The Cooperative Scope of Local Gods: Punishment, Omniscience and Distant Cooperation among the Sihanaka of Madagascar (Pre-Registration)

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1. Background

A range of convergent theories associate religious beliefs and practices with cooperation and the kinds of solidarity that bolster a relative stability that societies enjoy. Some contemporary work suggests that despite considerable cross-cultural variation, beliefs in supernatural punishment might have contributed to minimizing defection in cooperative relationships (Johnson, 2005; Schloss & Murray, 2011). Such beliefs may have even increased the scope of those relationships by fostering a sense of more general applicability (Norenzayan et al., 2016). Specifically, beliefs in gods that are maximally morally concerned, punitive, and knowledgeable may be especially effective in galvanizing the kinds of decisions necessary to foment cooperative bonds across individuals in anonymous interactions or in contexts without kinship or repeated interactions to structure cooperation. It is precisely this kind of cooperation that is assumed to be unique to human social complexity.

According to this work, what partially accounts for the current global coverage of the so-called "moralistic traditions" (e.g., the Abrahamic traditions, Buddhism, Hinduism), was this ability to harness cooperation and propel such behavior beyond parochial confines. The expanded cooperation they enjoyed facilitated alliances and wider trade networks that put such groups in a better position to incorporate, compete with, and dominate other groups. Yet, social scientists have debated the global ubiquity and utility of the relationship between religion and morality for generations (Purzycki, 2025b), leaving an open question: *are individuals in the "moralistic" traditions–those with beliefs about gods' moral punishment–more likely to cooperate beyond local boundaries?* Put differently: *are the cooperative effects of "local" traditions–those with gods that are more concerned with other human activities–more confined to local context than "moralistic traditions"?*

While group-level studies shows notable variation in this relationship between cooperation and moralistic supernatural punishment traditions (Beheim et al., 2021; Turchin et al., 2023; Watts et al., 2015), considerable cross-cultural work shows that on average, individuals

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who claim their gods punish and know about human activities are more likely to be generous and impartially fair toward anonymous, geographically distant co-religionists who are incapable of reciprocating than those who claim otherwise (Lang et al., 2023; Purzycki et al., 2024). However, at best, this previous empirical work showed a stable effect of beliefs about gods' punishment and knowledge breadth, but their attributed moral concerns did *not* show a similar effect (Bendixen et al., 2023; Purzycki et al., 2022). In other words, while gods' punishment and knowledge might boost cooperation beyond parochial boundaries, their specific moral concerns do not appear to do much of the work.[2] Here, we examine the relationship between the breadth of cooperation and the traditional belief sets of a Sihanaka community in Madagascar.

[2] Recent efforts (Bendixen et al., 2024; Bendixen & Purzycki, 2020) suggest that this particular domain of religious traditions – cultural models of gods' concerns – might be more of a reflection of social coordination where the concerns of gods revolve around behaviors that constitute cooperative options in locally salient social dilemmas. As such, they are more appeals to influence others' behavior rather than motivations of individual behavior (cf. Fitouchi et al., 2025).

2. Ethnographic Background of Field Site

2.1 The Sihanaka

The Sihanaka, whose name means “people of the marshes,” number over half a million and are among Madagascar’s oldest of the eighteen officially recognized ethnic groups (Norge, 2025). They inhabit the fertile Alaotra basin in the island’s central northeast, a lacustrine landscape of marshes, extensive rice plains, and Madagascar’s largest freshwater body - Lake Alaotra. This “granary of Madagascar” supports livelihoods based on irrigated riziculture, fishing, and the keeping of zebu cattle and domestic fowl such as geese and ducks. Over centuries, Sihanaka culture and cosmology have developed in close symbiosis with the wetland ecology, with riziculture and ritual structured by the annual cycle of the rainy season (November–April) and the dry season (May–October) as well as an ancient Sanskrit calendar.

The Sihanaka dialect of Malagasy is closely related to that of the highland Merina, incorporates Sakalava ritual vocabulary, and includes a distinctive Sihanaka lexicon associated with aquatic life. Archaeological and linguistic evidence suggests that the Alaotra basin was settled around the first millennium CE by Austronesian seafarers from Indonesia who mixed with African migrants moving inland from the east coast along the Maningory River. Sihanaka societies adapted Austronesian ritual calendars and fertility traditions while venerating metahuman beings of the wetlands such as the *zazavavindrano* (discussed below). From the thirteenth century, contacts with Javanese migrants introduced the noble title *andriana*, reinforcing social differentiation between free landowners (*andriana*) and enslaved laborers (*andevo*).

At least by the seventeenth century, Sihanaka polities had become powerful actors in Madagascar’s interior. The conversion of the Alaotra marshes into irrigated paddy fields, aided by irrigation techniques attributed to Javanese influence, generated agricultural surpluses that sustained population growth and military expansion. Federations of villages under semi-divine leaders known as *mpanazary* organized large-scale slave raids against neighboring populations on the eastern coast and in the central highlands. Captives, together with herds of zebu and baskets of rice, were marched northward to Arabo-Swahili slave ports such as Langany and New Masselage on the northwest coast, where they were sold to Arabo-Swahili and later European ships. These exchanges brought silver, firearms, and imported textiles, fueling both prosperity and warfare. In the eighteenth century, conflict with the rising Sakalava kingdom of Boina curtailed Sihanaka expansion but also produced deep cultural fusion: Sihanaka rulers appropriated Sakalava royal rituals and symbols, blending them with older fertility rites that remain visible in shrine practice today. In 1823 the Sihanaka region was conquered by the expanding Merina state, whose rulers had entered cooperation with Great Britain that restricted the slave trade and opened the kingdom to Christian missions and technological modernization. The Sihanaka were disarmed and made subjects of the Merina monarchy based in Antananarivo. Protestantism began spreading from the late 1860s, followed later by Catholicism, taking strongest root in hilltop towns such as Ambatondrazaka and Amparafaravola on the fringes of the Alaotra basin, where mixed Merina–Sihanaka populations resided. Marshland villages such as

Anororo, by contrast, remained relatively isolated within the wetlands and continued to preserve Sihanaka institutions of ritual authority and collective taboos (*fady*) (Razafimbelo, 1978, 1984).

As France colonized Madagascar in 1896, large tracts of ancestral Sihanaka land were expropriated and granted as agricultural concessions to European settlers. As of the 1940s, these concessions became sites of mechanized rice cultivation, further intensifying production and continuing the long transformation of marshland into an engineered landscape of paddy fields, canals, and dams. After independence in 1960, political power once again centralized in Antananarivo, but the *mpanazary* realms endured through local ritual orders; in several areas once ruled by a *mpanazary*, annual fertility rituals and the everyday observance of ancient taboos (*fady*) sustain the socio-cosmology order of the *mpanazary*.

2.2 Spiritual Landscape

2.2.1. General

Sihanaka cosmology is grounded in an immanentist ontology (Sahlins, 2022; Strathern, 2019) in which all realms of existence participate in a single continuous cosmos animated by the divine power of *hasina* (Norge, 2025). Comparable to Oceanian *mana* or Indonesian *semangat*, *hasina* circulates through plants, water, and words, and can be accumulated, preserved, and transmitted through ritual action. Rather than dividing nature from supernature, the cosmos is conceived as a graded continuum of beings, places and objects endowed with different degrees of *hasina*, the sacred force that animates all life. Those most saturated with *hasina* appear invisible to ordinary perception—not because they dwell in a separate metaphysical otherworld, but because their potency exceeds human sensory capacity. Unlike transcendentalist religions such as Christianity, where divine power is ontologically transcendent and external to the world, Sihanaka thought locates it within the world itself: *hasina* emanates from the celestial creator *Zanahary* and circulates as immanence throughout the cosmos, sustained and directed through ritual practice.

For the Sihanaka, the Alaotra basin is an enchanted landscape of multiple realms inhabited by beings of varying *hasina*: human villages bound by kinship and agriculture, tombs of the *razana* (ancestors), shrines (*doany*) housing divinised *mpanazary* (precolonial diviner-rulers), and the submerged settlements of *zazavavindrano* (aquatic humanoids) beneath Lake Alaotra. Each realm sustains and channels vitality in its own way, together forming a cosmopolitical world where humans and divinities interact across permeable boundaries. Through ritual, people engage the *zanahary* to secure rain, ensure fertile rice, or protect the living and their livestock. Some rituals are collective—such as shrine ceremonies for *Ndrianampanjaka*—while others are intimate healing rites held in the homes of spirit mediums. In both, collective concerns intertwine with individual supplications: community fertility and rain are sought alongside requests for help with infertility, marital discord, or sickness.

The Sihanaka pantheon is open, dynamic, and regionally varied. At its apex stands the celestial creator *Zanahary* (also *Andriamanitra*), source of all *hasina*, from whom emanate numerous lesser divinities—also termed *zanahary* with a minor z—that populate the world's manifold domains. Most are metahuman in Sahlins's (2022) sense: beings who share the

perceptual, affective, and bodily capacities of humans, yet in heightened form through the intensification of *hasina*, enabling powers of healing, prophecy, and invisibility. They care deeply about behaviour: the *razana* oversee kinship morality; *mpanazary* uphold ritual and social order; and *zazavavindrano* guard the purity of water and relational harmony between humans and their aquatic beings.

Foremost among these are the *zazavavindrano*—the "water people" and the Local God in our study—who dwell in the marshes and depths of Lake Alaotra. Renowned for their luminous beauty and long hair, they inhabit underwater villages with houses, fields, and zebus mirroring human life. Guardians of their watery domains, they reward purity, respect, and quiet ritual observance while punishing pollution, betrayal, and disorder with illness, infertility, or madness. Relations between humans and *zazavavindrano* vary: they appear in dreams or trances, intermarry with humans, or communicate through mediums who channel them in healing ceremonies.

Another major category of *zanahary* comprises the *mpanazary*—precolonial diviner-rulers celebrated in oral tradition for their thaumaturgical powers: walking across Lake Alaotra on water-lily leaves, curing epidemics, or commanding hailstorms. Rather than dying, they became immortal rulers residing invisibly in communal shrines (*doany*). In Anororo, *Ndrianampanjaka* (the Moralistic God in our study) and his successors *Andriatsimitoviaminandriana* and *Mahatolotrarivo* continue to govern their ancestral realm through ritual order and taboo. *Ndrianampanjaka* values respect, loyalty, and unity, while his anger is provoked by disrespect, impurity, or transgression. His order is embedded in the rhythm of local life—most notably the twelve-day ritual calendar regulating agricultural work and the enduring collective prohibition against pork.

The *razana* (ancestors) form another influential category of *zanahary*, dwelling in tombs resembling stone houses, sometimes in two storeys with gabled roofs and verandas (Moriyama, 1996). As the enduring members of the kin group (*firazanana*), they maintain moral authority over their descendants through nightly visions (*tsindrimandry*), demanding that ancestral customs be observed and tombs remain well kept, for neglect or violation of ancestral norms brings misfortune (Norge, 2020). Other *zanahary* manifest in animal form, such as the colossal seven-headed serpent *Faninimpitoloha* said to dwell in Lake Alaotra; ancestors reborn in crocodilian form; great moths (*Cyligramma disturbans*) regarded as revenants; and the bird *Ravolokobokobona*, emissary of *Zanahary*. Ritual prayers (*joro*) also address celestial bodies—the sun, moon, and stars—while older traditions recall divine presences in rice and marsh plants, possibly suggesting an earlier, more animistic kind of immanentism in which personhood extended even more throughout the environment.

The *hasina* of these beings is protected through taboos (*fady*), which define the moral and spatial contours of the Sihanaka world. To be human is to be moral, and to be moral is to respect *fady*. They may apply to a landscape feature (a marsh where salt is forbidden), a lineage (which abstains from onions or chicken), or a sacred object (an amulet intolerant of certain foods). Because *zanahary* are situated beings with heightened perception, they detect violations swiftly.

Transgressions against *fady* are punished according to scale: *fitaroka fohy* ("short flogging") denotes individual misfortune—an illness, accident, or death—whereas *fitaroka lava* ("long flogging") entails collective calamity such as fire, flood, or crop destruction. Villagers recall periodic fires interpreted as punishment for the introduction of pigs into Ndrianampanjaka's territory, or a devastating hailstorm in 2022 attributed to youths gathering shrine timber without the elders' blessing. During possession rituals, participants often plead with the possessing *zanahary* to limit retribution to "short flogging", particularly as Anororo's population has grown more heterogeneous and newcomers may unknowingly violate local *fady*. Each *zanahary* enforces its own moral jurisdiction: *Ndrianampanjaka* punishes social disorder and impiety with paralysis or death, while the *zazavavindrano* exact more intimate retribution—madness, infertility, or drowning—for pollution or betrayal.

Although Christianity was introduced in the nineteenth century and churches are now widespread, the immanentist premises endure. New entities such as *Jesosy* (Jesus) and *Jehovah* (God, Yahweh) have been incorporated into the cosmology as exceptionally powerful yet worldly *zanahary*. The Christian lexicon itself has been vernacularised: *Andriamanitra* ("the fragrant one") designates God, and *masina* ("imbued with *hasina*") translates as "holy." The earliest denominations—Protestant, Catholic, and Lutheran—were largely absorbed into Sihanaka cosmology, whereas newer evangelical churches have more forcefully opposed ancestral ritual, condemning possession and shrine worship as demonic. The relationship between Christianity and traditional cosmology remains ambivalent: Christianity is associated with modernity and education, while ritual practice is sometimes framed as backward—a hierarchy occasionally internalised by Sihanaka themselves. Yet this coexistence also fosters quiet pride: the endurance of ancestral ritual is seen as something distinctly and authentically Sihanaka, a moral heritage that continues to define belonging in the region.

In the heart of the Sihanaka world, along the shores of Lake Alaotra, communities such as Anororo continue to sustain a thoroughly immanentist cosmology in which *hasina* circulates between rice fields, tombs, shrines, and people through work and ritual. It remains a distinctly Austronesian system characterised by complementary dualities (Fox, 1987)—sky and earth, male and female, life and death, inside and outside, native and foreign—yet adapted to the wetland ecology of Alaotra: a "papyrus civilisation" of reciprocal relations between land and people, living and dead, humans and divinities (Norge, 2025).

2.2.2. Ethnographic free-lists and survey

To target the appropriate gods for our study, we conducted preliminary ethnographic interviews that, among other things, entailed freely listing gods and answering follow-up questions about those gods. Ethnographic free-lists have the advantage of soliciting naturalistic, ecologically valid data of cultural knowledge (Purzycki, 2025a). With this data, we can quantify and calculate cultural salience, a metric that collapses cultural prevalence and accessibility into a single metric. Specifically, we use Smith's *S*, (Smith & Borgatti, 1997) which is defined as follows:

$$S = \frac{\Sigma(\frac{n+1-ki}{n})}{N}$$

where k_i is item order number, n is the list length, and N is the sample size. As such, if every participant listed a particular deity *and* listed it first, it would be $S = 1.00$. To propagate uncertainty around deities' cultural salience scores, we modelled each item type independently in ordered beta-distributed models with uninformative priors (Major-Smith & Purzycki, 2025). We use the AnthroTools package (Purzycki & Jamieson-Lane, 2017) for R to perform all analyses.

After streamlining some of the codes, our sample of 39 individuals listed a total of 41 uniquely specified spirits and gods. The most culturally salient deity was *Ndrianampanjaka* (Ndriana. in Fig. 1), the name of the precolonial *mpanazary* (diviner) considered the "sovereign" (*mpanjaka*) of Anororo - followed by his two *mpanazary* successors *Andriatsimitoviaminandriana* (Andriat.) and *Mahatolotrarivo*. After these three *mpanazary*, the most culturally salient divinities are the aquatic metahumans *zazavavindrano* (zazavavin.), followed by the ancestors (*razana* in Malagasy), the *mpanazary Salovambolo* (a historical figure associated with *Ndrianampanjaka*), and finally *Andriamanitra* and *Zanahary*, the two names of the distant creator deity.

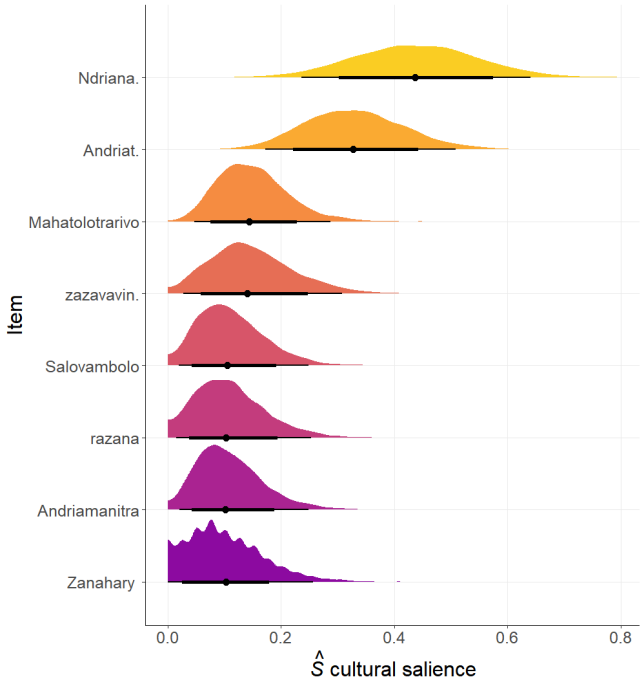

Figure 1. Cultural model of deities. Connection values are Smith's *S* and 95% credible intervals.

Of the 19 who answered follow-up questions about undying sovereign *Ndrianampanjaka*, all stated that he punished and rewarded people, and virtually all stated that he could see people when they were far away (18) and is concerned with how people behave (17). Of the eight who

answered follow-up questions about *zazavavindrano*, all said they reward people, seven said they punish people, and six said they were concerned with how people behaved. Six out of seven claimed they could see what people were doing in far away places. Thus, although *Ndrianampanjaka* is considerably more salient than the *zazavavindrano*, the data suggest that both are attributed with concern for human behaviour, with punitive and rewarding capacities, and with broad knowledge—although, as noted above, the specific domains and modes of engagement differ.

These patterns of cultural salience and attributed capacities—from precolonial diviners and aquatic metahumans to ancestors and creator gods—align closely with ethnographic findings. Ethnography shows that Sihanaka divinities consistently occupy positions of superior knowledge, and that they participate in the moral and social fabric of Sihanaka life by punishing and rewarding conduct much like humans do—albeit with far greater force and consequence (Norge, 2025). The modelled results therefore mirror, in aggregate form, dynamics that are well attested in long-term ethnographic work.

Based on these results and prior ethnographic research in the Sihanaka region (Norge, 2025), we selected *Ndrianampanjaka* as the *moralistic god* and the *zazavavindrano* as the *local god* for this study. *Ndrianampanjaka's* role in Sihanaka cosmology aligns closely with the criteria for a moralistic deity: he is understood to be the undying sovereign of the area surrounding Anororo—corresponding to his precolonial realm—and is strongly associated with social order, adherence to custom, and the protection of the community. These concerns are central to the biannual *Feraomby* ritual at his royal shrine, a ceremony aimed at securing rainfall and reinforcing social cohesion. Misfortunes such as floods, hailstorms, or town fires are commonly interpreted as expressions of his displeasure, and his high degree of *hasina* (divine power)—linked to his privileged connection to the creator deity *Zanahary*—is widely taken to confer omniscience.

In contrast, the *zazavavindrano* were chosen as the local god because, although they also punish, reward, and perceive more than ordinary humans, they do so to a markedly lesser degree than *Ndrianampanjaka*. As aquatic beings considered the masters of the wetlands that dominate the region, they belong to a stratum of divinity whose veneration likely predates ruler-centred ritual traditions—echoing comparative insights that water beings often constitute some of the earliest sacral presences prior to the emergence of more humanised deities (Strang, 2023). Despite their human appearance, *zazavavindrano* remain intimately tied to the watery realm, associated with eels, serpents, and the generative powers of marshland ecology. They are deeply local in both ecological and cultural terms, befitting a people known as the "marsh dwellers." *Ndrianampanjaka*, by contrast, is of foreign origin, stemming from the once powerful Boina Kingdom of the Sakalava on the northwestern littoral. Although firmly rooted in Anororo through his shrine and ritual tradition, his veneration does not extend across the entire Sihanaka region, where other communities maintain their own *mpanazary* rulers in their own shrines.

3. Methods

3.1. Theoretical Model

Our theoretical model of the data-generating process is summarised in the Directed Acyclic Graph (DAG) below (Figure 2; this model was adapted from our core causal model for the wider project, available: https://github.com/bgpurzycki/GGSL-Project/blob/main/Pre-Registration/Objective%201%20-%20Core%20Model/GGSL_Obj1_Core_Causal_Model.pdf). Our estimand - the target quantity of interest we want to estimate (Lundberg et al., 2021) - is the joint causal effect of supernatural beliefs (i.e., beliefs regarding whether *zazavavindrano* are punitive and omniscient) on cooperation with distant co-religionists of the same local god tradition (i.e., villagers in Ambohidava across Lake Alaotra who also cultivate relations with *zazavavindrano*). As data are cross-sectional we do not know the causal relations between the supernatural belief variables, hence focus on their *joint* effect, rather than any individual effects. This DAG makes several assumptions: i) supernatural beliefs cause religious cooperation, and not *vice versa* (i.e., there is no reverse causality); ii) the variables age, sex, education, material security, number of children and fisher occupation plausibly cause both the exposure (supernatural beliefs) and the outcome (religious cooperation), and hence are core confounders of this relationship; iii) there is a risk of unmeasured confounding by additional variables not considered above (denoted by the node '*U*'); and iv) features of the game, such as order of play and comprehension, cause only the outcome, and not the exposure. Based on these assumptions, adjusting for core confounders and assuming no unmeasured confounding, we can estimate an unbiased causal effect of our estimand of interest.

Of course, whether these assumptions - in addition to others required for valid causal inferences such as positivity, consistency and no interference - are met is an open question. For instance, perhaps one of the confounders is in fact a mediator (e.g., supernatural beliefs cause fertility/number of children), in which case any estimate will be biased. Despite this risk, based on previous empirical research and theory we believe that these assumptions are at least plausible for the sociodemographic variables (Baimel et al., 2022; Vardy et al., 2022). We also include fishing occupation as a confounder as fishers plausibly have different beliefs about *zazavavindrano* (as they are a water-based divinity) and may cooperate more with fellow *zazavavindrano* believers. By having a clear causal estimand and making our assumptions clear and discussing how they might be violated, we also facilitate critique and discussion of our causal model, and how different assumptions may impact conclusions.

For instance, although we believe these proposed sociodemographic confounders are plausible in general based on previous research, they may be less relevant in the Sihanaka context specifically. Based on ethnographic observation by AN - who has worked with the Sihanaka since 2015 - supernatural beliefs do not appear to be clearly structured by sociodemographic characteristics such as age, sex or education. Nonetheless, even if in reality

there is no relationship between these factors and supernatural beliefs, their inclusion as *potential* confounders is unlikely to result in bias if they are included in statistical models; we can also compare results between unadjusted and fully-adjusted models to explore whether the assumption that they are not confounders holds (i.e., if there is no difference in our estimand between unadjusted and adjusted models, this suggests that these sociodemographic factors are not confounders of the focal relationship).

A further factor to consider is the role of potential unmeasured confounders which could bias our causal estimates (denoted by '*U*' in the DAG in Figure 2). Ethnographic research shows that in Sihanaka society, subtle but socially consequential forms of postslavery and autochthony-based stratification continue to shape social relations (Norge, 2025). One dimension concerns *class descent*, namely locally recognised distinctions between descendants of slaves (*andevo*) and free people (*andriana*), which historically structured access to land, ritual authority, and *hasina* (divine power), and which continue to inform perceptions of personhood and belonging, even if rarely spoken of directly. Another dimension concerns *origin descent*—the distinction between long-established "children of the land" (*zana-tany*) and "newcomers" (*vahiny*)—which remains salient in shaping relations to land, wetlands, and the spirits associated with them. Both forms of descent could plausibly influence supernatural beliefs as well as patterns of cooperation with distant co-religionists, thereby acting as confounders. However, because the legacies of slavery and social stratification are among the most sensitive and difficult topics to work with in Madagascar (Evers, 2002; Regnier, 2021), and because such statuses are not openly discussed in Anororo, we did not attempt to collect systematic data on descent. Beyond these considerations, we believe that other major sources of unmeasured confounding are unlikely.

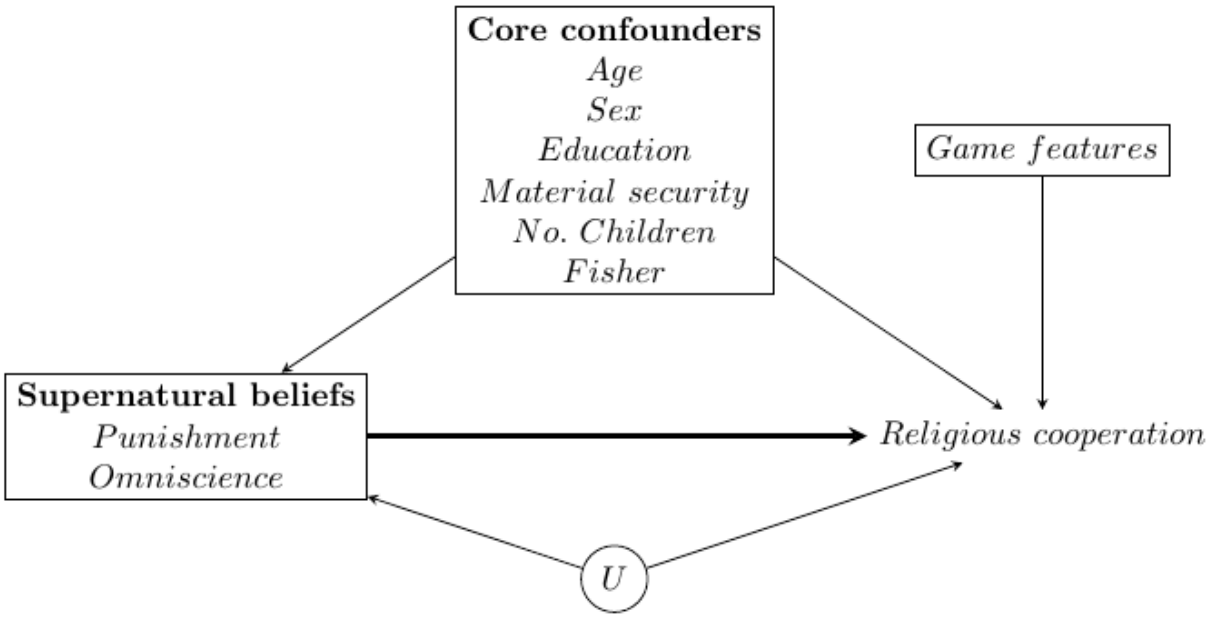

Figure 2: Directed Acyclic Graph (DAG) summarising our causal assumptions regarding the relationship between supernatural beliefs and cooperation with distant co-religionists. The bold arrow denotes our estimand of interest, which is the joint effect of supernatural beliefs on religious cooperation (discussed in more detail in the main text). causal relations between the core confounders are not displayed here. *U* = Potential unmeasured confounders.

3.2. Materials and Procedure

3.2.1. Procedure

Initial data collection took place in the summer of 2024. A local research assistant conducted interviews with 40 Sihanaka residents of Anororo, administering a short Demographic and Insecurity Survey followed by the Religious Landscape Interview (RLI). These interviews provided ethnographic background on the local religious context and informed the design and interpretation of the subsequent experimental study (as described above).

In the summer of 2025, the field researcher (AN), together with two research assistants, carried out the main experimental and survey components. Participants first completed two behavioural tasks—the Random Allocation Game (RAG) and the Dictator Game (DG)—followed by a 26-item Demographic questionnaire and a 62-item Religiosity questionnaire. These addressed participants' general religiosity, their perceptions of the mpanazary *Ndrianampanjaka* (selected as the "Moralistic God"), the *zazavavindrano* (selected as the "Local God"), and their attitudes toward other social and ethnic groups. A substantial proportion of the 2025 sample consisted of returning participants from the 2024 interview phase.

All materials and instructions were translated into Malagasy by a research assistant, piloted locally, and refined for clarity (available on the project gitHub page: https://github.com/bgpurzycki/GGSL-Project/tree/main/Protocols/Objective%201). Each session

was conducted in the participants' homes or, occasionally, at the research team's host family's house. Sessions were private, with no other persons present. Because illiteracy is common in this community, participants were given the option to complete the questionnaires orally. In such cases, a research assistant read each question aloud and recorded the participant's answers verbatim.

Before beginning the games, each participant drew a slip of paper bearing a unique ID number and a randomised game-order code. Gameplay took place on papyrus mats or tables inside participants' houses. For the "cups," we used plastic jugs with lids, and the tokens were small pieces of dried papyrus marked with numerical values. Participants were instructed that these tokens represented real money but were not themselves currency. After completing the session, participants received the corresponding amount in cash. Whenever possible, interviews were conducted immediately after gameplay; when interruptions occurred—for example, funerals or agricultural duties—they were conducted later the same day or, at the latest, on the following day.

3.2.2. Demographics

A number of demographic questions were asked to participants. Of most relevance to this study, this included questions regarding age (in years), sex (male or female), number of years in education, material/food insecurity (an average of four binary questions regarding concerns over running out of food in the next month/6 months/year/5 years), number of children and occupation (coded into 'fisher' vs 'other' [predominantly farmer]).

3.2.3. Religiosity variables

Participants were asked a battery of questions related to their religiosity, specifically regarding beliefs and practices towards the moralistic god (MG; *Ndriana*.) and the local god (LG; *zazavavindrano*). Of most relevance for this study were questions relating to[3]:

1. Punishment: Two questions used in previous research to indicate supernatural punishment were LGPUNISH (Do *zazavavindrano* ever punish people for their behaviour? [yes = 1; no = 0]) and LGDIE (Can *zazavavindrano* influence what happens to people after they die? [yes = 1; no = 0]), which have been averaged together into a punishment mini-scale (Purzycki et al., 2016). However, among the Sihanaka ideas regarding the afterlife are rather vague and are not something *zazavavindrano* can influence (instead, what is of key importance upon death is entering the family tomb with the ancestors, deities different to those assessed here). As such, approximately half of participants did not answer the

[3] Note that these questions were designed for consistency as part of a wider cross-cultural project and with previous waves of data collection (Lang et al., 2019; Purzycki et al., 2016). They may therefore lack some ethnographic nuance necessary relevant to beliefs and practices regarding religion in the Sihanaka region. For instance, what the gods punish for and the importance of where behaviour occurs. While this loss of ethnographic nuance is perhaps not ideal, it is a necessary trade-off with the wider project.

LGDIE question, and of those that did, only five responded 'yes'; for this paper, we will therefore focus on LGPUNISH only as our proxy for supernatural punishment.

2. Omniscience: Two questions were also used to assess omniscience/monitoring, LGFEEL (Can *zazavavindrano* see into people's hearts or know their thoughts and feelings? [yes = 1; no = 0]) and LGSEE (Can *zazavavindrano* see what people are doing if they are far away in Antananarivo (Malagasy capital) [distant town/city; yes = 1; no = 0]). These two questions will be averaged together into an omniscience mini-scale.

We focus on punishment and omniscience, rather than other supernatural beliefs such as moral concern or reward, for a few main reasons. A first reason is largely pragmatic; previous research has not found moral concern or supernatural rewards to be predictive of such cooperative behaviour (Bendixen et al., 2023; Purzycki et al., 2016). Given that supernatural punishment and omniscience may better motivate cooperative behaviour, we focus on these factors here. A second reason is both conceptual and methodological, as there is ambiguity regarding definitions of 'morality' (Purzycki, 2025b) and how to measure it, with previous research using comparable data from other societies finding no relationship between moral concern as measured by free-lists vs scales (Bendixen & Purzycki, 2025).

3.2.4. Behavioral experiments

Two experimental measures of cooperation were used: the Random Allocation Game (RAG) and the Dictator Game (DG). Two versions of both games were played, one with themselves versus a distant co-religionist (an anonymous recipient from Ambohidava across Lake Alaotra who also cultivate relations with *zazavavindrano*; SELF vs DISTANT condition), and another with a local co-religionist (anonymous resident of Anororo who also cultivates relations with *zazavavindrano*) vs a distant co-religionist (LOCAL vs DISTANT condition). The order of the conditions were counterbalanced, with RAGs always played before the DGs. Participants were given opaque cups to place allocations in, with each allocation worth 200 ariary (approx. 2% of a day's wage; meaning the full RAG allocation was worth approximately one day's wage). Participants were also given a show-up fee of 1,000 ariary (approx. 25% of a day's wage) for taking part.

For the RAGs, participants were given a fair two-coloured die (three faces black and three faces white) and 30 allocations (tokens made of papyrus with "200" ariary written on them). For each allocation, participants were asked to think which cup they would like to put the allocation in and then roll the die. If the die came up black, they were instructed to put the allocation in the cup they were thinking of, while if it came up white, they should put it in the other cup. If participants played fairly, then on average donations to each cup would be equal; but as participants played by themselves they could easily bias their allocation to whichever cup/recipient they preferred. For the DGs, participants simply divided 10 allocations into each cup as they wished. Comprehension tests were used to ensure that participants understood the

rules prior to playing, and that both themselves and recipients would be given the money they allocated.

3.3. Statistical Model

Our statistical model follows our causal model, outlined in the DAG above (Figure 2). That is, our exposure is the joint effect of supernatural beliefs in the local gods *zazavavindrano* - punishment and omniscience - on the outcome of cooperation towards anonymous distant co-religionists of the same local god tradition. Our core set of covariates to remove confounding bias are age, sex, education, material security, number of children and fisher occupation, with game features (comprehension and game order) also included as covariates (while game features are not confounders, their inclusion will not introduce bias, and may help improve precision our estimates). As discussed above, it is also plausible that sociodemographic characteristics do not structure supernatural beliefs, and hence are not confounders; we will therefore also explore models with only 'fisher' as a confounder, to explore whether this impacts our conclusions. Two sets of analyses will be conducted for each game, one for the SELF vs DISTANT condition, and another for the LOCAL vs DISTANT condition; in both, the outcome will be the number of tokens allocated to DISTANT. For the RAGs, we will use aggregated binomial models, while ordinal models will be used for the DGs.

All analyses will be conducted using Bayesian models using Stan in R software (R Core Team, 2024) using the 'brms' package (Bürkner, 2017). Four chains of 2,000 iterations (1,000 as warm-up) will be used, with visual inspection of trace plots between the chains, r-hat values near 1.00 and effective sample size statistics used to ensure model convergence. Weakly-regularising priors will be used.

To estimate the joint effect of supernatural beliefs on cooperation, we will use *g*-computation approaches (Hernán & Robins, 2020) to calculate the marginal causal effects of interest (i.e., a change in the punishment and omniscience exposures from both at a value of '0' to both of a value of '1'), based on the posterior predictions from our models. To aid interpretation, these marginal effects will be on the count scale (e.g., the change in the number of donations to DISTANT). Exposures will initially be treated as independent/additive, but a multiplicative model will also be tested to see whether it is a better fit to the data via interaction terms between the three exposure variables.

As some variables contain small amounts of missing data, we will use multiple imputation to impute this missing data (van Buuren, 2018; White et al., 2011). The amount of missing data is estimated to be relatively low - a few percent per variable, meaning perhaps an estimated 20% of cases missing from complete-case analyses - and we anticipate that the missing data mechanism will be either missing completely at random or missing at random (conditional on the observed data). In other words, while we do not expect this missing data to result in meaningful bias, it may result in inefficiency (i.e., wider standard errors/uncertainty intervals); multiple imputation may not therefore impact bias, but may improve efficiency. The number of imputations will depend on the proportion of missing data (White et al., 2011), but we anticipate

approximately 20% of missing cases, so will aim to impute 20 datasets (this will be updated, once we observe the final datasets). Imputation will be performed using the 'mice' R package (van Buuren, 2018), with imputed datasets analysed using the 'brm_multiple' command from the 'brms' package to pool estimates across imputations.

Example scripts demonstrating the proposed analyses on simulated data are available on the project GitHub page: https://github.com/bgpurzycki/GGSL-Project/tree/main/Pre-Registration/Objective%201%20-%20Sihanaka.

3.4. Sampling and Participants

The 79 participants in the 2025 study were recruited through door-to-door recruitment in Anororo. Recruitment aimed to capture a broad cross-section of the local population while maintaining feasibility within the constraints of field-based experimental research. Many participants had previously taken part in the 2024 interview phase, while others were newly recruited.

Participants ranged in age from 17 to 74 and reflected the local occupational composition of the village: most were rice farmers, with others working as fishers, market vendors, weavers, seamstresses, papyrus gatherers, or traditional healers. Approximately equal numbers of both women and men participated, and the sample included individuals of both free (*andriana*) and slave-descendant (*andevo*) backgrounds (although we are unable to link this data to individuals). Participation was voluntary. Some residents declined participation due to other commitments, advanced age, or intoxication.

To reduce the risk of collusion, coordinated responding, or information spillover about the experimental games, recruitment proceeded neighbourhood by neighbourhood. The research team worked intensively within one section of Anororo for several consecutive days before moving to another area on the opposite side of town. When individuals indicated prior knowledge of the games, or when bystanders began to gather during sessions, recruitment in that area was immediately discontinued.

3.5. Pre-registration

Note that as data has already been collected and audited, this is a pre-registration of our *analysis plan*, rather than for *data collection and analysis*. Plans for data collection can be found in the grant proposal, available here: https://github.com/bgpurzycki/GGSL-Project/blob/main/Pre-Registration/Proposal/TRT_Purzycki.pdf. This knowledge of the data and ethnographic context has been useful to help understand some of the complexities of the data and help inform analysis decisions (e.g., patterns of missing data, answering of the 'LGDIE' variable due to Sihanakan afterlife beliefs, inclusion of 'fishing' occupation as a confounder, potential lack of variation in Sihanakan religious beliefs by demographic variables such as age or sex). As also noted above, we initially developed core causal and statistical models for these site-specific analyses (see

https://github.com/bgpurzycki/GGSL-Project/blob/main/Pre-Registration/Objective%201%20-%20Core%20Model/GGSL_Obj1_Core_Causal_Model.pdf), which we then elaborated upon with the local context in mind for each of the site-specific papers. For full transparency, we note that descriptive statistics for key variables and regressions using this wider project core causal model were conducted in January 2026 for a project workshop, but this was *after* the causal model outlined here had been finalized. Any information from this regarding the data did not therefore influence our causal model or corresponding statistical approach.

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The authors declare no conflicts of interest.

Authors' roles
AN collected data, DM-S and BGP managed the project and contributed to analysis, and BGP designed the protocols. All authors contributed to writing this manuscript.

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Data availability statement
All data and analysis code will be made available on the project GitHub website: https://github.com/bgpurzycki/GGSL-Project/tree/main.

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