precise specification of nodes, revealing also that some of the nodes are publicly transmitted more frequently than others. Rather than aggregating the effects of frequency on religious systems as a whole, we were forced to recognize that some sectors of the system will be subject to decay (due to forgetting or garbling) more rapidly than other sectors, thereby helping to explain patterns of change in religious systems at a more detailed level.[3] For the purposes of modeling changes we needed to specify those rates of change and their consequences explicitly.

Second, modeling the DMR theory has revealed hidden complexities in the relationship between frequency and intuitiveness. It has long been appreciated that processes of decay (garbling and forgetting) in doctrinal systems are non-random, being skewed towards more intuitive versions of the orthodoxy. Crudely describable as "dumbing down" the more technical term for this process is the 'cognitive optimum effect' (Whitehouse 2004). Until building our Kivung simulation, however, nobody had considered how the relative proximity of nodes in a network to intuitive beliefs might affect rates of decay as frequency drops. Building Model 1 made us realize that nodes more distantly connected to intuitive anchor points would inevitably decay faster than those with a more immediate intuitive grounding, so further refining our predictions with regard to the transformation of religious systems.

Third, our models have produced new insights into the relationship between frequency, arousal, and motivation. It has long been observed that the more frequently a node is encountered the lower its emotional impact and motivating force are likely to be, all else being equal. Consequently religious traditions requiring the most frequent levels of participation will be vulnerable to the 'tedium effect' (Whitehouse 2004). Specifying the effects of frequency on the emotionality of beliefs and practices in the Kivung prompted an appreciation that the rate of decay in the affective and motivational qualities of nodes in the meaning system will be moderated by intrinsic content of the nodes themselves, leading to a more nuanced and explicit set of predictions regarding the processes by which demoralization and the tedium effect come about. Similar insights resulted from the development of Model 2, particularly with regard to the emotional and motivational characteristics of beliefs and practices.

Fourth, our efforts to model imagistic splintering revealed that not all religious innovations are created equal. Earlier formulations of the DMR theory proposed that low-frequency, high-arousal rituals would be most likely to arise in a doctrinal tradition as a consequence of the tedium effect. Although the process of splintering typically involves the stepwise introduction of novel nodes to a semantic network, little thought had previously been given to the effects of sequencing in the appearance of novel beliefs and practices on emotional and motivational

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[3]	Kirby (1999) shows similarly how selection on a culture for expressivity can result in artificial languages that show characteristics previously thought to be a consequence of innate, uniquely human cognitive capacities (Chomsky 1965).

states, both during the lifetime of a splinter group and following its collapse. Simulating the process of splintering in the Kivung required explicit consideration of the effects of sequencing, as nodes in the network would lose emotional salience and motivational force through repetition whereas late-appearing nodes would do so to a lesser extent. Exploring these previously neglected aspects of doctrinal-imagistic oscillations also forced us to consider more explicitly how the collapse of splinter groups impacts emotion and motivation in the mainstream tradition in which they occur. These insights also played an important role in building Model 2.

Fifth, our models generated novel insights into the nature of between-group competition among doctrinal traditions. While efforts to test the DMR theory have provided valuable insights into patterns of transformation within individual doctrinal traditions over time, less effort has been directed to the question of competition for members among rival traditions. In an environment where opportunities to convert to rival traditions are very limited emotional appeal and sanctions for defection can be quite limited. But when multiple groups compete for members, their survival (measured by numerical strength of membership) will be affected by the capacity of individual groups to attract non-members and to retain those already committed. The construction of Model 2 generated a raft of specific predictions concerning the relative pulling power and retention capacities of doctrinal traditions, prompting unforeseen questions about the evolution of religious systems.

Conclusions

We have shown that the interdisciplinary exercise of social simulation in general and of modeling religious change in particular can provide many benefits. We have demonstrated here how simulation illuminates and extends a theory while at the same time testing its plausibility and providing new predictions to be tested against empirical data. We have described two very different sorts of models. First, we modeled a particular documented case of religious change: the formation of a splinter group from the Kivung movement. This enabled us to explore the proximate causes of various features of splinter group formation and collapse. Note that this model did not miraculously replicate the exact course of historic events. Rather we programmed in the sorts of changes in belief and ritual observed, and then used this model to determine which parameter sets could account for agents shifting between networks of beliefs and practices, and which could not. Second, we described a model of competing doctrinal religions. This was far more abstract model developed from a population perspective. Here rather than directing the results toward a particular outcome, we explored the consequences of the theorized dynamics underlying the DMR. Again we find the outcomes surprising and indicative of additional research that needs to be carried out. Perhaps systems similar to those we observe in our model do exist in human societies but were previously unobserved or unrecognized for what they are, or perhaps our model and the theories it embodies need further development. Only data derived from observing real religions can tell us this.

Our overarching goal has been to demonstrate the utility of simulations for exploring and refining the coherence and plausibility of existing theory in the social science even prior to quantitative validation against empirical data. The work described here may be seen as work in progress, in that we still hope (and indeed plan) to take the new predictions forward by gathering more complete field data to test the validity of these models. But contributions have already been made here in terms of better specifying the theory itself, and of showing the

theory's consequences, as we outlined in the Discussion. The process of theory construction and communication is in itself an academic contribution.

Acknowledgements

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