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A test of functional theories of religion in a non-western sample

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*A thesis submitted in complete fulfilment of the requirements for the degree of Doctorate of
Philosophy, The University of Auckland, 2019.*

Abstract

Scholars of religion have long pondered why humans believe in supernatural agents and participate in religious rituals. Some propose that religious features evolved as adaptations for a range of functions, such as alleviating insecurity, structuring social support and cooperating in large groups. Most work in this area has been conducted in Western, Educated, Industrialised, Rich and Democratic (WEIRD) countries, in times of relative resource abundance. This thesis uses religious survey and behavioural economic methods to investigate variation in religiosity and cooperation and test a range of functional explanations for religion in non-WEIRD societies, and in times of relative abundance and crisis.

Fieldwork in 2014 in Christian and indigenous Kastom religious groups on the island of Tanna, Vanuatu, revealed that belief in an increasingly punitive deity predicted higher monetary offers to outgroup members but not coreligionists. Further fieldwork in 2015 allowed the same measures to be collected following the devastation of Cyclone Pam. Comparison of pre- vs post- cyclone data showed a general decrease in prosociality and more parochial giving to religious ingroup. Post-cyclone giving depended on the level and nature of affectedness; property damage predicted reduced prosociality and parochial giving, whereas exposure to others in distress predicted higher offers to coreligionists and outgroups. Cyclone experience did not predict changes in post-cyclone religiosity and religiosity did not buffer against perceived food insecurity. However, greater personal commitment to one's moralistic god predicted giving less to outgroup members and more parochial giving after the cyclone.

Collaboration with the Cultural Evolution of Religion Consortium allowed investigation into functional explanations for putative gender differences in religiosity across a global sample of 14 societies. Women generally showed greater religiosity towards moralistic (but not local) gods. However, the clearest mediator of this gender gap was formal education, consistent with a general process of secularization rather than proposed functional accounts.

Overall, the research presented in this thesis suggests individual experiences during a resource shock calibrate prosociality towards religious ingroups and outgroups. Individual religiosity predicted cooperation beyond the religious ingroup in times of plenty and more parochial giving in times of need. Less support was found for religion's function as a coping mechanism, be it in response to resource shocks or as an explanation of gender differences in religiosity.

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Glossary

ACME	Average Causal Mediation Effects
ADE	Average Direct Effect
CGS	Cultural Group Selection
CERC	Cultural Evolution of Religion Consortium
DG	Dictator Game
HADD	Hyperactive Agency Detection Device
OLS	Ordinary Least Squares
SPH	Supernatural Punishment Hypothesis
ToM	Theory of Mind
VIF	Variance Inflation Factors
WEIRD	Western, Educated, Industrialised, Rich, & Democratic

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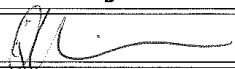
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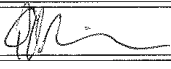
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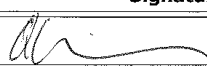
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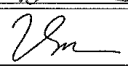
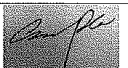
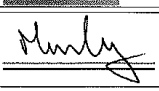

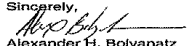
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Caitlyn Placek	Provided feedback on preregistration and manuscript
Martin Lang	Provided feedback on manuscript
Coren Apicella	Provided data
Alexander Bolyanatz	Provided data

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Chapter 1. Introduction

1.1. The puzzle of religion

Religion permeates almost every element of cultural life and influences what we believe in and what actions we take as a species. Anthropologists have long documented that religious beliefs, traditions and practices reoccur across cultures in important fitness relevant contexts, including taboos around food preparation (Meyer-Rochow, 2009), consumption of mind-altering substances in a spiritual context (Brunton, 1979; Gregory, Gregory, & Peck, 1981), weather-altering rituals (Metzner, 1998), rituals around warfare and foraging (Malinowski, 1948; Sosis, Kress, & Boster, 2007), divinely-ordained wedding ceremonies (Avagianou, 1992; Cressy, 1997), burying and blessing the dead (Metcalf & Huntington, 1991), and many more. Religion is also extraordinarily pervasive; more than 80% of the world's population identified as belonging to a religious tradition in 2010 (Pew Research Center, 2012), and the proportion of believers is estimated to grow (Pew Research Center, 2015).

However, why religion exists, and how it has become prevalent across the world is a mystery. First, religion is often very costly to the individual and the group. Religious rituals often require adherents to give up vast amounts of resources, including food offerings, money, time and physical energy in the service of supernatural agents (Firth, 1963; Osborne, 2004). Religious prohibitions often require people to forgo pleasures, for example by moralising sobriety (Glassner, 1991), commanding extended periods of fasting (Feeley-Harnik, 1995; Knutsson & Selinus, 1970), and promoting the taking of vows of chastity (McAllister, 1986; Thurston, 2006). Religious rites may also require people to inflict physical violence upon themselves, such as by plunging one's hands into gloves covered in bullet ants (Bosmia, Griessenauer, Haddad, & Tubbs, 2015), self-flagellation (Szanto, 2013), or skewering oneself with wires and hooks (Xygalatas et al., 2013). Second, religion supports unquestioning commitment to false

beliefs about the world, such as the workings of the cosmos, the age of our planet, the ability of supernatural agents to intervene in the world, and the efficacy of certain medical treatments. These misconceptions about reality might be expected to incur significant fitness costs.

The combination of often severe fitness costs of religious beliefs, rites and rituals might lead one to wonder why religion is so pervasive, and why it continues to persist, and indeed flourish, even in the face of scientific evidence against many key religious tenets and the efficacy of rites and rituals. The introduction to this thesis will set out the main evolutionary arguments that seek to explain the existence, persistence and ubiquity of religion. The remainder of the thesis itself will then test some of these key functional explanations of religion.

1.2. What is religion? A working definition

In *The Varieties of Religious Experience*, the famous philosopher and psychologist William James rather cryptically defined religion as “the feelings, acts, and experiences of individual men in their solitude, so far as they apprehend themselves to stand in relation to whatever they may consider the divine” (James, 1902, p. 31). However, such a definition simply begs the question of what exactly constitutes the divine. Esteemed British anthropologist Edward Tylor proposed that a minimal definition of religion could be a “belief in spiritual beings” (Tylor, 1871, p. 424). More recent attempts at a definition of religion have echoed this emphasis on spiritual beings, suggesting that to be called religious one should profess belief in supernatural agents, specifically ones that can supersede natural constraints such as by reading minds or moving through walls (Boyer, 2001; Dennett, 2006; Whitehouse, 2002).

A more inclusive conceptualisation of religion emphasises a series of recurring features that can vary to the extent that they are emphasised (or even occur) between and even within religions (Sosis, 2009). These features may include, but are not limited to synchronous rituals, afterlife beliefs, religious symbols, structures for collective worship, sacred texts, music,

myths, offerings and painful rites, and belief in single or multiple sprites, spirits, ancestors, witches, shamans, angels, demons, and creator deities. In this vein, scholars have argued that religion is more like a “loose family of phenomena, not a *natural kind*” (Dennett, 2006, p. 7), or a “convenient label that we use to put together all the ideas, actions, rules and objects that have to do with the existence and properties of superhuman agents such as God” (Boyer, 2001, p. 9).

This thesis favours this looser conceptualisation of religion as the integration of some, or all, of these features within a moral and behavioural framework, supported and enacted by a group of people. Taking a bottom up approach by considering religion’s constituent parts and the specific roles that they play means that one can test ultimate explanations for religion on specific religious elements, as well as test proximate functions of these elements (Atran & Norenzayan, 2004; Sosis, 2009; Sosis & Alcorta, 2003; Whitehouse, 2002). Further, the integration of cognitive processes and behaviours into what we term religion (Atran, 2004; Boyer, 2001; Dennett, 2006) means that we can pose questions about the cultural evolution of religion at different levels of selection, from the underlying cognitive mechanisms (e.g. Atran, 2004; Csibra & Gergely, 1998; Norenzayan, Gervais, & Trzesniewski, 2012), specific religious traits (e.g. Bulbulia & Sosis, 2011; Norenzayan & Hansen, 2006; Sosis & Alcorta, 2003), or the whole religious tradition (e.g. Henrich, 2015; Norenzayan et al., 2016; Purzycki et al., 2016).

1.3. By-product explanations for key elements of religion

1.3.1 Supernatural agents and ritualistic behaviours can emerge from natural cognitive processes

Some cognitive scientists have proposed that several key features of religion such as belief in supernatural agents, miracles, the afterlife, and participation in causally-opaque rituals, can

arise as by-products of ordinary cognitive adaptations that reliably develop in individuals to a large extent independently from cultural influences (Atran, 2004; Atran & Norenzayan, 2004; Barrett, 2000, 2004; Bloom, 2012; Boyer, 2001; Pyysiäinen & Hauser, 2010). One key aspect of cognition, variously referred to as ‘mentalising’, ‘intentionality detection’, or ‘theory of mind’ (ToM), concerns the ability to conceptualise and infer the mental states and intentions of other physical agents (Frith & Frith, 2003; Waytz, Epley, & Cacioppo, 2010). This ability has clear adaptive functions, allowing individuals to predict and react to the behaviour of potential predators (Bloom, 2012; Norenzayan et al., 2016), and manage social relations (Bering & Shackelford, 2004). However, some theorists have proposed that ToM could produce biases that act as the building blocks of religious belief.

Risk strategy models developed within error management theory (Haselton & Buss, 2000) propose that when a) information about agency and intentionality is vague or incomplete, and b) unequal trade-offs exist between the risks and rewards of attribution of events to intentional agents (for example where the cost of attributing a rustle in the bushes as wind is less costly than failing to attribute the rustle as a predator), then natural selection should favour a bias towards over-attributing agency in ambiguous events (Barrett, 2004). This bias, known as the Hyperactive Agency Detection Device (HADD) has been hypothesised to explain the tendency of people to attribute natural phenomena to unseen supernatural agents, thus allowing human minds to represent voices in the wind, faces in the clouds, and powerful creator deities (Barrett, 2004; Guthrie, 1995). In addition, Paul Bloom has argued that because ToM develops as a distinct neurological and functional system to ‘theory of body’, humans are ‘inuitive dualists’ predisposed to belief in souls, spirits, and other agents that can transcend the death of the body (Bloom, 2005, 2012).

Our species evolved sensitivity toward inferring intentional causality to agents and objects could also have led to an over-attribution of purpose in worldly events and objects generally,

including attributing the nature of our world and the events in it to the intent of supernatural agents (known as ‘promiscuous teleology’) (Atran, 2004; Csibra & Gergely, 1998; Kelemen, 1999; Kelemen & Rosset, 2009).

Similar biases may also explain religious ritual. Superstitious behaviour can evolve as a by-product when the fitness costs of errors of failing to infer a causal association between a behaviour and an effect are consistently larger than those for failing to reject belief in a causal association (Beck & Forstmeier, 2007; Foster & Kokko, 2009). Superstitious behaviour is observable in a variety of domains with uncertain outcomes, such as in sports (Keinan, 1994) and health (Hira, Fukui, Endoh, Rahman, & Maekawa, 1998), and is likely to be phylogenetically ancient (Foster & Kokko, 2009; Skinner, 1948). As such, superstition might underlie a willingness to conduct a range of causally-opaque religious rituals towards intentional supernatural agents.

1.3.2 Religious ideas can spread with the aid of complex human social cognition

Central to this cognitivist perspective is our ability to accumulate cultural knowledge via social learning. Humans have evolved several specialised social cognitive abilities, such as ToM, communication via language, and effective social learning, allowing us to rapidly and effectively acquire cultural information (Call, Carpenter, & Tomasello, 2005; Herrmann, Call, Hernández-Lloreda, Hare, & Tomasello, 2007; Herrmann, Hernández-Lloreda, Call, Hare, & Tomasello, 2010). This is facilitated by an evolved set of social learning biases and preferences, such as over-imitation (Horner & Whiten, 2005; Lyons, Young, & Keil, 2007), conformity (Boyd & Richerson, 1995), attention to prestigious and successful individuals (Cavalli-Sforza & Feldman, 1981), and punishment of deviant behaviours (Boyd & Richerson, 1992), that allow cultural information to be transmitted and maintained within groups. Are religions then

merely the culturally transmitted beliefs and superstitions of a species prone to find agency and design in the world? If so, why do some religions flourish while others die out?

1.3.3 Cultural parasitism and violation of core knowledge might explain the spread of some religious ideas

One attempt to explain the differential rates of success and extinction of religions proposes that religious ideas can be understood as *cultural parasites*. According to this idea, religious ideas (or memes) are successful to the extent that they can exploit aspects of our innate cognition, including cognitive biases and adaptations, to replicate in the minds of others (Blackmore, 2000; Dennett, 2006). This process of cultural parasitism occurs within an evolutionary landscape where religious ideas compete for cultural supremacy- space in human minds is finite and only the most catchy ideas survive. Here, fitness advantages conferred on those who host the trait are secondary to the proliferation of the cultural parasite, and those ideas which best promote copying fidelity and replication in the minds of others will outcompete the less successful. Beliefs and traditions that could confer selective advantages on religious systems might include exhortations to produce many children, proscriptions against questioning major religious tenets, punishment for apostasy, and promotion of witnessing and proselytization with the aim to convert non-believers.

1.3.4 Mickey Mouse and Moses highlight the problem of explaining strong religious commitment

One critique that has been levelled at the cognitivist approach to religion is that it appears unable to explain why people are willing to commit to some supernatural agents but not others (Atran, 1998; Atran & Norenzayan, 2004). Cognitive adaptations might produce, as a by-product, representations of intentional, agentic supernatural beings that can be successfully transmitted to other human minds. Further, particularly catchy memes might explain why some

religious icons are more memorable than others. However, cognitivist arguments seem unable to explain the motive behind emotional attachment to religious figures, often involving the offering of labour, time and cherished resources. Moreover, if fictional agents can emerge as cognitive by-products, why are some characters seen as myth or fiction while others are revered as supreme deities? This has led some to claim that these accounts seem unable to “distinguish Mickey Mouse from Moses, cartoon fantasy from religious belief” (Atran, 1998; Atran & Norenzayan, 2004, p. 714). One justification for the deep commitment associated with belief in and practices towards supernatural agents is that there may be functional payoffs for adherents and/or religious groups.

1.4. Functional explanations for key aspects of religion

1.4.1 Religion can promote health, wellbeing and psychological adjustment

Studies in the field of religious coping have found that people self-report using religion to cope with a range of negative life events, such as medical illness (Ayele, Mulligan, Gheorghiu, & Reyes-Ortiz, 1999; Koenig, Weiner, Peterson, Meador, & Keefe, 1997), chronic pain (Bush et al., 1999), mental illness (Bickel et al., 1998; Koenig, Pargament, & Nielsen, 1998), and natural disasters (Smith, Pargament, Brant, & Oliver, 2000). Moreover, religious coping has been linked with positive health outcomes, such as reduced rates of depression (Bickel et al., 1998; Bush et al., 1999; Smith et al., 2000), and alcohol dependence (Patock-Peckham, Hutchinson, Cheong, & Nagoshi, 1998), and may be correlated with better physical health (Koenig et al., 1998). Epidemiological and clinical studies have shown a link between religious involvement and a range of mental and physical health outcomes, including links between intrinsic religious commitment and lower rates of depression and anxiety (Aukst-Margetić & Margetić, 2005), church attendance and reduced rates of mortality (Powell, Shahabi, & Thoresen, 2003), meditation and better physiological health in clinical patients (Seeman, Dubin, & Seeman,

2003), and religious faith and greater self-reported happiness (Myers, 2000). What underlying features and functions of religion can account for these diverse protective and buffering effects on health and wellbeing?

One idea is that people will turn to magical beliefs and superstition to exercise some control over unpredictable situations (Burger & Lynn, 2005; Malinowski, 1948; Sosis, 2007), and promote self-control (McCullough & Willoughby, 2009). Some of the earliest anthropological evidence for what has been dubbed the ‘uncertainty hypothesis’ comes from the anthropologist Bronislaw Malinowski. Malinowski witnessed superstitious behaviour in Trobriand islanders when they fished in dangerous waters with changeable fish stocks, but not in calm areas with reliable fishing, suggesting a desire to enact control over an unpredictable environment (Malinowski, 1948). In one experimental test of the uncertainty hypothesis, participants were told that a herbal supplement pill that they were to consume would either produce no side effect (condition 1) or mild arousal or anxiety (condition 2). Participants were then randomly assigned to either a randomness or negative valence word-scramble prime. Consistent with the uncertainty hypothesis, participants from condition 1, who could not attribute feelings of anxiety elicited by the randomness prime to the supplement pill, were more likely to attribute a sense of control and agency to supernatural sources (Kay, Moscovitch, & Laurin, 2010). Related studies show that priming a lack of control can also lead to the development of superstitious behaviour (Whitson & Galinsky, 2008), and create a perception of efficacy from rituals (Legare & Souza, 2014).

Another popular and widespread idea is that, by providing hope of literal immortality, afterlife beliefs can buffer against highly aversive death anxieties (Jonas & Fischer, 2006; Jong, Bluemke, & Halberstadt, 2013; Jong et al., 2018; Kay et al., 2010; Laurin, Kay, & Moscovitch, 2008; Solomon, Greenberg, & Pyszczynski, 1991). Consistent with this proposal, intrinsic religiosity has been shown to reduce the ability to access death-related thoughts (Jonas &

Fischer, 2006), afterlife beliefs can buffer against shocks to self-esteem after being primed with thoughts of death (Dechesne et al., 2003), and priming thoughts about death can increase religious beliefs (Norenzayan & Hansen, 2006). A recent meta-analysis of 100 studies found a reliable negative relationship between religiosity and death anxieties (Jong et al., 2018).

Aspects of religion might also buffer against feelings of economic and existential insecurity. Facilitated by a shared system of meaning and social practices (Becker, 1971), religious congregations might provide social support and guidance (de Vaus & McAllister, 1987), financial support (Chen, 2010; Zapata, 2018), and child-care (de Vaus & McAllister, 1987; Martin, 1967), and might promote healthy behaviours (Aukst-Margetić & Margetić, 2005). Some have proposed that commitment to a personal god could also function like a surrogate companion (Epley, Akalis, Waytz, & Cacioppo, 2008) or attachment figure for the lonely (Granqvist, Mikulincer, & Shaver, 2010). Consistent with claims that religion can buffer against feelings of insecurity, surveys indicate that the most vulnerable in society tend to indicate greater religiosity, including the poor (Inglehart & Baker, 2000; Norris & Inglehart, 2004), minority groups, and women (Hackett, Cooperman, Schiller, & Cornibert, 2016; Norris & Inglehart, 2008; Sullins, 2006). At the group-level, evidence suggests that reported religiosity is greater in countries with lower life expectancy (Pew Research Center, 2012), and lower income security (Barber, 2011).

1.4.2 Aspects of religion can motivate within-group cooperation

A second, though perhaps complementary idea is that aspects of religion might have been selected at the individual and/or group level for their ability to promote cooperation within groups. Formal modelling in the context of social dilemmas has shown that while groups can benefit from the cooperation of regularly interacting group members, individuals are frequently motivated to maximise their own payoffs by defecting in any one interaction (Fehr &

Fischbacher, 2003; Fehr, Fischbacher, & Gächter, 2002). In the absence of effective barriers to defection, defectors can out-compete co-operators and cooperation breaks down (Robert Axelrod, Sigmund, & Nowak, 1998; Fehr & Fischbacher, 2003; Fischbacher, Gächter, & Fehr, 2001). Alongside other social norms and institutions that disincentivise defection and enable cooperators to identify each other, some aspects of religion might alter the trade-offs of cooperation and defection, leading to greater group cohesion and trust (Chudek & Henrich, 2011; Henrich, Ensminger, et al., 2010).

The Supernatural Punishment Hypothesis (SPH) contends that belief in morally concerned deities who can monitor people's behaviour and punish norm-transgressions in this life and after death can disincentivise cheating and free-riding (Bering, 2013; Johnson, 2011; Johnson & Krüger, 2004; Norenzayan, 2013; Norenzayan & Shariff, 2008; Norenzayan et al., 2016). This could function at the individual level by helping individuals avoid the worldly costs of retribution by other members of one's social group (Bering, 2013; Johnson & Bering, 2006; Johnson & Krüger, 2004; Schloss & Murray, 2011). It might also function at the group level by deterring norm-breaking behaviour in situations where social monitoring by community members is less effective, such as in large-scale societies (Norenzayan, 2013; Norenzayan et al., 2016).

In support of the SPH, humans have been shown to exhibit a high level of sensitivity to cues of monitoring when making cooperative decisions, increasing prosocial behaviour when exposed to pictures of 'watching eyes' (Bateson, Nettle, & Roberts, 2006) or black dots oriented to look like a face (Rigdon, Ishii, Watabe, & Kitayama, 2009). In a well-known study, children who were told that an invisible 'Princess Alice' was present in a room were found to be less likely to cheat in a task when there were no humans present (Piazza, Bering, & Ingram, 2011), trends also observed in a sample of college students (Bering, McLeod, & Shackelford, 2005). Subconscious priming of religious ideas has been shown to elicit greater monetary offers

in anonymous economic games (Norenzayan & Shariff, 2008; Shariff & Norenzayan, 2007; Shariff, Willard, Andersen, & Norenzayan, 2016), and lead to a greater willingness to help others, such as by distributing charity information (Pichon, Boccato, & Saroglou, 2007).

Behavioural economic data from a diverse range of societies indicates that belief in a more knowledgeable and punitive deity predicts a reduced willingness to break an impartiality rule to favour oneself or village member over distant coreligionists (Purzycki et al., 2016b), and give more money to coreligionists but not outgroup members when privately allocating money between oneself and an anonymous other (Lang et al., Under review). Further, findings from a large a cross-cultural survey indicate that god and afterlife beliefs are associated with lower permissibility of a range of moral transgressions, such as littering and tax evasion (Atkinson & Bourrat, 2011). A related idea proposes that individual differences in religiosity might be explained by differences in people's willingness to risk supernatural or social punishment for unbelief (Miller & Stark, 2002; Roth & Kroll, 2007; Stark & Bainbridge, 1980), and might explain the common finding that men, who tend to be greater risk takers (Byrnes, Miller, & Schafer, 1999), consistently report lower religiosity than women on a range of measures (Miller & Hoffmann, 1995; Miller & Stark, 2002; Stark, 2002).

Another mechanism first proposed by William Irons (1996c, 1996a, 1996b, 2001) adapts theories of honest-signalling that were developed in the biological sciences to explain the prevalence of seemingly costly religious behaviours. According to Irons, cooperators can reap the economic benefits of continued engagement in cooperative relationships, but only to the degree that these cooperators can discern and exclude non-cooperative free-riders (Bulbulia & Sosis, 2011; Irons, 2001). One solution is that some religious behaviours, such as taboos, dietary restrictions, strict sexual conventions, regular communal rituals, and even permanent scarification or body markings can signal sincere commitment to the faith, and to the religious group (Bulbulia & Sosis, 2011; Cronk, 1994; Iannaccone, 1992; Irons, 2001; Sosis & Alcorta,

2003). Insofar as ritualised signals of religious commitment are hard-to-fake, for example by evoking strong emotional reactions that are generally not under conscious control, such as anger, love, and passion (Frank, 1988), these rites and rituals can facilitate trust, foster a strong group identity, galvanise group solidarity, and may motivate outgroup hostility (Bloom, 2012; Bulbulia, 2008; Bulbulia & Sosis, 2011; Gervais et al., 2017; Ginges, Hansen, & Norenzayan, 2009; Norenzayan et al., 2016). Further, by exploiting humans' evolved inclinations to attend to social information backed up by ritualised signals of commitment to the group, cultural evolution could have favoured credibility enhancing displays among dedicated religious members as a mechanism to deepen religious faith and commitment in themselves and others (Henrich, 2009; Lanman, 2012; Lanman & Buhrmester, 2017; Whitehouse & Lanman, 2014).

Consistent with these proposals, a well-known study in Israeli Kibbutzim found that frequency of religious participation positively correlated with cooperation in a common pool resource dilemma (Sosis & Ruffle, 2003); findings that have since been replicated in New Zealand (Bulbulia & Mahoney, 2008) and Brazil (Soler, 2012). Further, costly displays of religious rituals have been shown to garner feelings of trust from others (Atran & Henrich, 2010; Ensminger, 1997), and experimental work has shown relationships between the experience of shared dysphoric experiences and identity fusion (Whitehouse et al., 2017), and cooperative behaviour (Xygalatas et al., 2013).

1.5. A role for religion in the evolution of large-scale societies?

The existence and prevalence of large-scale human cooperation is notoriously difficult to explain (Boyd & Richerson, 2009; Henrich, Ensminger, et al., 2010; Richerson et al., 2016). Many of the dominant mechanisms that purport to explain the diversity of cooperative behaviour witnessed across the animal kingdom begin to fail as groups increase in size. First, expanding social groups experience a reduction in the average genetic relatedness between

individuals, reducing the inclusive fitness benefits of cooperation (Chudek & Henrich, 2011; De Waal, 2008; Hamilton, 1964). Second, as groups get particularly large, the reduced likelihood of repeated interactions limits the development of cooperative relationships consistent with reciprocal altruism explanations (Trivers, 1971). Third, exacerbated by the limits of cognitive computational capacity (Dunbar, 1992), population growth leads to an exponential increase in the number of potential social relationships between individuals, reducing both the effectiveness of social monitoring and the quality of reputation-based information (Panchanathan & Boyd, 2003). How then can we explain the rapid scaling-up of human societies that began around 12,000 years ago (Richerson, Boyd, & Bettinger, 2001)?

One approach argues that large-scale cooperation could have evolved via the proliferation of more cooperative groups at the expense of less cooperative groups, a process known as Cultural Group Selection (CGS) (Bell, Richerson, & McElreath, 2009; Boyd & Richerson, 2009; Chudek & Henrich, 2011; Henrich, 2015; Henrich, Ensminger, et al., 2010; Richerson et al., 2016). Proponents of CGS argue that heightened levels of intergroup competition, a characteristic of settled societies, has played a key role in shaping cultural evolution since the onset of the Holocene, providing a fertile environment for selection to act at the group-level (Bowles, 2006; Chudek & Henrich, 2011; Henrich, 2004; Norenzayan et al., 2016; Turchin, Currie, Turner, & Gavrilets, 2013).

One line of reasoning proposes that cultural evolution could have harnessed aspects of our evolved psychology, including mentalising, teleological thinking, mind-body dualism, and sensitivity to reputation and norm-compliance to assemble a package of religious norms, beliefs and ritual behaviours that galvanise cooperation among large groups of coreligionists, promote ingroup cohesion, and facilitate success in intergroup competition (Lang et al., Under review; Norenzayan et al., 2016; Purzycki et al., 2016b; Shariff, Norenzayan, & Henrich, 2010).

Anthropological evidence suggests that particularly powerful Moralising High Gods are more likely to be found in cultures with high levels of social complexity (Roes & Raymond, 2003), places with greater ecological duress and resource insecurity (Botero et al., 2014; Peoples & Marlowe, 2012; Snarey, 1996), and are typically not found in small-scale societies (Boehm, 2012; Roes & Raymond, 2003; Swanson, 1964), suggesting that these kinds of gods might evolve in response to ecological and social pressures on cooperation. However, very little work has sought to test whether group-level differences in aspects of religion can lead to differential rates of group survival and extinction. In one such attempt, Sosis (2000) utilised historical data to predict the survival rates of 19th century American collectivist communes, finding that religious communes were four times more likely to survive than secular communes in any given year. Consistent with a CGS account, a follow-up study found that the number of costly requirements in religious communes correlated with the duration of commune survival, with those religious communes requiring the most number of costly requirements lasting the longest (Sosis & Bressler, 2003).

1.6. The problem with ‘WEIRD’ research

While the work reviewed above finds intriguing support for hypotheses that aspects of religion might be functional at the individual and/or group level, much of this has utilised student samples in so-called Western Educated Industrialised Rich and Democratic (WEIRD; Henrich, Heine, & Norenzayan, 2010) societies in times of relative resource abundance (e.g. Johnson & Krüger, 2004; Norenzayan & Hansen, 2006; Norenzayan & Shariff, 2008; Smith et al., 2000). Further, studies over-represent the Abrahamic faiths, and focus on beliefs about and commitment to powerful moralising deities, failing to consider local deities and spirits (e.g. Bulbulia, 2008; Johnson & Bering, 2006; Johnson & Krüger, 2004; Smith et al., 2000; Sosis & Bressler, 2003; Sosis & Handwerker, 2011).

This over-reliance on WEIRD samples is problematic because research has found that even very basic cognitive and motivational processes such as visual perception and cooperativeness in economic decision-making exhibit substantial variation between populations (Henrich, 2014; Henrich, Ensminger, et al., 2010; Henrich, Heine, & Norenzayan, 2010b; Henrich, Heine, et al., 2010a; Segall, Campbell, & Herskovits, 1966). To the extent that groups differ in cognitive and motivational domains that interact with religiosity and its proposed functions, research concerning the individual or social function of religion might not generalise to non-WEIRD societies. Further, if religion is an important facilitator of wellbeing and cooperation, it is important to test these proposed functions in times of acute resource stress, such as following a natural disaster, when wellbeing and cooperation are likely to become increasingly strained. Therefore, to understand the role religion has played in human evolution, research should test theories of religion in a diverse range of societies, religious traditions and deities, in times of both plenty and resource stress.

1.7. The cultural evolution of religion: key arguments and thesis outline

The research in this thesis was conducted in conjunction with the Cultural Evolution of Religion Consortium (CERC), with the goal of testing several key functional explanations of religion in non-WEIRD settings. The research presented here represents work from the second wave of this collaborative project, building upon the first wave by utilising a different measure of cooperation, testing cooperative behaviour beyond the religious ingroup, including a greater range of measures of religiosity, and expanding the number of sites.

The principle sites in which this research was conducted were in Tanna, an island of around 38,000 people in the South Pacific nation of Vanuatu. Tanna is an intriguing location to study religion because the island contains a number of diverse religious influences within a non-WEIRD socio-cultural setting. Christian, indigenous folk 'Kastom', cargo cult beliefs and

traditions are practiced in small-scale horticulturalist communities, with many inhabitants of Tanna (the Tannese) believing in local deities and ancestor spirits as well as powerful moralising creator deities. Thus, Tanna provides a rare opportunity to test a range of hypotheses concerning whether aspects of religion are functional in a sample of Christian and non-Christian participants and considering both moralistic creator deities and perhaps less morally-concerned local deities.

The remainder of this thesis will be structured as follows: In **Chapter 2**, this thesis utilises a religious survey, priming, and behavioural economic data to test whether aspects of religion, such as belief in a punishing deity and religious commitment, predict prosocial behaviour to religious ingroup and outgroup members in Tanna, Vanuatu. This thesis takes an evolutionary perspective to the definition and operationalisation of prosocial behaviour. At the proximate level, prosocial behaviour is any behaviour intended to benefit another individual (Jensen, 2016). At the ultimate level, prosocial behaviour is any behaviour that increases the evolutionary fitness of the receiver at a cost to the giver. This dual-level definition has the benefit of allowing us to distinguish between acts which are intended to benefit others and those which are benefit others only as a by-product of benefitting the giver, such as seeking to increase one's reputation or social standing as a cooperator, or helping a genetically-close relative. Further, this definition allows us to test hypotheses about the proximate and ultimate social function of aspects of religion.

In March 2015, eight months after the first round of data collection on Tanna, Category 5 Cyclone Pam unexpectedly struck the central and southern islands of Vanuatu. While there is little debate that culture can be shaped by environmental conditions, most work on religion and prosocial behaviour is conducted under conditions of resource abundance. It remains an open question as to how cooperative norms and behaviours vary in response to sudden resource shocks, such as those experienced during and after natural disasters. Taking advantage of this

unpredicted and devastating event, **Chapter 3** utilises behavioural economic data with the same people before and after Cyclone Pam to test whether individual differences in the nature and severity of exposure predict prosocial giving towards coreligionists and members of a religious outgroup in the aftermath of a natural disaster. Further, if religion functions at the individual and/or group level to buffer wellbeing and motivate cooperation, these effects should be particularly strong when wellbeing and cooperation are threatened the most. **Chapter 4** then tests whether aspects of religiosity can function to reduce feelings of insecurity and galvanise cooperation in the aftermath of a natural disaster.

While Tanna provides an interesting and useful field site in which to test functional explanations of religion, the larger CERC dataset affords the ability to test some of these explanations in a cross-cultural sample. The common finding in the literature that women tend to report greater religiosity provides a useful test case for evaluating the explanatory value of functional explanations of religion. This is because we can seek to understand whether gender differences in religiosity might be explained by systematic gender differences in personal or social needs, desires and preferences that can be fulfilled by religion. **Chapter 5** utilises the full CERC sample of 14 diverse societies worldwide to quantify and seek to explain this religious ‘gender gap’. Finally, **Chapter 6** summarises the findings from the four data chapters and concludes with an evaluation of these findings for our understanding of the cultural evolution of religion.

Chapter 2. Religion and the extent of prosocial preferences on Tanna Island, Vanuatu.

2.1. Introduction

This work in this current chapter is motivated by theories about the adaptive function of religion that argue religion helped humans to live in increasingly large groups (Henrich, 2009; Norenzayan, 2013). Scholars of religion have proposed that religion plays a key role in the formation and transmission of social values and behaviours (e.g. Durkheim, 2001; Weber, 1958), helping to unite individuals into cooperative communities centred around a common deity, or deities (Durkheim, 2001; Graham & Haidt, 2010). Several converging lines of evidence have linked religion with increased cooperation, including associations between religious engagement and self-reported charitability (Brooks, 2007; Putnam & Campbell, 2012), cooperation in economic games (Bulbulia & Mahoney, 2008; Soler, 2012; Sosis & Alcorta, 2003), and trust (Atran & Henrich, 2010; Ensminger, 1997). Experimental studies have shown that religious reminders increase cooperative behaviour and honesty (Gervais & Norenzayan, 2012; Norenzayan & Shariff, 2008; Shariff et al., 2016), and that priming religious concepts reduces lying or cheating behaviour (Randolph-Seng & Nielsen, 2007). Despite these advances, the psychological mechanisms responsible for links between religion and cooperation remain contested (Johnson & Bering, 2006; Norenzayan & Shariff, 2008; Norenzayan et al., 2016; Schloss & Murray, 2011).

One explanation introduced in Chapter 1, often referred to as the Supernatural Punishment Hypothesis (SPH), proposes that shared belief in morally-concerned, watchful, and punitive deities may reduce selfish behaviour by activating our evolved sensitivity to group norms, social monitoring, and reputation (Norenzayan et al., 2016; Shariff & Norenzayan, 2007; Shariff et al., 2016). Belief in supernatural punishment could have been selected at the

individual level for its ability to motivate individuals to refrain from selfish behaviour, thereby avoiding the real threat of sanctioning by others in their social group (Johnson & Bering, 2006; Johnson, 2005; Johnson & Krüger, 2004). Alternatively, or in addition, supernatural punishment beliefs may function at the group level by reducing conflict and selfish behaviour and promoting group cooperation (Atran & Norenzayan, 2004; Norenzayan, 2013; Norenzayan et al., 2016).

Current survey and experimental findings offer some support for an association between individual prosociality and belief in a punishing supernatural deity (Atkinson & Bourrat, 2011; Johnson, Li, Cohen, & Okun, 2013; Oviedo, 2016; Piazza et al., 2011; Shariff & Norenzayan, 2007, 2011; Shariff et al., 2016). However, most of this work has been conducted in western, developed and/or Christian countries and it is unclear to what extent these findings generalize outside a WEIRD cultural context. For example, priming god or religion could reflect supernatural monitoring and punishment effects but could equally reflect an association between religious institutions and prosociality specific to western subjects. Indeed, this is consistent with the finding that priming secular institutions of justice also increases prosocial behaviour (Oviedo, 2016; Randolph-Seng & Nielsen, 2008; Shariff & Norenzayan, 2007).

In order to establish a role for supernatural monitoring and punishment in the evolution of large-scale societies we need to systematically investigate the link between prosocial behaviour and specific beliefs about different kinds of gods across a range of cultural contexts. Moreover, while there is plenty of work describing religions around the world, much less work has attempted to quantify specific attributes of deities in a systematic way. Recent work undertaken by CERC has tested whether belief in supernatural monitoring and punishment predicted rule-following behaviour with participants from eight societies spanning a broad range of religious beliefs (Purzycki et al., 2016b). Purzycki and colleagues (2016) utilized the Random Allocation Game (Hruschka et al., 2014), an impartial allocation paradigm decided by the roll of a die, to

measure participants' willingness to cheat, favouring oneself or a random person from one's own village over a random person from another village of the same religion. Across all sites, belief in a more omniscient, punitive moralistic deity, but not local gods or spirits, predicted increased allocations to an anonymous individual of the same religion. These findings are consistent with the idea that belief in increasingly morally-concerned, punishing deities might expand the cooperative sphere from those in one's immediate village or interaction network to more distant coreligionists.

Christian and indigenous *Kastom* communities on Tanna Island, Vanuatu were two of the global set of societies sampled by CERC examining the link between religious beliefs and rule following (Atkinson, 2017; Purzycki et al., 2016b). Tanna island provides an ideal location for studying religious form and function. Situated at the southern end of the Vanuatu archipelago, Tanna's relative isolation, predominantly rural agrarian lifestyle, and diversity of religious beliefs provide an opportunity to explore the psychological effects of adherence to different religious traditions in a non-western sample. Despite the pervasive Christian missionization of the Pacific, Tanna has seen a revival of indigenous religious *Kastom* belief and traditions, as well as the emergence and integration of several Cargo Cults, amalgamations of traditional beliefs that incorporate elements of Christian teachings with reverence of specific western icons as deities, such as John Frum and Prince Phillip (Bonnemaison, 1994). This unique religious landscape allows one to test hypotheses about the function of beliefs about and commitment to a western moralising deity- the Christian god- and more local moralising gods, for example a powerful deity known as *Kalbaban* (Atkinson, 2017). Further, many Tannese from both Christian and *Kastom* communities believe in a variety of different supernatural beings located across the island. This provides a rare opportunity to test links between religiosity towards local supernatural forces who may be less concerned with morality and cooperation in communities that follow *Kastom* or Christian belief systems.

Analysis of the Tanna site data (Atkinson, 2017) supports a link between religiosity and prosociality, but also reveals some intriguing differences from the global findings. Increased rule following was associated with belief in a more omniscient and rewarding deity, but not a more punishing one, and these trends were similar whether predicting gameplay from beliefs about a powerful moralising deity or a local supernatural force (Atkinson, 2017). Moreover, these trends were broadly similar in the Christian and local Kastom sample. Nonetheless, whilst both Kastom and Christian individuals indicated a strong commitment to a moralistic deity, Christian participants indicated less commitment to a local supernatural force called *Tupunus*.

These findings are suggestive of the importance of some aspects of religion, particularly belief in an omniscient and rewarding deity, in facilitating increased cooperation. However, this study raises several questions providing opportunities for future research. First, while the previous CERC study focused on rule-following, the link between religion and other aspects of prosociality has yet to be explored. Second, the absence of non-coreligionist reference groups in the Random Allocation Game prevents a test of whether religious group members favour their religious ingroup over those of other religions, i.e. is the resulting prosociality parochial or indiscriminate (Bloom, 2012; Graham & Haidt, 2010; Norenzayan et al., 2016)? Third, the lack of experimental manipulation using religious primes precludes any claims of a causal link between religiosity and prosociality in Tanna. Finally, at the Tanna site, the limited Christian sample size may have contributed to a lack of statistical power and subsequent failure to detect an association between beliefs in a punishing god and cooperation.

Here we build on the previous study in four ways. First, by implementing a series of Dictator Games (DGs) we test whether religiosity is associated with a different aspect of prosociality – the sharing of windfall gains with, and between, others. Second, as well as testing participants' allocation decisions towards people from their own village and from another village of the same religion, we also test for allocation decisions towards people from a village of a different

religion. Third, by introducing three experimental conditions, an *own religion* prime, an *other religion* prime and a *neutral* prime, we can both test whether priming religion causes increased cooperation and determine whether these effects are unique to reminders of one's own religion or represent generalised effects of reminders of religion, regardless of whether one is a member of that religion. Finally, by recruiting a larger Christian sample on Tanna we can identify individual predictors of cooperation with greater power and test for differences between Kastom and Christian religiosity and gameplay.

We combine religious survey data with behavioural economic measures to gain insight into how Kastom beliefs differ from Christian beliefs with respect to characteristics relevant to the SPH, including beliefs about supernatural punishment, reward and omniscience. Further, we test several predictions related to supernatural monitoring and punishment and prosocial behaviour in a Christian and Kastom community on Tanna. We therefore seek to test the following hypotheses:

H1- a) *Belief in a more omniscient, punishing deity should predict increased prosociality towards coreligionists from another village, but not towards those of a different religion.*

b) *To the extent that powerful moralising deities are a more effective facilitator of expanded prosocial networks, commitment to and beliefs about moralising gods should have a greater effect on prosocial behaviour than local spiritual forces, at both sites.*

H2- a) *In both the Christian and Kastom site, priming an individual's own religion should cause increased prosociality beyond the local village towards distant coreligionists, but not to outgroup members.*

b) *If religious reminders prime religion-specific supernatural monitoring and punishment beliefs then we would expect that priming 'other religion' religious concepts should have little*

to no effect on prosociality. Conversely, if religious reminders prime more general supernatural monitoring and punishment concerns (regardless of the religion of the individual concerned) then priming 'other religion' should have a similar effect to priming one's own religion.

2.2. Ethnographic Context

Tanna is a mountainous, tropical, and volcanic island situated at the southern end of a chain of approximately 80 islands that make up the Pacific nation of Vanuatu. Like much of the Pacific, the written history of Vanuatu began with the accounts of European explorers, followed by those of traders, missionaries and settlers. These early ethnographies paint a picture of Tanna as an egalitarian, male-dominated society where village elders enjoyed no apparent advantage in material wealth or social status (Bonnemaison, 1994; Forster, 2000). Despite a lack of any outward signs of development, by the late 18th century the locals had a well-established root crop production and gift economy (Forster, 2000). To this day, most Tannese remain swidden horticulturalists, inheriting land and political titles through agnatic, patrilineal descent systems (Brunton, 1979).

In the 1860's, following a relatively peaceful period of Sandalwood trade with Europeans, a need for cheap labour in Fiji and Australia marked the start of a process of Blackbirding, the notorious system of indentured labour whereby locals were recruited, coerced, and sometimes kidnapped to work on sugar plantations abroad (Bonnemaison, 1994; Mortensen, 2000). Soon after, European settlers began to take up residence in the islands, establishing coconut plantations for copra trading. A period of uneasy cohabitation began, punctuated by sporadic outbursts of violence often as a response to claims that the Europeans had broken sacred tabu, engaged in black magic, or caused the spread of new diseases in the islands that decimated local populations (Bonnemaison, 1994).

Eventually, in 1906, the British and French governments cemented their interest in the islands by establishing a joint rule condominium. The formal establishment of European governance in what was then called the New Hebrides coincided with a rise in nationalism in the islands, with revivals of indigenous *Kastom* culture particularly prevalent in Tanna. Such revivals resulted in the formation of several cargo cults, most notably the John Frum and Prince Philip cults (Guiart, 1956; Lindstrom, 1993). These complex religious traditions combined traditional knowledge with belief in religious icons from Europe or America, believed to one day return to the islands bringing cargo and wealth for the adherents (Lindstrom, 1993). Following decades of post-war opposition to the condominium, independence from Britain and France was granted in 1980 with the establishment of the new nation of Vanuatu.

From the late 1830's, alongside early contacts with the outside world, Christian missionaries began arriving on Tanna beginning a process of proselytization and conversion that was to radically change the religious and social landscape of the island (Guiart, 1956; Lindstrom, 1982). Motivated by Christian sensibilities, the early missions aimed to eradicate some 'undesirable' aspects of Tannese culture, such as polygyny, nakedness, women engaging in manual labour, and kava drinking (Gregory et al., 1981; Lindstrom, 1982). Finding the populace resistant to conversion, the European missionaries promoted the engagement of highly-politicized local leaders. The local leaders were then able to control the communication, interpretation and implementation of Christian doctrine, leading to a widespread devaluation of old *Kastom* knowledge and emergence of new Christian knowledge (Lindstrom, 1982). By 1920, Christian converts on Tanna numbered upwards of 4,000 in a population of around 6,500 (Guiart, 1956), and today over 60% of the population of roughly 28,000 claim to follow one of a number of Christian churches. Life for Christian Tannese now is likely to be very different to their pre-contact lifestyle. Christian children are now educated in the many denominational schools on the island, and most attend church services at least once a week. Further, some

Tannese Christians have access to the internet, many have electricity, and some have spent time in the capital at Port Vila to work and to experience life in a busier town.

Despite being a predominantly Christian island, a 2009 census indicates that a fifth of the Tannese population identify as holding *Kastom* religious beliefs. A generally-accepted definition of *Kastom* at the national level is a matter of consistent discussion and re-evaluation (See Lindstrom, 1982, for a review of this debate), but *Kastom* on Tanna is often explained as a revival and re-interpretation of pre-contact mythology and traditional cultural practices (e.g. Lindstrom, 1982; Tonkinson, 1981). *Kastom* religion on Tanna encompasses a belief in a number of local gods and ancestor spirits spread across the island. One of the most powerful deities, *Kalbaben* features in many folk stories and is often referred to as the creator god, taking up residence in the highest peak on Tanna, Mt. Tukošmera. Further, *Kastom* individuals often emphasise the local importance of magic garden stones (or *Kapiel*), used by magic men to control weather and root crop production. During the height of the Christian missions, locals destroyed or lost many of the sacred stones, only recently seeking to find and utilise them once again (Lindstrom, 1982). *Kastom* rituals often revolve around the practices of food exchange, feasting and group dancing and can take place over many weeks. Key ceremonies such as the *Niel* and *Toka* festival can take years of planning and are attended by many hundreds of people from tribes across the island. By contrast, *Kastom* men engage in ritualistic kava-drinking every evening. Kava is seen as a gateway to the spirit world, allowing drinkers to communicate with deities and ancestors (Lindstrom, 1980). In an effort to preserve the traditional *Kastom* way of life, individuals in these villages are much less likely to own electronic devices, or have worked for a wage, instead living for the most part isolated and away from the more developed parts of the island. Nonetheless, a few *Kastom* children do attend church schools down in the more Christian areas and *Kastom* men will often venture to see relatives and to trade with the money and goods that they have.

It is clear that while Kastom incorporates longstanding indigenous beliefs and practices, there is evidence of bi-directional borrowing and sharing of both religious beliefs and cultural practices between Kastom and Christian communities. For example, Kastom land tenure and dispute resolution protocols are generally followed in both Kastom and Christian groups. Moreover, many Christian communities celebrate Kastom ceremonies and rituals such as yam and taro planting, harvesting rites, and most adhere to tabu dictating where and when one can fish and harvest crop. Indeed, many Christians are content to believe in the coexistence of the Christian God and local gods and spirits, having “worked out a local version of Christianity that matched their own view of the world” (Bonnemaïson, 1994, p. 253). Even so, Christian and Kastom villages are geographically and culturally dissimilar, and worship different moralistic supernatural agents.

2.3. Methods

Study Sites and design. Our first study site is a Christian village of approximately 250 adults. The village is divided into 6 hamlets of between 30 and 40 inhabitants, organised under one area council. All hamlets are located within a 15-minute walk of each other and are within a half an hour’s walk to a market village. Villagers profess belief in several Christian denominations and as such, the village contains a number of churches, including Presbyterian, Seventh Day Adventist and Assemblies of God. Located close to the village is a community primary school and a small coffee processing plant which employs several community members and receives coffee crop from villages all over the island.

Our second study site is a group of three Kastom hamlets comprising around 120 adults in total. The village is a precarious 30-minute drive from the coast along a muddy bush track. Whilst not comprising a single village, the three hamlets claim to follow the same Kastom, often inter-marry and engage in regular cultural and religious rituals together. The hamlets show few

outward signs of modernization; houses are made of bamboo and flax, raised for storage and shelter for pigs and chickens.

Data collection was conducted over eight weeks from June to July 2014. Our Christian sample were recruited from the same broad community as the 2013 Random Allocation Game study (Atkinson, 2017), but had not played the game the previous year. Due to the size of the Christian community it was not possible to sample every adult. As a result, our Christian participants were recruited via cluster sampling of a village census, from which we aimed to sample at least one individual from each household. Due to the small community size of the Kastom hamlets, most of these participants had participated in the 2013 Random Allocation Game study (Atkinson, 2017). All scripts were translated by a local research assistant from English into the participants' local language; *Bislama* in the Christian site and *Navhal* in the Kastom site. The translated scripts were then back-translated into English by another research assistant and any errors were discussed and resolved with both the assistants and the investigator.

Due to village size and villagers' intensive schedules tending to their gardens at the Christian site, many individuals leave the village at dawn and do not return until the early evening. Therefore, to prevent biased sampling, we conducted study sessions throughout the day, from very early morning to late evening. Over four days we sampled 134 participants (50% male) between the ages of 18 and 78 ($M = 35$, $SD = 14.3$) from six village hamlets. At the three Kastom village hamlets, we sampled 108 participants (50% male) between the ages of approximately 18 and 75 ($M = 35$, $SD = 15.3$) over four days.

Dictator game. Participants played four rounds of a DG which tested participants' willingness to share a monetary endowment with others (Table 1). In each game, participants were presented with two cups. A single stack of ten 50 vatu coins was then placed directly in front

of the participant. Players were told that they had been tasked with deciding how many of these ten coins they would like to allocate to each cup. In order to avoid reputational effects on gameplay, testing was conducted in private (participants played in a beach tent) and was anonymous (payouts were given anonymously so that no other community members were aware of what was paid out). Participants were told that they would not know who had received their monetary allocations and that the recipient would not know who had allocated this money to them. Further, participants were told that all of the money they allocated would be delivered by us to the designated recipients after our research was complete, but that the recipients would not know who specifically had given them this money.

We tested a willingness to share an endowment between oneself and another person in two *self games*. In the Self-Corel game participants could decide how much of an endowment to keep (Self) versus share with an anonymous individual from another village of the same religious tradition (Corel). In the Self-Outgroup game, participants' could decide how much of an endowment to keep (Self) versus share with an anonymous individual from a different religious tradition (Outgroup). We also measured decisions when sharing an endowment between two people from different reference groups in two *group games*. In the Village-Corel game, participants could allocate money between an anonymous individual from their own village (Village) and another village of the same religious tradition (Corel). Lastly, the Corel-Outgroup game tested allocation decisions when sharing between an anonymous individual from another village of the same religious tradition (Corel) and an anonymous individual from a different religious tradition (Outgroup). Game order was randomised to control for order effects.

Each participant played with 500 vatu per game, with a total of 2000 vatu over the four games. The maximum individual payoff of 1000 vatu amounts to approximately a day's wage for a manual labourer (1500 vatu including the show-up fee). As of testing in June 2014, the maximum individual payoff amounted to approximately 10.5USD. In order to avoid deception

and fulfil our promise to give money to individuals represented by the cups in game play, we distributed all game allocations to the appropriate individuals on Tanna (Village payments to their village, Corel payments to another village of the same religion and/or Outgroup payments to villages with another religion) within two weeks of the completion of the research.

Table 1. Reference groups in each game dyad

Game Dyads	
Cup 1	Cup 2
The participant (Self)	V A person from another village of the same religion on Tanna (Corel)
The participant (Self)	V A person from another village of a different religion on Tanna (Outgroup)
A person from the participant's own village (Village)	V A person from another village of the same religion on Tanna (Corel)
A person from another village of the same religion on Tanna (Corel)	V A person from another village of a different religion from the participant (Outgroup)

Primes. Participants were each exposed to one of three randomly allocated prime conditions for the duration of game testing; a neutral control, an own religion condition, or an other religion condition. Due to sample size constraints and varying levels of exposure to Christianity at the Kastom site, Kastom participants were primed with only the own religion prime or neutral control. The religious primes consisted of three religion-specific items painted onto a white cloth with an orange background. The Christian prime consisted of a church, bible and crucifix necklace. The Kastom prime consisted of three items used in Kastom ritualistic dance: a ritual *Toka* stick, a feather stick, and a bundle of dried grass known as a *Wilgen* (See Figure S1 in Supplementary information). Thus, the own religion condition for the Christian and Kastom sites involved Christian and Kastom priming, respectively. The other religion condition at the Christian site involved the Kastom prime. The neutral prime consisted of three painted flowers. Primes were placed in front of the participant before they arrived for testing and remained there until after they left the testing area, thereby ensuring that the participant

played all DGs under the same prime conditions. During gameplay, the cups were placed on top of the prime material.

Religiosity measures. We returned to the villages two weeks after the completion of game testing to conduct in-depth religiosity surveys with all participants who had played the games. In the Christian village, we asked questions concerned with belief in, and commitment to, the Christian god. In the Kastom village, based on a previous exploration of key deities on Tanna (Atkinson, 2017) we asked these same questions about their creator god, Kalbaben. Further, to establish whether the potential associations between religiosity and gameplay might be attributable to belief in powerful creator gods and/or local supernatural forces, we asked these same questions about a local spirit force linked to garden magicians called Tupunus, who is locally important to both Kastom and Christians. Our survey asked a range of questions designed to target a variety of aspects of religious beliefs and practices towards the Christian God, Kalbaben and Tupunus.

To operationalise religiosity and facilitate comparison with prior work, we considered three scales as utilised by Atkinson (2017); a Commitment scale, combining scores on three ordinal measures measuring how much one thinks about moralistic god, worries about what moralistic god thinks about oneself, and how often one performs activities or practices to talk to, or appease moralistic god; an Omniscience scale, the sum of two binary variables measuring ability of one's moralistic deity to monitor human thoughts and behaviours; an ordinal Reward scale, measuring how frequently one's moralistic deity is believed to reward people for good behaviour; and a Punishment scale, consisting of the sum of three ordinal measures measuring how important punishment of moral transgressions is perceived to be to the moralistic deity (See Table S1 for all scale items) . We constructed the same composite scales for commitment and beliefs about Tupunus. All measures of religiosity were standardised between 0 and 1. In order to test for multi-collinearity between the religiosity measures, we extracted Variance

Inflation Factors (VIFs) for both the moralistic god measures and Tupunus measures. All VIF scores were below the recommended threshold of 3, indicating low levels of multi-collinearity (Zuur, Ieno, & Elphick, 2010).

Analysis. To test for individual-level associations between religiosity and gameplay across our whole sample, we ran a series of Tobit models on coin allocations to the distal cup in each game. The dependent variable for each regression was the allocation to the distal cup in each game, ranked by geographical and ideological closeness: Self > Village > Corel > Outgroup. We ran one set of regressions predicting coin allocations using commitment to and beliefs about Kalbaben/Christian god and another using commitment to and beliefs about Tupunus. It is worth noting that Tannese communities are not religiously homogeneous; migration between groups has led to a minority of individuals not following the religion (Kastom or Christianity) of their community. If we remove these individuals from analysis ($n = 9$), our results remain qualitatively the same; we therefore retain these individuals in our final analyses. Each model controlled for an effect of site (Kastom or Christian), and perceived food insecurity, measured as the sum of binary (yes/no) responses to whether one is worried that one's household will have a time when it is not able to buy or produce enough food to eat in the next: a) month, b) six months, c) year, and d) five years.

To explore whether religious priming had any effect on gameplay we conducted a series of Tobit regressions on coin allocations to the distal cup, testing for allocation differences between those primed with religious icons and those primed with neutral icons, on each game. Prime condition was operationalised as Neutral, Own religion (Christian for Christians and Kastom for Kastom participants), and Different religion (Kastom for Christians). Neutral was the reference category. All models additionally controlled for site and perceived food insecurity.

2.4. Results

Between-site comparison of religiosity

Figure 1 shows means and bootstrapped confidence intervals for our religiosity measures at each site. At the Christian site, the Christian god was perceived to hold the punishment of moral transgressions as between “important” and “very important” on our scale, $M = 0.66$, 95% CI = [0.60-0.71]. At the Kastom site, punishing moral transgressions was also rated as between important and very important, to Kalbaben, $M = 0.66$, 95% CI = [0.57, 0.74]. The perceived importance of punishment to the respective gods did not vary significantly between sites, Wilcoxon Rank Sum; $W = 4096$, $p = 0.991$.

Ratings of the omniscience of the Christian god were at ceiling; all participants stated that the Christian god knows people’s thoughts and feelings both locally, and when the participant is in a foreign country. Kalbaben, $M = 0.96$, 95% CI = [0.91, 1], was rated as only slightly less omniscient than the Christian god $M = 1$, 95% CI = [1-1]. While a Wilcoxon Rank Sum test shows that this difference was statistically significant, $W = 4340$, $p = 0.018$, this difference is driven by 4 Kastom individuals of the total 81 who did not rate Kalbaben as fully omniscient. As this measure shows minimal variation, we were forced to remove our omniscience measure from all further analyses.

Further, participants indicated that both the Christian God, $M = 0.83$, 95% CI = [0.78, 0.88], and Kalbaben, $M = 0.85$, 95% CI = [0.79, 0.92], regularly reward good behaviour; however, there was no significant difference in this measure between sites, $W = 3928$, $p = 0.454$.

Finally, both Christian, $M = 0.73$, 95% CI = [0.69, 0.77], and Kastom participants, $M = 0.71$, 95% CI = [0.63, 0.78], reported high levels of commitment to their respective moralistic gods. There was no significant site difference in this measure.

When considering local god religiosity, Kastom participants, $M = 0.71$, 95% CI = [0.64, 0.91], indicated that they were more committed to Tupunus, compared to Christian participants, $M = 0.26$, 95% CI = [0.21, 0.31], $W = 1522$, $p < 0.001$. Further, Kastom participants believed Tupunus to be more omniscient (Kastom; $M = 0.83$, 95 % CI = [0.75, 0.91], Christian; $M = 0.44$, 955 CI = [0.35, 0.53], $W = 1861$, $p < 0.001$), more punitive (Kastom; $M = 0.61$, 95% CI = [0.54, 0.69], Christian; $M = 0.49$, 95% CI = $W = 2732$, $p = 0.010$), and more rewarding (Kastom; $M = 0.88$, 95% CI = [0.83, 0.94], Christian; $M = 0.46$, 95% CI = [0.39, 0.53], $W = 1515$, $p < 0.001$), than did Christian participants.

Comparing levels of commitment and beliefs about each site's main god and Tupunus revealed substantial between- and within-site differences. Wilcoxon Signed-Rank tests showed that Kastom participants rated Kalbaben as more omniscient than Tupunus, $V = 52$, $p = 0.012$. However, Kalbaben was not rated as more punitive ($V = 389.5$, $p = 0.378$), or more rewarding than Kalbaben ($V = 23$, $p = 0.218$), and Kastom participants showed only a borderline significantly higher commitment to Kalbaben than Tupunus ($V = 233.5$, $p = 0.057$). However, Christians reported more commitment to the Christian god than to Tupunus ($V = 6538.5$, $p < 0.001$), and rated him as more punitive ($V = 2165$, $p < 0.001$), omniscient ($V = 1711$, $p < 0.001$), and rewarding ($V = 2260.5$, $p < 0.001$), than Tupunus.

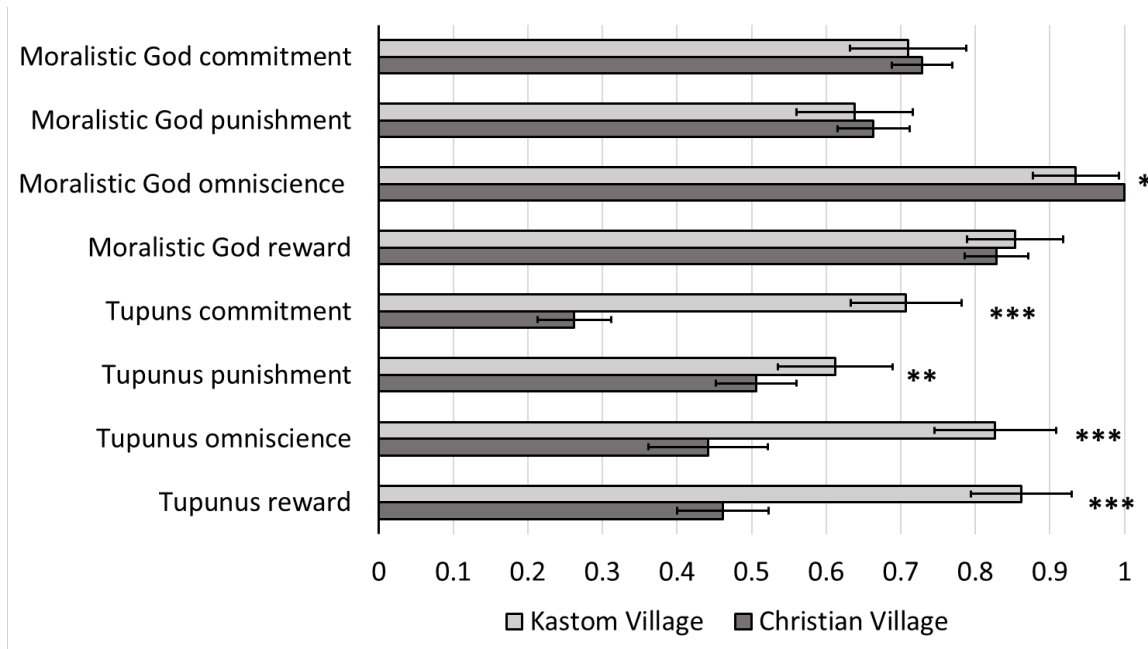


Figure 1. Mean measures of religiosity by site with bootstrapped 95% confidence intervals. * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

Between-site comparison of gameplay

Figure 2 shows the distribution of coins and mean allocations to the distal cup in each DG, split by site. When considering the two self games, Christians allocated significantly more to the distal cup on average than Kastom participants in the Self-Corel game (Christian; Mean coin allocation (M) = 4.33, 95% CI = [3.94, 4.73], Kastom; M = 3.56, 95% CI = [3.13, 3.86], W = 5590, p = 0.002), and the Self-Outgroup game (Christian; M = 4.34, 95% CI = [3.99, 4.70], Kastom; M = 3.45, 95% CI = [3.07, 3.84], W = 9272, p < 0.001). When considering the two group games, Christian participants gave more on average to the outgroup cup in the Corel-Outgroup game than did Kastom participants (Christian; M = 4.85, 95% CI = [4.57, 5.16], Kastom; M = 4.16, 95% CI = [3.74, 4.57], W = 8829, p = 0.002), but allocations to the distal cup in each site did not significantly differ in the Village-Corel game (Christian; M = 4.84, 95% CI = [4.55, 5.14], Kastom; M = 4.78, 95% CI = [4.36, 5.20], W = 9272, p = 0.385).

As can be seen in the violin plots in Figure 2, the modal response for each game was an equal allocation between each cup. To test whether there was a site difference in people’s willingness to meet or exceed this threshold, we compared whether people gave a less than equal (< 5 coins) versus an equal or higher offer (≥ 5 coins) to the distal cup in each DG. The results shown in Figure 3 indicate that Christian participants were more likely than Kastom participants to give an equal or higher offer to the distal cup in the Self-Corel game ($\chi^2(1) = 10.86, p < 0.001$), the Self-Outgroup game ($\chi^2(1) = 13.86, p = 0.001$), and the Corel-Outgroup game ($\chi^2(1) = 13.15, p < 0.001$). This trend was also shown in the Village-Corel game but the difference was only statistically significant at the 0.1 level ($\chi^2(1) = 3.19, p = 0.074$).

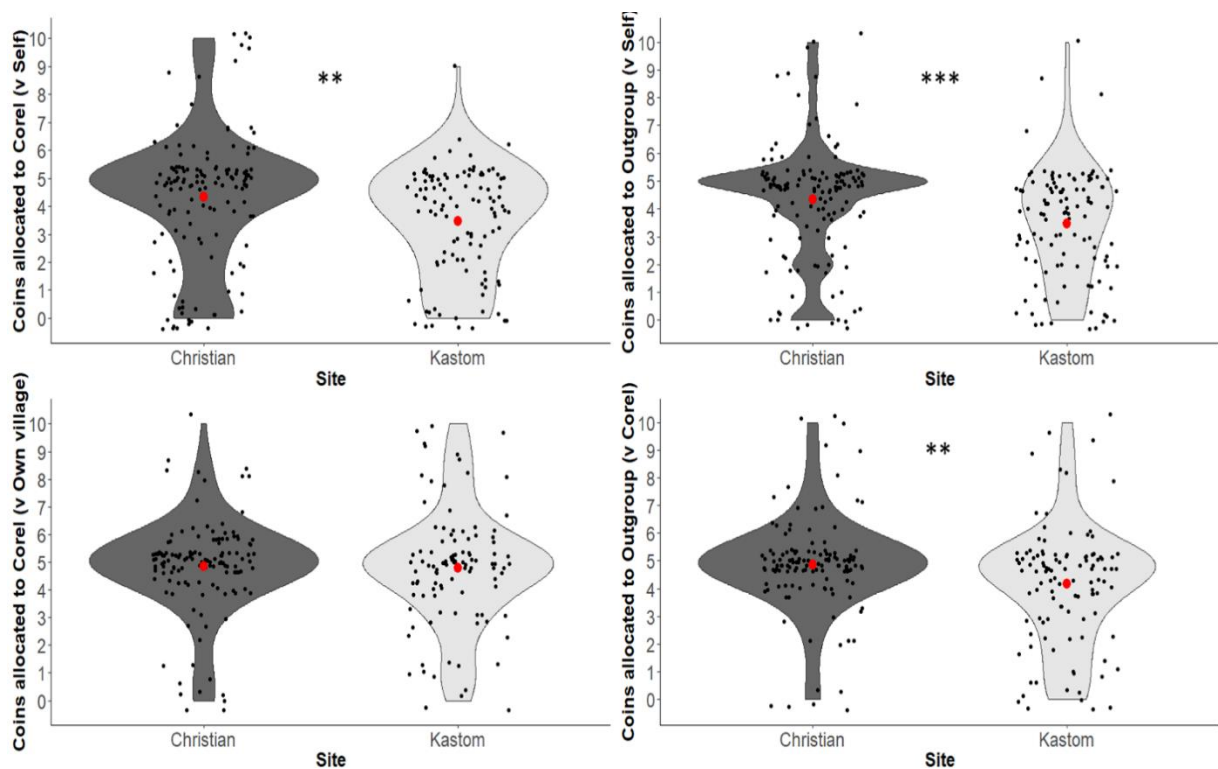


Figure 2. Violin plots displaying allocations to the distal cup in each DG, split by site. Data points are jittered. Red data point represents the mean allocation to the distal cup in each game, at each site. ** $p < 0.01$ *** $p < 0.001$

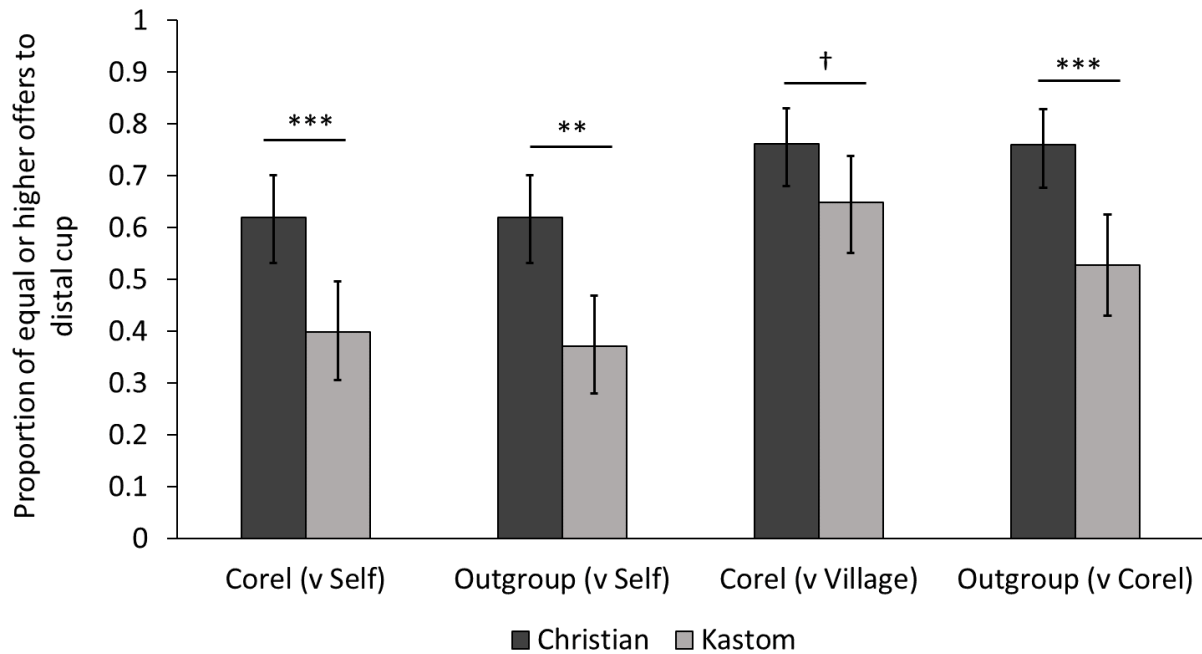


Figure 3. Bar plots displaying the proportion of the sample who gave an equal or higher offer to the distal cup in each game by site. Error bars represent binomial proportion 95% confidence intervals. † $p < 0.1$ ** $p < 0.01$ *** $p < 0.001$

Did belief in a more omniscient, punishing moralistic deity predict higher contributions towards distant coreligionists, but not religious outgroup members?

Table 2 shows the results of a series of Tobit models testing whether individual differences in religiosity were associated with prosocial giving in each game. When considering the self games, we find no evidence that commitment to moralistic god or beliefs about how punitive one's moralistic god is predicted prosocial giving to coreligionists or outgroup members. However, belief in a more rewarding moralistic deity predicted keeping more money against the outgroup. When considering the group games, while commitment to moralistic god was associated with giving more to a distant coreligionist over someone from one's own village, belief in a more rewarding deity predicted giving more to someone from one's own village over a distant coreligionist. Finally, belief in a more punitive deity predicted giving more to an outgroup member than a distant coreligionist, but this was only significant at the 0.1 level.

A different pattern of results emerges when considering the relationships between religiosity and whether one gave an equal or higher offer to the distal cup (See Table 3). Belief in a more punishing deity was associated with increased giving to the outgroup in the Self-Outgroup game, and higher odds of giving an equal or higher offer to the outgroup when sharing between the coreligionist and outgroup cup. Associations between other aspects of religion and allocation decisions were small, inconsistent, and not significant at the 0.05 level.

Table 2. Results of Tobit regressions predicting coin allocations to the distal cup in each game from moralistic god religiosity

Predictor	Coin allocations to the distal cup in each game			
	Self-Corel β-est	Self-Outgroup β-est	Village-Corel β-est	Corel-Outgroup β-est
Intercept	4.62 [2.84, 6.39]***	4.67 [3.13, 6.21]***	4.64 [3.48, 5.80]***	4.42 [3.20, 5.64]***
Religiosity				
Commitment	-0.29 [-2.15, 1.58]	0.67 [-0.94, 2.29]	1.61 [0.39, 2.82]**	-0.49 [-1.76, 0.79]
Punishment	0.11 [-1.04, 1.26]	0.56 [-0.43, 1.55]	0.02 [-0.73, 0.76]	0.71 [-0.09, 1.50]†
Reward	-0.17 [-1.56, 1.23]	-1.37 [-2.58, -0.17]*	-1.16 [-2.07, -0.25]*	0.28 [-0.68, 1.23]
Controls				
Site	-0.49 [-1.28, 0.31]	-0.69 [-1.38, 0.00]†	-0.42 [-0.94, 0.09]	-0.43 [-0.98, 0.11]
Perceived food insecurity	-0.09 [-0.34, 0.16]	-0.11 [-0.33, 0.10]	-0.03 [-0.19, 0.14]	0.04 [-0.13, 0.22]
McFadden's pseudo R ²	0.24	0.25	0.30	0.29
n	185	185	185	184

Note: We report unstandardized Tobit coefficients with 95% confidence intervals in brackets. The reference category for site was Christian. † $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

Table 3. Results of logistic regressions predicting whether one gave an equal or higher offer to the distal cup in each game from moralistic god religiosity

Predictor	Gave an equal or higher offer to the distal cup in each game			
	Self-Corel OR	Self-Outgroup OR	Village-Corel OR	Corel-Outgroup OR
Intercept	2.78 [0.66, 12.25]	2.42 [0.55, 11.10]	3.00 [0.63, 15.51]	1.12 [0.24, 5.36]
Religiosity				
Commitment	0.25 [0.05, 1.14]†	0.53 [0.11, 2.51]	2.07 [0.39, 10.99]	1.34 [0.26, 6.86]
Punishment	1.39 [0.54, 3.56]	5.11 [1.93, 14.27]**	1.10 [0.39, 3.04]	3.34 [1.22, 9.32]*
Reward	1.60 [0.51, 5.05]	0.35 [0.10, 1.14]†	0.62 [0.16, 2.19]	0.84 [0.23, 2.87]
Controls				
Site	0.64 [0.34, 1.22]	0.47 [0.24, 0.90]*	0.56 [0.28, 1.12]†	0.42 [0.21, 0.83]*
Perceived food insecurity	0.92 [0.75, 1.13]	0.93 [0.75, 1.15]	0.90 [0.73, 1.13]	1.17 [0.93, 1.49]
Cox and Snell pseudo R ²	0.04	0.11	0.02	0.07
n	185	185	185	184

Note: We report odds ratios with 95% confidence intervals in brackets. The reference category for site was Christian. † $p < .10$. * $p < .05$. ** $p < .01$.

Did commitment to, and beliefs about, the local god predict prosocial behaviour?

Table 4 shows the results of a series of Tobit regression models, predicting gameplay from measures of belief in, and commitment to, the local spirit Tupunus. Our results suggest that none of these religiosity measures significantly predicted gameplay in any of the four games. These results remain qualitatively the same when considering whether one gave an equal or higher offer to the distal cup (See Table S2).

Table 4. Results of Tobit regressions predicting coin allocations to the distal cup in each game from local god religiosity

Predictor	Coin allocations to the distal cup in each game			
	Self-Corel β-est	Self-Outgroup β-est	Village-Corel β-est	Corel-Outgroup β-est
Intercept	4.16 [3.17, 5.15]***	4.70 [3.78, 5.62]	5.00 [4.29, 5.71]***	5.34 [4.68, 6.00]***
Religiosity				
Commitment	0.27 [-1.30, 1.84]	-0.40 [-1.86, 1.06]	-0.47 [-1.60, 0.66]	0.29 [-0.76, 1.34]
Punishment	-0.35 [-1.54, 0.84]	0.11 [-1.00, 1.22]	0.05 [-0.81, 5.71]	-0.50 [-1.30, 0.29]
Omniscience	0.30 [-0.75, 1.34]	0.14 [-0.83, 1.12]	-0.08 [-0.83, 0.67]	-0.42 [-1.12, 0.28]
Reward	0.26 [-1.05, 1.57]	-0.62 [-1.84, 0.59]	-0.12 [-1.06, 0.82]	0.37 [-0.50, 1.25]
Controls				
Site	-0.79 [-1.82, 0.24]	-0.29 [-1.25, 0.66]	0.21 [-0.52, 0.95]	-0.94 [-1.63, -0.24]**
Perceived food insecurity	-0.15 [-0.40, 0.10]	-0.12 [-0.35, 0.12]	-0.03 [-0.21, 0.15]	-0.06 [-0.23, 0.11]
McFadden's pseudo R ²	0.39	0.39	0.42	0.45
n	153	153	153	152

Note: We report unstandardized Tobit coefficients with 95% confidence intervals in brackets. The reference category for site was Christian. ** $p < .01$. *** $p < .001$.

Did priming one's own or a different religion cause increased generosity towards distant coreligionists but not outgroup members?

The results presented in Table 5 show that, at both sites, religious priming had no significant main effect on behaviour, in any game. When considering whether one gave equal or higher offers to the distal cup, there was some evidence that Christians primed with Kastom images had greater odds of giving less than an equal offer to the Corel cup in the Self-Corel game and

the Outgroup cup in the Self-Outgroup game, though the coefficient was only significant at the 0.1 level in the latter game (See Table S3 in Supplementary information).

Table 5. Results of Tobit regressions testing the effect of religious priming on coin allocations to the distal cup in each game

Predictor	Coin allocations to the distal cup in each game			
	Self-Corel β-est	Self-Outgroup β-est	Village-Corel β-est	Corel-Outgroup β-est
Intercept	4.52 [3.84, 5.21]***	4.52 [3.91, 5.17]***	4.77 [4.23, 5.32]***	4.91 [4.35, 5.47]***
Prime				
Own religion	-0.15 [-0.85, 0.55]	0.12 [-0.52, 0.76]	-0.05 [-0.61, 0.51]	-0.28 [-0.85, 0.29]
Other religion	-0.51 [-1.48, 0.45]	-0.39 [-1.27, 0.49]	-0.21 [-0.98, 0.56]	0.20 [-0.59, 0.99]
Controls				
Site	-1.08 [-1.78, -0.38]**	-1.10 [-1.75, -0.46]	-0.10 [-0.66, 0.46]	-0.63 [-1.20, -0.05]*
Perceived food insecurity	-0.04 [-0.26, 0.17]	-0.14 [-0.33, 0.06]	0.11 [-0.06, 0.28]	-0.03 [-0.21, 0.14]
McFadden's pseudo R ²	0.01	0.01	0.00	0.01
n	242	242	242	241

Note: We report unstandardized Tobit coefficients with 95% confidence intervals in brackets. The reference categories for prime and site were neutral and Christian, respectively. * $p < .05$. ** $p < .01$. *** $p < .001$.

2.5. Discussion

In conducting this research, we sought to quantify participants' self-reported religious beliefs and behaviour, and investigate the link between beliefs about supernatural punishment and prosociality in Tanna, Vanuatu. Taking advantage of the diversity of religious beliefs on Tanna, we found that Christian and Kastom participants reported similarly strong commitment to their respective moralistic deities and, to a similar degree, believed them to be highly punitive, rewarding, and highly omniscient. While this result is surprising given how rare particularly potent moralising high gods appear to be outside the Abrahamic faiths (Murdock & White, 1969; Snarey, 1996; Watts et al., 2015), the complex history of missionisation and colonialism might explain this result. For many years, Kastom knowledge was heavily devalued, leading to the near eradication of traditional life and ritual (Lindstrom, 1982). Current Kastom beliefs and practices might therefore represent a revival of old ideas but with some idea flow from the Christian tradition. Further, competition between Christian and Kastom groups, who likely

interact multiple times per year, may have contributed to a gradual increase in the perceived potency of Kalbaben, a kind of supernatural arms race in which Kastom ideas evolve to compete with Christian ideas.

Relatedly, Christian participants showed more commitment to the Christian God and rated him as more punitive, omniscient and rewarding than the local supernatural forces, Tupunus. Kastom participants did not differ in their responses for Tupunus and those for their moralistic god, Kalbaben. This might reflect a Christian prohibition against indigenous religious beliefs at the Christian site, a key condition of religious membership in the doctrines of the Abrahamic religions (Atkinson, 2017).

Our individual-level results failed to support the SPH; across both sites, supernatural punishment did not predict increased allocations to coreligionists in any game. Instead, belief in a more punitive moralistic deity predicted greater odds of giving an equal or higher offer to the Outgroup cup in the Self-Outgroup and Corel-Outgroup games. Religious commitment to moralistic god appeared to predict an expansion of the cooperative sphere in the Village-Corel game by allocating more to a distant coreligionist over a member of one's local village. Further, belief in a more rewarding moralistic deity predicted reduced allocations to the distal cup in the Village-Corel and the Self-Outgroup game. Commitment to and beliefs about the local god did not predict giving in any game.

These results did not replicate previous findings on Tanna that belief in a more omniscient and rewarding moralistic and local deity predicted reduced cheating in the Random Allocation Game (Atkinson, 2017). One possibility is that some of these results could be false-positives or false-negatives. However which effects might reflect either of these types of errors is unclear; the apparent discrepancy between the current and previous trends might therefore suggest that there are not clear effects evident in this data. However, the divergent trends in the

current and previous studies do not necessarily contradict each other, since the previous study used a Random Allocation Game and the current one utilised Dictator games, and included an additional two games. It is possible that the psychological effects of beliefs about and commitment to supernatural agents operate differently on willingness to cheat versus prosocial giving; thus, the effects could be real across both studies.

The religious priming results failed to support hypotheses that religious reminders can activate supernatural monitoring and punishment concerns to increase generosity towards coreligionists. An alternative explanation is that our priming method was too subtle; a recent meta-analysis found that the subtler the religious prime, the weaker the effect the prime has on behaviour (Willard, Shariff, & Norenzayan, 2016). While priming techniques should be subtle enough to reduce the effects of demand characteristics on game behaviour, we may have also reduced the effectiveness of our priming. Indeed, in many cases religious priming in the ‘real world’ is more forthright, consisting of awe-inspiring contextual primes such as grand cathedrals and holy festivals, and frequently repeated, visceral reminders such as the Islamic call-to-prayer. Emotive religious symbols and rituals that prime the notion of being watched and judged by omniscient and punitive deities may more effectively produce group norm-consistent behaviour (Alcorta & Sosis, 2005). Alternatively, or in addition, participants may already have been primed to cooperate based on contextual cues, such as the cups, money, or game scenario, or from experimenter demand effects (Zizzo, 2010), thus obscuring any priming effects.

A key element of our findings was the unexpectedly high level of prosocial behaviour to individuals of a different religious tradition. Not only did punishment beliefs seem to predict increased generosity towards the Outgroup cup in the Self-Outgroup and Corel-Outgroup games, mean allocations to the outgroup cups in these games were also high. At the proximate level, belief in a punishing deity might motivate generosity towards outgroup members if

norms of inclusivity and charitability regardless of the religious identity of others are salient. Whilst certainly not ubiquitous, kindness towards members of other religions is mentioned in Christian scripture. For example, a parable for religious tolerance, the book of John notes that Jesus was said to have conversed with, and accepted water from a Samaritan woman, a member of a group of apostate Jews treated with contempt by those following the faith. In this way, scriptural interpretations of how Christians should relate to those of other faiths might depend on, and reflect, local socio-cultural contexts.

At the ultimate level, a degree of tolerance for other religious traditions could enable good relations with outgroups and facilitate the conversion of ‘heathens’, a strategy that might be important for proselytising religions such as Christianity. Indeed, high levels of social cohesion and mutual help has been suggested to have been a key force in making Christianity attractive to outsiders and aiding in the spread of the religion (Stark, 1996). As a consequence, supernatural punishment could act to motivate adherence to a cultural norm of inclusive prosociality. This kind of inclusive prosociality might facilitate ‘competition by attraction’, providing a novel way in which cultural group selection might work on.

Testing whether group-level competition of this kind could have had a significant role in the spread of the world religions requires testing specific hypotheses in a variety of socio-economic contexts. A cultural norm of prosociality towards outgroup members might be an effective conversion strategy when basic supplies of food and water are adequate. However, when times are tough, such a strategy would unlikely be adaptive for the group or its members, as precious resources may be needed to be retained for survival. In this case, to the extent that cooperation during periods of resource scarcity can produce better group-level outcomes we might expect that aspects of religiosity such as belief in and commitment to monitoring and sanctioning deities will instead predict increased cooperation within religious groups, but not between them.

Research is beginning to be conducted on this very question. In the first study of its kind, McNamara, Norenzayan, & Henrich (2016) found that in a sample of Fijian Christians, supernatural punishment beliefs predicted decreased ingroup favouritism when material insecurity was low and moderate, but not when it was high, offering tentative evidence that the link between religiosity and prosocial behaviour may be moderated by perceived material insecurity. It is worth noting that participants in our study had fairly high food security (23.6% of participants stated they were worried about being able to buy or produce enough food to eat in the next month). Further investigation into the interactions between ecological hardships such as resource scarcity, religion, and prosocial behaviour, making use of more overt religious priming which targets specific aspects of religion, may offer novel insights into the link between religion and cooperation.

While our results provide some intriguing site-level differences in gameplay, with the Christian site allocating more than the Kastom site across games, and individual-level predictions of gameplay from self-reported religiosity, several issues are worth bearing in mind in regards to the interpretation of these findings, and the potential direction of future research. First, it is not possible to isolate any one variable that could have contributed to between-site differences in gameplay. The sites differ in many other ways than their religious beliefs, such as wealth, education, and access to foreign goods, variables sometimes linked with allocations in economic games (Cardenas, 2003; Henrich, Ensminger, et al., 2010); eliminating these alternative explanations for site difference would require a considerably larger sample of sites.

Another concern is the ecological validity of economic games in the field. It is often claimed that economic games miss key situational and contextual features that occur in 'real-life' social dilemmas (e.g. Zizzo, 2010). Whilst this is no doubt the case, the ability to control contextual cues and manipulate giver-receiver relationships within economic games allows us to isolate potential variables and better understand their interactions. Further, our study was primarily

concerned with testing specific hypotheses of the evolution of both cooperation and religion; while our experimental set-up might be artificial, the mechanisms we are testing should be expected to work in the context of controlled experiments. In order to mitigate the important issue of ecological validity, research in this field can benefit from the use of lab-based studies alongside field experiments and ethnographic methods (Falk & Fehr, 2003).

Finally, there are a number of alternative explanations that might account for our failure to find an association between supernatural punishment and increased prosociality towards coreligionists. First, due to the resource and time constraints of field work, our sample size was not as large as is sometimes found in lab-based experiments. Our relatively small sample size and the high proportion of fair offers across all games could have led to a lack of power, contributing to a reduced likelihood of finding an association where there was one. Conversely, a small sample also makes false positives more likely, meaning caution is required when interpreting the priming and individual-level associations that we identify. Secondly, due to our measure of omniscience being at ceiling, its relationship with supernatural punishment could not be tested. For example, it is possible that when god is viewed as omniscient, a certain level of belief in supernatural punishment could be sufficient to produce the degree of fair behaviour that we see in our games. Even if God does not always punish, as long as god can monitor all behaviour, one risks damaging one's reputation in the eyes of God by engaging in selfish behaviour against coreligionists. Finally, it is possible that some participants scored low on supernatural punishment due to their belief that punishment occurs only after 'Judgement Day', interpreting that our question asked about punishment during people's lives. This would mean that a real effect of supernatural punishment beliefs on giving could not be detected by our measures. To mitigate these concerns, future research should aim to recruit larger samples from a larger set of diverse populations and document specific beliefs about the way punishment occurs.

Together, these findings build upon existing research, providing some support for a link between some aspects of religion and prosocial behaviour in two non-western communities. Our group-level results show that Christian participants allocated more money than Kastom participants to both coreligionists and outgroup members. At the individual level, religious priming did not cause individuals to engage in more prosocial giving. We find some associations between religiosity and prosocial behaviour, however these patterns were not as expected, and need to be interpreted with caution. Across sites, supernatural punishment beliefs were not associated with increased prosociality towards those of the same religion in any game, instead predicting giving more to a religious outgroup in two games. Further, greater religious commitment predicted allocating more money to coreligionists over local village members. Finally, belief in a more rewarding deity was associated with allocating more money to one's own village over more distant coreligionists, and allocating more money to oneself over an outgroup member. Together these findings highlight potentially complex, likely context-dependent, relationships between religiosity, religious identity and prosocial behaviour, suggesting directions for future work and hinting at a potentially richer, more flexible role for religion in the evolution of cooperation than current theory can accommodate.

Chapter 3. Property damage and exposure to others in distress differentially predict prosocial behaviour following a natural disaster

3.1. Introduction

The ability to cooperate in large groups of unrelated individuals is a defining characteristic of our species (Bowles & Gintis, 2011; Fehr & Fischbacher, 2003; Sober & Wilson, 1998). An extensive body of research in behavioural economics has begun to map out the precise conditions under which humans cooperate and the limits of human altruism (Camerer, 2011; Fehr & Fischbacher, 2003). Among other motives, this research has identified a general willingness to share windfall gains with anonymous strangers (Fehr & Fischbacher, 2003; Gächter & Herrmann, 2009) and to establish norms of fairness (Fehr & Fischbacher, 2004; Fehr & Gächter, 2002)- behaviours thought to be critical to the evolution of large-scale, complex human societies (Tomasello & Vaish, 2013).

Much of what we know about human prosocial behaviour is based on research conducted in times of relative security and resource abundance, often in affluent western countries (Henrich, Heine, et al., 2010b). However, periodic threats to life and livelihood, such as those experienced during natural disasters, were a common feature of the environment in which modern humans evolved (Boehm, 2012; Lowe et al., 2012; Reilly, 2009). By altering the costs and benefits of cooperation, these events may have selected for behavioural responses very different from those observed in times of plenty. Whether and how human cooperation responds to resource shocks like natural disasters, and the psychological mechanisms underlying this, is therefore important both for predicting post-disaster social outcomes and for our understanding of the evolution of human cooperation more generally.

One hypothesis is that natural disasters *reduce* cooperation by motivating individuals to prioritise short term needs over the more diffuse and long-term benefits of relationship building and cooperation (Nowak & Sigmund, 2005; Trivers, 1971). Boehm (2012) uses evidence from contemporary forager groups to argue that the highly variable ecological conditions humans experienced during the Pleistocene selected for flexible cooperative tendencies that allowed us to exploit the benefits of cooperation in times of plenty but revert to increasingly parochial and selfish behaviour in times of extreme resource scarcity. Consistent with this hypothesis, research has shown that exposure to unpredictable and resource-scarce environments can lead to increased preference for immediate payoffs over uncertain rewards (Griskevicius, Tybur, Delton, & Robertson, 2011; Pepper & Nettle, 2013), antisocial behaviour (Prediger, Vollan, & Herrmann, 2014), and even violent conflict (Ember & Ember, 1992). In the context of natural disasters, this ‘disaster as divider’ hypothesis predicts that resource loss following a natural disaster will cause both a general reduction in generosity towards others and an increase in favouritism of one’s ingroup over outgroups.

An alternative prediction is that natural disasters motivate *increased* prosocial behaviour. Certain features of the disaster experience itself are likely to prime proximate psychological mechanisms that have been linked to prosocial behaviour. For example, witnessing suffering in others can invoke empathic concern for their wellbeing (Batson, 2010; De Waal, 2008), and shared painful experiences can facilitate a feeling of emotional closeness (Korchmaros & Kenny, 2001). Further, recent theoretical work argues that even in groups of non-kin, community members can be ‘fitness interdependent’, such that they each have a stake in one another’s survival and wellbeing (Aktipis et al., 2018), promoting cooperation as a strategy to overcome shared adversity in times of need. Consistent with this argument, groups in harsh and unpredictable environments (Aktipis, Cronk, & de Aguiar, 2011) or small-scale societies (Kaplan & Gurven, 2005) use egalitarian sharing norms and institutions to mitigate the risks

associated with variable or scarce resources. This ‘disaster as galvanizer’ hypothesis predicts that traumatic disaster experiences will cause an increase in generosity to others. To the extent that the proximate mechanisms supporting cooperation involve perceptions of interdependence, generosity should be greater within more interdependent groups.

Previous studies of natural disaster victims provide conflicting evidence as to their effects on prosocial behaviour. For example, surveys in disaster-hit regions have found individuals from affected communities report greater prosocial intentions (Rao et al., 2011) and more trustworthy and egalitarian motivations (Veszteg, Funaki, & Tanaka, 2015) compared to individuals from unaffected communities. However, victims also report elevated rates of hostility towards others (Bland, O’leary, Farinaro, Jossa, & Trevisan, 1996) and anti-immigrant sentiment (Andrighetto, Vezzali, Bergamini, Nadi, & Giovannini, 2016). Likewise, studies using behavioural measures of cooperation have found that individuals affected by natural disasters show significantly less trustworthy behaviour (Fleming, Chong, & Bejarano, 2014), but exhibit greater trust (Cassar, Healy, & von Kessler, 2017) and (among 9 year olds but not 6 year olds) are more giving (Li, Li, Decety, & Lee, 2013).

These apparently contradictory findings may reflect limitations with the design and interpretation of some studies. For example, the use of hypothetical scenarios (Rao et al., 2011; Veszteg et al., 2015) may not track actual behaviour change, and it is difficult to isolate the causal effects of disaster exposure when only considering post-disaster behaviour (Cassar et al., 2017; Fleming et al., 2014), or sampling different individuals before and after the disaster (Li et al., 2013; Veszteg et al., 2015). Furthermore, it may be wrong to look for a single underlying mode of response to natural disasters – whether disasters act as divider or unifier may depend on a range of factors, such that the two hypotheses are not mutually exclusive. Variation in the nature of the disaster experience is likely to be an important factor both across disaster events and also across individuals affected by the same disaster. Most studies treat

people as either ‘exposed’ or ‘unexposed’ to the disaster, and those that measure individual exposure tend to utilise only one criterion, such as material damage (Cassar et al., 2017), displacement (Norris, Baker, Murphy, & Kaniasty, 2005), or a single composite measure (Andrighetto et al., 2016). To the extent that different features of disasters act on different psychological mechanisms, there is a need to explore how different dimensions of disaster exposure and their severity interact to alter cooperative decision-making. Finally, as noted above, we may expect prosocial behaviour following a disaster to differ depending on the group identity of the recipient and their relationship to the actor.

Here we address some of these unknowns by investigating how specific elements of a disaster experience impact individuals’ actual prosocial giving to both ingroup and outgroup members. We do this using a natural experiment in which we tracked prosocial giving before and after a major cyclone among the same individuals who were differentially affected by the disaster. We use this within-subjects pre- and post- cyclone data to test the following: - 1) did people generally become more or less giving, keeping more for the self over the group, following the cyclone?; 2) did people become more or less parochial, favouring the more local group, following the cyclone?; 3) how consistent were the effects of the cyclone on behaviour across individuals?; 4) did those most affected by the cyclone show the largest effect on prosocial behaviour, consistent with a causal role of the cyclone experience?; and 5) did the effect of the cyclone vary predictably depending on the nature of the experience?

3.2. Method

Participants. In June 2014 we recruited 242 participants from two communities on the small volcanic island of Tanna, in the Pacific nation of Vanuatu (age: $M = 34.96$, $SD = 14.81$; 50% female) to play a series of economic games and answer survey questions as part of a broad cross-cultural project examining the relationship between religion and morality (Lang et al.,

Under review; Purzycki et al., 2016b; Vardy & Atkinson, 2018). Our first site was a predominantly Christian village situated near a locally important market town (age: $M = 34.85$, $SD = 14.43$; 50% female; $n = 134$). The community includes a school, several churches, and a small store. Most of the locals engage primarily in subsistence farming, supplementing their income by engaging in periods of wage labour for local businesses. Our second site was a rural community whose members follow traditional cultural and religious lifestyles, locally known as *Kastom* (age: $M = 35.10$, $SD = 15.31$; 50% female; $n = 108$). *Kastom* communities utilise traditional house-building methods, engage primarily in subsistence farming and only rarely are individuals employed in wage labour. While the majority of adults from the *Kastom* community participated in our pre-cyclone study, in the larger Christian village, participants were recruited by cluster sampling from a village census, from which we aimed to identify and test at least one adult from every family in the village.

Eight months after our initial round of data collection, category five Cyclone Pam struck Vanuatu, destroying most of Tanna's buildings, and leaving locals without electricity and shelter. Both communities and their surrounding areas were badly damaged as a result of the cyclone (See

Figure 4). International aid was required to meet food and water demands in both communities as crops and forests were stripped bare. Whilst cyclones are relatively frequent on Tanna during the summer months, those causing more than minor damage are rare, occurring less than once every decade, and Cyclone Pam is the only category 5 cyclone to have hit Tanna in the last 50 years. The most recent large cyclone to strike Tanna prior to Pam was Cyclone Jasmine in 2012, which caused relatively minor damage to crops and water systems. Four months after the cyclone, when the recovery of the island was well under way, we returned to the island to conduct a second round of data collection. We were able to locate and collect data from 164 of the original participants from across both sites (age: Mean = 38.5, $SD = 15.49$; 54% female;

Christian age: $M = 36.25$, $SD = 14.80$; 53% female; $n = 101$; *Kastom* age: $M = 39.54$, $SD = 16.46$; 56% female; $n = 63$). Due to our interest in the effect of the cyclone on behaviour, data from the 78 participants who could not be located after the cyclone were not considered in the present study. Pre-cyclone game offers of those who were retained did not differ significantly from those who we could not relocate (Wilcoxon Rank-Sum; all p -values > 0.05). The resulting sample of 164 individuals is sufficient to detect even small ($d_z = 0.2$) within-subjects effects comparing pre- versus post- cyclone offers, with a power of 80%. Statistical power for regressions with multiple predictors is contingent on many factors, however the widely cited rule of thumb that one should obtain at least 10 data points per predictor variable (Concato, Peduzzi, Holford, & Feinstein, 1995; Vittinghoff & McCulloch, 2007) suggests our sample is sufficiently powered for the main analyses we report (with between 6 and 8 predictors).



Figure 4. Images of Vanuatu four months after its devastation by Cyclone Pam showing (A) Cyclone Pam commemorative sign- Port Vila, (B) Damage to the governor of Tanna's house, (C) Abandoned guest house in a Christian village, and (D) Recovery in a *Kastom* village

Experimental protocol. In June 2014 we recruited participants from the Christian and *Kastom* communities to play a series of economic games with real money. Participants played four counter-balanced variants of the dictator game in a private beach tent; play was thus designed to be private and anonymous.

In each game, participants were presented with two cups and were told that they could decide how much of a 10-coin endowment to allocate to each cup (see Figure 5b for the game dyads). Depending on the game, people could give and keep some money (self-games) or split the endowment between two groups (group-games). Participants were informed they would not know who would receive the money, and the receiver of the money would not know who had given them this money.

Following gameplay, participants completed a short demographic survey and were paid out their personal allocations anonymously by a research assistant in a payout tent. In each game, participants allocated 500 Vanuatu Vatu (about \$4.75 USD), amounting to a total allocation of 2000 Vatu (about \$19 USD). Before the session participants were given a 500 Vatu show-up fee. Including the show-up fee, the total potential earnings were 1500 Vatu, constituting about an average day's wage.

In June 2015 (4 months after the cyclone), we located participants from the first wave and invited them to play the same games as the previous year. All participants were given an additional 500 Vatu show-up fee and took home the money they allocated to themselves in the games. Following testing, participants completed a short demographic survey and an affectedness survey measuring the types of experiences people were exposed to during and immediately following the cyclone. Game and post-cyclone affectedness scripts can be accessed at: osf.io/fpsu8. All survey and game scripts were translated from English into the local language and then back-translated into English by two different native speakers of the

local language. Instructions and interviews were given by a local research assistant in the participant's local language.

As part of the broader cross-cultural study (Lang et al., Under review), participants were randomly assigned to one of three priming conditions: Neutral, Coreligionist (same religion) or Outgroup (different religion). The primes consisted of painted icons associated with each condition, placed under the game apparatus during play (See Figure S1 in Supplementary information). None of the primes were found to reliably affect game behaviour (Vardy & Atkinson, 2018). Nevertheless, in order to ensure that changes in game allocations pre- versus post cyclone were not due to participants receiving different primes, all participants were exposed to the same prime pre- and post-cyclone.

Prosociality measures. We used four variants of the dictator game to measure participants' prosocial behaviour before and after Cyclone Pam. The two 'self games' evaluated individuals' willingness to share an endowment at personal cost with an anonymous other who did or did not share their religious identity. In the Self-Corel game participants could allocate money between a *cup for themselves* and a *cup for a person from another village of the same religion on Tanna*. In the Self-Outgroup game participants could allocate money between a *cup for themselves* and a *cup for a person from a village of a different religion on Tanna*. The distinction based on religious identity exploits the identities of the two communities in our sample: the outgroup for participants at the Christian site was a *Kastom* community, and the outgroup for participants at the *Kastom* site was a Christian community.

We also measured participants' preferences for deciding how to split a monetary endowment between two anonymous individuals from two reference groups, in two 'group games'. In the Village-Corel game participants could allocate money between a *cup for a person from the participant's own village* and a *cup for a person from another village of the same religion on*

Tanna. In the Corel-Outgroup game participants could allocate money between a *cup for a person from another village of the same religion* and a *cup for a person from a village of a different religion on Tanna*. These games allowed us to investigate the extent to which people’s cooperative sphere is maintained or reduced following a natural disaster; do people prefer to allocate resources to those closest to them by giving more to their village, or do victims’ cooperative spheres extend to their coreligionists, or even their outgroup? Figure 5 shows the game dyads and a diagram representing the spheres of cooperation. Order of games and cups were counterbalanced and randomly allocated for each participant. We do not include order in the models we report because adding them involves 15 additional parameters and always reduced Bayesian Information Criterion estimates of model fit.

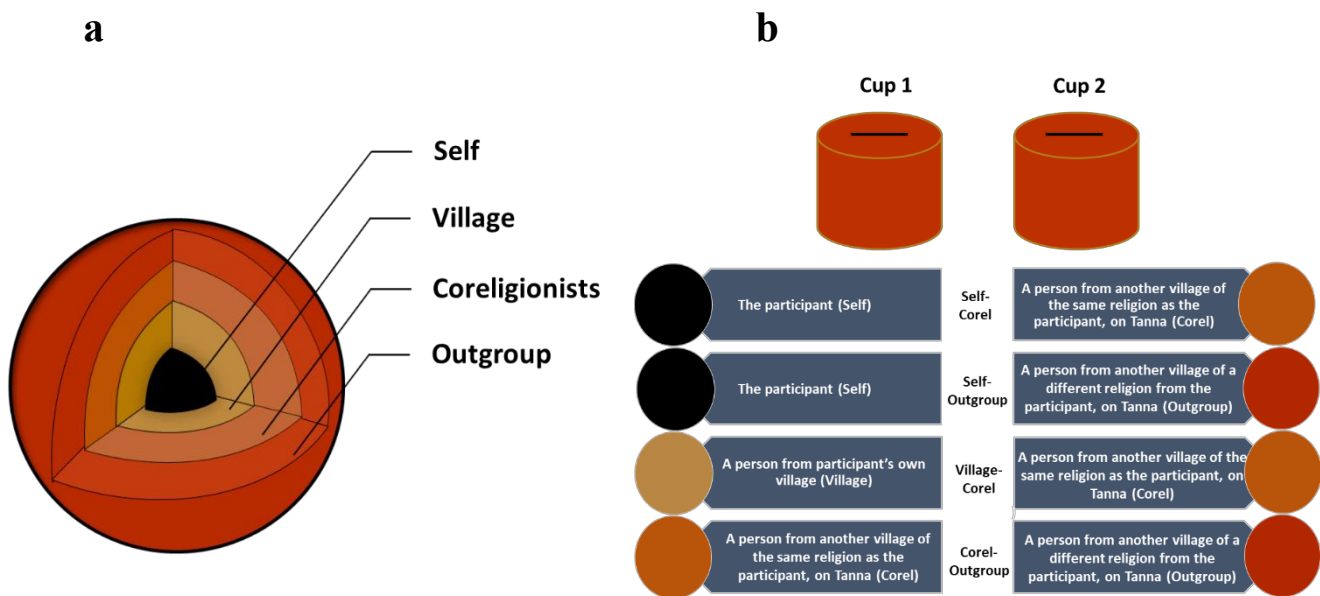


Figure 5. (a) Conceptual sphere of relatedness for each reference group. Concentric circles in target do not represent relative size or number of individuals in each group, and (b) Game dyads.

Affectedness indices. After completion of the dictator game in 2015, participants completed an adapted 16-item version of the Traumatic Experience Severity Scale (TESS; Elal & Slade, 2005) survey. The survey consists of a series of ‘yes or no’ questions aimed to cover a range of potential experiences that could have occurred during, and immediately following, a natural

disaster. Questions include asking whether one needed shelter, was physically injured, was involved in rescue work, or suffered damage to one's house as a result of the cyclone (the full list of questions is reported in Table S4 in Supplementary information).

3.3. Results

Cyclone affectedness measures

Responses to our affectedness questions indicate the scale of destruction inflicted by Cyclone Pam on Tanna. 85% of our sample indicated that their home suffered damage as a result of the cyclone, and 80% of people had to relocate their house on account of damage suffered to their dwelling. However, only 17% of our sample reported suffering an injury caused by the cyclone, possibly due to effective advanced warning of the approaching storm. Nonetheless, 75% of the sample report being in financial difficulty as a result of losses from the cyclone, and 85% reported needing food aid, which was still being distributed at the time of our second round of testing.

We used a principle components analysis with oblique rotation to identify the main dimensions of cyclone affectedness in our study. Based on an eigenvalue cut-off of 1 the scree plot suggested that four components be extracted (Figure S2; Factor loadings are shown in Table S4 in Supplementary information). We identified these four components as relating to damage to property, need for resource aid, injury to self and loved ones, and exposure to others in distress which account for 17%, 16%, 13% and 13% of the total variance, respectively. Two items loaded moderately onto two factors and were removed from analysis. We summed the scores of the items that loaded onto each to create four composite affectedness variables with reasonably strong reliability: damage to property ($\alpha = .81$), need for resource aid ($\alpha = .74$), and acceptable reliability for injury to self and loved ones ($\alpha = .64$), and exposure to others in distress ($\alpha = .61$).

Did prosocial behaviour change following the cyclone?

We conducted a series of non-parametric Wilcoxon signed-rank tests for paired data to compare allocations to the cup belonging to the most conceptually-distant (distal) reference group for each participant in each game. Comparisons between ‘pre’ and ‘post’ cyclone cup offers across the whole sample failed to support the hypothesis that people become generally more prosocial after a natural disaster; participants did not give significantly more to the distal cup after the cyclone in any game (see Figure 6). Instead, after the cyclone on average people kept more for themselves against both their coreligionists, $W = 4251$, $p = 0.010$, $r = 0.20$, and their outgroup, $W = 5063$, $p = 0.001$, $r = 0.26$, compared to before. Participants were also more likely to allocate more money to their coreligionists over their outgroup after the cyclone compared to before, $W = 3543.5$, $p = 0.014$, $r = 0.19$. However, there was no difference in how people shared money between their own village and distant coreligionists after the cyclone, $W = 2843.5$, $p = 0.323$, $r = 0.08$. For all four games there was no difference between Christian and Kastom sites in the change from pre- to post-cyclone allocations (See Table S5 in Supplementary information), and so we do not report separate analyses for each site.

Across all games, the modal response was a ‘fair’ or equal distribution of coins to each cup. To ascertain whether people’s willingness to meet or exceed this threshold changed following the cyclone, we compared whether participants gave a less than equal share (<5 coins) versus an equal or higher share (≥ 5) to the distal cup in each game, before and after the cyclone (See Figure 7). Within subjects McNemar chi-squared tests show that in the Self-Outgroup game participants were less likely to give an equal or higher share to the distal cup after the cyclone compared to before, $\chi^2(1, N = 164) = 11.16$, $p < 0.001$. While the trend was in the same direction in the Self-Corel game, this effect was only significant at the 0.1 level, $\chi^2(1, N = 164) = 3.02$, $p = 0.082$. Compared to before the cyclone, participants were also less likely to give an equal or higher share to outgroup over coreligionists after the cyclone in the Corel-Outgroup

game, $\chi^2(1, N = 163) = 5.82, p = 0.016$, but were not less likely to give an equal or higher share to coreligionists over their own village after the cyclone in the Village-Corel game, $\chi^2(1, N = 164) = 0.94, p = 0.332$.

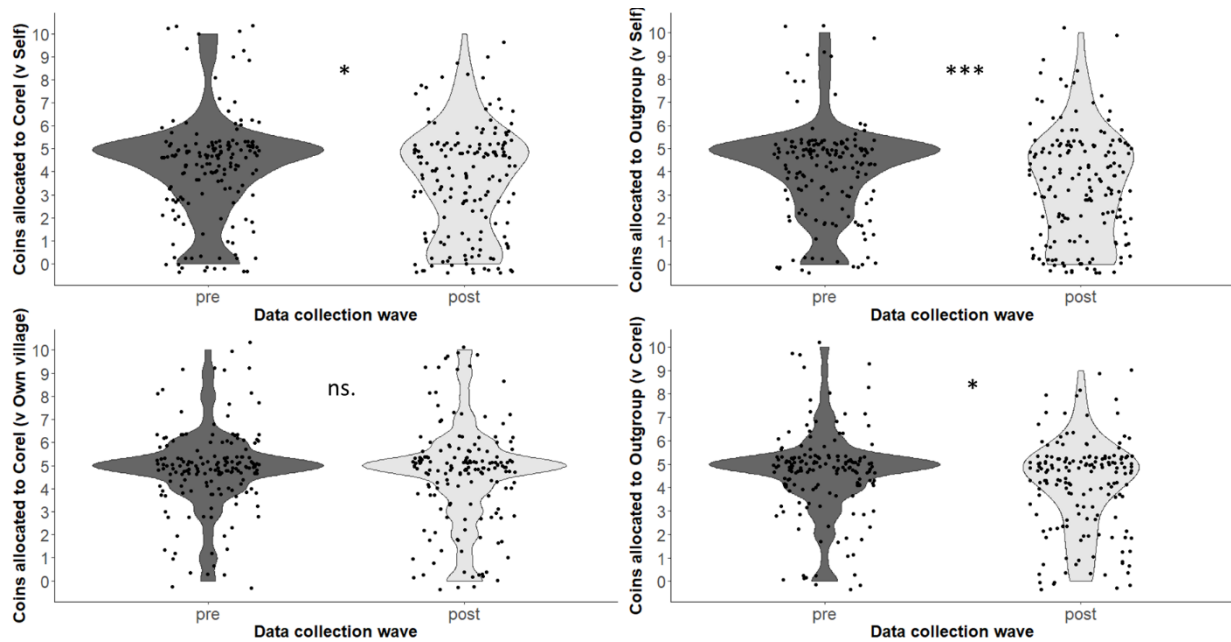


Figure 6. Violin plots showing the distribution of game offers to the distal cup pre and post cyclone. Data points are jittered. Wilcoxon signed-rank test for paired data. ns $p > 0.10$. * $p < .05$. *** $p < .001$

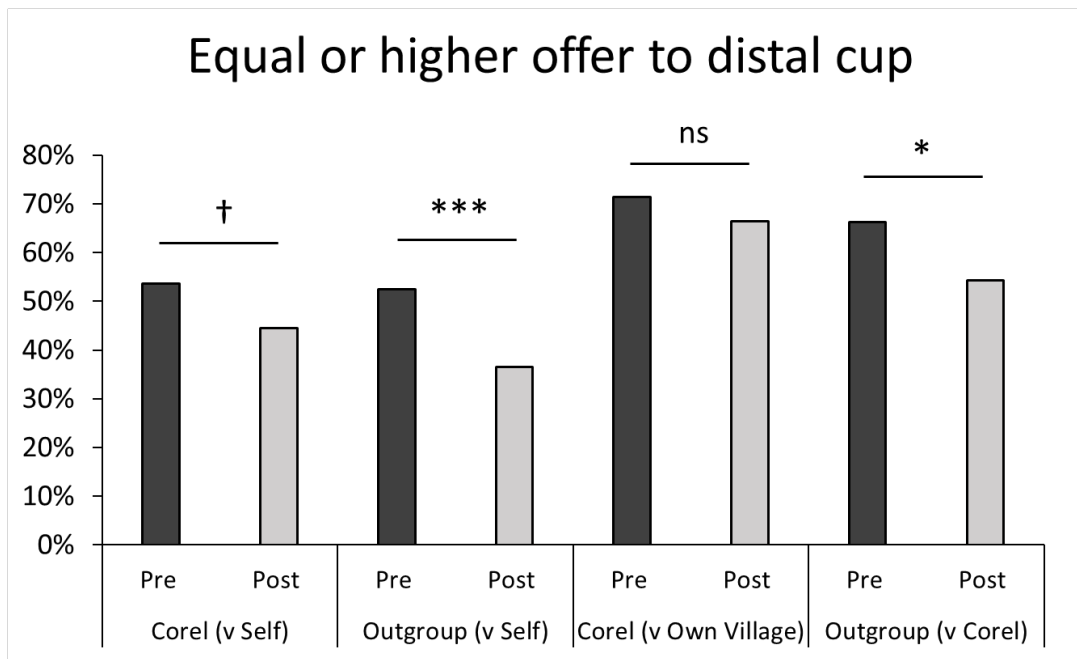


Figure 7. The percentage of equal or higher offers to the distal cup in each game before and after the cyclone. ns $p > 0.10$. † $p < .10$. * $p < .05$. *** $p < .001$

How consistent was behaviour change following the cyclone?

While there were generally lower levels of giving in the self games and increased parochialism in the group games, behaviour change following the cyclone was remarkably heterogeneous (See Figure 8). In no game did more than 50% of the sample give less to the distal cup after the cyclone than they did before, and across all games at least one quarter of the sample gave more than they did before the cyclone.

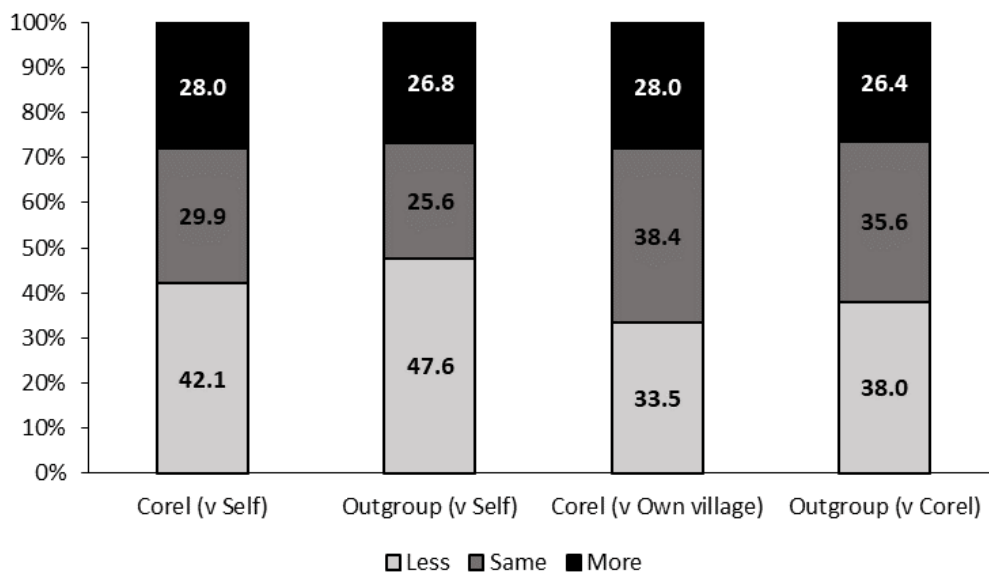


Figure 8. Percentages showing direction of change in allocation amounts in each game in the sample. Less; allocated fewer coins to the distal cup after the cyclone than before, Same; allocated the same number of coins to the distal cup before and after the cyclone, More; allocated more coins to the distal cup after the cyclone than before.

Did people’s experiences during and immediately after the cyclone predict prosocial giving?

We assessed whether individual differences in affectedness predicted coin allocations to the distal cup in each post-cyclone game with a series of Tobit regressions (See Table 6). All models controlled for pre-cyclone offers in the corresponding game as well as for site (Christian or Kastom). Property damage suffered as a result of the cyclone was associated with increased allocations to the self cup in the self-outgroup game, and the corel cup in the Corel-

Outgroup game. While the trends were in the same direction in the other games, the coefficients were not significant in the Village-Corel and Self-Corel games. There was some evidence that exposure to others in distress predicted giving to the distal cup in both the Self-Corel game, and the Self-Outgroup game. Finally, a greater need for resource aid predicted giving less to the distal cup in the self-outgroup game. Injury to self and loved ones was not a significant predictor of coin allocations in any game (p values $> .05$).

These results are supported by a clearer pattern of relationships between our affectedness measures and whether or not participants' post cyclone offers were equal or higher (≥ 5). We used a series of logistic regressions to test whether cyclone affectedness predicted a binary variable indicating an equal or higher offer to the distal cup (coded as 1) versus less than equal (coded as 0) in each game, controlling for pre-cyclone offer (coded the same way) and site (See Table 7). These analyses revealed that greater property damage was associated with a reduced likelihood of allocating an equal or higher amount to the distal cup across all games. By contrast, greater exposure to others in distress was associated with increased odds of giving an equal or higher offer to the distal cup in the Self-Corel game, the Self-Outgroup game, and the Village-Corel game, though the coefficient was only significant at the 0.1 level in the latter game. Greater need for resource aid was no longer a predictor of gameplay in the Self-Outgroup game, instead predicting a greater likelihood of giving equal or higher offers to the outgroup cup in the Corel-Outgroup game.

To test the robustness of these results, we ran a series of additional Tobit and logistic regressions, including each of sex, age, pre-cyclone annual income, and religious prime. These models show qualitatively the same trends across all games (See Table S6 & Table S9 in Supplementary information). The effects of property damage that we identify are consistent across all models. The effects of witnessing others in distress that we identify are broadly consistent but vary slightly across some models. For the Tobit models predicting post-cyclone

game offers, the effect of witnessing others in distress in the Self-Corel game drops below the 0.05 threshold but remains significant at the 0.1 level. For the logistic models predicting equal or higher post-cyclone game offers, the effect of witnessing others in distress in the Village-Corel game achieves significance at the 0.05 level when controlling for prime condition (whereas it was significant only at the 0.1 level in our main analyses), but is no longer significant (though the effect is in the same direction) when controlling for pre-cyclone annual income. The effect of witnessing others in distress in the Corel-Outgroup game achieves significance at the 0.05 level when controlling for pre-cyclone annual income (whereas it was not significant in our main analyses).

Finally, if the population-level change in giving that we observe is attributable to the effect of the cyclone, then those unaffected by the cyclone should behave more consistently between time points. To test this, we regressed our four cyclone affectedness measures against change in pre- to post- disaster giving for each of the four games (Supplementary information section 7.2.3). In each game, the intercept (the predicted change in giving when all exposure measures are set to zero) is not significantly different from zero ($p > 0.05$), supporting the assumption that unaffected individuals behave consistently and that the effects of post cyclone giving that we observe are attributable to the cyclone.

Table 6. Results of Tobit regressions for cyclone affectedness, predicting coin allocations to the distal cup in each game after the cyclone

Predictor	Post-cyclone allocations to the distal cup in each game			
	Self-Corel	Self-Outgroup	Village-Corel	Corel-Outgroup
Intercept	2.41 [0.67, 4.15]**	2.52 [0.92, 4.11]**	3.65 [2.03, 5.26]***	4.03 [2.73, 5.34]***
Affectedness				
Damage to property	-0.27 [-0.61, 0.08]	-0.50 [-0.82, -0.18]**	-0.22 [-0.52, 0.08]	-0.36 [-0.62, -0.11]**
Need for resource aid	-0.22 [-0.59, 0.16]	-0.37 [-0.72, -0.02]*	-0.11 [-0.44, 0.22]	0.13 [-0.16, 0.41]
Injury to self and loved ones	-0.09 [-0.55, 0.36]	0.03 [-0.40, 0.45]	-0.22 [-0.62, 0.18]	0.05 [-0.29, 0.39]
Witnessing others in distress	0.50 [0.01, 0.99]*	0.58 [0.12, 1.04]*	0.30 [-0.14, 0.73]	0.05 [-0.31, 0.42]
Controls				
Pre-cyclone allocation	0.35 [0.16, 0.54]***	0.44 [0.25, 0.64]***	0.28 [0.07, 0.49]**	0.19 [0.02, 0.36]*
Site	-0.41 [-1.31, 0.49]	0.06 [-0.79, 0.91]	0.17 [-0.62, 0.97]	-0.62 [-1.30, 0.06]†
McFadden's pseudo R ²	0.04	0.07	0.03	0.04
n	163	163	163	162

Note: We report unstandardized coefficients with 95% confidence intervals in brackets. The reference category for site was Christian. † $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

Table 7. Results of logistic regression for cyclone affectedness, predicting an equal or higher offer to the distal cup in each

Predictor	Gave an equal or higher offer to the distal cup in each game post-cyclone			
	Self-Corel	Self-Outgroup	Village-Corel	Corel-Outgroup
Intercept	0.65 [0.17, 2.40]	0.36 [0.09, 1.35]	3.09 [0.69, 15.95]	1.46 [0.38, 5.82]
Affectedness				
Damage to property	0.73 [0.54, 0.97]*	0.57 [0.40, 0.78]***	0.59 [0.38, 0.85]**	0.47 [0.31, 0.67]***
Need for resource aid	0.86 [0.63, 1.17]	0.88 [0.62, 1.24]	0.95 [0.67, 1.34]	1.47 [1.05, 2.11]*
Injury to self and loved ones	0.96 [0.66, 1.39]	1.06 [0.70, 1.58]	0.80 [0.53, 1.17]	0.88 [0.59, 1.31]
Witnessing others in distress	1.71 [1.13, 2.67]*	1.93 [1.22, 3.20]**	1.54 [0.98, 2.45]†	1.44 [0.93, 2.26]
Controls				
Equal or higher offer pre-cyclone	2.35 [1.19, 4.73]*	5.44 [2.52, 12.50]***	3.16 [1.50, 6.77]**	2.89 [1.37, 6.30]**
Site	0.72 [0.34, 1.52]	0.85 [0.36, 1.95]	0.68 [0.31, 1.49]	0.42 [0.19, 0.90]*
Cox and Snell pseudo R ²	0.12	0.23	0.14	0.20
n	163	163	163	162

Note: We report odds ratios and 95% confidence intervals of the odds ratios. The reference category site was Christian. † $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

3.4. General discussion

By comparing monetary allocations in four modified dictator games before and after Cyclone Pam, we found that people tended to keep more money for themselves over both religious ingroup and outgroup members, and increasingly favoured their religious ingroup over the

outgroup. This general pattern at the group level is consistent with the ‘disaster as divider’ hypothesis, that resource scarcity and threats to security linked to natural disasters can reduce our cooperative sphere and motivate us to prioritise short term survival needs (Boehm, 2012). However, our within-subjects pre-/post- design also revealed considerable variation in individual behaviour change following the cyclone. This highlights the potentially heterogeneous effects of natural disasters on individual behaviour and points to the possibility that whether a disaster acts as a ‘divider’ or ‘galvanizer’ may depend on individuals’ particular disaster experiences.

Our analysis of the association between individual cyclone affectedness and post-cyclone game play is important for two reasons. First, we find that controlling for pre-cyclone game play, post-cyclone game play is predicted by measures of cyclone affectedness. We see these effects across the self and group versions of the dictator game and the patterns we observe are broadly consistent whether we consider the raw amount allocated or a binary indicator of equal or higher offers, though the results are clearer in the case of the latter. By linking change in prosocial behaviour to each individual’s affectedness, our study represents some of the clearest evidence to date that experiencing a natural disaster causes individuals to alter their prosocial behaviour.

Second, by tracking cyclone affectedness across four dimensions, our findings suggest that the nature of each individual’s experience, and not simply its severity, is indeed important for understanding how people respond to a disaster. Those who experienced greater property damage were less likely to allocate equal or higher amounts to the distal cups across all games and tended to give less to the distal cup in the two outgroup games (consistent with the ‘disaster as divider’ hypothesis). By contrast, those who experienced greater exposure to others in distress were more likely to allocate equal or higher amounts towards coreligionists and

outgroup members versus the self, and tended to give more in these games generally (consistent with the ‘disaster as galvanizer’ hypothesis).

The mechanisms underlying these divergent effects are yet to be established but may reflect the activation of different cognitive domains. Witnessing others in distress may involve the kind of shared traumatic or painful experiences that have been shown to motivate within-group cooperation (Bastian, Jetten, & Ferris, 2014). If this were the case, however, it is unclear why we do not also see an effect of ‘injury to self and loved ones’. Alternatively, witnessing others in distress may activate an empathic response, which is well known to motivate altruistic behavior (De Waal, 2008). The fact that this effect is strongest in the self-games, in which prosocial behaviour is truly altruistic, supports this interpretation.

By contrast, suffering damage to property is likely to prime feelings of environmental unpredictability and harshness that can motivate people to prefer resource allocations that favour immediate returns to themselves and their social group (Frankenhuis, Panchanathan, & Nettle, 2016; Navarrete, Kurzban, Fessler, & Kirkpatrick, 2004). Cooperating less with more socially distant others following property damage caused by a natural disaster may reflect the activation of these motives as an adaptive response to a survival threat to oneself and one’s kin.

It is worth noting several caveats to these findings. First, it was not possible to randomly allocate participants to levels of affectedness. It is possible that those who rated themselves as more or less affected by the cyclone happened to have divergent, pre-existing prosocial motivations. However, by controlling for pre-cyclone gameplay in our models, we go some way to controlling for individual-level differences in pre-cyclone cooperative intentions. It is also possible that those who were less prosocial felt inclined to self-report higher affectedness to justify their behaviour. However, the divergent effects of different aspects of affectedness,

and the positive association between exposure to others in distress and prosociality make this interpretation more difficult to justify.

Second, the patterns we identify were stronger and more consistent when predicting equal or higher offers than when predicting total amount given. Taking these results at face value suggests that the effect of the disaster may relate most directly to whether and to whom people extended sharing norms (Aktipis et al., 2011), rather than simply how much they were willing to give.

Third, the generalisability of our findings remains to be established. One question concerns the relatively high rates of giving in our sample even after the cyclone. We observed offers (even to religious outgroup members) that were greater than offers to ingroup members typically seen in some small-scale societies (Henrich et al., 2005). It is noteworthy that the Christian and *Kastom* groups in our study coexist in relative harmony, sharing many kin ties and a common cultural history. While the group identities are salient, and this can result in occasional prejudice and antagonism, direct conflict is rare. Future work should examine how resource shocks like natural disasters affect cooperative relationships between less cordial groups.

Another atypical feature of our study location may be Vanuatu's status as one of the most disaster-prone countries in the world. The destruction wrought by Cyclone Pam has no precedent on Tanna in at least the last 50 years, but moderate cyclone damage has occurred in the living memory of most inhabitants of the island. One possibility is that whilst we observed a drop in levels of cooperation immediately following the cyclone (consistent with the 'disaster as divider' hypothesis), the long run effect of disaster exposure on average levels of cooperation in a population may be to increase cooperation, perhaps via the development of cultural norms and institutions that facilitate cooperation to overcome shared adversity (consistent with the 'disaster as galvanizer' hypothesis) (Aktipis et al., 2011; Hao, Armbruster, Cronk, & Aktipis,

2015). To test this idea, future work would need to compare multiple populations with a range of disaster exposure.

Our findings contribute to a growing body of research (Cassar et al., 2017; Fleming et al., 2014; Li et al., 2013; Norris et al., 2005) that supports a link between natural disasters and human prosocial behaviour. Crucially, our results demonstrate there is not a single mode of human response to disaster. Rather, individuals appear to actively respond to the type and severity of their specific disaster experience. Following the devastation of natural disaster, general cognitive mechanisms linked to material loss and exposure to others in distress appear to adaptively calibrate prosocial behaviour in predictable and contrasting ways.

Chapter 4. Testing theories about the personal and social function of religion after a natural disaster

4.1. Introduction

Several hypotheses have been developed that propose that aspects of religion can serve a functional purpose for individuals and/or groups during times of sudden resource stresses, such as following a natural disaster. In this current chapter, we test key predictions of two broad hypotheses about the functions of religion in a community of Christian individuals on Tanna Island, Vanuatu who were differentially affected by a major Cyclone.

4.1.1 The Religious Comfort Hypothesis

As outlined in Chapter 1, researchers from a range of disciplines have proposed that aspects of religion can buffer against threats to wellbeing and perceptions of security. For example, belief in a controlling god who is concerned with one's wellbeing and can offer eternal life in paradise in exchange for religious commitment might reduce death anxieties (Jonas & Fischer, 2006; Norenzayan & Hansen, 2006), help people to cope with illness (Ayele et al., 1999; Koenig, Weiner, et al., 1997), and stress (Park, Cohen, & Herb, 1990), and reduce anxieties associated with a perception of the world as random and unpredictable (Kay et al., 2010; Laurin et al., 2008; Park, 2005). Alternatively, or in addition, religious institutions might provide effective social networks to support the wellbeing of their congregation (de Vaus & McAllister, 1987; Koenig, Weiner, et al., 1997), and offer economic resources to help insure against income shocks and increase perceptions of resource security (Chen, 2010; Zapata, 2018). Research indicates that exposure to natural disasters can have significant negative effects on psychological wellbeing, which can lead to post-traumatic stress (Schwartz, Liu, Lieberman-Cribbin, & Taioli, 2017), and depression (Catani, Jacob, Schauer, Kohila, & Neuner, 2008). Therefore, the Religious Comfort Hypothesis should predict that people will turn to religion

after a resource shock in an attempt to ameliorate negative psychological and/or material effects. Moreover, religiosity before such events should be expected to buffer against feelings of insecurity after resource shocks, for the reasons detailed above and in Section 1.4.1.

Support for these predictions is mixed. Consistent with claims that religion might serve a palliative effect in times of distress, lab studies provide some evidence that people turn to religion when primed with danger (Boyer & Liénard, 2006) and mortality (Norenzayan & Hansen, 2006). Further, surveys in the context of natural disasters suggest that natural disaster victims are more likely than unaffected people to convert to a religion (Sibley & Bulbulia, 2012), and indicate greater religiosity, both in terms of personal commitment and ritual participation (Bentzen, 2015). However, others fail to corroborate this effect. While some find that affected people report no change in religiosity (Hussain, Weisaeth, & Heir, 2011), others find that survivors report a reduction in a sense of spirituality (Stratta et al., 2013), or indicate more frequent attendance in religious rituals, but reduced belief after natural disasters (Zapata, 2018). Further, evidence of religion's effect on reducing insecurity and distress after natural disasters is inconclusive. The results of one survey in a disaster-hit region suggested that religious participation predicted fewer symptoms of mental health distress (Frazier, 2009). However, others find that prayer but not church attendance predicts reduced psychological distress (Smith et al., 2000), or fail to find a buffering effect of pre-disaster belief on perceptions of post-disaster health (Sibley & Bulbulia, 2012).

These conflicting results may reflect differences in the operationalisation of key variables between studies. For example, some studies measure exposure to natural disasters as whether or not one lived in an affected area (Sibley & Bulbulia, 2012; Stratta et al., 2013; Zapata, 2018), distance from the epicenter (Bentzen, 2015), or perceived levels of affectedness (Hussain et al., 2011). As such, studies are unable to account for individual differences in both the kinds of

experiences and/or their severity, and their relationships with feelings of wellbeing, resource insecurity, and religiosity.

Further, while some have utilised measures of perceived intensification or lessening of religious commitment after a disaster (Hussain et al., 2011; Smith et al., 2000), others measured self-reported religiosity after the cyclone in terms of religious coping (Frazier, 2009), a binary measure of belief in god (Zapata, 2018), conversion versus deconversion (Sibley & Bulbulia, 2012) or a composite measure of religiosity (Bentzen, 2015). This is problematic for several reasons. First, measuring religiosity on only one measure prevents a test of whether specific aspects of religiosity might function in different ways to increase wellbeing and reduce feelings of insecurity. Second, operationalising religiosity as either a self-reported de/intensification of belief or commitment, or as self-reported religiosity only after a natural disaster is insufficient to make clear predictions about the direction of any relationship between religiosity and wellbeing and/or insecurity. For example, if people have recently intensified their religiosity to alleviate symptoms of distress, post-disaster religiosity will correlate positively with insecurity. However, if people have been benefitting from the distress-reduction effects of religiosity for a while, then post-disaster religiosity will correlate negatively with symptoms of distress. Therefore, a rigorous test of the Religious Comfort Hypothesis should include multiple measures of disaster exposure and religiosity and assess whether a) an increase in insecurity predicts an increase in religiosity after a disaster, and b) whether pre-disaster religiosity predicts lower symptoms of insecurity after the disaster.

4.1.2 The Cooperative Buffering Hypothesis

It has long been argued that religion can bind coreligionists together against threats to group cohesion (Bulbulia, 2016; Freud, 2008). The SPH argues that the belief in punitive and morally-concerned deities can function to legitimise moral codes around cooperation and resource

management and monitor morally-relevant behaviour within social groups (Henrich, Ensminger, et al., 2010; Norenzayan, 2013; Purzycki et al., 2016b; Swanson, 1964). Participation in public religious rituals might also act as a costly signal of group commitment, promoting trust within religious groups and prevent group disintegration (Bulbulia & Sosis, 2011; Ruffle & Sosis, 2006; Sosis, 2000; Sosis & Bulbulia, 2011). Relatedly, some have argued that cultural evolution should favour cultural traits, including religious beliefs and behaviours, that reduce competition within groups and enhance success in competition with other groups (Norenzayan et al., 2016). Under this scenario, religious beliefs and practices that promote more parochial forms of cooperation (Bloom, 2012; Choi & Bowles, 2007; Durkheim, 2001; Graham & Haidt, 2010; Norenzayan et al., 2016) could be favoured, especially when between-group competition is heightened, such as when groups compete for scarce resources.

Consistent with the Cooperative Buffering Hypothesis, cross-cultural research has found that particularly powerful and omniscient Moral High Gods are more likely to be present in societies with more intensive modes of subsistence (Peoples & Marlowe, 2012), and in environments with frequent ecological stresses (Botero et al., 2014; Roes & Raymond, 2003; Snarey, 1996), suggesting that these deities might evolve to facilitate the management of natural resources. At the individual level, studies of religious prosociality with diverse samples of religions and cultures across the world have indicated that aspects of supernatural punishment beliefs and frequency of ritual practices predict prosocial giving to coreligionists (Purzycki et al., 2016b; Sosis & Ruffle, 2003), but not outgroup members (Galen, 2012). However, the results of one correlational study failed to support the Cooperative Buffering Hypothesis, finding that belief in a more punitive deity predicted greater cooperation with coreligionists at low but not high levels of material insecurity (McNamara et al., 2016).

However, little is known about how well religion functions to alter levels of cooperation after a sudden resource shock, such as a natural disaster. Periodic threats to life and livelihood such

as drought, famines and natural disasters occur frequently in much of the world today, and likely occurred throughout our evolutionary past (Lowe et al., 2012; Reilly, 2009). Further, people tend to prefer cooperation with more parochial groups after a cyclone (Vardy & Atkinson, in press), and after an earthquake (Andrighetto, Baldissarri, Lattanzio, Loughnan, & Volpato, 2014; Vezzali, Andrighetto, Di Bernardo, Nadi, & Bergamini, 2017). To the extent that resource shocks present a real threat to within-group cooperation and intensify between-group competition for increasingly scarce resource, norms, beliefs and behaviours that function to motivate cooperation within groups and reduce cooperation towards other groups are likely to be especially adaptive in the aftermath of a major natural disaster.

4.1.3 The Current study

Here we test the Religious Comfort Hypothesis and Cooperative Buffering Hypothesis in a sample of differentially-affected survivors of a major natural disaster. We do this with a pre-post- design in which we measured self-reported religiosity, levels of disaster affectedness and actual prosocial behaviour with a series of economic games in the same participants from Tanna Island, Vanuatu both before and after Cyclone Pam. The Category 5 Cyclone which made landfall in March 2015 devastated much of the Pacific nation of Vanuatu, hitting Tanna hardest of all islands, and became the most devastating natural disaster to affect the country in the last 50 years. We use these within-subjects data to test the following hypotheses:

The Religious Comfort Hypothesis- If aspects of religion, such as personal religious commitment, ritual participation, prayer, and social and economic support of religious organisations can buffer against threats to feelings of insecurity in the aftermath of a natural disaster, this theory predicts:

H1- People should indicate greater religiosity after the cyclone compared to before

H2- Greater levels of disaster affectedness should predict greater positive shifts in religiosity after the cyclone.

H3- A positive shift in worrying about being able to produce or buy enough food to eat after the cyclone (hereafter perceived food insecurity) should predict an increase in religiosity after the cyclone

H4- Pre-cyclone religiosity should predict lower perceived food insecurity after the cyclone.

The Cooperative Buffering Hypothesis- If aspects of religion, such as belief in a punishing deity and participation in religious rituals, can motivate cooperation towards coreligionists (but not outgroup members) after a resource shock, this theory predicts:

H5- Religious reminders should predict greater cooperation towards coreligionists but not outgroup members after the cyclone, controlling for pre-cyclone cooperation

H6- Pre-cyclone religiosity should predict greater cooperation to coreligionists but not outgroup members after the cyclone, controlling for pre-cyclone cooperation.

4.2. Methods

Participants. Prior to Cyclone Pam in June 2014 we recruited 242 participants from two communities on Tanna Island in Vanuatu to play a series of dictator games and answer questions about religion as part of a large cross-cultural project examining the relationship between religion and morality (Lang et al., Under review; Purzycki et al., 2016b; Vardy & Atkinson, 2018). Our first site was a predominantly Christian community by the coast (age: $M = 34.85$, $SD = 14.43$; 50% female; $n = 134$). This community consists of a collection of small hamlets located close to a locally-important market and centred around a number of small

churches and a primary school. Locals primarily engage in subsistence farming for a living, though a small number are employed in local stores, hotel resorts and in administrative roles. Our second site was a community that primarily engages in indigenous *Kastom* cultural and religious practices (age: $M = 35.10$, $SD = 15.31$; 50% female; $n = 108$). However, as we were unable to collect sufficient religiosity survey data after the cyclone, we do not analyse the data from this site in this chapter.

In March 2015, eight months after we had concluded our first round of data collection, a category five tropical cyclone swept through the island chain, causing catastrophic damage. Cyclone Pam cut off communication between Tanna and the outside world for several days, while aid workers scrambled to reach Tanna by ship. The toll of the cyclone was severe; while few people died, food gardens and fruit trees were devastated and almost all buildings on Tanna were damaged or destroyed. Four months after the cyclone, when power had been restored and much of the rebuilding work had been accomplished, we returned to the island to conduct a second round of dictator games, and religiosity and affectedness surveys with the same participants. We were able to locate and collect data from 101 of the original 134 Christian participants (age: $M = 36.25$, $SD = 14.80$; 53% female).

Protocol. Participants were invited to participate in a study in which they would make decisions with money. In each of four counter-balanced games, participants were presented with two cups directly in front of them and ten coins to distribute between each cup. Depending on the game, participants could distribute some money between themselves and an anonymous member of a particular reference group (self games) or distribute some money between two anonymous members of two different reference groups (group games). Play was designed to be private and anonymous; all allocation decisions were made while the participant was alone in a beach shelter, and the participant was told that they would not know the recipient of any allocated money, and that the recipient would not know who had given them the money.

After the games, participants were asked a series of follow-up demographic questions and the allocation distribution was counted by an anonymous ‘banker’, who then paid out any money the participant allocated to themselves. In each game participants played with 500 Vatu (10 x 50 Vatu coins; about \$4.75 USD), for a total of 2000 Vatu. Including a 500 Vatu show-up fee, participants could earn up to 1500 Vatu, constituting about an average day’s wage. We returned to the communities two weeks after the initial game testing was completed to conduct an in-depth religiosity survey, asking a variety of questions related to belief in and commitment to their society’s moralistic deity, as well as a more local deity (*See Lang et al., Under review; also see: osf.io/2twnf* for all survey questions asked as part of the broader cross-cultural study). Once testing was completed, we travelled to various communities around the island to distribute the money that was allocated in the cups.

Four months after Cyclone Pam, we returned to these same communities and asked the same participants if they would like to play the same games as the previous year. We conducted the same protocol as the first wave of data collection, except that participants completed the religiosity survey and an additional affectedness survey immediately following the economic games. This change was made due to the limited time available to find and test participants in the second wave and to minimize dropout rates during the island’s important focus on rebuilding and replanting crops. For those individuals who relocated to another village, we ran the second wave of the study with these participants in their new villages, in private.

Religiosity measures. We considered three measures of religiosity that specifically targeted aspects of religious commitment and practice. First, we operationalized *personal commitment* to the Christian god (hereafter *God*) as the sum of two ordinal variables: the frequency one thinks about God and the frequency one worries about what God thinks about them. This measure differs from the measure of commitment to god that we utilised in Chapter 2 in that it omits the item concerned with how often one performs practices to talk to or appease god. We

make this distinction because we aim to separately model both measures of personal commitment and measures of religious practice. Second, we separately considered two ordinal measures of religious practice: the frequency one performs rituals or ceremonies to God (hereafter *ritual practices*), and the frequency one engages in prayer. Finally, we operationalized *supernatural punishment* beliefs at each wave of data collection as the sum of scores on three ordinal variables: how important the participant thinks punishing people for a) lying, b) stealing, and c) murder is to God. Scores on all religiosity variables were standardized between 0 and 1. To create measures of change of religiosity for each variable after the cyclone, we subtracted pre-cyclone scores on each measure from the post-cyclone score. For more details about the religiosity measures see Supplementary information section 7.3.

Perceived food insecurity. We measured food concern with four binary Yes/No questions before and after the cyclone. Participants were asked: “Do you worry that in the next [one month/six months/one year/five years] your household will have a time when it is not able to buy or produce enough food to eat?” All ‘yes’ scores were combined to create a composite measure of food concern at each wave of testing. Perceived food insecurity before the cyclone ($\alpha = 0.82$) and after the cyclone ($\alpha = 0.78$) were internally reliable. As with the religiosity measures, pre-cyclone perceived food insecurity scores were subtracted from post-cyclone scores to create a measure of change in levels of food concern after the cyclone.

Measures of prosocial giving. Participants played four modified dictator games, administered in a randomized order. In each game, participants allocated a 10-coin endowment between two cups. In two ‘self games’, the money could be split between a *cup for themselves* and a *cup for a person from another village of the same religion on Tanna* (Self-Corel game), and between a *cup for themselves* and a *cup for a person from a village of a different religion on Tanna* (Self-Outgroup game). In two ‘group games’, the money could be split between a *cup for a person from the participant’s own village* and a *cup for a person from another village of the*

same religion on Tanna (Village-Corel game), and a *cup for a person from another village of the same religion* and a *cup for a person from a village of a different religion on Tanna* (Corel-Outgroup game).

Following Vardy & Atkinson (in press), we operationalise prosocial giving as a binary measure of whether one gave an equal or higher offer versus a less than equal share to the distal cup in each game, both before and after the cyclone. As participants' modal response at each time point was to allocate five coins to each cup, we therefore aim to test whether aspects of religiosity might buffer against a desire to allocate a greater than equal share to the proximal cup.

Experimental manipulation. In the first wave of testing, participants were randomly allocated to one of three experimental conditions: a Christian religious prime, an outgroup (Kastom) prime, or a neutral prime. Each prime consisted of a cloth painted with icons relevant to each condition; the Christian painting was composed of a church house, bible and necklace with a cross, the outgroup prime consisted of a *Toka* stick, *Wilgen*, and feather stick all used for *Kastom* dancing, and the neutral prime consisted of two flowers. The primes were placed under the game apparatus during testing and were removed once the games had been completed. In the second wave of testing, participants were exposed to the same prime they had been exposed to in the first wave. As the Cooperative Buffering Hypothesis makes no strong predictions about the cooperation-relevant effects of being primed with foreign religious ideas, we only consider the neutral and Christian conditions.

Affectedness measures. Here we utilize four composite measures of cyclone affectedness, aimed to quantify exposure to different kinds of experiences during and immediately after the disaster: property damage, exposure to others in distress, injury to self and loved ones, and need for resource aid. These scales were derived from a principle components analysis of an

affectedness survey adapted from the Traumatic Exposure Severity Scale (Elal & Slade, 2005), as part of a related study with the same participants (Vardy & Atkinson, in press).

4.3. Results

Did people become more religious after the cyclone?

The results shown in Figure 9 indicate that, at the group level, people did not report a change in personal commitment to God, Wilcoxon Signed Rank: $W = 819$, $p = 0.266$, Hedge's $g = -0.14$, or prayer after the cyclone, $W = 465.5$, $p = 0.444$, $g = 0.08$. However, we found a small but statistically significant reduction in the frequency of reported ritual practices to God after the cyclone, $W = 1003.5$, $p = 0.019$, $g = 0.24$.

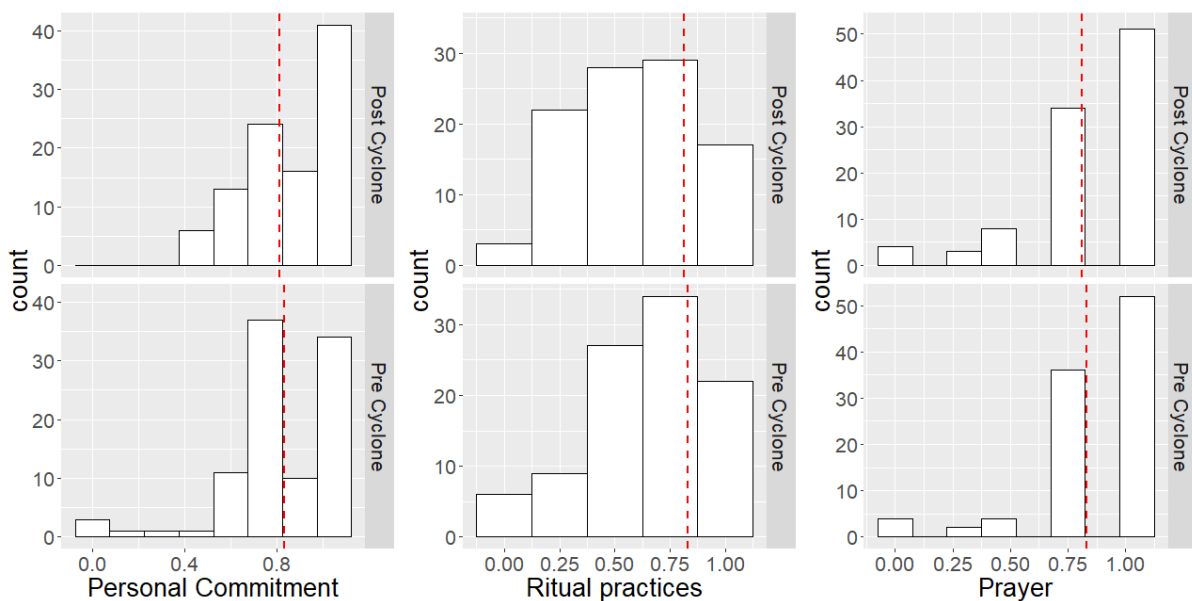


Figure 9. Histograms of reported religiosity before and after the cyclone. Dashed red lines indicate mean religiosity at each time point.

Did the type and severity of affectedness predict a change in religiosity?

We assessed whether individual differences in the nature and severity of cyclone exposure predicted a change in religiosity after the natural disaster. The results shown in Table 8 show

that neither damage to property, need for resource aid, injury to self and loved ones, or witnessing others in distress predicted a shift in religiosity in terms of personal commitment and ritual participation to God, or prayer.

Table 8. Results of OLS regressions predicting shifts in religiosity after the cyclone from measures of cyclone affectedness

	Personal commitment	Ritual	Prayer
	β -Est	β -Est	β -Est
Damage to property	-0.01 [-0.24, 0.22]	-0.03 [-0.25, 0.20]	-0.00 [-0.23, 0.22]
Need for resource aid	0.02 [-0.23, 0.28]	0.04 [-0.22, 0.29]	0.21 [-0.05, 0.56]
Injury to self and loved ones	0.04 [-0.19, 0.28]	-0.20 [-0.43, 0.04]	-0.12 [-0.35, 0.12]
Witnessing others in distress	0.06 [-0.16, 0.28]	0.15 [-0.07, 0.37]	-0.03 [-0.25, 0.19]
R ²	0.01	0.04	0.03
n	97	96	97

Notes: We report standardized coefficients with 95% confidence intervals in brackets.

Did religiosity buffer against the effects of the cyclone on perceived food insecurity?

First, we tested the prediction that an increase in perceptions of food insecurity after the cyclone would predict an increase in reported religiosity. Contrary to this prediction, a positive shift in perceived food insecurity after the cyclone did not predict a positive shift in personal commitment, $\beta = -0.01$, 95% CI = [-0.21, 0.20], $p = 0.960$, or ritual participation to God, $\beta = 0.01$, 95% CI = [-0.20, 0.21], $p = 0.948$, or prayer, $\beta = 0.02$, 95% CI = [-0.18, 0.22], $p = 0.863$.

Second, we tested the prediction that pre-cyclone religiosity would buffer against increases in feelings of food insecurity after the cyclone. The results of a single OLS model indicate that neither personal commitment, $\beta = 0.08$, 95% CI = [-0.12, 0.28], $p = 0.422$, ritual participation to God, $\beta = 0.14$, 95% CI = [-0.09, 0.36], $p = 0.228$, nor prayer before the cyclone, $\beta = -0.08$, 95% CI = [-0.30, 0.13], $p = 0.450$, significantly predicted perceived food insecurity after the disaster, controlling for pre-cyclone perceived food insecurity.

Did religious priming predict prosocial behaviour after the cyclone?

The results presented in Table 9 indicate that participants who were exposed to reminders of their Christian religion were not more likely to give an equal or higher offer to the distal cup after the cyclone than those exposed to a neutral prime, in any game.

Table 9. Results from a series of logistic regressions predicting whether one gave an equal or higher offer to the distal cup after the cyclone from experimental condition.

	Self-Corel <i>OR</i>	Self-Outgroup <i>OR</i>	Village-Corel <i>OR</i>	Corel-Outgroup <i>OR</i>
Christian prime	0.94 [0.35, 2.52]	1.27 [0.46, 3.55]	1.49 [0.51, 4.58]	0.98 [0.36, 2.73]
Pre-cyclone offer	0.29 [0.35, 2.92]	3.52 [1.20, 11.46]*	1.72 [0.45, 6.28]	1.16 [0.37, 3.52]
Cox & Snell Pseudo R ²	0.00	0.08	0.02	0.00
n	66	66	66	66

Notes: We report odds ratios with 95% confidence intervals in brackets. Reference prime was Neutral. * $p < .05$.

Did pre-cyclone religiosity predict prosocial behaviour after the cyclone?

We tested whether pre-cyclone religiosity predicted equal or higher (≥ 5 coins) versus less than equal offers (<5) to the distal cup with a series of logistic regressions. All models additionally controlled for pre-cyclone offers coded the same way. These analyses suggested that pre-cyclone frequency of ritual participation to God and prayer did not predict prosocial giving after the cyclone in any game (see Table 10). Further, we find no evidence that belief in a more punitive deity before the cyclone was correlated with prosocial giving after the cyclone. However, we do find significant relationships between pre-cyclone personal commitment to God and giving, predicting greater odds of giving a less than equal offer to the distal cup in the Self-Outgroup game, Corel-Outgroup game, and Village-Corel game, though this effect was significant at the 0.1 level in the latter game. While this trend was in the same direction in the Self-Corel game, this effect was not significant.

Table 10. Results of a series of logistic regressions predicting whether one gave an equal or higher offer to the distal cup after the cyclone from pre-cyclone religiosity.

	Self-Corel <i>OR</i>	Self-Outgroup <i>OR</i>	Village-Corel <i>OR</i>	Corel-Outgroup <i>OR</i>
Punitiveness	1.31 [0.35, 4.92]	0.58 [0.13, 2.55]	0.98 [0.23, 4.13]	0.58 [0.13, 2.55]
Personal commitment	0.15 [0.12, 1.50]	0.06 [0.01, 0.78]*	0.08 [0.01, 1.14]†	0.06 [0.01, 0.78]*
Ritual practices	0.89 [0.14, 5.83]	1.12 [0.15, 8.46]	0.27 [0.03, 2.19]	1.12 [0.15, 8.46]
Prayer	1.50 [0.35, 4.92]	4.80 [0.38, 60.00]	8.31 [0.79, 86.95]†	4.80 [0.38, 60.00]
Pre-cyclone offer	1.99 [0.83, 4.81]	4.86 [1.74, 13.55]**	2.02 [0.72, 5.68]	4.86 [1.74, 13.55]
Cox & Snell Pseudo R ²	0.06	0.15	0.08	0.15
n	95	95	95	94

Notes: We report odds ratios with 95% confidence intervals in brackets. † $p < .10$. * $p < .05$. ** $p < .01$.

4.4. Discussion

Our results fail to support key predictions within the Religious Comfort Hypothesis, including proposals that people will be drawn to aspects of religion, such as a belief in a controlling god (Kay et al., 2010; Laurin et al., 2008), participation in religious rituals (Legare & Souza, 2014), and benefit from economic and social support from coreligionists (de Vaus & McAllister, 1987; Norris & Inglehart, 2004), to buffer against threats to wellbeing (Cohen et al., 2005; Koenig, Hays, et al., 1997; Park, 2005). By comparing self-reported religiosity on a range of measures before and after a major natural disaster we found that, at the group-level, people did not become either more or less personally committed to their God, or alter their frequency of prayer after the cyclone. However, we found a small reduction in reported frequency of ritual practices to god after the cyclone compared to before. Our measures of affectedness did not predict a shift in religiosity after the cyclone on any measure. Our analysis of the relationship between religiosity and perceived food insecurity indicated that an increase in food insecurity after the cyclone did not predict a positive shift in religiosity on any measure. Further, we found no evidence that pre-cyclone religiosity buffered against an increase in perceived food insecurity after the cyclone.

One interesting possibility our results raise is that in times of resource stress, aspects of religion might motivate people to reduce cooperation with other religious groups and prefer more parochial giving as a way to prevent exploitation of scarce resources by other groups, thus

supporting one key prediction of the Cooperative Buffering Hypothesis. This is supported by the finding that greater personal commitment before the cyclone predicted a preference for giving less than an equal amount to the outgroup against the self and when sharing between the outgroup and corel cups. However, we found no significant relationships between our other religiosity measures and giving after the cyclone, and no evidence that being primed with religion predicted post-cyclone giving to coreligionists or outgroup members, or parochial giving when sharing between groups.

There are a number of factors to consider when interpreting our results. First, while our group-level results suggested that people reported participating in less frequent ritual participation to God, this may not in fact represent an intentional reduction in religiosity. Cyclone Pam was a particularly powerful disaster for Tanna island, destroying the vast majority of buildings made from local materials and removing the corrugated iron roofs of the predominantly cement constructed churches. Therefore, it is possible that the reduction in ritual participation to God after the cyclone might be explained by both a reduction in free time for group worship and the lack of intact churches; we do not have data on this, however.

Second, our results do not rule out a role for religion in reducing distress in the aftermath of the cyclone; it is plausible that aspects of pre-cyclone religiosity could have buffered against post-cyclone distress, while having little effect on food concern. Behavioural neuroscientists and psychologists argue that emotions, such as feelings of distress, likely evolved to orient people to pay attention to salient environmental conditions and prepare them for action, including by resolving the causes of the problem (Inzlicht & Legault, 2014; Izard, 2010). As such, while the ability of religion to reduce excessive levels of distress might be individually adaptive (Sibley & Bulbulia, 2012), it may not necessarily be adaptive to reduce perceived food insecurity to the extent that this insecurity is moderate, or that it would reduce motivation to resolve the problem, for example by assessing stocks of food and planting crops. Future work

should therefore consider a range of measures that consider the severity of psychological distress to assess religion's role in buffering wellbeing in the aftermath of disasters.

Thirdly, the patterns that we observe between aspects of religiosity and prosocial giving differ from those seen in the pre-cyclone study reported in Chapter 2, where belief in a more punitive deity predicted giving an equal or higher share to the outgroup against the self, and when sharing with a coreligionist. One reason for this could be that some of the religiosity measures differ between the two studies. While religious commitment was operationalised in Chapter 2 as a composite measure of how often one thinks about god, worries about what god thinks about you and performs activities or practices to talk to, or appease god, in the current chapter we explicitly model personal commitment without the third item, allowing us to separately model frequency of ritual practice. Personal religious commitment might be a better predictor of cooperation than more general religious commitment that includes both measures of personal commitment and appeasement practices. Another reason could be due to sampling differences between the two studies; Chapter 2 utilised both Christian and Kastom participants, whereas we were only able to obtain religiosity survey responses from Christian participants post-disaster. This may have resulted in a lower power with which to observe effects of supernatural punishment beliefs on giving. Nevertheless, these two sets of results are not necessarily incompatible. It is possible that different mechanisms are responsible for promoting cooperation beyond the group in times of plenty and promoting more parochial giving in times of resource strain. However, further theoretical development and testing specific hypotheses about the perceived function of aspects of religion at different levels of resource stress is necessary.

Overall, these results contribute to an emerging field of literature concerned with the function of religion in times of resource stress (Botero et al., 2014; McNamara et al., 2016; Sibley & Bulbulia, 2012; Smith et al., 2000). Importantly, we find no support for the hypothesis that

people increase their levels of religiosity in response to a natural disaster, or that religion can buffer against feelings of distress. Instead, we find evidence that pre-disaster personal commitment to the Christian God predicted allocating a reduced share of a windfall to outgroup members, and to prefer parochial giving when sharing between groups. Together, these results provide some of the first pre-post disaster analyses of the role of religion in reducing distress and highlight the potentially important role of religion in calibrating cooperation to more proximal social groups in times of resource stress.

Chapter 5. Quantifying and explaining the religious gender gap in 14 diverse societies

5.1. Introduction

5.1.1 Gender and religiosity

One of the most widely cited findings in the study of religion is that women tend to be more religious than men (Argyle & Beit-Hallahmi, 1975; Beit-Hallahmi & Argyle, 1997; Collett & Lizardo, 2009; Francis, 1997; Stark, 2002; Walter & Davie, 1998). Numerous studies over many decades have shown that women report a greater interest in religion (Sasaki, 1975), are more committed to their faith (Argyle & Beit-Hallahmi, 1975), and pray more than men (Beit-Hallahmi & Argyle, 1997; Davie, 1990; Miller & Stark, 2002; Schnabel, 2016). Some have gone as far as to suggest that women indicate greater religiosity than men on every possible measure (Argyle & Beit-Hallahmi, 1975), and that this trend holds in countries and religions across the world (e.g. Stark, 2002).

However, scholars of religion question whether the ‘gender gap’ in religiosity is as consistent as first thought (Cornwall, 1989; Feltey & Poloma, 1991; Sullins, 2006). Firstly, the size of the gender gap may depend on what is measured. Some have claimed that women’s greater reported religiosity could be driven by a prevailing tendency in the literature to operationalize religiosity solely as a subjective rating of religion’s importance in one’s life (e.g. Miller & Stark, 2002; Stark, 2002), ignoring measures of religious practice (Sullins, 2006). When studies do consider multiple dimensions of religiosity, evidence is mixed; while some find that women consistently rate themselves higher on measures of religious ritual (Cornwall, 1989; Roth & Kroll, 2007), others find smaller effects for ritual (Davie, 1990; Sullins, 2006), or fail to find an effect at all (Beit-Hallahmi & Argyle, 1997).

Secondly, the size of the gender gap might depend on the religious tradition being sampled. While studies consistently show that Christian women tend to indicate that religion plays a more central role in their lives than do Christian men, Muslim men and women tend to indicate similar levels of personal commitment and frequency of prayer (Hackett et al., 2016; Sullins, 2006). Further, survey evidence suggests that Hindus and Buddhists report similar attendance rates at worship services (Hackett et al., 2016), and in some countries Jewish and Muslim men report engaging in more collective religious participation than women by more regularly attending Synagogue or Mosque (Lazerwitz, 1961; Sullins, 2006). Whether such differences in participation reflect differences in personal religious commitment versus externally-imposed doctrinal demands, is unclear.

Thirdly, most research has focused on powerful moralistic deities within monotheistic religions and large-scale societies (e.g. de Vaus & McAllister, 1987; Miller & Hoffmann, 1995; Schnabel, 2016; Walter & Davie, 1998). Many religions contain multiple deities and spirits within their pantheon, but demographic trends in religiosity towards more local gods have been largely ignored by researchers. Testing the universality of the religious gender gap, and explanations for it, requires sampling beyond these select monotheistic traditions, from a more diverse range of potentially less morally-concerned local deities within small and larger-scale societies (e.g. Purzycki et al., 2016b).

5.1.2 Theoretical accounts for the gender gap in religiosity

Accompanying, and often motivating, attempts to quantify the religious gender gap, social scientists have sought to explain why gender differences in religiosity exist and continue to persist in the first place (Luckmann, 1967; Martin, 1967). Here we focus on three broad categories of explanation of the religious gender gap: a risk aversion account (Hoffmann, 2009; Miller & Hoffmann, 1995; Miller & Stark, 2002), a reproductive strategy account (Kurzban,

Dukes, & Weeden, 2010; Weeden, Cohen, & Kenrick, 2008), and a structural location account (de Vaus & McAllister, 1987; Norris & Inglehart, 2008; Trzebiatowska & Bruce, 2012).

Risk aversion account

The risk aversion account attributes the religious gender gap to differential tolerance for spiritual and/or social risk for irreligiosity among men and women. This account builds upon criminological research, which has consistently found that men show higher levels of risk-taking than women (Booth & Dabbs, 1993; Byrnes, Miller, & Schafer, 1999; Wilson & Daly, 1985), and are more more likely to engage in ‘risky’ behaviours such as drinking, smoking, drug-taking, speeding, gambling, and sexual promiscuity than women (Gottfredson & Hirschi, 1990; Gove, 1985). Proponents of a risk aversion explanation argue that religious belief and participation may be partly understood as a strategy to mitigate the risk of punishment by god or community members for irreligiosity (Miller & Stark, 2002; Stark, 2002). First, similar to Pascal’s wager, religious belief is argued to be a risk-averse strategy; in the Abrahamic faiths, religious belief may lead to eternal life if the religion is true, however the best a non-believer can attain after death is annihilation if the religion is untrue, and the worst is eternal damnation in hell if it is (Miller & Hoffmann, 1995; Roth & Kroll, 2007). Second, irreligiosity can confer social costs; recent research for example, suggests that people exhibit an intuitive moral prejudice against non-believers (Gervais et al., 2017). In communities where the majority of people are religious, being irreligious could lead to especially negative social consequences, such as a damaged reputation, suspicion, ostracism, and even being killed (Johnson & Krüger, 2004).

Reproductive strategy account

A more recently-developed account argues that individual differences in religiosity can be explained as an outcome of people pursuing different reproductive strategies (Kurzban et al.,

2010; Weeden et al., 2008; Weeden & Kurzban, 2013). The contemporary world religions set a moral premium on monogamous, high fertility, heterosexual marriages as the basis of the family unit. Individuals engaging in pre-marital sex and infidelity face the threat of social and spiritual punishment for transgression of sacred sexual norms (Weeden et al., 2008). Strict norms around sex are argued to function to rebalance the trade-offs of those pursuing high-commitment mating strategies by deterring marriage infidelity and reducing women's risk of mate abandonment and men's risk of cuckoldry (Weeden & Kurzban, 2013). Within this framework, individuals who want to pursue high-commitment relationships and incentivize their partners to remain faithful and committed are more likely to be drawn to religions that preach those values.

This account predicts that men tend to report less religiosity than women because a higher frequency of men than women are pursuing low commitment strategies in a population (Kirkpatrick, 2005; Weeden et al., 2008). While, in theory, women's higher investment in gestation and nurturing of offspring may lead to higher fitness benefits for men who seek low commitment sexual relationships (Buss, 1989), this logic is debated by some evolutionary biologists (Parker & Birkhead, 2013) and in practice such strategies' payoffs are limited by male-male competition (Kokko & Jennions, 2003). Nonetheless, while on average men may not receive higher fitness benefits than women by following low-commitment strategies, high status males who gain a disproportionate benefit from low-commitment strategies could theoretically drive the gender gap.

Structural location account

A third account proposes that contrasting social roles for men and women in society have contributed to gender differences in religiosity (de Vaus & McAllister, 1987; Steggerda, 1993; Thompson, 1991). This argument tends to take one of three forms. First, the *Social networks*

and support version argues while men engaged in paid work can benefit from social networks and support at the workplace, for example through male friendship and camaraderie, women's primary role as homemakers and caregivers means that they may feel greater social isolation (Moberg, 1962), and may be motivated to seek child-rearing support (Martin, 1967). Within this framework, women are hypothesised to be more religious because they are disproportionately likely to seek social networks and alloparental care provided by religious institutions (de Vaus & McAllister, 1987; Martin, 1967).

Second, the *Secularisation* version of the structural location account proposes that women's relative absence from the workplace and limited access to secular education provided in school may have isolated them from so-called 'secularising forces' that have led to the gradual erosion of religion's centrality in the daily lives of people in many Western countries (Berger, 1967; Trzebiatowska & Bruce, 2012; Wilson, 2016). Through workforce participation and secular education, people may be increasingly exposed to values and meaning outside of religion (Luckmann, 1967), such as feeling like one is contributing to one's society, lessening the appeal of religion and/or reducing the perceived plausibility of religious teachings.

Finally, a more recent *Existential insecurity* version argues that women tend to be more vulnerable to periods of existential insecurity than men (Norris & Inglehart, 2008; Voas, McAndrew, & Storm, 2013; Walter & Davie, 1998). Defined in its broadest sense as "the extent to which survival is seen as secure or uncertain" (Norris & Inglehart, 2008: 3), enduring gender inequalities in political power and economic opportunities make women more vulnerable to economic insecurity. Alternatively, or in addition, through socialisation into submissive and caring roles (Suziedelis & Potvin, 1981), women may feel more vulnerable in general during their lives. Within this framework, women may be drawn to religion because they find greater comfort believing in a deity that listens and responds to their anxieties in this life and may

reward them after death, and can benefit from economic support provided by religious institutions (Chen, 2010; Zapata, 2018).

5.1.3 The current study

Here, we conduct a systematic cross-cultural investigation into the prevalence of, and explanations for, the religious gender gap in a sample of over 2,000 individuals from 14 diverse societies. We employ religiosity and demographic survey data from a dataset collected by investigators of CERC between 2013 and 2015. We obtained information on a wide range of measures of religiosity, including questions about personal religious commitment, beliefs, practices and socio-demographic context. Further, we collected data on beliefs about and commitment to two categories of supernatural agents –Moralistic Gods and Local Gods. Moralistic deities were identified within each society as gods highly concerned with morality, whereas local gods were identified as supernatural agents of local importance who were expected to have less concern for morality. The selection of deities recorded includes the Christian god, other powerful creator deities from communities with non-Abrahamic religious traditions, and many local deities and spirits.

We utilise the CERC dataset to first quantify the religious gender gap and establish the extent to which the gap is consistent across measures of religiosity, religious traditions, and towards different kinds of deities. Secondly, a dataset as diverse as this allows us to test a range of hypotheses for *why* women tend to indicate greater religiosity than men. Here we test a number of hypotheses under each of the three theories outlined above (see Table 11 for the fully operationalised hypotheses). While these accounts are not an exhaustive list of proposed explanations for the gender gap, they are some of the most developed and provide testable predictions compatible with the CERC dataset for where one should see a gender gap and what should moderate and mediate this difference. Methods for testing ordinal moderated mediation

are not currently available in the hierarchical regression framework we employ and therefore an additional three preregistered hypotheses involving moderated mediation are not included here.

First, we will test the risk aversion account in two ways. If women's greater religiosity is explained by their heightened aversion to risking the threat of supernatural punishment for unbelief, this theory predicts that the perceived threat of supernatural punishment for unbelief should be a better predictor of religiosity in women than men (H1). Alternatively, or in addition, if women's greater religiosity is explained by their heightened aversion to the threat of social castigation for unbelief, women should indicate greater religiosity when social threat is perceived to be higher, whereas this should have less of an effect on men (H2). We note that the risk aversion account makes no strong predictions for which measures of religiosity we should see a gender gap, nor whether this difference should be unique to moralistic or local gods.

Second, if as proposed by the reproductive morality account, the religious gender gap can be explained by greater male aversion to religious institutions that moralise against short-term and multiple-mate mating strategies, the gender gap in religiosity should be wider with respect to more morally-concerned deities (H3). Further, this theory predicts that indicators of a high-commitment reproductive strategy should be a good predictor of religiosity; we posit that marital status is one such indicator. However, to the extent that men are more likely to be engaged in short-term mating strategies in general, marital status should be a better predictor of religiosity in men than women (H4), especially among high-status males (H5), and gender differences in religiosity should be greater in societies with greater opportunities for males to obtain multiple mates (H6). We note that the reproductive strategy account makes no strong predictions about whether the gender gap should be larger for measures of personal religious commitment or ritual.

Lastly, we test three versions of the structural location account outlined above. A major prediction made by multiple versions of the structural location account is that employment in the workforce might provide alternate sources of social networking and support to religious institutions, expose people to secular values and norms, and regular income can ward off existential threats associated with resource scarcity. This theory therefore predicts that gender differences in access to work should explain the religious gender gap (H7 & H8).

Testing between the three versions of the structural location account requires more specific predictions about the role of work and other aspects of structural location, such as gender differences in formal education, material insecurity, child rearing responsibilities, and access to alternate sources of social networking, and how they may affect religious affiliation. First, if women's greater religiosity is attributable to their greater desire for social networks and support provided by religious institutions, then measures of religious participation should drive the religious gender gap (H9). Further, the gender gap should widen where women require greater access to networking and support systems (H10), and narrow where alternative, non-religious sources of networking and support systems exist (H11). While moralistic gods attached to highly structured religious traditions often provide a variety of social institutions to aid adherents in their daily lives, we have no data on the specific network provisions linked to local gods in our sample. As such, the moralistic gods alone provide an opportunity to test the predictions of this account.

Second, if women's greater religiosity is due to their slower rate of secularisation, then gender differences in access to secular information via formal education should explain the religious gender gap (H12). While the secularisation version proposes that the religious gender gap may be explained by males and females becoming less religious at different rates, the account appears to make no strong predictions about whether the gender gap should be larger for measures of personal religious commitment or ritual, or for moralistic gods or local gods.

Finally, if the gender gap in religiosity is due to religion's ability to allay the greater existential anxiety of women then the gender gap in religiosity should be greater concerning commitment and ritual practices towards deities who can better allay anxieties (H13), in cultures where women are exposed to greater existential threat than men (H14 & H15), and be explained by women's greater exposure to existential insecurity than men (H16). We note that the existential insecurity account does not make predictions about what measures of religiosity should show the largest gender gaps.

Table 11. Hypotheses to test explanations for the religious gender gap

Account name	Hypothesis
Risk aversion	
H1	The perceived punitiveness of one's deity and/or belief that one's deity can influence life after death should be a better predictor of religiosity in women than men.
H2	To the extent that greater average religiosity in a community indicates a stronger social norm of religiosity, this account predicts that the average religiosity of one's community should be a better predictor of religiosity in women than men.
Reproductive strategy	
H3	Women should report greater religiosity towards their moralistic god than men. As prior work has suggested that local gods are less concerned with morality (Purzycki et al., 2016b), gender differences are likely to be smaller or non-existent for local gods.
H4	Married men should be relatively more religious than unmarried men, whereas marital status should have less of an effect on female religiosity.
H5	To the extent that high status men are more competitive in obtaining multiple mates than low status men, high status men should be less religious than low status men, and women.
H6	Groups with higher single male to female ratios in the population might restrict opportunities for men to acquire multiple mates and should therefore show smaller religious gender gaps.
Structural location	
H7	Gender differences in workforce participation should mediate the relationship between gender and religiosity.
H8	Cultures with a higher share of women in paid employment should show smaller gender gaps.
Social networks and support	
H9	Women will report greater frequency of ritual practices towards moralistic gods. To the extent that participation in rituals drives belief, ritual participation measures should mediate the effect of gender on personal religious commitment.
H10	To the extent that women are motivated to seek child-rearing resources provided by religious institutions, greater need for child-rearing support should moderate the gender gap.
H11	Gender differences in time spent socialising at market should mediate the relationship between gender and religiosity.
Secularisation	
H12	Women are less exposed to secularizing forces via formal education. As a result, years of formal education should predict less religiosity in both men and women. Gender differences in exposure to formal education should mediate the relationship between gender and religiosity.
Existential insecurity	
H13	To the extent that moralistic gods are perceived to be more benevolent, and more likely to be able to influence life after death, women should indicate greater religiosity towards moralistic gods, but not local gods. Nevertheless, the effect of gender on religiosity should be greatest among women who believe in a rewarding god, and a god that can influence life after death.
H14	The gender gap in moralistic god religiosity should be greater in societies with higher levels of economic insecurity.
H15	The gender gap in moralistic god religiosity should be greater in societies with higher levels of gender inequality.
H16	Women are more religious because they disproportionately benefit from religions' ability to allay existential anxieties. Under this scenario, women should report greater perceived food insecurity, which should in turn predict greater moralistic god religiosity. As such, perceived food insecurity is expected to mediate the relationship between gender and religiosity.

Notes: All preregistered hypotheses for this study can be found at: <https://osf.io/xg7kp/>.

5.2. Method

The present data were collected as part of the Evolution of Religion and Morality Project (Lang et al., Under review; Purzycki et al., 2016b) carried out in collaboration with the Cultural Evolution of Religion Consortium. The data were compiled over two waves of data collection to investigate questions around religion and cooperation. The dataset for Wave 1 is publicly available and can be accessed online (Purzycki et al., 2016a). The present study includes both Wave 1 and Wave 2 data. For further information about our measures, and for protocols for both waves see <https://osf.io/6ha2d/>.

Participants. Over both waves of data collection, we recruited 2,228 participants (1,226 females; Mean age = 37.0, SD = 14.8) from 15 different field sites: (1) Coastal and (2) Inland Tanna, Vanuatu; (3) Cachoeira and (4) Marajó, Brazil; (5) Samburu and (6) Turkana, Kenya; (7) Lovu and (8) Yasawa, Fiji; (9) Huatasani, Peru; (10) Kananga, Democratic Republic of Congo; (11) Mysore, India; (12) Tyva, Russia; (13) Hadza, Kenya; (14) Sursuranga, Papua New Guinea; and (15) Mauritius (see Table 12 for basic site characteristics). Due to divergent religiosity measures at the Hadza site, we were forced to exclude all participants from this site from both waves. Recruitment for this study was conducted via different methods at different sites, though random sampling on the street was the most common. Sites that collected data over two waves sampled different participants at each time; we therefore utilise data from both waves in these sites. For the purposes of this study we excluded participants from our analyses for whom we had no information on gender, or who did not identify as male or female. After exclusion of participants, we had a working sample size of 2002 participants (1,126 females; Mean age = 36.9, SD = 14.87) from 14 field sites.

Table 12. Site descriptions

Site	Wave	N	% Female	Moralistic God	Local God	Sampling	Economy
Cachoeira	II	262	68	Christian God	Candomblé God (<i>Ogum</i>)	Chain sample (temples)	Market
Coastal Tanna	I + II	178	50	Christian God	Garden spirit (<i>Tupunus</i>)	Cluster sample (census)	Horticulture
Huatasani	II	94	61	Christian God	Mountain Spirits/Christian Saints	Random/chain sample (street)	Farming/ Herding
Inland Tanna	I + II	112	49	<i>Kalpapan</i> (Traditional)	Garden spirit (<i>Tupunus</i>)	Entire community	Horticulture
Kananga	II	200	61	Christian God	<i>Kadim</i> /Ancestor spirits	Random sample (census)	Market
Lovu	I	76	68	Hindu Bhagwan	None available	Door-to-door	Market
Marajó	I	77	52	Christian God	Virgin Mary	Random sample (census)	Market
Mauritius	I + II	243	41	Hindu Shiva	Ghost (<i>Nam</i>)	Random sample (street)	Market/ Farming
Mysore	II	165	43	Hindu Shiva	Chamundeshwari	Random sample (street)	Market
Samburu	II	40	70	Christian God (<i>Nkai</i>)	None available	Random sample (households)	Herding
Sursurunga	II	163	55	Christ. God (<i>Káláu</i>)	Spirit (<i>Sírmát</i>)	Random/chain sample (street)	Horticulture
Turkana	II	236	61	Christ. God (<i>Akuj</i>)	Ancestor spirits	Door-to-door	Herding
Tyva	I	81	72	Buddha Burgan	Spirit-masters (<i>Cher eezi</i>)	Random/chain sample (street)	Market/ Herding
Yasawa	I	75	55	Christian God	Ancestor spirits (<i>Kalou-vu</i>)	Door-to-door (cluster)	Fishing/ Farming

Dependent religiosity measures. We attempted to measure commitment to two supernatural agents in each site: one deity highly concerned with morality (“moralistic god”), and another supernatural agent of local importance expected to have less concern for morality (“local god”). These two kinds of supernatural agents were chosen at each site following in-depth ethnographic interviews about local religious beliefs and traditions (Lang et al., Under review; Purzycki et al., 2016b). Religiosity surveys were conducted at each site targeting different aspects of religious beliefs and practices towards their culture’s moralistic and local deities. For the present study, we utilise measures of religiosity that target specific aspects of personal religious commitment and religious practices.

First, to test whether men and women indicate different rates of religious belief we utilise a binary measure of belief or unbelief in the culture’s moralistic and local deities (hereafter *belief*). Next, we measure *personal commitment* to moralistic and local gods by combining scores on two ordinal measures: the frequency one thinks about each deity, and the frequency one worries about what each deity thinks about them. The scores on each composite measure were then standardised between 0 and 1. We also separately consider two ordinal measures of religious practice to moralistic and local deities; the frequency that one performs rituals or ceremonies devoted to the deity (hereafter *ritual practices*), and the frequency of engagement in activities or practices to talk to, or appease, moralistic god or local god (hereafter *appeasement*). Finally, we examine a general ordinal measure of the frequency one engages in prayer (hereafter *prayer*), not specific to a god (for the religiosity scales used, see Table S12 in Supplementary information).

Other religiosity measures. Participants were asked a range of questions concerning beliefs about each deity; we utilise a number of these to test some explanations of the gender gap. First, we operationalised the perceived punitiveness of each deity as a proxy for supernatural risks for irreligiosity. To do so we calculate the mean score of three ordinal questions

concerning how often each participant thinks the deity punishes people for a) lying, b) stealing, and c) murder. We also utilise a binary measure of belief that moralistic or local deity can influence life after death or not. As a proxy for social risks for irreligiosity, we utilise average site religiosity by computing a mean value for each dependent religiosity measure at each site. Finally, we also utilise an ordinal measure for how often one's moralistic or local deity rewards people for good behaviour. For the scales of each independent religiosity measure used, see Table S12 in Supplementary information.

Demographic measures. Participants at all sites were asked the same series of demographic questions; we utilise a variety of these measures to test explanations for the religious gender gap. Variables used to test the hypotheses include: marital status, the number of days one usually works for a wage or goes to market per month, age, number of children, years of formal education, and logged annual income in USD. We consider two proxies of social status; 1) annual income (in USD) relative to others in one's community, which we operationalise as income split into quintiles for each site, and 2) years of formal education. We operationalise perceived food insecurity by summing scores on four binary questions pertaining to whether one is, or is not, worried that one's household will have a time when it is not able to buy or produce enough food in the next a) week, b) month, c) year, and d) five years.

We also consider society-level data using male to female birth-rates, the share of women in paid employment, GDP per capita, and gender inequality. These measures were obtained from the United Nations Development Programme (UNDP) Human Development Data (HDD) reports from 1990-2015. For each site, we used national level data from the most recent estimate available.

Analyses. Analyses were conducted using linear regressions with appropriate outcome distributions for each variable: ordinal outcome data were fit with cumulative link models,

binary outcome data were fit with logistic regressions, and composite variables with OLS regressions. As our data are nested within different cultures, we included higher-level random intercept effects for site when we ran models on more than two sites. To provide more interpretable gender coefficients in analyses that involve moderation, we mean centred all numeric, non-binary, moderators before running analyses.

Our analyses were conducted in two sections. First, we quantified the religious gender gap by regressing gender on each dependent religiosity measure. As we ran these models without consideration of the causes of the gender gap, these analyses did not control for any additional variables. Second, we tested the hypotheses that attempt to explain the gender gap. As we could only explain gender differences in religiosity where they existed, and because the accounts we test claim to explain women's greater religiosity, we only tested our explanatory hypotheses on the religiosity measures where women rated themselves as significantly more religious across the whole sample. All mediations were carried out using the Baron & Kenny (1986) method, by comparing changes in the gender coefficient when models controlled for the proposed mediator variable versus when the mediator was omitted from the model. To test whether any mediation effects were significant we calculated the Average Causal Mediation Effects (ACME) and Average Direct Effect (ADE) estimated within the Mediation package in R (Tingley, Yamamoto, Hirose, Keele, & Imai, 2014). We estimated quasi-Bayesian Monte Carlo confidence intervals with 5000 bootstrap resamples for all mediation analyses. As the Mediation package is incompatible with hierarchical ordinal models, we ran multilevel OLS regressions when calculating ACME and ADE effects on ordinal dependent variables.

To test our moderated mediation predictions, we ran mediation analyses in the same way as stated above, but instead obtain estimates of ACME coefficients at one standard deviation above and below the mean for each proposed ordinal or continuous moderator, or at 0 and 1

for binary moderators. To ascertain whether moderated mediation has occurred, we then compare the ACME coefficients at low and high levels of each moderator.

For our group-level predictions we included the relevant national-level variables as fixed effects in regression analyses. As these group variables would be perfectly colinear with the site variable, we ran single level rather than hierarchical regressions, omitting site as a covariate. To facilitate model identification, group-level variables were mean centred and scaled by dividing the centred values of each variable by their standard deviations.

We note that the preregistration of this project stated that all explanatory models would additionally control for participant age. We decided against doing this for several reasons: 1) our explanatory models aimed to simply explain the gender gap as quantified in our descriptive models, 2) participant age was a key component of an explanatory hypothesis we tested, and 3) there was no *a priori* reason to suppose that gender differences in age across our sample explain gender differences in religiosity. We observe that rerunning the models with which we quantify the religious gender gap with the addition of participant age as a covariate does not change the interpretation of these results (Section 7.4.2 in Supplementary information).

5.3. Results

5.3.1 Quantifying the religious gender gap

Do women report greater religiosity than men?

The results of our quantification of the gender gap suggest that women in our sample did tend to rate themselves as more religious than men on some measures of religiosity. Across all sites, women indicated greater personal commitment towards their moralistic deity than men, $\beta = 0.06$, 95% CI = [0.02, 0.10], $p = 0.003$ (Figure 10 a-d). In our measures of religious participation, women indicated greater religiosity than men in terms of frequency of ritual

practices to their moralistic god, OR = 1.40, 95% CI = [1.13, 1.72], $p = 0.002$, and prayer, OR = 1.52, 95% CI = [1.18, 1.95], $p = 0.001$. However, we observed no gender difference in appeasement of moralistic gods, OR = 0.98, 95% CI = [0.82, 1.17], $p = 0.789$. Further, we found no gender differences in whether one believes in the moralistic god, OR = 1.98, 95% CI = [0.84, 5.01], $p = 0.129$. This result is likely to have been affected by ceiling effects; 98% of the full sample indicated belief in their society's moralistic god. For this reason, we did not estimate site-level gender differences in belief in moralistic god. Nonetheless, this is suggestive that no gender differences exist in terms of belief or unbelief in their society's moralistic deity; almost everyone believes, regardless of gender.

By contrast, analysis of local god data showed that women did not indicate greater religiosity than men on any measure (See Figure 10 e-h). Our models showed no evidence for a gender gap in belief in, OR = 0.84, 95% CI = [0.62, 1.14], $p = 0.270$, or personal commitment to local gods, $\beta = -0.02$, 95% CI = [-0.06, 0.01], $p = 0.214$. In our measures of religious practice, we observed no gender differences in frequency of ritual practices to local gods, OR = 0.98, 95% CI = [0.77, 1.27], $p = 0.906$, and found that men indicated significantly greater appeasement of local gods than did women, OR = 0.73, 95% CI = [0.59, 0.91], $p = 0.006$.

Is the gender gap consistent across sites?

Our models revealed substantial cultural variation in the size and direction of the gender gap between sites. While most sites showed trends towards greater female than male personal commitment to moralistic gods, this effect was only statistically significant at Mysore, $\beta = 0.16$, 95% CI = [0.01, 0.31], $p = 0.043$, and Cachoeira, $\beta = 0.19$, 95% CI = [0.05, 0.32], $p = 0.008$, whereas Inland Tanna showed significantly greater male than female religiosity on this measure, $\beta = -0.23$, 95% CI = [-0.44, -0.02], $p = 0.035$. When considering our measures of religious participation, the effect of gender was not statistically significant at any one site,

although women trended towards greater frequency of ritual practices to moralistic god than men at most sites, with the largest trends in Mysore, OR = 0.72, 95% CI = [0.97, 3.04], $p = 0.062$. Between-site variation in the gender gap was most pronounced in appeasement of moralistic gods. Men indicated more appeasement of moralistic gods in both Inland Tanna, OR = 0.20, 95% CI = [0.08, 0.49], $p < 0.001$, and Lovu, OR = 0.24, 95% CI = [0.07, 0.77], $p = 0.016$, while women were more likely to indicate greater appeasement of moralistic god in Sursurunga, OR = 2.62, 95% CI = [1.44, 4.77], $p = 0.002$. Finally, women indicated greater frequency of prayer than men in Mysore, OR = 3.18, 95% CI = [1.40, 7.21], $p = 0.006$, Mauritius, OR = 2.35, 96% CI = [1.05, 5.23], $p = 0.037$, and Turkana, OR = 2.10, 95% CI = [1.25, 3.52], $p = 0.005$, while the other sites showed no consistent gender effect.

Analysis of local god data indicated that the size and direction of the gender gap was small and inconsistent across all but the two Tanna sites, where Tupunus is the local god. In Coastal Tanna, men were significantly more likely than women to believe in, OR = 0.32, 95% CI = [0.15, 0.66], $p = 0.002$, indicate greater personal commitment to, $\beta = -0.35$, 95% CI = [-0.50, -0.21], $p < 0.001$, appeasement of, OR = 0.19, 95% CI = [0.09, 0.37], $p < 0.001$, and more frequent ritual practices towards their local god, OR = 0.27, 95% CI = [0.14, 0.53], $p < 0.001$. Similar trends were found for Inland Tanna in terms of appeasement, OR = 0.40, 95% CI = [0.17, 0.91], $p = 0.030$, and personal commitment of Tupunus, $\beta = -0.18$, 95% CI = [-0.40, 0.03], $p = 0.095$.

Is the gender gap a Christian phenomenon?

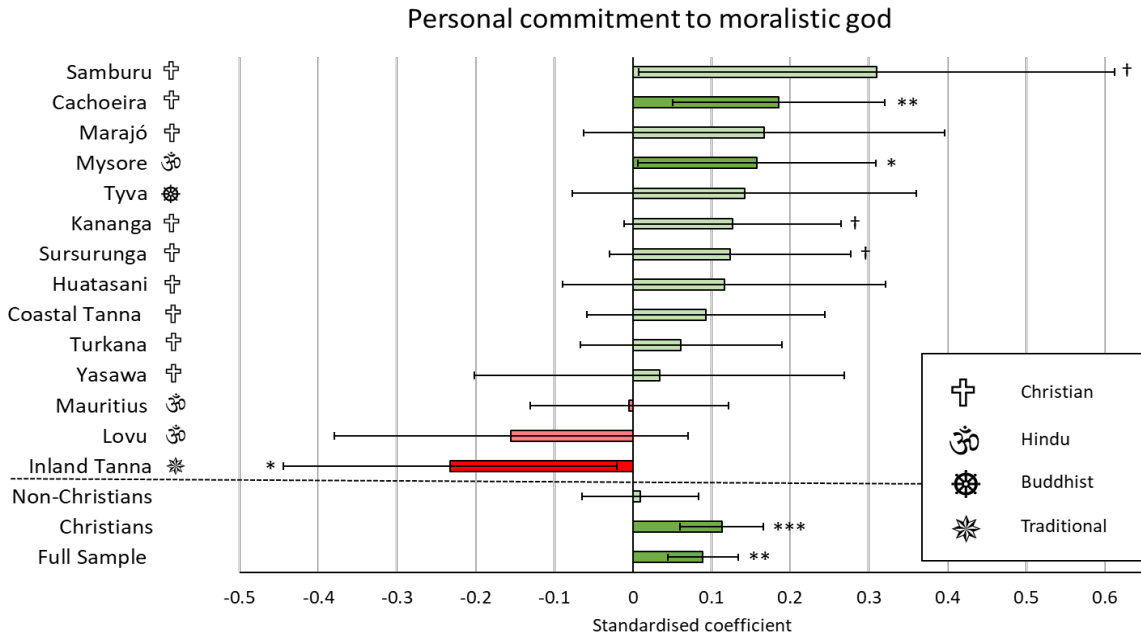
Analysis of moralistic god data provided some evidence that the size of the gender gap varied between Christian and non-Christian sites. While women in Christian sites indicated greater personal commitment to their moralistic gods than men, $\beta = 0.11$, 95% CI = [0.06, 0.17], $p < 0.001$, participants in non-Christian sites showed no gender gap in this measure, $\beta = 0.01$, 95%

CI = [-0.06, 0.08], $p = 0.789$. A marginally-significant interaction effect provides tentative evidence that the effect of gender on personal commitment to moralistic god was stronger for Christian than non-Christian sites (Table 13). Considering our measures of religious participation, while women from both Christian, OR = 0.39, 95% CI = [1.08, 1.79], $p = 0.009$, and non-Christian sites, OR = 1.42, 95% CI = [0.96, 2.12], $p = 0.083$, indicated greater frequency of ritual practices than men, in the Christian sites the gender effect was only significant at the 0.05 level. A non-significant interaction effect suggests that the size of the gender gap did not vary significantly between Christian and non-Christian sites (Table 13).

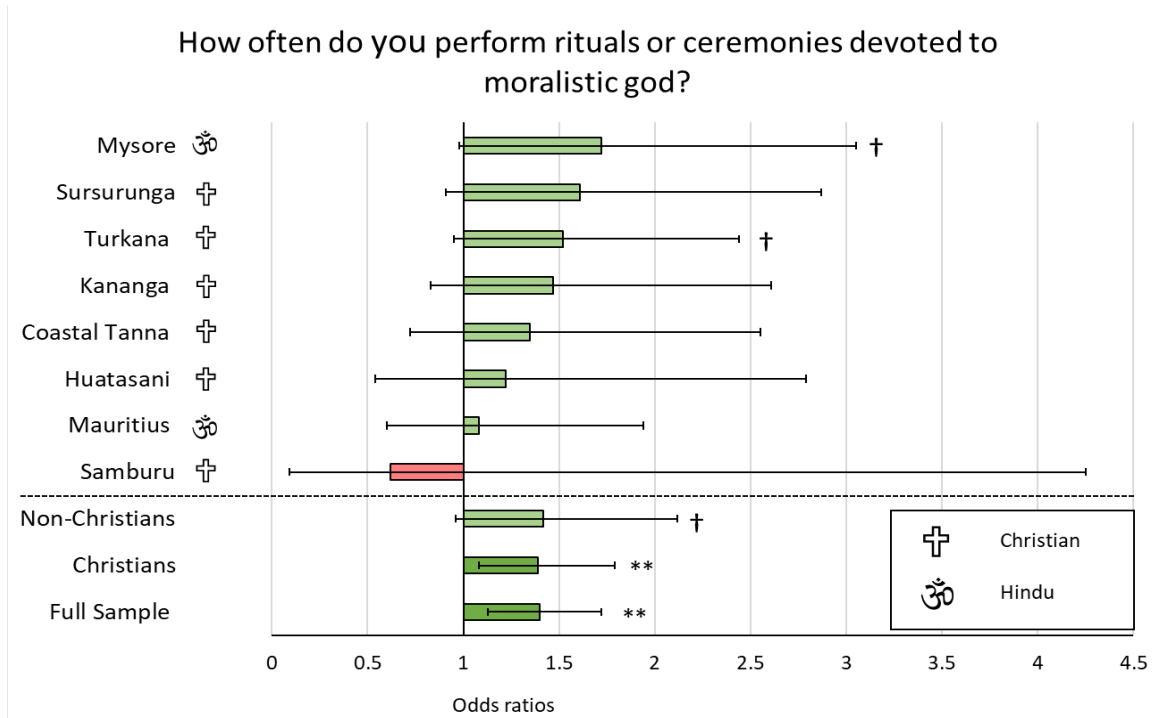
By contrast, while women from Christian, OR = 1.30, 95% CI = [0.97, 1.75], $p = 0.078$, and non-Christian sites, OR = 2.51, 95% CI = [1.45, 4.36], $p = 0.001$, indicated greater frequency of prayer than men, this effect was only significant at the 0.05 level in the non-Christian sites. Further, Table 13 shows that the gender gap in prayer was significantly moderated by site religion; that is, the effect of gender was stronger for our two Hindu sites than for the Christian sites who were sampled on this measure. Finally, while a marginally significant interaction effect suggests that the gender gap in appeasement of moralistic gods may have been stronger for Christian sites, we saw no consistent gender gap in this measure at either Christian, OR = 1.10, 95% CI [0.88, 1.38], $p = 0.10$, or non-Christian sites, OR = 0.81, 95% CI = [0.60, 1.09], $p = 0.158$.

When considering local god data, we found no evidence that Christian sites showed greater gender gaps than non-Christian sites in terms of belief, personal commitment, or appeasement of local gods. Further, while we found some evidence that the gender difference in frequency of ritual practices to local gods was moderated by site religion (Table 14), men and women did not significantly differ in this measure in either Christian, OR = 0.79, 95% CI = [0.57, 1.08], $p = 0.140$, or non-Christian sites, OR = 1.40, 95% CI = [0.92, 2.11], $p = 0.113$.

a

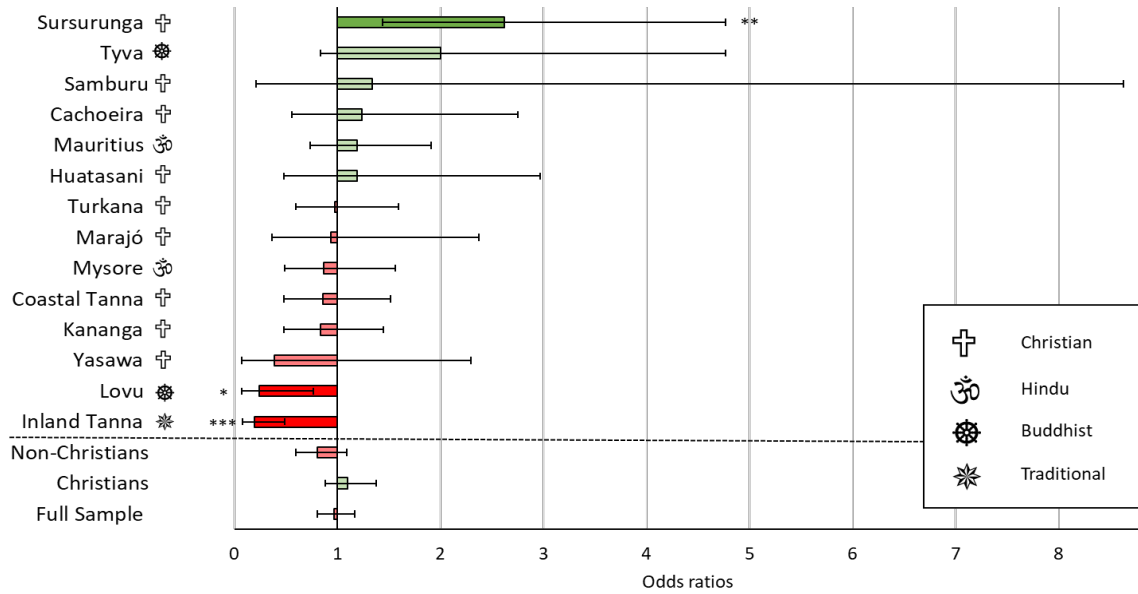


b



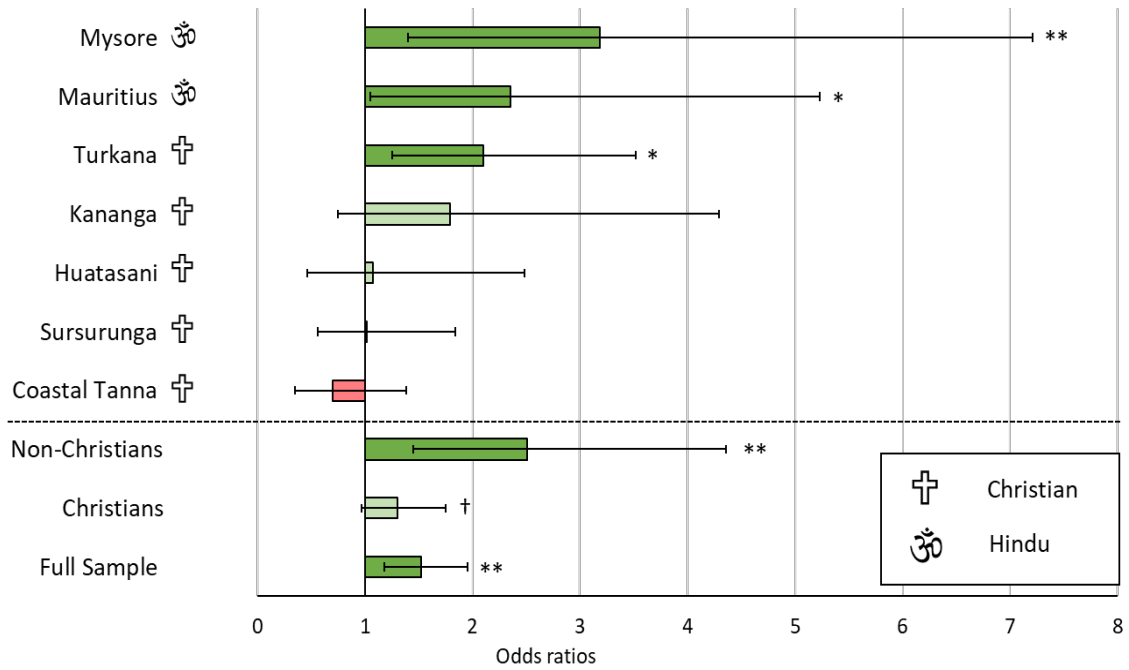
c

How often do you perform activities or practices to talk to, or appease moralistic god?

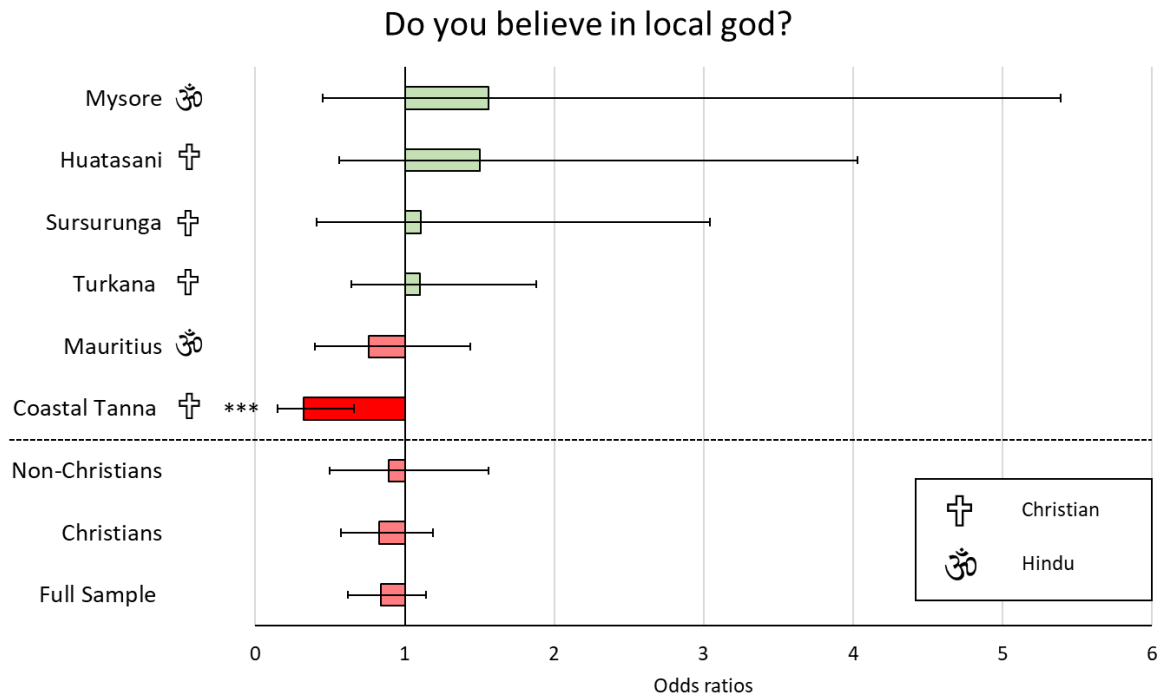


d

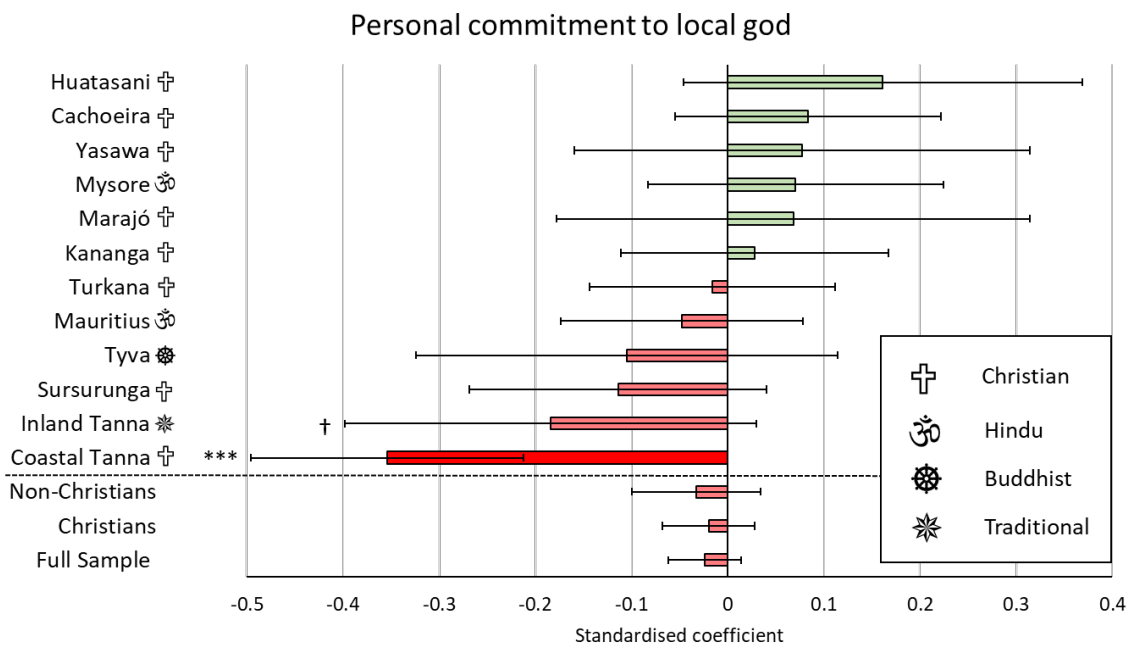
How often do you pray?



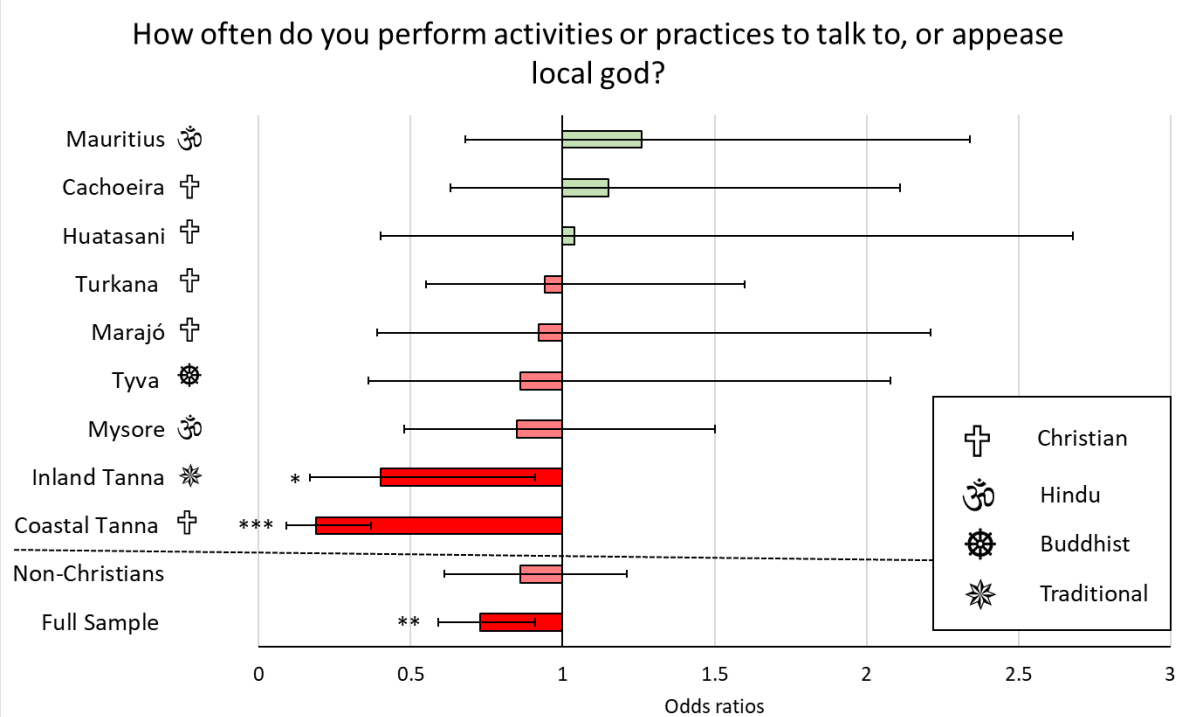
e



f



g



h

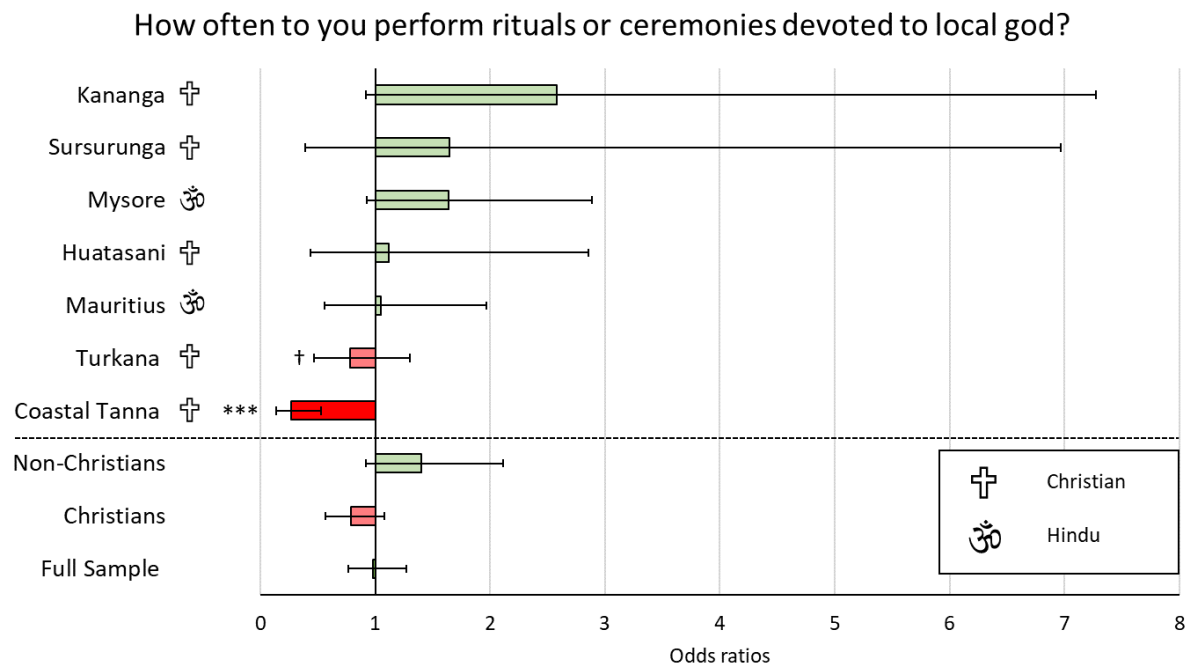


Figure 10. Coefficients of gender, predicting each measure of religiosity by site and across sites. Men were the reference category in each model: positive β -estimates and Odds ratios greater than one indicate greater female religiosity. All error bars represent 95% confidence intervals. Where number of sites was greater than two, models predicting religiosity across several groups (below dashed line) included a higher-level effect for site. † $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$. a.-c. Gender coefficients of religiosity towards moralistic god. d. Gender coefficients of frequency of prayer. The gender coefficients for the Samburu and Inland Tanna sites are not shown due to prayer being at ceiling and insufficient sample size ($n = 9$), respectively e.-h. Gender coefficients of religiosity towards local god. Kananga data are not presented in Fig 1e. as all participants at this site indicated a

lack of belief in their local deity. Kananga, Yasawa & Sursurunga data are not presented in Fig. 1h. as these models could not converge due to low variation, with observations clustered around zero. Similarly, group-level Christian data are not presented in Fig. 1h as this model could not converge due to low variation, with observations clustered around zero.

Table 13. Linear regression coefficients for the interaction between gender and whether one is from a Christian site or a site of another religion, predicting moralistic god religiosity and prayer.

	Personal commitment to Moralistic God <i>β-Est.</i>	Ritual practices to Moralistic God <i>OR</i>	Appeasement of Moralistic God <i>OR</i>	Prayer <i>OR</i>
Site religion	-0.39 [-0.60, -0.18]**	2.56 [0.57, 11.55]	0.19 [0.06, 0.61]**	0.88 [0.19, 4.12]
Gender	0.09 [0.04, 0.13]**	1.33 [1.05, 1.70]*	1.08 [0.87, 1.35]	1.28 [0.96, 1.71]†
Site religion x Gender	-0.06 [-0.12, 0.01]†	1.22 [0.75, 2.00]	0.72 [0.49, 1.06]†	2.13 [1.13, 3.99]*
N participants	1897	1178	1840	1162
N sites	14	9	14	9

Note: Men were the reference category in each model: positive β -estimates and Odds ratios greater than one indicate greater female religiosity. Models included a higher-level effect of participant site. Site religion reference was Christian. Numbers in square brackets indicate 95% confidence intervals. † $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

Table 14. Linear regression coefficients for the interaction between gender and whether one is from a Christian site or a site of another religion, predicting local god religiosity.

	Belief in Local God <i>OR.</i>	Personal commitment to Local God <i>β-Est.</i>	Ritual practices to Local God <i>OR</i>	Appeasement of Local God <i>OR</i>
Site religion	17.58 [0.27, 1146.19]	0.35 [-0.01, 0.70]†	6.30 [1.20, 33.04]*	5.79 [0.52, 63.89]
Gender	0.83 [0.57, 1.19]	-0.02 [-0.06, 0.03]	0.80 [0.59, 1.09]	0.67 [0.51, 0.89]**
Site religion x Gender	1.07 [0.55, 2.11]	-0.01 [-0.07, 0.05]	1.80 [1.07, 3.05]*	1.25 [0.80, 1.96]
N participants	1134	1763	1072	1718
N sites	8	12	8	12

Note: Men were the reference category in each model: positive β -estimates and Odds ratios greater than one indicate greater female religiosity. Models included a higher-level effect of participant site. Site religion reference was Christian. Numbers in square brackets indicate 95% confidence intervals. † $p < .10$. * $p < .05$. ** $p < .01$.

5.3.2 What explains the religious gender gap?

In the following section, we present the results of testing key hypotheses from the risk aversion, reproductive morality and structural location accounts of the religious gender gap. As we only sought to explain the gap where it existed across our sample, we tested predictions on three measures of religiosity: personal commitment and frequency of ritual practices to moralistic god, and frequency of prayer.

Risk aversion

H1-The perceived punitiveness of one's deity and/or belief that one's deity can influence life after death should be a better predictor of religiosity in women than men.

First, we tested whether women's greater religiosity might be attributable to their greater unwillingness to risk supernatural punishment for unbelief. Across both genders, our analyses indicated that belief in a more punitive moralistic god and belief that one's moralistic god can influence life after death were both associated with greater personal commitment and ritual participation towards this deity, but not greater prayer (see Table 15 & Table 16), providing some evidence for a link between the perceived risk of supernatural punishment and religiosity.

Testing whether the effect of risk of supernatural punishment on religiosity was stronger for women than men, we found that the relationship between moralistic god's perceived punitiveness and personal commitment and ritual frequency to this deity was significantly moderated by gender (Table 15). However, an investigation of the interaction effect contradicts this hypothesis, indicating that belief in a more punitive deity was a better predictor of religiosity in men than women. Figure 11 a & b indicates that men and women indicate similar levels of personal commitment and ritual participation when moralistic god is perceived to be high in punitiveness, but men indicate less religiosity than women on these measures when moralistic deity is perceived to be low in punitiveness. The results show no evidence that that the relationship between whether one believed that one's moralistic god can influence life after death and personal commitment and ritual frequency to this deity varied between men and women.

Table 15. Linear regression coefficients for the interaction between moralistic god punitiveness and gender, predicting religiosity.

	Personal commitment to Moralistic God <i>β-Est.</i>	Ritual practices to Moralistic God <i>OR</i>	Prayer <i>OR</i>
Moralistic God punitiveness	0.05[0.01, 0.09]***	2.01 [1.17, 3.46]*	0.84 [0.44, 1.59]
Gender	0.14 [0.06, 0.22]**	1.31 [1.06, 1.63]*	1.56 [1.21, 2.03]***
Moralistic God punitiveness x Gender	-0.07 [-0.12, -0.01]*	0.40 [0.19, 0.84]*	1.15 [0.47, 2.83]
N participants	1839	1142	1132
N sites	14	9	9

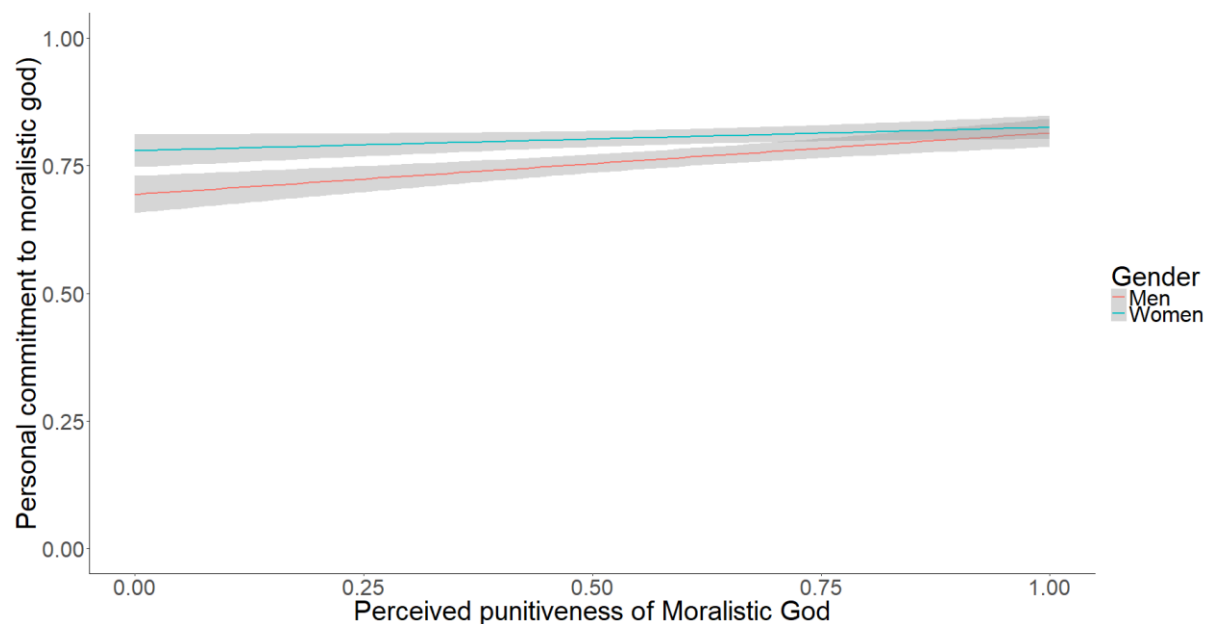
Note: Men were the reference category in each model: positive β -estimates and Odds ratios greater than one indicate greater female religiosity. Models included a higher-level effect of participant site. Moralistic God punitiveness was mean centred. Numbers in square brackets indicate 95% confidence intervals. * $p < .05$. ** $p < .01$. *** $p < .001$.

Table 16. Linear regression coefficients for the interaction between beliefs about moralistic god's ability to influence in life after death and gender, predicting religiosity.

	Personal commitment to Moralistic God <i>β-Est.</i>	Ritual practices to Moralistic God <i>OR</i>	Prayer <i>OR</i>
Moralistic God influences life after death	0.15 [0.09, 0.21]***	1.62 [1.07, 2.43]*	1.21 [0.73, 1.98]
Gender	0.11 [0.04, 0.18]**	1.77 [1.10, 2.84]*	1.78 [0.98, 3.22]†
Moralistic God influences life after death x Gender	-0.06 [-0.15, 0.02]	0.73 [0.43, 1.25]	0.85 [0.44, 1.65]
N participants	1840	1152	1137
N sites	14	9	9

Note: Men were the reference category in each model: positive β -estimates and Odds ratios greater than one indicate greater female religiosity. Models included a higher-level effect of participant site. Numbers in square brackets indicate 95% confidence intervals. † $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

a



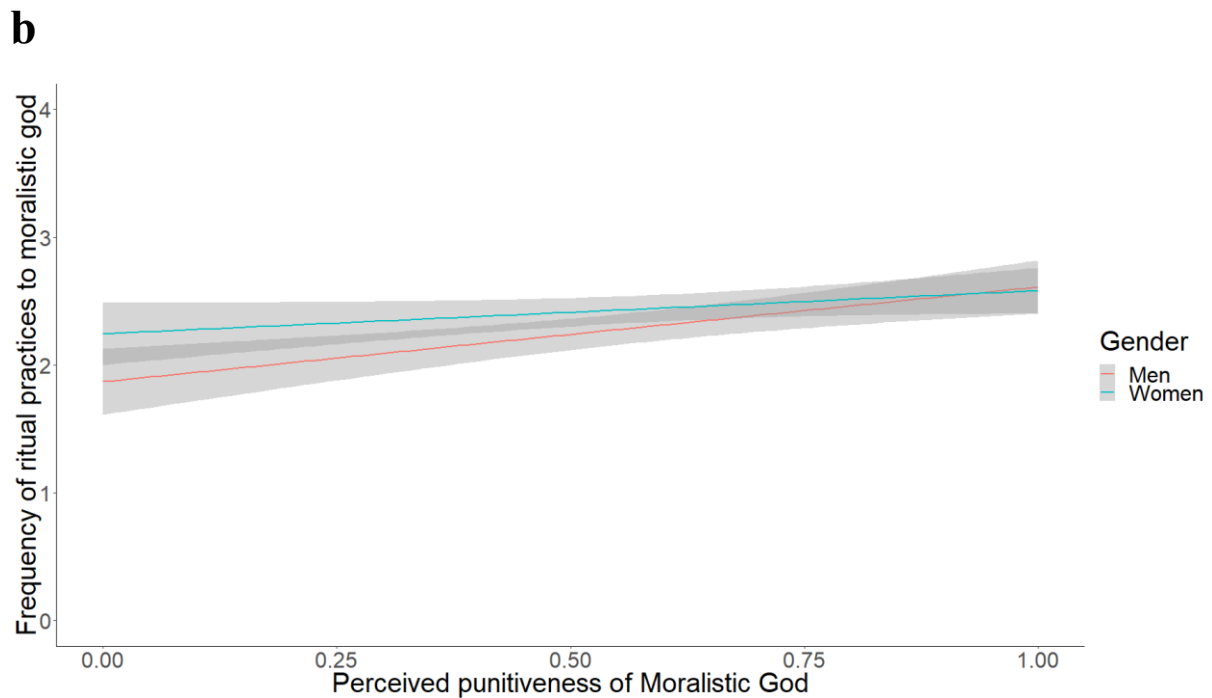


Figure 11. Perceived punitiveness of one’s moralistic deity better predict religiosity in men than in women. a & b) Regression lines indicate conditional means with linear smoothing. Shaded areas represent 95% confidence intervals of the mean.

H2- To the extent that greater average religiosity in a community indicates a stronger social norm of religiosity, this account predicts that the average religiosity of one’s community should be a better predictor of religiosity in women than men.

We tested whether women’s greater religiosity might be attributed to their reduced willingness to risk social punishment for not believing in one’s society’s moralistic god. Contrary to this prediction, Table 17 indicates that the effect of average site religiosity on individual religiosity on all three measures was not moderated by gender.

Table 17. Linear regression coefficients for the interaction between average site religiosity and gender, predicting individual religiosity.

	Personal commitment to Moralistic God <i>β-Est.</i>	Ritual practices to Moralistic God <i>OR</i>	Prayer <i>OR</i>
Site religiosity	0.48 [0.42, 0.55]***	2.55 [2.17, 3.00]***	1.92 [1.44, 2.56]***
Gender	0.06 [0.02, 0.10]**	1.40 [1.13, 1.73]**	1.61 [1.23, 2.10]***
Site religiosity x Gender	0.04 [-0.03, 0.10]	1.06 [0.86, 1.29]	1.18 [0.89, 1.58]
N participants	1897	1169	1153
N sites	14	8	8

Note: Men were the reference category in each model: positive β -estimates and Odds ratios greater than one indicate greater female religiosity. Models included a higher-level effect of participant site. Site religiosity for each measure was mean centred and scaled. Numbers in square brackets indicate 95% confidence intervals. ** $p < .01$. *** $p < .001$.

Reproductive strategy

H3 - Women will report greater religiosity towards their moralistic god than men. As prior work has suggested that local gods are less concerned with morality (Purzycki et al., 2016b), gender differences are likely to be smaller or non-existent for local gods.

Consistent with this hypothesis the results of our quantification of the gender gap indicated that women reported greater religiosity than men on measures of prayer as well as personal commitment and frequency of ritual practices to moralistic god across all sites. Further, we found no evidence that women indicated greater religiosity towards local gods across sites on any measure (See Figure 10 e-h).

H4- Married men should be relatively more religious than unmarried men, whereas marital status should have less of an effect on female religiosity.

The results of our regressions shown in Table 18 indicate that single people were less personally committed to their moralistic god and engaged in less frequent prayer than married people. However single people did not report less frequent ritual practices to moralistic god than married people. Our models provided no evidence that marital status had a stronger effect on religiosity for men than women. Interestingly, our models indicated that divorced people

reported less personal commitment to moralistic gods than married people, and that men drove this effect.

Table 18. Linear regression coefficients for the interaction between marital status and gender, predicting religiosity.

	Personal commitment to Moralistic God <i>β-Est.</i>	Ritual practices to Moralistic God <i>OR</i>	Prayer <i>OR</i>
Gender	0.03 [-0.02, 0.09]	1.43 [1.09, 1.88]*	1.39 [1.00, 1.95]†
Single	-0.09 [-0.15, -0.03]**	0.78 [0.55, 1.10]	0.61 [0.41, 0.90]*
Engaged	0.02 [-0.05, 0.09]	0.51 [0.11, 2.36]	1.26 [0.13, 12.50]
Divorced	-0.10 [-0.18, -0.02]*	0.44 [0.13, 1.54]	0.32 [0.07, 1.41]
Widowed	-0.01 [-0.12, 0.11]	2.02 [0.56, 7.35]	1.06 [0.19, 6.00]
Other	-0.01 [-0.08, 0.06]	0.99 [0.39, 2.54]	0.52 [0.16, 1.69]
Single x Gender	0.04 [-0.02, 0.10]	1.10 [0.66, 1.83]	1.11 [0.61, 2.00]
Engaged x Gender	-0.03 [-0.10, 0.04]	0.67 [0.10, 4.35]	0.31 [0.02, 3.83]
Divorced x Gender	0.10 [0.02, 0.18]*	1.07 [0.25, 4.63]	2.91 [0.48, 17.54]
Widowed x Gender	-0.00 [-0.12, 0.12]	0.39 [0.10, 1.56]	1.08 [0.17, 6.92]
Other x Gender	-0.03 [-0.09, 0.04]	0.56 [0.19, 1.65]	0.59 [0.16, 2.16]
N participants	1880	1178	1162
N sites	14	9	9

Note: Men were the reference category in each model: positive β -estimates and Odds ratios greater than one indicate greater female religiosity. Reference category for marital status was Married. Models included a higher-level effect of participant site. Numbers in square brackets indicate 95% confidence intervals. † $p < .10$. * $p < .05$. ** $p < .01$.

H5- To the extent that high status men are more competitive in obtaining multiple mates than low status men, high status men will be less religious than low status men, and women.

When considering annual income, we found no evidence that having more income relative to others in one's society predicted lower religiosity on any measure, nor that this effect was moderated by gender (Table 19). The results shown in Table 20 indicate that years of formal education predicted lower rates of prayer, personal commitment, and marginally less frequent ritual practices to moralistic god among both men and women. Contrary to this hypothesis, a marginally significant interaction between formal education and gender on personal commitment to moralistic god provides tentative evidence that years of formal education correlated was a better predictor of reduced religiosity for men than women on this measure. No significant interaction of gender and formal education was found with the other measures of religiosity.

Table 19. Linear regression coefficients for the interaction between income relative to others at each site and gender, predicting religiosity.

	Personal commitment to Moralistic God <i>β-Est.</i>	Ritual practices to Moralistic God <i>OR</i>	Prayer <i>OR</i>
Total annual income	0.07 [-0.03, 0.16]	0.99 [0.85, 1.14]	0.95 [0.80, 1.12]
Gender	0.08 [0.02, 0.14]**	1.46[1.12, 1.90]**	1.35 [0.98, 1.85]†
Total annual income x Gender	-0.05 [-0.14, 0.04]	1.06 [0.88, 1.28]	1.14 [0.91, 1.43]
N	1056	769	767
N Sites	8	6	6

Note: Men were the reference category in each model: positive β -estimates and Odds ratios greater than one indicate greater female religiosity. Total annual income was coded as quintiles of income within each site; it was then mean centred. Models included a higher-level effect of participant site. Numbers in square brackets indicate 95% confidence intervals. † $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$

Table 20. Linear regression coefficients for the interaction between years of formal education and gender, predicting religiosity.

	Personal commitment to Moralistic God <i>β-Est.</i>	Ritual practices to Moralistic God <i>OR</i>	Prayer <i>OR</i>
Formal education	-0.14 [-0.22, -0.07]***	0.97 [0.93, 1.00]†	0.95 [0.91, 0.99]*
Gender	0.05 [0.01, 0.09]*	1.33 [1.08, 1.65]**	1.46 [1.13, 2.12]**
Formal education x Gender	0.05 [-0.01, 0.11]†	1.00 [0.96, 1.04]	1.01 [0.96, 1.06]
N	1866	1172	1156
N Sites	14	9	9

Note: Men were the reference category in each model: positive β -estimates and Odds ratios greater than one indicate greater female religiosity. Models included a higher-level effect of participant site. Years of formal education was mean centred. Numbers in square brackets indicate 95% confidence intervals. † $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

H6 – Groups with higher single male to female ratios in the population might restrict opportunities for men to acquire multiple mates and should therefore show smaller religious gender gaps.

Table 21 indicates that a higher male to female birth-rate was associated with generally lower personal commitment and ritual participation to moralistic god, but not lower prayer. However, we find no evidence that societies with higher relative male to female birth-rates showed smaller religious gender gaps in these measures.

Table 21. Linear regression coefficients for the interaction between country-level sex birth-rates rates and gender, predicting religiosity.

	Personal commitment to Moralistic God <i>β-Est.</i>	Ritual practices to Moralistic God <i>OR</i>	Prayer <i>OR</i>
Ratio of male to female births	-0.22 [-0.28, -0.16]***	0.88 [0.77, 0.99]*	0.92 [0.80, 1.05]
Gender	0.07 [0.03, 0.12]**	1.21 [0.99, 1.49]†	1.44 [1.12, 1.84]**
Ratio of male to female births X Gender	-0.02 [-0.09, 0.04]	1.05 [0.88, 1.25]	0.89 [0.74, 1.09]
N sites	14	8	7

Note: Men were the reference category in each model: positive β -estimates and Odds ratios greater than one indicate greater female religiosity. Ratio of male to female births was mean-centred and scaled. Numbers in square brackets indicate 95% confidence intervals. Ratio of male to female births was centred at its mean. Inland Tanna omitted from models predicting ritual practices and prayer due to low n (n=9). Samburu omitted from model predicting prayer due to lack of variation. † $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

Structural location

H7- Gender differences in workforce participation should mediate the relationship between gender and religiosity.

Analysis of the indirect path of gender on religiosity via workforce participation indicated that women were currently engaged in less frequent wage labour, $\beta = -0.14$, 95% CI = [-0.18, -0.10], $p < 0.001$. However, contrary to this hypothesis, more frequent participation in wage labour did not predict a decrease in personal commitment, $\beta = 0.02$, 95% CI = [-0.03, 0.08], $p = 0.441$, ritual practices to moralistic god, OR = 1.01, 95% CI = [0.99, 1.02], $p = 0.289$, or prayer, OR = 1.00, 95% CI = [0.99, 1.02], $p = 0.645$, controlling for gender.

H8- Cultures with a higher share of women in paid employment should show smaller gender gaps.

The results in Table 22 indicate that sites situated in countries with higher rates of female labour force participation indicated greater personal commitment to moralistic god, but not ritual participation or prayer. Consistent with this prediction, a significant interaction effect suggests that sites situated in countries with higher female participation in wage labour showed smaller

gender gaps in prayer (See Figure 12). However, this effect was not found in the other religiosity measures.

Table 22. Linear regression coefficients for the interaction between country-level female labour force participation rates and gender, predicting religiosity.

	Personal commitment to Moralistic God <i>β-Est.</i>	Ritual practices to Moralistic God <i>OR</i>	Prayer <i>OR</i>
Female labour force participation rate	0.29 [0.23, 0.35]***	0.99 [0.86, 1.13]	0.98 [0.84, 1.15]
Gender	0.07 [0.02, 0.11]**	1.27 [1.03, 1.56]*	1.57 [1.22, 2.02]***
Female labour force participation rate X Gender	0.03 [-0.03, 0.09]	0.93 [0.76, 1.13]	0.75 [0.59, 0.96]*
N sites	14	8	7

Note: Men were the reference category in each model: positive β -estimates and Odds ratios greater than one indicate greater female religiosity. Numbers in square brackets indicate 95% confidence intervals. Female labour force participant rate was centred at its mean and scaled. Inland Tanna omitted from models predicting ritual participation and prayer due to low n (n=9). Samburu omitted from model predicting prayer due to lack of variation. * $p < .05$. ** $p < .01$. *** $p < .001$.

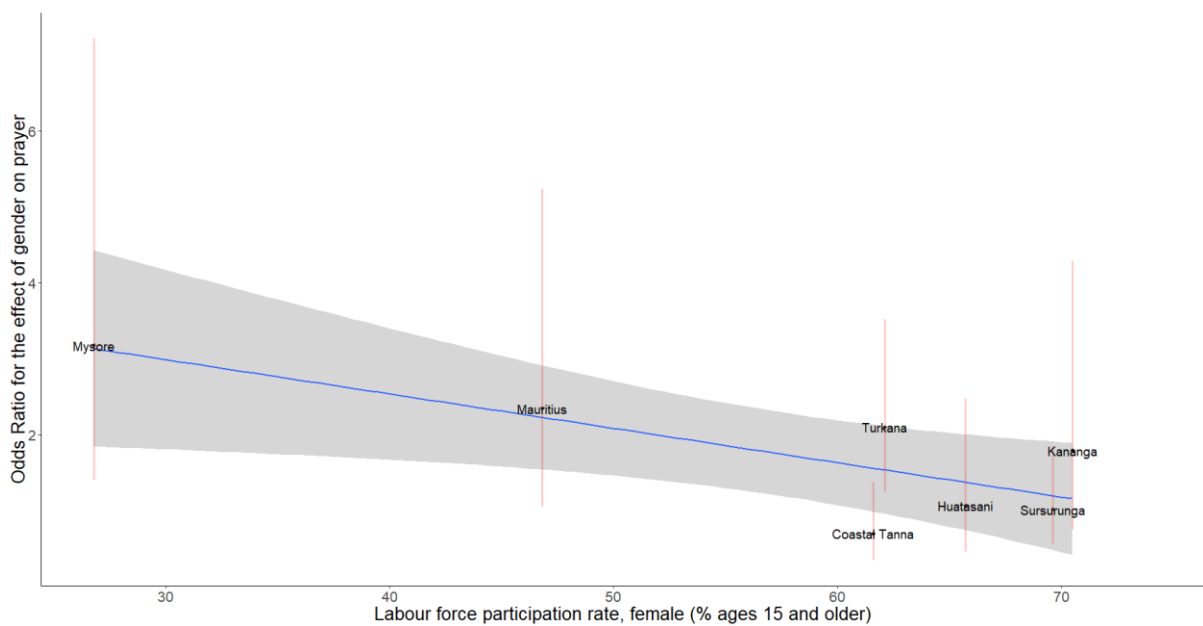


Figure 12. Country-level female labour force participation rates negatively correlate with the gender gap in prayer. Data points indicate site-level odds ratios for the effect of gender on prayer; error bars represent 95% confidence intervals for each coefficient. Regression line indicates smoothed conditional means with linear smoothing. Shaded area represents 95% confidence interval of the mean

Social networks and support

H9- Women should report greater frequency of ritual practices towards moralistic gods. To the extent that participation in rituals drives belief, ritual participation measures should mediate the effect of gender on personal religious commitment.

The results of our quantification of the religious gender gap indicated that women reported greater frequency of ritual practices to moralistic gods than men. Controlling for gender and site as fixed and random effects respectively, ritual participation, $\beta = 0.33$, 95% CI = [0.28, 0.39], $p < 0.001$, and prayer were associated with greater personal commitment to moralistic god, $\beta = 0.26$, 95% CI = [0.21, 0.31], $p < 0.001$. Consistent with this hypothesis, the average causal mediation effects shown in Table 23 indicate that ritual practices to moralistic god and prayer partially mediated the gender gap in personal commitment to moralistic god.

Table 23. Results of a mediation analysis, testing whether the gender gap in personal commitment to moralistic god is mediated by ritual participation to moralistic god, or prayer.

	Mediator	
	Ritual practices	Prayer
ACME	0.01 [0.00, 0.02]**	0.01 [0.01, 0.02]***
ADE	0.03 [0.01, 0.06]**	0.03 [0.00, 0.05]*
Total Effect	0.05 [0.02, 0.07]***	0.04 [0.02, 0.07]***
Prop. Mediated	0.28 [0.11, 0.58]**	0.35 [0.17, 0.86]***

Note: Numbers in square brackets indicate quasi-Bayesian Monte Carlo confidence intervals with 5000 bootstrap resamples. ACME, average causal mediation effect; ADE, average direct effect; prop., proportion. Mediation models included a higher-level effect of participant site. * $p < .05$. ** $p < .01$. *** $p < .001$.

H10- To the extent that women are motivated to seek child-rearing resources provided by religious institutions, greater need for child-rearing support should moderate the gender gap.

Table 24 shows the results of a model testing whether women's greater need for child-rearing support, as measured by number of children, moderates the religious gender gap. The results indicate that having more children did not predict greater religiosity in women, across any measure. Further, a non-significant three-way interaction between gender, age and number of

children provide no evidence that this effect was stronger for younger women with more children.

Table 24. Linear regression coefficients testing for a three-way interaction between gender, age and number of children, predicting religiosity.

	Personal commitment to Moralistic God <i>β-Est.</i>	Ritual practices to Moralistic God <i>OR</i>	Prayer <i>OR</i>
Children	0.04 [-0.05, 0.13]	1.03 [0.96, 1.11]	0.95 [0.87, 1.04]
Age	0.10 [0.02, 0.18]*	1.01 [0.99, 1.02]	1.02 [1.01, 1.04]**
Gender	0.07 [0.02, 0.11]**	1.36 [1.06, 1.75]*	1.59 [1.16, 2.17]**
Gender x Children	-0.01 [-0.09, 0.07]	0.98 [0.89, 1.08]	0.98 [0.87, 1.10]
Gender x Age	-0.03 [-0.11, 0.05]	1.00 [0.98, 1.02]	1.00 [0.98, 1.03]
Children x Age	-0.05 [-0.11, 0.02]	1.00 [1.00, 1.00]	1.00 [1.00, 1.00]
Gender x Children x Age	-0.02 [-0.08, 0.04]	1.00 [1.00, 1.00]	1.00 [0.99, 1.00]
N	1861	1170	1155
N sites	14	9	9

Note: Men were the reference category in each model: positive β -estimates and Odds ratios greater than one indicate greater female religiosity. Models included a higher-level effect of participant site. Number of children and age were centred at their means. Numbers in square brackets indicate 95% confidence intervals. * $p < .05$. ** $p < .01$.

H11- Gender differences in time spent socialising at market should mediate the relationship between gender and religiosity.

Controlling for site as a random effect, men and women did not report going to market at different rates, $\beta = -0.05$, 95% CI = [-0.13, 0.03], $p = 0.223$. Further, controlling for gender, greater frequency of visits to market was not associated with lower personal commitment, $\beta = -0.00$, 95% CI = [-0.09, 0.09], $p = 0.997$, frequency of ritual practices towards moralistic god, OR = 1.02, 95% CI = [0.99, 1.06], $p = 0.202$, or prayer, OR = 1.02, 95% CI = [0.98, 1.06], $p = 0.434$. As such, gender differences in frequency of attendance at market did not mediate the religious gender gap in our sample.

Secularisation

H12- Women are less exposed to secularizing forces via formal education. As a result, years of formal education should predict less religiosity in both men and women. Gender differences

in exposure to formal education should mediate the relationship between gender and religiosity. This effect should not be moderated by need for social resources, material security or specific beliefs about the nature of moralistic or local gods.

Figure 13 shows the coefficients for each path of a mediation model testing whether gender differences in years of formal education explain the gender gap. The results of the indirect paths show that: a) women across our sample reported lower levels of formal education than men and that, b) controlling for gender, more years of formal education predicted lower personal commitment, frequency of rituals to moralistic god, and prayer, partially explaining women’s greater religiosity than men in each measure. Mediation analyses indicate that gender differences in education significantly mediated the religious gender gap, in personal commitment, ACME = 0.00, 95% CI = [0.00, 0.01], $p < 0.001$, ritual participation to moralistic god, ACME = 0.03, 95% CI = [0.00, 0.05], $p = 0.014$, and prayer, ACME = 0.02, 95% CI = [0.01, 0.04], $p = 0.008$.

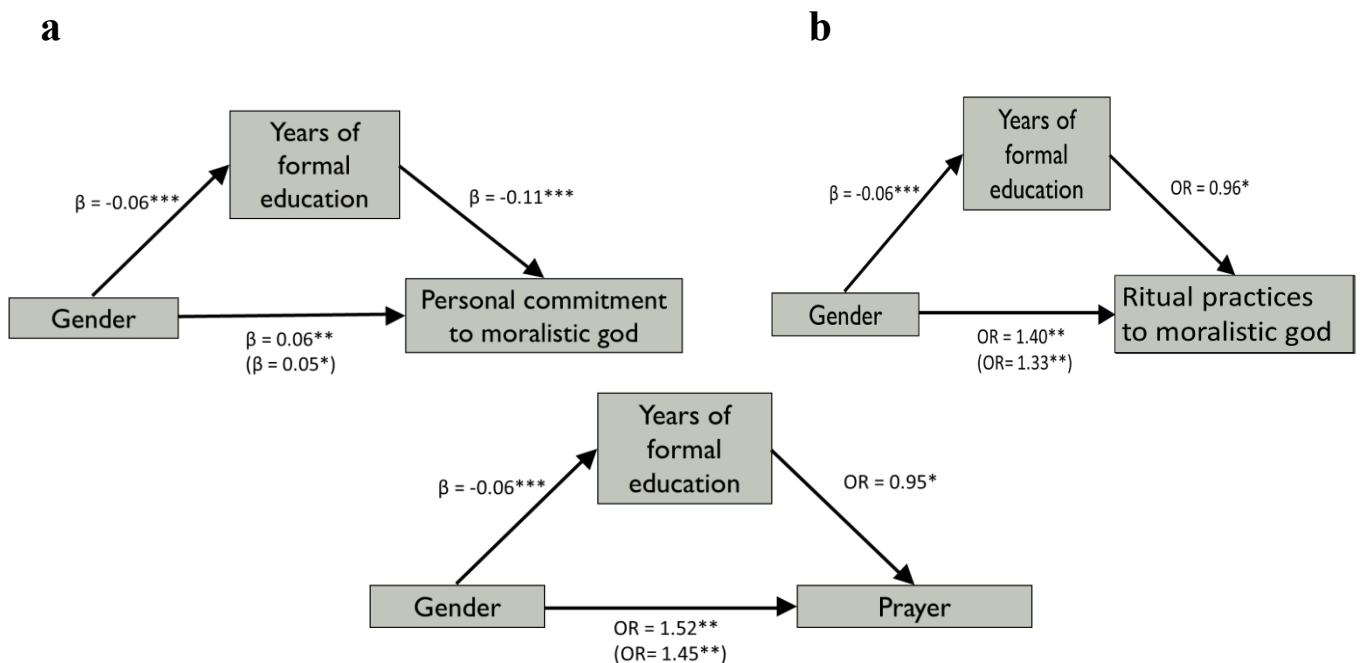


Figure 13. a-c) Years of formal education partially mediates the gender gap in commitment and ritual practices towards moralistic god, and prayer. Men were the reference category in each model: positive β -estimates and Odds ratios greater than one indicate greater female religiosity. Models predicting religiosity from years of formal education additionally controlled for gender. Numbers in parentheses indicate the gender coefficients predicting religiosity when education was included as a covariate. * $p < .05$. ** $p < .01$. *** $p < .001$.

Existential anxiety

H13- To the extent that moralistic gods are perceived to be more benevolent, and more likely to be able to influence life after death, women should indicate greater religiosity towards moralistic gods, but not local gods. The effect of gender on religiosity should be greatest among women who believe in a rewarding god, and a god that can influence life after death.

Consistent with the first part of this hypothesis, the quantification of the religious gender gap showed that women indicated greater religiosity than men to moralistic gods, but not to local gods (See Figure 10 a-h). However, the test of the Risk aversion account indicated that the size of the gender gaps in personal commitment and ritual participation to moralistic god, as well as prayer, were not moderated by whether one believed moralistic god could influence life after death (See Table 16). Further, the results shown in Table 25 fail to support this hypothesis, indicating that while belief in a more rewarding moralistic deity was associated with greater religiosity across all three of these measures, this effect was not stronger for women than men.

Table 25. Linear regression coefficients for the interaction between beliefs about how rewarding moralistic god is and gender, predicting religiosity.

	Personal commitment to Moralistic God <i>β-Est.</i>	Ritual practices to Moralistic God <i>OR</i>	Prayer <i>OR</i>
Moralistic God rewarding	0.24 [0.18, 0.30]***	1.37 [1.16, 1.62]***	1.23 [1.02, 1.49]*
Gender	0.05 [0.01, 0.09]*	1.30 [1.04, 1.61]*	1.45 [1.11, 1.89]**
Moralistic God rewarding x Gender	-0.02 [-0.08, 0.03]	0.91 [0.73, 1.13]	0.91 [0.70, 1.18]
N participants	1846	1162	1147
N sites	14	9	9

Note: Men were the reference category in each model: positive β -estimates and Odds ratios greater than one indicate greater female religiosity. Models included a higher-level effect of participant site. Numbers in square brackets indicate 95% confidence intervals. Moralistic god rewarding was centred at its mean. * $p < .05$. ** $p < .01$. *** $p < .001$.

H14- In societies with higher levels of economic insecurity the gender gap in moralistic god religiosity should be greater

The results in Table 26 indicate that a higher GDPPC at the country level was associated with a smaller gender gap in prayer, though this effect was small and only significant at the 0.1 level.

Table 26. Linear regression coefficients for the interaction between country-level GDP per capita and gender, predicting religiosity.

	Personal commitment to Moralistic God <i>β-Est.</i>	Ritual practices to Moralistic God <i>OR</i>	Prayer <i>OR</i>
GDPPC	-0.15 [-0.22, -0.08]***	0.89 [0.74, 1.07]	0.96 [0.78, 1.18]
Gender	0.09 [0.04, 0.13]***	1.10 [0.87, 1.40]	1.48 [1.12, 1.96]**
GDPPC X Gender	0.01 [-0.05, 0.08]	0.80 [0.62, 1.03]†	1.05 [0.78, 1.41]
N	1897	1178	1162
N sites	14	9	9

Note: Men were the reference category in each model: positive β -estimates and Odds ratios greater than one indicate greater female religiosity. Numbers in square brackets indicate 95% confidence intervals. GDPPC was centred at its mean and scaled. † $p < .10$. ** $p < .01$. *** $p < .001$.

H15- In societies with higher levels of gender inequality, there should be larger gender gaps in moralistic god religiosity.

The results shown in Table 27 indicate that a higher level of gender inequality at the country level was associated with a larger gender gap in ritual participation to moralistic god, though this effect was only significant at the 0.1 level.

Table 27. Linear regression coefficients for the interaction between country-level gender inequality and gender, predicting religiosity.

	Personal commitment to Moralistic God <i>β-Est.</i>	Ritual practices to Moralistic God <i>OR</i>	Prayer <i>OR</i>
Gender inequality	0.21 [0.13, 0.28]***	1.46 [1.22, 1.76]***	1.24 [0.99, 1.54]†
Gender	0.11 [0.06, 0.16]***	1.03 [0.79, 1.34]	1.55 [1.13, 2.11]**
Gender inequality X Gender	0.04 [-0.03, 0.12]	1.28 [0.98, 1.66]†	1.06 [0.78, 1.44]
N	1645	1042	1026
N sites	12	7	7

Note: Men were the reference category in each model: positive β -estimates and Odds ratios greater than one indicate greater female religiosity. Numbers in square brackets indicate 95% confidence intervals. † $p < .10$. ** $p < .01$. *** $p < .001$. Gender inequality was centred at its mean and scaled.

H16- Women are more religious because they disproportionately benefit from religions' ability to allay existential anxieties. Under this scenario, women should report greater perceived food insecurity, which should in turn predict greater moralistic god religiosity. As such, perceived food insecurity is expected to mediate the relationship between gender and religiosity.

Consistent with this hypothesis, controlling for site as a random effect, women indicated higher levels of material insecurity than men, $\beta = 0.04$, 95% CI = [0.01, 0.07], $p = 0.021$. However, controlling for gender, our models found no evidence that material insecurity was positively associated with greater personal commitment, $\beta = 0.03$, 95% CI = [-0.02, 0.08], $p = 0.324$, ritual participation towards moralistic god, OR = 0.97, 95% CI = [0.90, 1.05], $p = 0.441$, or prayer, OR = 0.96, 95% CI = [0.88, 1.05], $p = 0.409$.

5.4. Discussion

Across our sample of 14 diverse societies, women indicated greater personal commitment and frequency of ritual practices to their society's moralistic god than men, as well as more frequent prayer. The general patterns we observe in our data are consistent with proposals that the religious gender gap may extend beyond measures of personal religious commitment to participation in religious rituals (e.g. Argyle & Beit-Hallahmi, 1975; Hackett et al., 2016). While these trends appear more robust across the Christian sites, women also reported significantly greater religiosity to their moralistic god on some measures in some Hindu sites with non-significant trends also occurring in one Buddhist site. Extending on prior work with data from both small-scale and larger-scale societies, these results provide further support for the existence of a religious gender gap towards moralistic deities. Cultural context appears to play an important role, with considerable variation across sites in the size of gender differences in any one religiosity measure. However, the general tendency we observe is not a uniquely Christian or even Abrahamic phenomenon.

When considering commitment to local gods, we find no evidence that women reported greater religiosity on any measure. Instead, the size and direction of the religious gender gap varied significantly between sites, with some sites showing significantly greater male religiosity to

local gods. The reasons why we see gender differences in moralistic god religiosity but not in local god religiosity are unclear. One explanation could be that specific beliefs about and practices to moralistic gods differ systematically from those of local gods. While moralistic gods are by definition concerned with morality, local gods as a category of deity may not be so specifically defined. Indeed, results from a subset of our field sites suggest that people consistently report morality and virtue as key concerns for moralistic gods, but do so less consistently for local gods, in most sites (Purzycki et al., 2016b, 2018). Therefore, to the extent that specific beliefs and practices have consequences for the size and direction of the gender gap, between-site variation in beliefs about and practices to local gods might explain why we do not see a consistent gender gap in religiosity to these deities.

Testing explanations for the gender gap, our results provided some support for the structural location account but failed to support either the risk aversion or reproductive morality account. First, we found that gender differences in years of formal education partially mediated the gender gap in personal commitment and ritual participation to moralistic god, as well as frequency of prayer. One interpretation is that women's reduced access to formal education across our sites has meant that they have been less exposed to secular ideas and values through the education system and therefore lag behind men in giving up religion (Berger, 1967; Trzebiatowska & Bruce, 2012). An alternative explanation could be that formal education may affect other aspects of structural location in ways that reduce religiosity. For example, formal education may lead to better paid jobs: a) reducing time for religious participation, b) limiting economic insecurities that would otherwise be alleviated by religion (Norris & Inglehart, 2008), and c) allowing women to prioritise a career over domestic duty, potentially reducing the need for social networking and child-care resources provided by religion (Martin, 1967). However, the fact that we find no significant moderation effect of workforce participation, food

insecurity, or number of children on the gender gap somewhat counts against these alternate explanations.

Second, our results suggested that belief in a less punitive deity was associated with reduced personal commitment and ritual participation to moralistic gods in men but not women, with the greatest gender gap occurring when god was perceived to be less punitive. This finding contradicts the hypothesis that belief in a more punitive deity should predict increased female but not male religiosity due to females' greater risk aversion than men. Importantly, we note that this result may not in fact contradict the risk aversion account itself. It is possible, for example, that while men indicate greater religiosity as the threat of supernatural punishment increases, women may: a) exhibit greater sensitivity to even very small threats of supernatural punishment, and b) be more sensitive to social risks of irreligiosity than they are to supernatural threats.

Finally, in a test of the reproductive morality account, our results indicated that the gender gap in religiosity was not significantly larger for single versus married people. Further, we found little evidence that the gender gap was driven by more wealthy men at each site, or years of formal education. As such, powerful, less religious men pursuing short-term mating strategies did not appear to be significant drivers of the gender gap in our sample. We note that these findings also fail to lend support to the reverse prediction- that high-status males will be the most religious because they seek to acquire long-term mates and wish to avoid cuckoldry. Nonetheless, marital status may not accurately track reproductive strategies. While men might be more likely than women to be pursuing low-commitment strategies, some men could be adulterous, while others could be single and pursuing high-commitment relationships, skewing our results. Future testing of the reproductive morality account should seek to utilise more explicit measures of reproductive strategies behaviour and test their association with religiosity in men and women.

We note several general limitations to these findings. First, our measure of personal commitment to moralistic gods exhibited low variation at some sites, with maximum commitment being the mode across all sites. This may partly be a consequence of a reliance on three or four-point likert scales, restricting variation around each level of this variable. Other measurements of religiosity in future may help to improve estimates of the gender gap and religiosity more generally. Second, despite sampling from a diverse array of cultures practicing various religious traditions, most of our sites were Christian. Future research should seek to explore how widespread gender differences in religiosity are by including data from yet more sites with different religious traditions.

Overall, our results show that across 14 diverse societies women generally reported greater religiosity than men towards their culture's moralistic god on measures of personal commitment and ritual participation, as well as frequency of prayer. Further, we provide some of the first evidence that the religious gender gap appears limited to moralistic deities; local god religiosity shows no consistent gender gap, and in some sites, men may in fact indicate greater religiosity towards these deities. The results of our explanatory analyses failed to fully account for women's greater religiosity across all sites, showing little support for a risk aversion or reproductive morality account. Nonetheless, gender differences in formal education partially mediated the gender gap on all three measures where a significant difference was detected, providing tentative evidence that gender differences in religiosity may partly be a product of women's and men's different structural location within society. As women's access to education increases to a similar level to men, we may therefore expect to see a narrowing, but not total negation, of the religious gender gap.

Chapter 6. **Concluding remarks**

In conducting the four studies presented here, this thesis aimed to test several theories about the adaptive function of religion in a non-WEIRD cultural setting. The hypotheses tested in this thesis might loosely be grouped into two partly overlapping categories of explanation: religion as a facilitator of cooperation, and religion as a facilitator of psychological adjustment and wellbeing. In what follows, this chapter will summarise and discuss the main findings of each experiment within the relevant category of explanation, offer directions for future work and some conclusions that can be drawn.

6.1. Religion as a facilitator of cooperation: Summary and discussion of the findings

Chapter 2 tested key predictions of the Supernatural Punishment Hypothesis in a sample of Christian and indigenous religious Kastom participants in Vanuatu. Whilst punishment beliefs were associated with a greater likelihood of giving equal or higher offers to outgroup members, this did not apply to co-religionists. This runs counter to the prediction, common among Cultural Group Selection accounts of religious prosociality (Norenzayan, 2013; Norenzayan et al., 2016), that belief in an increasingly punitive deity should motivate cooperation towards coreligionists in particular, due to the benefits conferred to the ingroup. Further, exposure to religious primes had no consistent effect on monetary allocations, either to coreligionists or outgroup members.

One unknown identified in Chapter 1 was whether and how religion might affect decisions around prosocial giving when cooperative relationships are likely to be increasingly strained, such as after a natural disaster. Chapter 3 utilised a within-subjects pre-post design with differentially-affected individuals to evaluate the effects of a major natural disaster on prosocial giving after a major cyclone in Tanna, Vanuatu. Following the disaster, participants were

generally less likely to show prosocial motives towards both religious ingroup and outgroup members, and more likely to show parochialism when sharing between groups. Experiencing greater property damage predicted a general decrease in prosocial offers and a preference for the religious ingroup over the outgroup. By contrast, exposure to others in distress predicted reduced offers to the self, with increased offers to both the religious ingroup and outgroup. These results not only suggest that people appear to adjust their prosocial behaviour in response to natural disasters, but also that the nature and direction of the effect depends on the type and severity of their experience.

Chapter 4 tested key predictions of the Cooperative Buffering Hypothesis among survivors of Cyclone Pam. Partial support was found for the hypothesis, which proposes that aspects of religiosity should function to buffer cooperation to coreligionists but reduce cooperation to religious outgroups in times of resource stress. Pre-cyclone personal commitment to the Christian god was associated with an increased likelihood of keeping more than half of one's endowment against outgroup members and predicted parochial giving when sharing between coreligionists and outgroup members. However, pre-cyclone religiosity did not predict allocations to coreligionists against the self after the cyclone. Greater frequency of prayer, frequency of ritual practices and belief in a more punitive Christian god before the cyclone was not a significant predictor of post-cyclone giving in any game, failing to support hypotheses that supernatural punishment beliefs and engagement in costly religious rituals can function to facilitate within-group cooperation, even when group cohesion is under threat. The results also failed to find an effect of religious priming on giving decisions after the disaster, thus replicating the findings of Chapter 2.

Together, the results from ChaptersChapter 2Chapter 3, Chapter 4 provide evidence that people adjust their giving to religious ingroups and outgroups depending on resource availability, keeping more for themselves in general and preferring the religious ingroup over the outgroup

after a natural disaster compared to before. Further, aspects of religion appear to calibrate giving decisions to outgroup members, promoting cooperation towards members of religious outgroups in times of plenty, but reduced giving to outgroups and promoting more parochial sharing in times of need. However, the findings in these chapters fail to corroborate studies that find links between ritual participation (Sosis & Ruffle, 2003; Xygalatas et al., 2013), or religious priming (Shariff & Norenzayan, 2007; Shariff et al., 2016; Willard et al., 2016) and prosocial giving. Further, these results fail to support key findings across the whole CERC sample that supernatural punishment beliefs promote cooperation within groups of coreligionists (Purzycki et al., 2016c). One potential reason for this divergence from the global findings is that the games were somewhat different, testing willingness to cheat rather than prosocial giving. For example, it is possible that supernatural punishment beliefs might better function to disincentivise cheating than to promote prosocial giving. Further, the practical limitations of the cost, time and logistics of larger samples in the field limit the power of a single site. While our work was among the largest of the CERC samples, these hypotheses should be tested on the full CERC sample.

Nevertheless, one interesting application of our results could be to challenge assumptions about the implications of Cultural Group Selection (CGS) for predicted cooperation-enhancing effects of religion. As noted in Section 1.5, proponents of CGS argue that competition between groups that exhibit stable intergroup cultural variation can generate selection at the group-level (Bowles, 2006; Chudek & Henrich, 2011; Henrich, 2004; Norenzayan et al., 2016; Turchin, Currie, Turner, & Gavrillets, 2013). Groups that have evolved sets of norms and institutions that promote and maintain high levels of cooperation within the group are argued to enjoy a relative cultural survival advantage, especially when intergroup competition is fierce, such as during warfare or when competing for scarce resources (Norenzayan et al., 2016). Indeed, establishing group boundaries and selective cooperation directed towards group members only

is seen as a potentially crucial outcome of CGS in humans (Richerson et al., 2016). This argument is predicated on the idea that when intergroup competition is fierce, groups of parochial altruists and cooperators gain a selective advantage and are likely to proliferate at the expense of both non-cooperative groups and groups of indiscriminate altruists (Bowles, 2008; Choi & Bowles, 2007).

However, norms and institutions that promote altruistic acts to outgroup members (of the sort seen in Chapters 2, 3 and 4) could nevertheless evolve if they confer a selective advantage to groups that adhere to these behaviours. For example, altruism towards outgroup members could act as a signal of prosperity and cooperativeness of the group. This could lead to a biased migration towards the seemingly prosperous group, creating a group size differential between groups. To the extent that groups can benefit from between-group cooperation, religious beliefs and practices, as well as other cultural norms and institutions might facilitate indiscriminate prosociality. Indeed, this could have contributed to the success of the proselytising Abrahamic faiths. Consistent with this idea, one study found that engagement in intense, painful religious rituals increased identification with the broader Mauritian culture among Hindu Mauritians (Xygalatas et al., 2013), and another found that Muslims engaging in the Hajj pilgrimage indicated a greater belief in tolerance and peace among adherents of different religions (Clingingsmith, Khwaja, & Kremer, 2009).

While our findings support this kind of altruism, this result (as Chapter 3 shows) is likely to be context dependent; there is no denying that religions also seem to promote intense religious conflict under some conditions, for example by promoting holy wars, jihad, inquisitions, and genocide. It is possible that groups are able to compete with shows of generosity only when resources are plentiful for the giving group, or when formal institutions can deter warfare between groups. A flexible, resource-dependent giving to religious outgroups is consistent with

the patterns we observe in our data. To better understand the environmental and cultural predictors of these different outcomes, more work is clearly needed.

6.2. Religion as a facilitator of psychological adjustment and wellbeing:

Summary and discussion of the findings

With a sample of survivors of a major natural disaster in Tanna, Chapter 4 tested key predictions related to religion's perceived function as a source of comfort in times of distress. Contrary to the Religious Comfort Hypothesis, which predicted that people should turn to religion as a source of comfort in times of distress, analysis at the group level suggested that people did not tend to become more religious after the disaster. Instead, people indicated similar levels of personal commitment to their moralistic god, similar frequency of prayer and tended to report a reduction in the frequency of ritual practices to their moralistic god after the cyclone. We also found no evidence that more affected individuals, or those who perceived the greatest increase in food insecurity, were the most likely to increase their religiosity after the cyclone. Further, participant's reported religiosity prior to the cyclone did not appear to buffer against an increase in perceived food insecurity after the cyclone.

Chapter 5 quantified and sought to explain gender differences in religiosity in a sample of over 2,000 individuals from 14 diverse societies. Across sites, women tended to indicate greater religiosity than men in terms of personal commitment and frequency of ritual practices to moralistic god, as well as greater frequency of prayer, whereas we found no evidence of greater female religiosity towards more local deities on any measure. However, these effects are culturally contingent, with large differences in the gender effect across cultures. Our explanatory models highlight the importance of gender differences in formal education as an factor mediating women's greater religiosity. This suggests a general secularising effect over time as men and women gain more equal access to education. Our models did not support

hypotheses that women's greater religiosity was due to their greater need and/or desire than men to obtain the buffering effects of religion on psychological adjustment and wellbeing. Testing several key explanations for the gender gap, we found no support for claims that women were more religious because they were more likely than men to benefit from religion's ability to provide access to alloparental care, alleviate existential concerns, moralise against marriage infidelity, and help them avoid threat of punishment for unbelief.

Together, the results from Chapter 4 and Chapter 5 fail to support hypotheses that aspects of religion, specifically personal commitment, frequency of ritual practices towards one's moralistic god, and prayer might function to buffer psychological adjustment and wellbeing in a non-WEIRD sample. As such, the studies presented here do not corroborate the many studies in WEIRD societies that find evidence that aspects of religion can benefit religious adherents, such as by providing a framework for coping with stress and suffering (Abu-Raiya & Pargament, 2015; Pargament et al., 1990, 1992; Smith et al., 2000), assuaging fear of mortality (Jonas & Fischer, 2006; Norenzayan & Hansen, 2006), reinstating feelings of control (Laurin et al., 2008; Legare & Souza, 2014), and providing social networking and support (de Vaus, 1984; Koenig, Weiner, et al., 1997; Zapata, 2018).

One possibility is that alternative measures of religiosity could have produced different results to those that we obtained. Two observations make such an explanation unlikely, however. First, our range of measures of religiosity span multiple dimensions, considering religious beliefs, commitment, and participation. Second, many of the dependent and independent measures we operationalised were driven by theory and motivated by ideas about how individual differences in exposure to dysphoric experiences such as natural disasters, demographic characteristics, and specific beliefs about and practices towards deities might contribute to positive wellbeing and psychological adjustment outcomes. Similarly, while we found no evidence that religion buffered against insecurity or that insecurity explained the religious gender gap regarding

availability of a key variable for survival – perceived food insecurity, it is possible that other psychological outcomes are associated with religiosity, such as reduced stress, fear and anxiety. However, we lacked the measures to test these predictions in the CERC sample. Nevertheless, the scale of damage of cyclone Pam on infrastructure and crops was substantial, and food insecurity is no doubt an important contributor to stress. It is therefore noteworthy that we find no association between religiosity and perceived food insecurity and fail to support a buffering effect of religion.

One explanation of our failure to find evidence for religion's proposed ability to promote wellbeing and psychological adjustment despite positive evidence in WEIRD societies is that this function could be evolutionarily novel. As noted in Section 1.5, large urban societies are a very recent development in the time-scale of human evolution (Richerson et al., 2001). As well as declines in average genetic relatedness between individuals, larger groups may suffer strains on cooperation exacerbated by increasing anonymity, insufficient reputation information and constraints on reciprocal relationships (Chudek & Henrich, 2011; Panchanathan & Boyd, 2003; Trivers, 1971). These factors could limit the effectiveness of kin-based altruism, as well as locally-evolved non-religious norms and institutions that could function to promote wellbeing and psychological adjustment among group members in small-scale societies, such as social support networks (Pilisuk & Froland, 1978), cooperative child-rearing (Meehan, 2009), and need-based resource transfers (Aktipis et al., 2011; Hao et al., 2015). Hence, elements of religion that promote wellbeing and psychological adjustment in WEIRD societies may not be long-held, perhaps biologically scaffolded adaptations to human living but recent, perhaps culturally-evolved co-adaptations that function in larger scale societies.

6.3. Limitations and directions for future research

A major feature of this thesis is the novelty of the pre-post cyclone design. Tracking cooperative behaviour and religious belief and ritual frequency change in the same individuals before and after a natural disaster allows us to provide clearer evidence for causal effects of disaster exposure than only considering post-disaster behaviour, or sampling different individuals before and after the disaster (Li et al., 2013; Veszteg et al., 2015). However, the design falls short of the gold standard in identifying causality - it was not possible to randomly allocate participants to levels of affectedness, thus preventing the manipulation of the hypothesised causal variable. This is seemingly an insurmountable problem. Experimentally manipulating a natural disaster to study the functions of religion would not only be a near impossible task, but also highly unethical. Further, our measures of affectedness were self-report. Ideally, objective, independent metrics of cyclone affectedness could be developed to overcome some of the biases that may be present in self-report affectedness data. Nonetheless, the work presented in this thesis contributes to an understanding of the potential role of religion in times of resource stress; future work should continue to utilise a variety of methods, including similar pre-post measures where possible, or matched samples where only post-stress data is available.

The results presented in this thesis provide some evidence for a link between aspects of religion and cooperation. These results appear to support a claim that one adaptive function of religion could be to increase cooperation beyond the religious ingroup in times of plenty but prefer more parochial giving in times of resource stress. As such it is possible that when resources are plentiful, competitive altruism between groups might provide a mechanism whereby selection can work at the group level (Hardy & Van Vugt, 2006; Roberts, 1998). However, testing whether group-level competition of this kind could have had a significant role in human evolution is difficult. Future work should seek to ascertain the conditions under which

indiscriminate altruism can evolve, and whether aspects of religion can be a mechanism to promote it. Analysis of the same measures reported in Chapter 2 with the global CERC sample of fifteen societies could begin to answer this question. However, this analysis was not able to be included in this thesis.

Tanna is an ideal location to test the putative effects of religion on wellbeing and cooperation during resource shocks like natural disasters, outside a WEIRD setting. Tanna's location in the tropical South Pacific means that Tanna is particularly susceptible to tropical cyclone. The relative lack of modern structural development and the ability of the Tannese to quickly rebuild destroyed homes from local natural materials also means that natural disasters are rarely fatal, and most victims of the disasters remain on the island, making it easier to track study participants. Importantly, however, Tanna is only one site. Determining the generalisability of these results to other societies requires replicating the methodologies implemented here in a wider range of societies. This is particularly important in the context of natural disasters because, as a small-scale society on a disaster-prone island with strong kinship bonds and relatively low levels of resource inequality, local behavioural norms around cooperation and religion could differ from areas that are less susceptible to sudden resource stresses. As a result, it is possible that people spontaneously helped their kin and close friends, while previous experience with natural disasters enabled people to get over the worst of the effects of the cyclone without a substantial need for religious beliefs and behaviour. To the extent that people in anonymous large-scale societies would be less likely to spontaneously help unrelated others, it is possible that the buffering effects of religion on wellbeing after a natural disaster could be more important in these societies.

The research in this thesis also contributes to an important endeavour to test explanations about the function of religion across a broader range of non-WEIRD societies, in communities following a wider range of religious traditions, and concerning beliefs about and commitment

to powerful moralistic deities as well as more local gods and spirits. Broadening the range of field sites is important to understand the extent to which findings in what are primarily Western student samples generalise. However, the research in this thesis was only able to sample from a small number of societies. While the full CERC dataset included 14 diverse sites, this sample was over-represented by Christian sites, with no Muslim sites and only one traditional religion. Future work should continue to expand the range of societies, religious traditions and types of deities being studied, thus offering a richer and more complete picture of religion and its functions across the world.

6.4. Conclusion

Given the diversity of religious beliefs, traditions and behaviours found throughout the world, it is problematic that a disproportionate amount of published studies investigating functional theories of religion have been conducted with participants in large-scale, Abrahamic, Western societies during times of relative resource abundance. This thesis contributes to a growing field of research that seeks to test functional explanations of religion in non-WEIRD cultural settings. Across four chapters, the results described in this thesis provided little support for hypotheses that religion can function to buffer against threats to psychological adjustment and wellbeing, even in times of acute resource insecurity. When considering whether religion can function to promote cooperation, we find evidence that aspects of religion might function to calibrate prosocial giving in response to levels of resource security, such as by promoting cooperation beyond the religious ingroup in times of plenty and more parochial giving in times of need. Finally, our results demonstrate the importance of culture and context in our understanding of how and when religion functions for its adherents and the group.

Chapter 7. **Supplementary information**

7.1. Supplementary information for Chapter 2. Religion and the extent of prosocial preferences on Tanna Island, Vanuatu

7.1.1 Religious priming

Religious primes consisted of three painted icons on coloured cloth (See figure S1). As in the reference groups for the dictator game, the coreligionist prime differed depending on the village in which one lived- Christian icons in the Christian village and Kastom icons in the Kastom village. The Christian icons were pictures of a holy bible, a church house, and a necklace with a cross. The Kastom icons were pictures of three items commonly used in Kastom dance ceremonies- a Wilgen (stack of sticks), Nou (Feathered stick), and Toka (ceremonial stick). As only the Christians were primed with outgroup, the outgroup prime was three Kastom icons. The Neutral prime consisted of two images of flowers. Primes were placed on top of a plastic tray in the testing area and the cups for the first game and a stack of 10 coins was placed on top of the prime prior to the participant entering (as below). The prime remained in place until all games had been completed and was then removed prior to starting any further surveys.



Figure S1. Prime images with example game setup. Clockwise from top left: Christian, Kastom, Neutral.

7.1.2 Religiosity measures

Table S1. Summary of religiosity measures

Scales relating to ‘moralistic god’ (Christian God or *Kalbabén*) and local spirit (*Tupunus*)

1. Commitment scale (item scores summed and standardised to range from 0 [lowest commitment] to 1 [highest commitment])

a. How often do you think about _____?

i. (0) Very rarely/Never, (1) Every day or multiple times per day, (2) A few times per week, (3) A few times per month, (4) A few times per year

b. Do you perform activities or practices to talk to, or appease _____? If yes, how often?

i. (0) Very rarely/Never, (1) Every day or multiple times per day, (2) A few times per week, (3) A few times per month, (4) A few times per year

c. How frequently do you worry about what _____ thinks about you?

i. (0) Very rarely/Never, (1) Every day or multiple times per day, (2) A few times per week, (3) A few times per month, (4) A few times per year

2. Punishment scale (item scores averaged and standardised to range from 0 [punishment rare/unimportant] to 1 [punishment important and constant])

a. How important is punishing thieves to _____?

i. (0) Not important at all, (1) A little important, (2) Important, (3) Very important, (4) It's a main concern.

b. How important is punishing liars to _____?

i. (0) Not important at all, (1) A little important, (2) Important, (3) Very important, (4) It's a main concern.

c. How important is punishing murderers to _____?

i. (0) Not important at all, (1) A little important, (2) Important, (3) Very important, (4) It's a main concern.

3. Omniscience scale (item scores summed and standardised to range from 0 to 1)

a. Can _____ see into people's hearts or know their thoughts and feelings?

i. (1 = yes, 0 = no)

b. Can _____ see what people are doing if they are far away, in Noumea [distant town known to Tannese]

i. (1 = yes, 0 = no)

4. Reward scale (single item standardised to range from 0 to 1)

a. How often does _____ assist people in their lives or reward them for proper behaviour?

i. (0) Never, (1) sometimes, (2) frequently/all the time

7.1.3 Game allocations

Table S2. Results of logistic regressions predicting whether one gave an equal or higher offer to the distal cup in each game from local god religiosity

Predictor	Gave an equal or higher offer to the distal cup in each game			
	Self-Corel OR	Self-Outgroup OR	Village-Corel OR	Corel-Outgroup OR
Intercept	2.26 [0.93, 5.72]†	2.09 [0.85, 5.32]	4.55 [1.70, 13.40]**	4.37 [1.59, 13.03]**
Religiosity				
Commitment	1.27 [0.31, 5.34]	1.30 [0.31, 5.70]	0.77 [0.16, 3.53]	2.48 [0.49, 13.42]
Punishment	0.60 [0.25, 2.20]	2.12 [0.71, 6.58]	0.75 [0.22, 2.44]	0.65 [0.19, 2.16]
Omniscience	0.73 [0.32, 3.46]	0.73 [0.28, 1.91]	0.58 [0.20, 1.65]	0.70 [0.23, 2.12]
Reward	1.04 [0.32, 3.46]	0.35 [0.10, 1.14]†	1.35 [0.36, 5.14]	1.13 [0.28, 4.75]
Controls				
Site	0.59 [0.23, 1.47]	0.67 [0.26, 1.71]	0.83 [0.30, 2.27]	0.20 [0.06, 0.58]**
Perceived food insecurity	0.87 [0.69, 1.09]	0.94 [0.71, 1.18]	0.94 [0.74, 1.21]	1.13 [0.89, 1.49]
Cox and Snell pseudo R ²	0.03	0.08	0.02	0.10
n	153	153	153	152

Note: We report odds ratios with 95% confidence intervals in brackets. The reference category for site was Christian. † $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

Table S3. Results of logistic regressions testing the effect of religious priming on coin allocations to the distal cup in each game

Predictor	Gave an equal or higher offer to the distal cup in each game			
	Self-Corel OR	Self-Outgroup OR	Village-Corel OR	Corel-Outgroup OR
Intercept	2.56 [1.44, 4.69]**	2.68 [1.50, 4.95]**	3.91 [2.09, 7.69]***	3.50 [1.91, 6.70]***
Prime				
Own religion	0.99 [0.55, 1.78]	0.90 [0.50, 1.63]	0.97 [0.52, 1.82]	0.75 [0.41, 1.36]
Other religion	0.42 [0.19, 0.93]*	0.46 [0.20, 1.01]†	0.65 [0.29, 1.59]	0.96 [0.39, 2.46]
Controls				
Site	0.29 [0.16, 0.53]***	0.27 [0.15, 0.49]***	0.50 [0.26, 0.94]*	0.37 [0.20, 0.67]**
Perceived food insecurity	0.89 [0.74, 1.06]	0.85 [0.71, 1.02]†	0.97 [0.80, 1.17]	1.01 [0.84, 1.22]
McFadden's pseudo R ²	0.07	0.08	0.02	0.06
n	242	242	242	241

Note: We report odds ratios with 95% confidence intervals in brackets. The reference categories for prime and site were neutral and Christian, respectively. † $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

7.2. Supplementary information for Chapter 3. Property damage and exposure to others in distress differentially predict prosocial behaviour following a natural disaster

7.2.1 Affectedness measures

Table S4. Principle component analysis of affectedness items with oblique rotation. Four components were extracted.

Item	Damage to property	Need for resource aid	Injury to self and loved ones	Exposure to others in distress
I had to relocate because my house became structurally unsafe to live in	0.87			
My home was damaged in the cyclone	0.87			
In the days following the cyclone I had to spend the night somewhere other than in my home	0.72			
I needed shelter after the cyclone	0.51			
I needed financial assistance from others because of hardships caused by the cyclone		0.84		
I suffered financial difficulties because of the cyclone		0.83		
I needed food and water aid after the cyclone		0.69		
I became dependent on others because of the physical injuries/losses I suffered?		0.46		
Members of my family/loved ones were physically injured in the cyclone			0.78	
I lost relatives/loved ones (e.g., aunts, uncles, cousins, grandparents) in the cyclone			0.76	
I was physically injured in the cyclone			0.67	
I was involved in rescue work				0.73
There was a period when I was uncertain about the welfare of loved ones, when I was unable to establish contact or unable to locate them				0.68
I heard sounds and cries for help from individuals in distress				0.67
A/some loved one[s] became dependent on me for physical care because of their injuries ^a			0.41	0.43
I lost some of my belongings in the cyclone ^a	0.39			0.41
Eigenvalue	4.57	2.22	1.40	1.13
Percentage of variance explained	17%	16%	13%	13%

Note: Factor loadings for individual affectedness using principle components analysis with oblique (direct oblimin) rotation.

^aThese variables loaded to a small degree (<0.5) onto two factors and were therefore not included in any composite variables for this study.

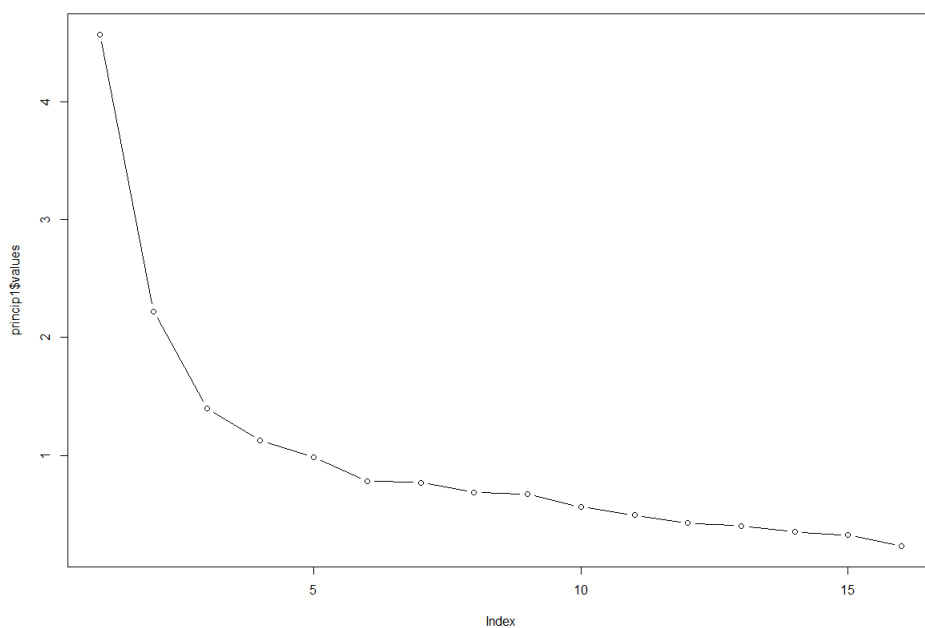


Figure S2. Scree plot of Eigenvalues for each component of cyclone affectedness. Based on an eigen cutoff of 1, this plot suggests that four components can be extracted.

7.2.2 Game allocations

Table S5. Change in the number of coins allocated to the distal cup in each post-cyclone game compared to each pre-cyclone game, at each site.

	Christian	Kastom	Wilcoxon Rank sum
Self-Corel game	-0.48 (0)	-0.65 (0)	$W = 3305.5, p = 0.671$
Self-Outgroup game	-0.74 (0)	-0.51 (0)	$W = 2954.5, p = 0.438$
Village-Corel game	-0.29 (0)	-0.05 (0)	$W = 3028.5, p = 0.594$
Corel-Outgroup game	-0.40 (0)	-0.65 (0)	$W = 3247, p = 0.736$

Note: Values represent the mean change in number of coins allocated to the distal cup after the cyclone. The median change is shown in parentheses. Positive values indicate higher allocations to the distal cup after the cyclone compared to before. Negative allocations indicate reduced allocations to the distal cup after the cyclone compared to before.

Table S6. Multiple Tobit regressions predicting coin allocations to the distal cup after the cyclone.

	1 Self-Corel game	2 Self-Corel game	3 Self-Corel game	4 Self-Corel game	5 Self-Corel game	6 Self-Outgroup game	7 Self-Outgroup game	8 Self-Outgroup game	9 Self-Outgroup game	10 Self-Outgroup game
Intercept	2.41** [0.67, 4.15]	2.56** [0.82, 4.31]	2.34** [0.60, 4.09]	3.65*** [1.74, 5.56]	1.54 [-0.87, 3.95]	2.52** [0.92, 4.11]	2.74*** [1.13, 4.34]	2.46** [0.88, 4.04]	3.17*** [1.42, 4.91]	1.85 [-0.37, 4.06]
Affectedness										
Damage to property	-0.27 [-0.61, 0.08]	-0.26 [-0.61, 0.08]	-0.27 [-0.61, 0.07]	-0.29† [-0.62, 0.05]	-0.28 [-0.64, 0.08]	-0.50** [-0.82, -0.18]	-0.50** [-0.81, 0.18]	-0.50** [-0.82, -0.19]	-0.50** [-0.82, 0.19]	-0.48** [-0.82, -0.15]
Need for resource aid	-0.22 [-0.59, 0.16]	-0.21 [-0.59, 0.16]	-0.20 [-0.57, 0.18]	-0.23 [-0.60, 0.13]	-0.18 [-0.58, 0.22]	-0.37* [-0.72, -0.02]	-0.37* [-0.71, -0.02]	-0.34† [-0.68, 0.01]	-0.37* [-0.72, -0.03]	-0.37† [-0.75, 0.01]
Injury to self and loved ones	-0.09 [-0.55, 0.36]	-0.09 [-0.54, 0.36]	-0.12 [-0.57, 0.34]	-0.06 [-0.51, 0.38]	-0.11 [-0.60, 0.37]	0.03 [-0.40, 0.45]	0.03 [-0.39, 0.45]	-0.01 [-0.43, 0.41]	0.04 [-0.38, 0.46]	0.00 [-0.45, 0.46]
Witnessing others in distress	0.50* [0.01, 0.99]	0.45† [-0.04, 0.94]	0.44† [-0.06, 0.94]	0.40† [-0.08, 0.89]	0.53* [0.02, 1.04]	0.58* [0.12, 1.04]	0.53* [0.07, 0.99]	0.49* [0.02, 0.96]	0.53* [0.07, 0.99]	0.60* [0.12, 1.08]
Demographics and controls										
Pre-cyclone allocations to distal cup	0.35*** [0.16, 0.54]	0.34*** [0.16, 0.53]	0.35*** [0.16, 0.54]	0.31*** [0.13, 0.50]	0.38*** [0.18, 0.58]	0.44*** [0.25, 0.64]	0.42*** [0.23, 0.61]	0.43*** [0.24, 0.62]	0.43*** [0.24, 0.62]	0.44*** [0.24, 0.64]
Site	-0.41 [-1.31, 0.49]	-0.47 [-1.37, 0.43]	-0.42 [-1.31, 0.48]	-0.78 [-1.73, 0.18]	-0.18 [-1.33, 0.97]	0.06 [-0.79, 0.91]	-0.01 [-0.86, 0.83]	0.03 [-0.81, 0.88]	-0.22 [-1.14, 0.70]	0.38 [-0.71, 1.48]
Age		0.28 [-0.12, 0.69]					0.31 [-0.07, 0.69]			
Sex			0.42 [-0.41, 1.25]					0.64 [-0.14, 1.42]		
Corel prime				-0.70, [-1.60, 0.20]					-0.26 [-1.11, 0.59]	
Outgroup prime				-1.63** [-2.77, 0.49]					-1.02† [-2.11, 0.07]	
Log of pre-cyclone annual income					0.12 [-0.19, 0.42]					0.12 [-0.16, 0.41]
BIC	741.95	745.163	746.0638	744.1928	685.8269	717.6539	720.2103	720.159	724.4932	669.4687
McFadden's pseudo R ²	0.04	0.04	0.04	0.05	0.12	0.07	0.07	0.07	0.07	0.14
n	163	163	163	163	149	163	163	163	163	149

Note: For these Tobit models we report unstandardized coefficients and 95% confidence intervals. Age was centred at its mean. The reference categories for Sex and Prime were Women and Neutral prime, respectively. † $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$

Table S7. Multiple Tobit regressions predicting coin allocations to the distal cup after the cyclone.

	11 Village-Corel game	12 Village-Corel game	13 Village-Corel game	14 Village-Corel game	15 Village-Corel game	16 Corel-Outgroup game	17 Corel-Outgroup game	18 Corel-Outgroup game	19 Corel-Outgroup game	20 Corel-Outgroup game
Intercept	3.65*** [2.03, 5.26]	3.65*** [2.03, 5.27]	3.56*** [1.95, 5.17]	3.24*** [1.46, 5.03]	4.03*** [1.89, 6.18]	4.03*** [2.73, 5.34]	4.10*** [2.79, 5.41]	3.99*** [2.70, 5.29]	4.25*** [2.84, 5.66]	4.04*** [2.24, 5.84]
Affectedness										
Damage to property	-0.22 [-0.52, 0.08]	-0.22 [-0.52, 0.08]	-0.22 [-0.52, 0.08]	-0.21 [-0.51, 0.09]	-0.29† [-0.59, 0.02]	-0.36** [-0.62, -0.11]	-0.36** [-0.61, -0.10]	-0.36** [-0.61, -0.11]	-0.36** [-0.62, -0.11]	-0.34* [-0.60, -0.07]
Need for resource aid	-0.11 [-0.44, 0.22]	-0.11 [-0.44, 0.22]	-0.09 [-0.42, 0.24]	-0.10 [-0.44, 0.23]	-0.11 [-0.46, 0.23]	0.13 [-0.16, 0.41]	0.13 [-0.15, 0.41]	0.14 [-0.14, 0.42]	0.13 [-0.15, 0.41]	0.08 [-0.22, 0.39]
Injury to self and loved ones	-0.22 [-0.62, 0.18]	-0.22 [-0.62, 0.18]	-0.25 [-0.65, 0.16]	-0.23 [-0.64, 0.17]	-0.19 [-0.60, 0.21]	0.05 [-0.29, 0.39]	0.05 [-0.29, 0.39]	0.03 [-0.31, 0.37]	0.05 [-0.29, 0.39]	0.09 [-0.27, 0.45]
Witnessing others in distress	0.30 [-0.14, 0.73]	0.30 [-0.14, 0.74]	0.24 [-0.21, 0.68]	0.32 [-0.11, 0.76]	0.23 [-0.21, 0.66]	0.05 [-0.31, 0.42]	0.03 [-0.34, 0.40]	-0.01 [-0.38, 0.36]	0.03 [-0.34, 0.40]	0.05 [-0.33, 0.44]
Demographics and controls										
Pre-cyclone allocations to distal cup	0.28** [0.07, 0.49]	0.28** [0.07, 0.49]	0.28** [0.07, 0.49]	0.29** [0.08, 0.50]	0.20† [-0.02, 0.42]	0.19* [0.02, 0.36]	0.19* [0.02, 0.36]	0.18* [0.01, 0.35]	0.20* [0.03, 0.37]	0.17† [-0.02, 0.35]
Site	0.17 [-0.62, 0.97]	0.17 [-0.63, 0.97]	0.16 [-0.63, 0.96]	0.22 [-0.64, 1.09]	0.00 [-0.97, 0.97]	-0.62† [-1.30, 0.06]	-0.65† [-1.33, 0.03]	-0.64† [-1.31, 0.04]	-0.75* [-1.48, -0.02]	-0.49 [-1.36, 0.37]
Age		0.02 [-0.34, 0.38]					0.14 [-0.17, 0.44]			
Sex			0.45 [-0.29, 1.19]					0.45 [-0.17, 1.08]		
Corel prime				0.38 [-0.43, 1.20]					-0.09 [-0.78, 0.59]	
Outgroup prime				0.45 [-0.59, 1.48]					-0.47 [-1.34, 0.40]	
Log of pre-cyclone annual income					0.06 [-0.20, 0.31]					0.02 [-0.20, 0.25]
BIC	746.5417	751.6248	750.2181	755.5874	681.6684	700.8875	705.2216	703.9499	709.9387	652.3328
McFadden's pseudo R ²	0.03	0.03	0.03	0.03	0.12	0.04	0.04	0.04	0.04	0.11
n	163	163	163	163	149	162	162	162	162	148

Note: For these Tobit models we report unstandardized coefficients and 95% confidence intervals. Age was centred at its mean. The reference categories for Sex and Prime were Women and Neutral prime, respectively. † $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$

Table S8. Multiple logistic regressions predicting whether one gave a fair or higher offer to the distal cup after the cyclone.

	21 Self-Corel game	22 Self-Corel game	23 Self-Corel game	24 Self-Corel game	25 Self-Corel game	26 Self-Outgroup game	27 Self-Outgroup game	28 Self-Outgroup game	29 Self-Outgroup game	30 Self-Outgroup game
Intercept	0.65 [0.17, 2.40]	0.66 [0.17, 2.46]	0.63 [0.17, 2.31]	1.65 [0.36, 7.56]	0.33 [0.05, 2.04]	0.36 [0.09, 1.35]	0.36 [0.09, 1.38]	0.34 [0.08, 1.32]	0.48 [0.10, 2.23]	0.34 [0.05, 2.13]
Affectedness										
Damage to property	0.73 * [0.54, 0.97]	0.73* [0.54, 0.97]	0.73* [0.53, 0.97]	0.70* [0.51, 0.95]	0.72* [0.52, 0.97]	0.57*** [0.40, 0.78]	0.57*** [0.40, 0.78]	0.56*** [0.40, 0.78]	0.57*** [0.40, 0.78]	0.61** [0.43, 0.84]
Need for resource aid	0.86 [0.63, 1.17]	0.86 [0.63, 1.17]	0.88 [0.64, 1.20]	0.84 [0.61, 1.16]	0.90 [0.64, 1.25]	0.88 [0.62, 1.24]	0.88 [0.62, 1.24]	0.91 [0.64, 1.30]	0.88 [0.62, 1.25]	0.86 [0.60, 1.22]
Injury to self and loved ones	0.96 [0.66, 1.39]	0.96 [0.66, 1.39]	0.94 [0.64, 1.36]	0.99 [0.68, 1.44]	0.94 [0.63, 1.40]	1.06 [0.70, 1.58]	1.06 [0.70, 1.59]	1.00 [0.66, 1.52]	1.06 [0.70, 1.59]	1.05 [0.69, 1.59]
Witnessing others in distress	1.71* [1.13, 2.67]	1.70* [1.11, 2.66]	1.60* [1.05, 2.53]	1.62* [1.05, 2.55]	1.81** [1.17, 2.91]	1.93** [1.22, 3.20]	1.92** [1.21, 3.20]	1.72* [1.07, 2.89]	1.88* [1.18, 3.12]	1.90** [1.20, 3.15]
Demographics and controls										
Pre-cyclone allocations to distal cup	2.35* [1.19, 4.73]	2.34* [1.18, 4.72]	2.27* [1.14, 4.60]	2.05* [1.01, 4.20]	2.71* [1.31, 5.76]	5.44*** [2.52, 12.50]	5.40*** [2.49, 12.53]	4.93*** [2.26, 11.41]	5.13*** [2.36, 11.89]	5.31*** [2.42, 12.43]
Site	0.72 [0.34, 1.52]	0.72 [0.34, 1.51]	0.71 [0.33, 1.49]	0.55 [0.24, 1.25]	0.72 [0.28, 1.83]	0.85 [0.36, 1.95]	0.84 [0.36, 1.96]	0.79 [0.34, 1.85]	0.74 [0.30, 1.82]	0.90 [0.32, 2.50]
Age		1.04 [0.74, 1.46]					1.02 [0.69, 1.49]			
Sex			1.57 [0.78, 3.13]					2.07† [0.95, 4.57]		
Corel prime				0.56 [0.26, 1.20]					0.90 [0.39, 2.08]	
Outgroup prime				0.30* [0.10, 0.80]					0.61 [0.20, 1.82]	
Log of pre-cyclone annual income					1.08 [0.85, 1.39]					1.00 [0.77, 1.31]
BIC	238.6153	243.6463	242.0874	242.6014	221.5395	206.6402	211.7222	208.371	216.0356	202.7573
McFadden's pseudo R ²	0.12	0.12	0.13	0.15	0.14	0.23	0.23	0.25	0.23	0.22
n	163	163	163	163	149	163	163	163	163	149

Note: For these logistic models we report odds ratios and confidence intervals of the odds ratios. Age was centred at its mean. The reference categories for Sex and Prime were Women and Neutral prime, respectively. † $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

Table S9. Multiple logistic regressions predicting whether one gave a fair or higher offer to the distal cup after the cyclone.

	31 Village-Corel game	32 Village-Corel game	33 Village-Corel game	34 Village-Corel game	35 Village-Corel game	36 Corel-Outgroup game	37 Corel-Outgroup game	38 Corel-Outgroup game	39 Corel-Outgroup game	40 Corel- Outgroup game
Intercept	3.09 [0.69, 15.95]	3.08 [0.69, 15.90]	3.11 [0.70, 16.07]	2.30 [0.43, 13.66]	1.13 [0.16, 8.81]	1.46 [0.38, 5.82]	1.50 [0.39, 6.06]	1.43 [0.37, 5.71]	1.83 [0.41, 8.45]	1.07 [0.17, 6.71]
Affectedness										
Damage to property	0.59** [0.38, 0.85]	0.59** [0.38, 0.85]	0.59** [0.38, 0.85]	0.58** [0.37, 0.85]	0.56** [0.35, 0.82]	0.47*** [0.31, 0.67]	0.47*** [0.31, 0.67]	0.47*** [0.31, 0.67]	0.46*** [0.30, 0.66]	0.50*** [0.33, 0.71]
Need for resource aid	0.95 [0.67, 1.34]	0.95 [0.67, 1.34]	0.95 [0.67, 1.34]	0.96 [0.67, 1.35]	0.99 [0.69, 1.43]	1.47* [1.05, 2.11]	1.48* [1.05, 2.12]	1.49* [1.06, 2.14]	1.48* [1.05, 2.12]	1.37† [0.96, 1.99]
Injury to self and loved ones	0.80 [0.53, 1.17]	0.80 [0.54, 1.18]	0.80 [0.54, 1.19]	0.79 [0.53, 1.17]	0.79 [0.51, 1.18]	0.88 [0.59, 1.31]	0.89 [0.59, 1.31]	0.87 [0.58, 1.30]	0.90 [0.60, 1.33]	0.94 [0.63, 1.41]
Witnessing others in distress	1.54† [0.98, 2.45]	1.55† [0.99, 2.48]	1.55† [0.98, 2.49]	1.58* [1.01, 2.54]	1.40 [0.88, 2.25]	1.44 [0.93, 2.26]	1.42 [0.92, 2.25]	1.40 [0.90, 2.23]	1.43 [0.92, 2.27]	1.46† [0.94, 2.31]
Demographics and controls										
Pre-cyclone allocations to distal cup	3.16** [1.50, 6.77]	3.14** [1.49, 6.75]	3.17** [1.51, 6.83]	3.33** [1.56, 7.30]	3.06** [1.39, 6.88]	2.89** [1.37, 6.30]	2.86** [1.35, 6.25]	2.83** [1.34, 6.20]	2.86** [1.36, 6.25]	2.61* [1.19, 5.90]
Site	0.68 [0.31, 1.49]	0.68 [0.31, 1.51]	0.68 [0.31, 1.49]	0.74 [0.31, 1.75]	0.97 [0.36, 2.65]	0.42* [0.19, 0.90]	0.41* [0.19, 0.89]	0.41* [0.19, 0.89]	0.43* [0.19, 0.99]	0.58 [0.22, 1.50]
Age		0.96 [0.67, 1.39]					1.06 [0.74, 1.52]			
Sex			0.93 [0.45, 1.94]					1.23 [0.59, 2.54]		
Corel prime				1.22 [0.55, 2.73]					0.72 [0.32, 1.59]	
Outgroup prime				1.52 [0.54, 4.49]					0.88 [0.31, 2.46]	
Log of pre-cyclone annual income					1.28† [1.00, 1.66]					1.05 [0.82, 1.34]
BIC	219.3217	224.3738	224.3794	228.832	206.4489	223.7025	228.6873	228.4868	233.2238	216.1858
McFadden's pseudo R ²	0.14	0.14	0.14	0.14	0.17	0.20	0.20	0.20	0.20	0.17
n	163	163	163	163	149	162	162	162	162	148

Note: For these logistic models we report odds ratios and confidence intervals of the odds ratios. Age was centred at its mean. The reference categories for Sex and Prime were Women and Neutral prime, respectively. † $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .00$

7.2.3 Change in giving among unaffected individuals

We used a series of ordinary least squares regression models to quantify the effects of each affectedness measure on change in cooperation, where change in cooperation for each game was operationalised by subtracting pre-cyclone coin allocations from post-cyclone coin allocations to the distal cup, in each game. If the model intercepts (the predicted change in coin allocation when all four affectedness measures are set to zero) do not differ from zero, this supports the assumption that levels of cooperation would not have changed had the cyclone not occurred. If the intercepts are significantly different from zero, the departure could still be attributable to the cyclone, since it is unlikely that we have measured all possible types of cyclone affectedness. This means the test can offer support for the assumption of no change in the absence of Cyclone Pam, but a failed test would not disconfirm the assumption of no change.

Our analysis shows that in each game the intercept is not significantly different from zero ($p > 0.05$), supporting the assumption that unaffected individuals will behave consistently, and hence that the population-level change in giving that we observe is attributable to the cyclone (Table S10). One game (the self-corel game) did show a borderline significant intercept. If we take this as a real departure from zero, it may suggest a change in cooperation in this game independent of the cyclone, or it could be attributable to other, unmeasured forms of cyclone affectedness not captured by our scales.

Table S10. Multiple ordinary least squares regressions predicting change in coin allocations to the distal cup pre to post cyclone.

Predictor	Self-Corel <i>b-Est</i>	Self-Outgroup <i>b-Est</i>	Village-Corel <i>b-Est</i>	Corel-Outgroup <i>b-Est</i>
Intercept	-1.28 [-2.73, 0.17]†	-0.17 [-0.59, 0.98]	-0.00 [-1.31, 1.31]	0.16 [-1.10, 1.42]
Affectedness				
Damage to property	-0.07 [-0.43, 0.30]	-0.32 [-0.64, 0.00]†	-0.14 [-0.47, 0.19]	-0.44 [-0.76, -0.13]**
Need for resource aid	-0.04 [-0.43, 0.36]	-0.25 [-0.60, 0.10]	-0.02 [-0.38, 0.33]	0.14 [-0.21, 0.48]
Injury to self and loved ones	-0.06 [-0.51, 0.39]	-0.07 [-0.47, 0.32]	-0.15 [-0.55, 0.26]	0.07 [-0.32, 0.46]
Witnessing others in distress	0.46 [-0.06, 0.98]†	0.58 [0.12, 1.04]*	0.18 [-0.29, 0.65]	0.12 [-0.33, 0.57]
R ²	0.02	0.08	0.01	0.05
n	163	163	163	162

Note: For these ordinary least square models we report unstandardized coefficients and 95% confidence intervals. † $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$

It is worth noting that the above test regarding the interpretation of population level change in cyclone affectedness is orthogonal to our interpretation of the main regression analyses reported in Table 6 and Table 7. The effect of each affectedness measure on individual differences in cooperation reported in these tables is meaningful whether or not mean levels of cooperation might also have increased, decreased or stayed the same in the absence of Cyclone Pam. This is because our multiple regressions quantify the effect of each affectedness measure, controlling for other affectedness measures, pre-cyclone giving and mean levels of giving post cyclone. We see this combination of individual affectedness measures and pre- post- measures of cooperation as a unique strength of our paper.

7.3. Supplementary information for Chapter 4. Testing theories about the personal and social function of religion after a natural disaster

Table S11. Summary of religiosity measures

Scales relating to 'moralistic god' (Christian God or *Kalbabén*) and local spirit (*Tupunus*)

1. Personal commitment scale (pre and post cyclone item scores were summed and standardised to range from 0 [lowest commitment] to 1 [highest commitment])

a. How often do you think about _____?

i. (0) Very rarely/Never, (1) Every day or multiple times per day, (2) A few times per week, (3) A few times per month, (4) A few times per year

b. How frequently do you worry about what _____ thinks about you?

i. (0) Very rarely/Never, (1) Every day or multiple times per day, (2) A few times per week, (3) A few times per month, (4) A few times per year

2. Punishment scale (pre and post cyclone item scores averaged and standardised to range from 0 [punishment rare/unimportant] to 1 [punishment important and constant])

a. How important is punishing thieves to _____?

i. (0) Not important at all, (1) A little important, (2) Important, (3) Very important, (4) It's a main concern.

b. How important is punishing liars to _____?

i. (0) Not important at all, (1) A little important, (2) Important, (3) Very important, (4) It's a main concern.

c. How important is punishing murderers to _____?

i. (0) Not important at all, (1) A little important, (2) Important, (3) Very important, (4) It's a main concern.

3. Ritual practices scale (pre and post cyclone single item score standardised to range from 0 to 1)

a. How often do you perform rituals or ceremonies devoted to _____?

i. (0) Very rarely/Never, (1) Every day or multiple times per day, (2) A few times per week, (3) A few times per month, (4) A few times per year

4. Prayer scale (pre and post cyclone single item score standardised to range from 0 to 1)

a. How often do you pray?

i. (0) Very rarely/Never, (1) Every day or multiple times per day, (2) A few times per week, (3) A few times per month, (4) A few times per year

7.4. Supplementary information for Chapter 5. Quantifying and explaining the religious gender gap in 14 diverse societies.

7.4.1 Religiosity scales

Table S12. Summary of religiosity measures

Dependent religiosity scales relating to ‘moralistic god’ and local spirit

1. Binary measure of belief or unbelief

a. Do you believe in _____?

i. (0) No, (1) Yes

2. Personal commitment scale (item scores were summed and standardised to range from 0 [lowest commitment] to 1 [highest commitment])

a. How often do you think about _____?

i. (0) Very rarely/Never, (1) Every day or multiple times per day, (2) A few times per week, (3) A few times per month, (4) A few times per year

b. How frequently do you worry about what _____ thinks about you?

i. (0) Very rarely/Never, (1) Every day or multiple times per day, (2) A few times per week, (3) A few times per month, (4) A few times per year

3. Ritual practices scale

a. How often do you perform rituals or ceremonies devoted to _____?

i. (0) Very rarely/Never, (1) Every day or multiple times per day, (2) A few times per week, (3) A few times per month, (4) A few times per year

4. Appeasement scale (if participant answered yes to 4a, their appeasement score was noted as their response to 4b. If participant answered no to 4a, their appeasement score was 0.

a. Do you perform activities or practices to talk to, or appease _____?

i. (0) No, (1) Yes

b. If yes, how often?

i. (0) Very rarely/Never, (1) Every day or multiple times per day, (2) A few times per week, (3) A few times per month, (4) A few times per year

5. Prayer scale

a. How often do you pray?

i. (0) Very rarely/Never, (1) Every day or multiple times per day, (2) A few times per week, (3) A few times per month, (4) A few times per year

Independent religiosity scales relating to ‘moralistic god’ and local spirit

6. Punishment scale (item scores averaged and standardised to range from 0 [punishment rare/unimportant] to 1 [punishment important and constant])

a. How important is punishing thieves to _____?

i. (0) Not important at all, (1) A little important, (2) Important, (3) Very important, (4) It's a main concern.

b. How important is punishing liars to _____?

i. (0) Not important at all, (1) A little important, (2) Important, (3) Very important, (4) It's a main concern.

c. How important is punishing murderers to _____?

i. (0) Not important at all, (1) A little important, (2) Important, (3) Very important, (4) It's a main concern.

7. Afterlife beliefs scale

a. Can _____ influence what happens to people after they die?
i. (0) No, (1) Yes

8. Rewarding scale

a. How often does _____ assist people in their lives or reward them for proper behavior?
i. (0) Never, (1) sometimes, (2) frequently, (3) all the time

7.4.2 Quantification models controlling for age

Table S13. Results of linear regressions predicting moralistic god religiosity from gender and age

	Personal commitment to Moralistic God <i>β-Est.</i>	Ritual practices to Moralistic God <i>OR</i>	Appeasement of Moralistic god <i>OR</i>	Prayer <i>OR</i>
Gender	0.06 [0.02, 0.10]**	1.39 [1.13, 1.72]**	0.97 [0.81, 1.16]	1.50 [1.16, 1.93]**
Age	0.08 [0.04, 0.12]***	1.10 [0.99, 1.22]†	1.22 [1.11, 1.33]***	1.29 [1.13, 1.47]***
n participants	1890	1174	1834	1159
n sites	14	9	14	9

Note: Men were the reference category in each model: positive β -estimates and Odds ratios greater than one indicate greater female religiosity. Models included a higher-level effect of participant site. Site religion reference was Christian. Participant age was mean-centred. Numbers in square brackets indicate 95% confidence intervals. † $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

Table S14. Results of linear regressions predicting moralistic god religiosity from gender and age

	Belief in Local god <i>OR</i>	Personal commitment to Local God <i>β-Est.</i>	Ritual practices to Local God <i>OR</i>	Appeasement of Moralistic god <i>OR</i>
Gender	0.86 [0.63, 1.17]	-0.02 [-0.06, 0.01]	0.98 [0.76, 1.26]	0.73 [0.59, 0.91]**
Age	0.99 [0.85, 1.15]	0.06 [0.02, 0.09]**	1.11 [0.99, 1.26]†	1.34 [1.20, 1.29]***
n participants	1130	1757	1069	1712
n sites	8	12	8	12

Note: Men were the reference category in each model: positive β -estimates and Odds ratios greater than one indicate greater female religiosity. Models included a higher-level effect of participant site. Site religion reference was Christian. Participant age was mean-centred. Numbers in square brackets indicate 95% confidence intervals. † $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

Chapter 8. References

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