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Religion and Parental Cooperation: An Empirical Test of Slone's Sexual Signaling Model

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Sexual signaling theory posits that religions evolved, at least in part, to support mate discrimination (Slone, 2008). According to this theory, potential mates attend to religious expressions to assess each other's qualities. As such, sexual signaling models of religion are a sub-group of commitment signaling models of religion, which hold that religious expressions function to identify traits relevant to assessing partner qualities, quite generally (Irons, 2001a; Mahoney, 2008; Sosis, 2003; Sosis & Bulbulia, 2011).[1] That is, sex is a special case of a cooperation dilemma because the interests of potential mates do not perfectly overlap. The dilemma is fundamental to all human life. Offspring link parents to a common genetic fate. Though sex is one of many collaborative interactions, from a gene's eye view, it is ultimate. Given this importance, and knowing nothing else, we might expect religion to evolve, at least in part, to facilitate mate discrimination. What evidence might enable us to test the predictions of sexual signaling models of religion?

Sexual signaling theory posits that human males and females have different reproductive potentials, and for this reason, that males and females ought to differentially value the traits of prospective mates. Sex differences in religious behaviors associated with mate-evaluation can thus be used to test predictions derived from the sexual signaling theory. Regarding religion, if certain religious expressions are associated with qualities that are differentially valued by females, we might expect men to express such behaviors more frequently

than women. By the same token, if certain religious expressions are associated with qualities that are differentially valued by males, we might expect women to express such behaviors more frequently than men.

Sexual signaling can be assessed without knowledge of the mechanisms that underpin different expressions. In humans, such mechanisms are likely to involve complex dependencies between genetic endowment, cultural endowment, and life experiences. Nevertheless we can obtain initial evidence for sexual signaling models of religion by focusing on sex differences in behavior, and by assessing the associations of signaling behaviors (prayer, church attendance) with fertility. The present study examines two cooperative traits relevant to human mating: fidelity and social reputation, and investigates the links between religious behaviors that identify these traits and their association with fertility.

Fidelity and social reputation

Infidelity can lead to resource loss for both men and women. Yet for men the risk is much greater; female infidelity can lead to males unwittingly investing in children sired by other men. The biology of birth assures accurate assessment of maternity. However, males risk cuckoldry (Low, 2001).[2] Though male infidelity exposes women to the potential diversion of resources towards other women/unrelated offspring, life-history theory (e.g., Hill & Kaplan, 1999) predicts that males will be more interested in the sexual infidelity of the opposite sex than females (holding social and ecological differences equal).[3]

Among humans, divisions of labor involve complex and extensive, direct and indirect reciprocity with non-kin. This includes, among other things: bush craft, collective defense, construction, education, foraging, hunting, long-distance trade, and tool-making (Alexander, 1987; Sterelny, 2011). It has been claimed that children remain mainly dependent on this cooperation for nearly two decades after birth (Gurven & Walker, 2006) and that parents require support from the wider social group when providing for offspring (Kaplan et al., 2000).[4] It is not enough to judge whether a potential mate has resources, but also whether a mate can draw resources from others, including unrelated exchange partners.

Social reputation gradients are thought to enable predictable help from non-kin through a kind of image-scoring: people who demonstrate commitment and utility to a social group are accorded greater social prestige (Nowak & Sigmund, 1998). Individuals within a social network tend to trade with those who reliably exhibit prestige, and they avoid those with low or uncertain prestige (Henrich & Gil-White, 2001). Put simply, social prestige is a form of social capital. Focusing on the mating dilemma, it would appear that mates who are able to display high social prestige will thereby convey information about a core resource relevant to the success of potential offspring, namely an ability to marshal help from others in a community.

Though both males and females are expected to signal prestige to potential and current mates, sex differences in the relative importance of social reputation are thought to arise from differences in reproductive potential, and become manifest in divisions of labor and economic stratification. It is theorized that across most of human history, men have tended to engage in high-risk cooperation with unrelated men in areas such as big-game hunting, defense, military expansion, and inter-group economic trade, whereas female cooperation in foraging and provisioning has tended to occur through repeated interactions with familiar and typically genetically related women (Bliege-Bird et al., 2001; Byrne et al., 1989; Fessler, 2002; Gurven & Hill, 2009). For this reason, evolutionary theorists conjecture that female interest in male social reputation tends to be more valued as a mating signal than male interest in female social reputation (Pillsworth, 2008). Again, our present interest is in whether men signal their social-network reputations more frequently than women, on average and holding all else constant.

Theoretical predictions

To assess the predictions of sexual signaling on fidelity (attribute 1) and social reputation (attribute 2), it is first necessary to assess which religious expressions might be associated with fidelity and which religious expressions might be associated with social-network reputation. This task amounts to a problem of signal identification. Having identified and measured religious expressions that people may employ, it is then necessary to assess whether

men and women differ in their average expression of such signals. This second task amounts to a problem of model evaluation. A secular country provides a good test because its religious residents have readily available the alternatives for assessing mate quality. Such alternatives might be expected to dilute the relevance of religious behavior to mate-evaluation (Hoverd et al., 2012). Our study was conducted in New Zealand, a largely secular country with many residents who do not identify with any particular religion (Wilson et al., 2013). Indeed, analysis of census trends shows a gradual and steady decline in Christian affiliation in New Zealand over the last 40 years (Hoverd, Bulbulia, Partow, & Sibley, in press).

Signal identification: Prayer will be associated with fidelity, as indicated by greater belief in God

We could not assess fidelity directly using our survey data because the study does not ask participants about whether they were faithful (this would arguably be very hard to assess reliably using self-report data). However, previous research indicates that belief in God, when recollected or primed, is positively associated with pro-normative behavior and restraint from acting in self-interest (Norenzayan & Shariff, 2008). Belief in God is also associated with greater self-regulation and inhibition (McCullough & Willoughby, 2009). Recent neurological studies show that frequency of personal prayer—whether repeated and ritualistic or private and improvisational—is positively associated with greater belief in God (Bulbulia & Schjoedt, 2010; Schjoedt et al., 2009). Given past evidence for the relationship between reminders of God and self-restraint, we argue that the frequency of prayer may function as a signal of fidelity. (Note: signals do not need to be infallible to evolve as cooperative signals [Bulbulia, 2004]).

Signal identification: Church attendance will be associated with greater social capital, as indicated by stronger religious ingroup commitments

Previous research suggests that church attendance is associated with religious ingroup reputation. By "church attendance" we include attendance at any

public religious service such as a temple, mosque, or synagogue. The motivations for the predicted relationship between church attendance and religious ingroup reputation were both theoretically and empirically motivated. First, drawing on a large American sample (n = 21,131), Weeden and colleagues found that the best predictor of church attendance is (restrained) sexual behavior (Weeden et al., 2008). The authors found an association between sexual behaviors and sexual mores in a sample of (n = 902) American university students. Though we would caution against inference to the larger American population based on this university sub-sample (as this ignores multilevel dependencies of the data), the behavioral measures in the study were nevertheless consistent with a model in which people use church to obtain social capital and display virtue.

Second, postulated reputation enhancements from church attendance have received empirical support from cross-cultural studies. For example, Shaver (2012) reported that in Fiji, church attendance was associated with greater social standing and a reputation for being a cooperator. Third, we note that church attendance in New Zealand occurs in public settings among groups of mainly unrelated individuals. Put simply, going to church is an act that may be witnessed by a broader social network than one's family. Signaling theorists argue that drawing attention to the expected audiences of religious practices helps to distinguish different types of functionality in religious signaling (Bulbulia & Sosis, 2011; Sosis, 2009). From a theoretical perspective, then, church attendance should be an ideal vehicle for expressing one's cooperative commitments to a religious social network, and as such, for receiving reputation enhancements.

The present study asks the question: why might church attendance in New Zealand function as an honest signal of one's cooperative commitments to a religious social network? That is, we expect from previous studies that church-going is associated with reputation enhancement. We expect that this reputation enhancement is related to the time and resources invested in a group. However the present study sought to deepen the explanation for why religious attendance is linked to reputation enhancement by tracking psychological variables associated with religious ingroup commitment.

Irons (2008) proposes that religious behaviors function as honest cooperation signals because the subjective value of religious behaviors is conditional

upon the acceptance of values that would otherwise appear, to use Irons's terminology, "crazy." That is, it is more difficult to go to church if one lacks commitments to a religious group. In terms of the present study, Irons's model predicts that, in addition to identifying commitments to a moralizing God (who sanctions social-network cooperation and who sanctions fidelity), church attendance should also identify values about the special entitlement of one's own religious group. By contrast, we did not expect to find religious group commitments associated with prayer frequency.

To identify religious ingroup values we capitalized on a novel measure assessing religious ingroup entitlement attitudes administered as part of the New Zealand Attitudes and Values Study (NZAVS; see below: Method). The measure assessed the degree to which participants believed their own religious group is deserving of special recognition and benefit. Importantly, the measure should not be taken as an indicator of out-group hostility. An analogy might help to understand the key distinction between within-group pride and out-group prejudice. Several of the authors of the present study are strong Pittsburgh Steelers fans. We think this team is better than all others in the history of the sport. However we do not bear other US football teams any animosity. And it is possible (we think probable) that our judgment is correct. Ingroup commitment taps into the value one places on one's own religious group as special. That's all. The measure does not specifically ask about ingroup values in relation to other religious groups.

To summarize, the traits associated with church attendance remain poorly understood, quite generally. Signaling theory postulates that some of this variance will be explained by religious ingroup commitment. Our novel religious ingroup entitlement scale tapped into the strength of these commitments by asking participants to identify whether their religious group is especially deserving of esteem over all other religious groups.

Model evaluation: Religiously identified women pray more frequently than religiously identified men

Conditional on the validity of the hypothesized association between prayer rate and strength of commitment to God, we predicted that religious women should pray more frequently than religious men.

Model evaluation: Religiously identified men will attend church more frequently than religiously identified women

Conditional on the predicted association between church attendance and strength of both belief in God and religious ingroup entitlement values, we hypothesized that men should express greater social-network commitments by attending church more frequently than women.

Among religiously identified New Zealanders, prayer and church attendance will be associated with greater fertility

Sexual selection theory, then, makes quite specific predictions about differences in fertility effects associated with prayer and church attendance within the religious population. Recall that prayer is expressed within family settings, among those who have already succeeded in attracting mates—the potential/current mates are already at intimate range. In cross-sectional datasets such as ours, we would expect the effects of praying as a signal of sexual fidelity to manifest in greater fertility among the population of women who pray frequently, as well as a lower probability of having zero children. This is because, within the religious population, women who have been successful at signaling their commitment and fidelity should have been more likely to reproduce relative to women who have been less successful at signaling their commitment and fidelity.

Slone's model also predicts differences in the composition of frequent church attendees. We have argued that church is a forum in which people express their cooperative virtues to a wider social network. Slone points out that among those lacking mates, this broader network consists of potential, but as yet unfamiliar, mates (Slone, 2008). Hence, according to Slone's model, church not only functions as a venue to display social commitment and receive social prestige, but also functions as a setting for attracting new mates. Hence, Slone's model predicts a mixed population among frequent churchgoers: those who have succeeded in reproducing and remain committed to the religious group, as well as those who wish to display the magnitude of their religious commitments to potential mates.

That is, the congregation of a given church should consist of a population of successful breeders alongside of a population of lonely hearts. In a

cross-sectional dataset such as ours, we would expect the predicted mixed population of frequent church-goers to consist of one group that has greater overall expected children and another that has a higher overall probability of having zero children at that point in time (but perhaps hoping to have many children in the future). We can assess this prediction in the context of zero-inflated regression models by modeling zero-inflation as a deviation from expected fertility while adjusting for and assessing the variances of denominations (see Method).

Results

Correlation of variables

Bivariate correlations between all variables are presented in Table 2.1.

Table 2.1 Bivariate correlations between all continuous variables that were modeled to test sexual signaling theory predictions.

	Age	Conservative	Belief in God	Ingroup	Prayer	Church	Deprivation	Children
Age								
Conservative	0.07*							
Belief in God	-0.11***	0.22***						
Ingroup	-0.05	0.14***	0.25***					
Prayer	0.02	0.09**	0.20***	0.15***				
Church	0.00	0.17***	0.27***	0.31***	0.26***			
Deprivation	-0.04	-0.07*	0.06	0.03	0.08*	0.03		
Children	0.36***	0.10**	0.09**	0.01	0.18***	0.12***	0.10***	
Children Home	-0.48***	0.04	0.12***	0.06*	0.07*	0.08*	0.00	0.22***

These correlations are presented for descriptive purposes. The bivariate associations do not adjust for demographic effects, for denominational correlations, or for zero-inflation in rates of prayer and church attendance. We used zero-altered mixed effects regression models deployed in a Bayesian setting to model the probability of zero-outcomes, while at the same time assessing the covariates of non-zero-outcomes. Findings 1a and 1b (signal evaluation):

Table 2.2 Regression model predicting belief in God (left set of panels) and religious ingroup commitment (right set of panels).

	Belief in God				Religious Group Commitment			
	b	-95% CI	+95% CI	p_{MCMC}	b	-95% CI	+95% CI	p_{MCMC}
Intercept	5.616	5.217	6.014	.000	4.049	3.805	4.297	.000
Prayer (standardized)	0.156	0.080	0.227	.000	0.099	0.036	0.164	.004
Church (standardized)	0.269	0.193	0.341	.000	0.341	0.273	0.405	.000
Men	-0.207	-0.364	-0.055	.010	0.168	0.027	0.302	.016
Partner	-0.012	-0.173	0.153	.882	-0.279	-0.422	-0.134	.000
Age (centered)	-0.010	-0.015	-0.006	.000	-0.008	-0.013	-0.004	.000
NZ European	-0.098	-0.228	0.056	.180	-0.190	-0.311	-0.063	.004
Conservative (standardized)	0.203	0.126	0.273	.000	0.176	0.111	0.243	.000
Deprivation (standardized)	0.110	0.038	0.185	.002	0.005	-0.070	0.059	.889
Urban	-0.052	-0.208	0.100	.504	0.052	-0.088	0.186	.449

prayer is positively associated with belief in God; church attendance is associated with both religious ingroup entitlement values and belief in God. Models 1a and 1b: Our first statistical model aimed to assess the relationship between inner beliefs and values and outward religious behaviors (prayer and church attendance). Results are presented in Table 2.2.

As predicted, we found that prayer was associated with belief in God (β = 0.156, 95 percent HPD interval from 0.08 to 0.23, pMCMC <0.001), and church attendance was also associated with belief in God (β = 0.269, 95 percent HPD interval from 0.19 to 0.63, pMCMC = <0.001). We focus on prayer as the religious signal more relevant to predicting fidelity because prayer is most commonly expressed within the private setting of a home and because prayer is expected to prime fidelity. We were not surprised that church attendance was associated with belief in God because a central hypothesis of religious signaling literature is that public rituals express commitments to God. As expected, we found that church attendance was positively associated with greater religious ingroup entitlement values (β = 0.41 (95% HPD interval from 0.33 to 0.49). Table 2.2 gives these coefficient values.

To assess denominational covariances in religious belief and ingroup entitlement values, we calculated the intra-class correlation coefficient for the repeatability of denominational effects. The expected correlation for belief by denomination was r = .19, and the expected correlation of religious ingroup commitment by denomination was r = .04, at the boundary of zero, with the expected co-variation of belief and ingroup commitment also at the boundary of zero (-.05). Our task here was not to predict denominational variance, but rather to account for denominational correlations. Notably, however, the model hints at substantial denominational variance in levels of belief in God.

Prediction 2a: Women pray more frequently than men

We next investigated whether religious women prayed more frequently than men with equivalent levels of belief in God. Because prayer outcomes were zero-inflated (i.e., a larger proportion of religiously identified participants stated they prayed zero times per week than would be expected by chance), we employed zero-altered mixed effects regression to investigate zero-inflation when investigating prayer rates. We followed Hadfield's method, which

Table 2.3 Regression model predicting gender differences in average frequency of prayer for those who prayed (left panel) and probability of not praying at all (right panel) among the sample of religious respondents. (Note: positive coefficients indicate lower probability of not attending church.)

	Frequency of prayer				Probability of not praying			
	b	-95% CI	+95% CI	P_{MCMC}	b	-95% CI	+95% CI	P_{MCMC}
Intercept	1.958	1.645	2.255	.000	-1.204	-1.701	-.710	.000
Men	-.244	-.410	-.073	.007	.019	-.276	.330	.902
Belief in God (standardized)	.329	.212	.453	.000	.749	.572	.939	.000
Partner	.059	-.132	.232	.531	-.001	-.326	.319	.996
Age (centered)	.013	.007	.019	.000	-.004	-.016	.006	.426
NZ European	.102	-.057	.256	.191	-.210	-.475	.069	.130
Conservatism (standardized)	.085	.009	.168	.039	-.022	-.174	.121	.761
Deprivation (standardized)	.116	.043	.198	.004	-.048	-.186	.096	.505
Urban	.081	-.082	.254	.334	-.199	-.509	.109	.212

involves constraining over-dispersion (the "R-structure" of the model) to be the same for both the Poisson (a.k.a. rate) process and the zero-inflation process (Hadfield, 2012). We then set up the contrasts in the model so that the zero-altered regression coefficients were estimated as deviations from the Poisson regression coefficients. Note that a negative zero-inflation coefficient suggests zero-inflation, whereas a positive zero-inflation coefficient suggests zero-deflation.

As predicted, we found that religiously identified men pray less frequently than religiously identified women (βpois = -0.244, 95 percent HPD interval from -0.41 to -0.07, pMCMC = .007); though we did not observe gender differences in zero-inflation (β-zeroinfl. = -0.019 ; 95 percent HPD interval from -0.28 to 0.330, pMCMC = 0.902). We again found that belief in a higher power was associated with prayer (βpois = 0.329 95 percent HPD interval from 0.21 to 0.45, pMCMC = < 0.001), and that belief was associated with zero-deflation in the prayer rate (β-zeroinfl. = 0.749; 95 percent HPD interval from 0.57 to 0.94, pMCMC = < 0.001).

To assess the effects of denominational variances, we calculated an intra-class correlation coefficient for the repeatability of denominational which was r = .12, and for the effect of having children at home which was r = .02. This result suggests little effect from children at home on prayer, however there is some evidence for denominational variances in the prayer rate.

Prediction 2b: Men attend church more frequently than women

As with prayer, monthly church attendance outcomes were zero-inflated (i.e., a larger proportion of religiously identified participants stated that they attended church zero times per week than would be expected by chance), and thus we applied zero-altered mixed effects regression models to investigate zero-inflation when investigating church attendance rates. Again, we followed Hadfield's method, which involves constraining over-dispersion (the "R-structure" of the model) to be the same for both the Poisson process and the zero-inflation process. Again, we also set up the contrasts in the model so that the zero-altered regression coefficients were estimated as deviations from the Poisson regression coefficients. Here again, a negative zero-inflation coefficient suggests zero-inflation whereas a positive zero-inflation coefficient

Table 2.4 Regression model predicting gender differences in average frequency of church attendance for those who attended church (left panel) and probability of not attending church at all (right panel) among the sample of religious respondents. (Note: positive coefficients indicate lower probability of not attending church.)

	Frequency of Church				Probability of not attending Church			
	b	-95% CI	+95% CI	p_{MCMC}	b	-95% CI	+95% CI	p_{MCMC}
Intercept	1.061	0.831	1.320	.000	-1.408	-1.791	-0.983	.000
Men	0.164	0.036	0.284	.009	-0.339	-0.557	-0.113	.002
Religious Group (standardized)	0.174	0.106	0.232	.000	0.439	0.322	0.549	.000
Partner	-0.109	-0.244	0.021	.000	0.192	-0.041	0.434	.111
Age (centered)	0.006	0.002	0.010	.112	-0.004	-0.012	0.004	.296
NZ European	0.158	0.049	0.276	.006	-0.051	-0.267	0.148	.626
Conservatism (standardized)	0.073	0.014	0.131	.013	0.017	-0.086	0.127	.767
Deprivation (standardized)	0.047	0.010	0.107	.114	-0.071	-0.175	0.030	.178
Urban	0.042	-0.081	0.170	.523	-0.094	-0.313	0.137	.416

suggests zero-deflation. The expectation for the Poisson process is estimated using a log link and the zero-probability process is estimated using a complementary log/log link.

As predicted, we found that religiously identified men attend church more frequently on average than religiously identified women (βpois = 0.164, 95% HPD interval from 0.04 to 0.28 pMCMC = < 0.01); though men were somewhat more zero-inflated in church attendance (β-zeroinfl. = -0.339, 95 percent HPD interval from -0.56 to -0.11, pMCMC = < 0.01). Religious ingroup comment was strongly associated with both monthly church attendance rate (βpois = 0.170, 95 percent HPD interval from 0.106 to 0.232, pMCMC = 0.0002) and zero-deflation in monthly church attendance (β-zeroinfl. = 0.439, 95 percent HPD interval from 0.32 to 0.55, pMCMC = < 0.01). This finding is consistent with religious signaling theory, which holds that commitment to special entitlements for one's group predicts both the rate of one's attendance at church and the probability of whether one attends church at all.

Prediction 3a: Comparison of religiously identified and non-identified New Zealanders

We next assessed whether religion was associated with overall fertility. Of the 3,736 participants who reported whether or not they had children from the previous wave 3 NZAVS survey, 28 percent (a total of 1,045) reported having no children. 31 percent of the sample that did not identify with a religion reported having no children (715/2,319) while 23 percent of the religion-identified sample who responded to this question also reported no children (330/1,417). Given such an abundance of zeroes, we modeled the expected number of children using a zero-inflated Poisson regression, while controlling for age, ethnicity, political conservatism, and regional deprivation. Sexual signaling theory predicts that religion identification will be associated with greater fertility, given the hypothesized availability of mate-assuring commitment signals.

If religious behaviors were to signal qualities important to potential mates, we would expect religious people to have more offspring, on average, than nonreligious people. This is because we expect religious signals to be honest indicators of cooperative parenting. As such, religious signals may be reliably

Table 2.5 Regression model predicting gender differences in the average number of children for those who were parents (left panel) and probability of not being a parent, i.e. having zero children (right panel), among the entire sample of religious and nonreligious respondents. (Note: positive coefficients indicate lower probability of not attending church.)

	Birth rate				Probability of having zero children			
	b	-95% CI	+95% CI	p_{MCMC}	b	-95% CI	+95% CI	p_{MCMC}
Intercept	0.580	0.485	0.677	.000	-0.754	-0.934	-0.576	.000
Religious	0.151	0.090	0.213	.000	-0.174	-0.301	-0.048	.008
Men	0.024	-0.040	0.087	.455	-0.132	-0.258	-0.006	.037
Age (centered)	0.014	0.012	0.017	.000	0.033	0.029	0.038	.000
NZ European	-0.040	-0.099	0.019	.185	0.056	-0.058	0.172	.338
Partner	0.084	0.003	0.162	.038	0.831	0.686	0.974	.000
Conservativism (standardized)	0.017	-0.014	0.049	.281	0.095	0.037	0.155	.002
Deprivation (standardized)	0.065	0.036	0.096	.000	0.019	-0.039	0.075	.526
Urban	-0.055	-0.114	0.006	.077	-0.204	-0.331	-0.081	.001

acted on. Thus, we assessed evidence for such a predicted increase in fertility among religiously identified New Zealanders.

Consistent with theoretical expectations, we found that religious affiliation was positively associated with fertility (βpois = 0.151; 95 percent HPD interval from 0.09 to 0.21, pMCMC <.001); though also with more zero-inflation (β-zeroinfl. = -0.174; 95 percent HPD interval from -0.30 to -0.05, pMCMC <.001). There was no evidence for gender differences in the expected number of children (pMCMC = 0.455); however, there was some marginal evidence for greater zero-inflation expected by gender, with men showing greater zero-inflation (β-zeroinfl. = -0.132; 95 percent HPD interval from -0.26 to 0.01, pMCMC <.037), however this is estimate is close to the boundary of zero.

Consistent with theoretical expectations, we found that religious affiliation was positively associated with fertility (βpois = 0.151; 95 percent HPD interval from 0.09 to 0.21, pMCMC <.001); though also with more zero-inflation (β-zeroinfl. = -0.174; 95 percent HPD interval from -.30 to -.05, pMCMC <.001). This suggests a positive relationship between religion and expected fertility as has been observed in other studies (e.g. Blume 2009; Rowthorn, 2011).

To put this association in perspective, the expected number of children in the nonreligious identified population (with a romantic partner) at baseline was 1.95 and expected zero-deflation was pr = .34. The expected number of children among those who identified with a religion (and had partners) was 2.26; expected zero-deflation was pr = .40. Whether the association with an increase in a probability of zero children is evidence for the use of religion to attract mates, as Slone's theory predicts, is a matter of speculation. However we do find evidence for a positive association between religious identification and overall expected offspring, an effect that appears to be globally widespread (e.g. Blume, 2009; Rowthorn, 2011).

Comparisons of fertility in religiously identified New Zealanders according to weekly prayer rate and monthly Church attendance

Slone's sexual selection model predicts that people use religious behavior to attract mates. For prayer, the predicted outcomes are straightforward. Greater prayer frequency should be associated with more children and less zero-deflation. For church attendance, Slone's model might predict a mixed

Table 2.6 Regression model predicting the association between rates of prayer and church attendance with the average number of children for those who were parents (left panel) and probability of not being a parent (right panel) for religious participants.

	Birth rate				Probability of having zero children			
	b	-95% CI	+95% CI	p_{MCMC}	b	-95% CI	+95% CI	p_{MCMC}
Intercept	0.786	0.629	0.942	.000	-0.949	-1.212	-0.680	.000
Prayer (standardized)	0.065	0.027	0.102	.000	0.172	0.051	0.301	.012
Church (standardized)	0.059	0.014	0.104	.013	-0.136	-0.238	-0.032	.005
Men	0.091	0. 001	0.187	.051	-0.278	-0.505	-0.070	.008
Age (centered)	0.012	0.009	0.016	.000	0.030	0.022	0.037	.000
NZ European	-0.032	0.126	0.058	.468	0.059	-0.115	0.252	.519
Partner	0.091	0.032	0.209	.171	1.054	0.849	1.277	.000
Conservativism (standardized)	0.004	0.042	0.054	.864	0.058	-0.034	0.160	.227
Deprivation (standardized)	0.070	0.020	0.116	.004	-0.031	-0.132	0.073	.559
Urban	-0.059	0.153	0.025	.186	-0.306	-0.500	-0.089	.002

population of successful breeders and lonely hearts. Greater church attendance in the successful breeding group should be associated with more children, however greater church attendance is also expected to be associated with greater zero-deflation. If we were to focus on average offspring alone, the variances of the two populations might tend to cancel each other out when lumped together.

Prayer and fertility

Overall, we found an ambiguous relationship between gender and fertility rate. Religiously identified men were expected to have more children (βpois = 0.091 95 percent HPD interval from 0.01 to 0.18, pMCMC = 0.051), though this effect is at the boundary of zero and thus we infer that the gender association on fertility is uncertain; religious men exhibited more evidence of zero-inflation in expected offspring (β-zeroinfl. = -0.278, 95 percent HPD interval from -0.51 to -0.07, pMCMC = < 0.01).

Recall that sexual signaling theory does not assume a difference in the effects of a signal by gender, but rather a difference in the rates of expressing a signal. A signal is reliable if it identifies a trait relevant to fertility, but there was no theoretical reason to suppose that a religious signal should be more reliable for one sex. Our theoretical interest was in predicted offspring associated with the signal itself. As expected, we found an association between prayer rate and fertility (βpois = 0.065; 95 percent HPD interval from 0.03 to 0.10, pMCMC <.05); (β-zeroinfl. = 0.172; 95 percent HPD interval from 0.05 to 0.30, pMCMC = 012).

To assess the relationship between prayer and expected offspring, we first estimated the expected offspring when all predictors were set to zero, except romantic partners (set to 1, to recover the effect in people with partners) and urban (set to 1, to recover the effect in people who live in urban settings). In the population that prays at the average sample rate (11 times per week) there was an expectation of 2.27 children. Among the population who prays 35.37 times per week (a one standard deviation increase), the expected number of offspring was 2.41.

Weekly prayer was also associated with a decrease in zero-inflation. The expected probability of zero offspring among those who pray at an average prayer rate (11 times per week) was pr = .44. Among the population who prays 35.37 times per week (a one standard deviation increase), the expect probability of zero offspring was pr = .38. Thus prayer predicts having more children as well as a diminished likelihood of failing to reproduce at all.

Church and fertility

As predicted, we found an association between church attendance and overall fertility (βpois = 0.059, 95 percent HPD interval from 0.01 to 0.10, pMCMC = <.001; β-zeroinfl. = -0.136, 95 percent HPD interval from -0.24 to -0.03, pMCMC = 0.005.) To assess the relationship between church and expected offspring, we first estimated the expected offspring when all predictors were set to zero, except romantic partners (set to 1, to recover the effect in people with partners) and urban (set to 1, to recover the effect in people who live in urban settings). In the population that attends church at the average sample rate (2.08 times per month) there was an expectation of 2.27 children. Among the population who attends church 5.40 times per month (a one standard deviation increase), the expected number of offspring was 2.41.

Unlike prayer, however, church attendance was associated with greater zero-inflation. In the population that attends church at the average sample rate (times per month) the expected probability of zero children was pr = .44. Among the population who attends church per 4.50 times per month (a one standard deviation increase), the expected number of offspring was pr = .49. Hence, our analysis reveals a mixed population of frequent church-goers consisting of those with greater fertility and those with a diminished likelihood of having any children at all. This finding makes sense from the vantage point of sexual selection theory. According to Slone, people use religious behavior as a way to advertise their worthiness to potential mates. Consistent with Slone's model, increasing the monthly church attendance rate was also associated with an increase in zero-inflation. The relationship between prayer and church attendance on expected children and zero-inflation is depicted in Figure 2.1.

In Figure 2.1 units are in standard deviations (prayer SD = 24.08, church SD = 3.32) and zero represents the sample average rate (prayer = 11.30 times per week, church = 2.08 times per month.) Greater zero-inflation as church

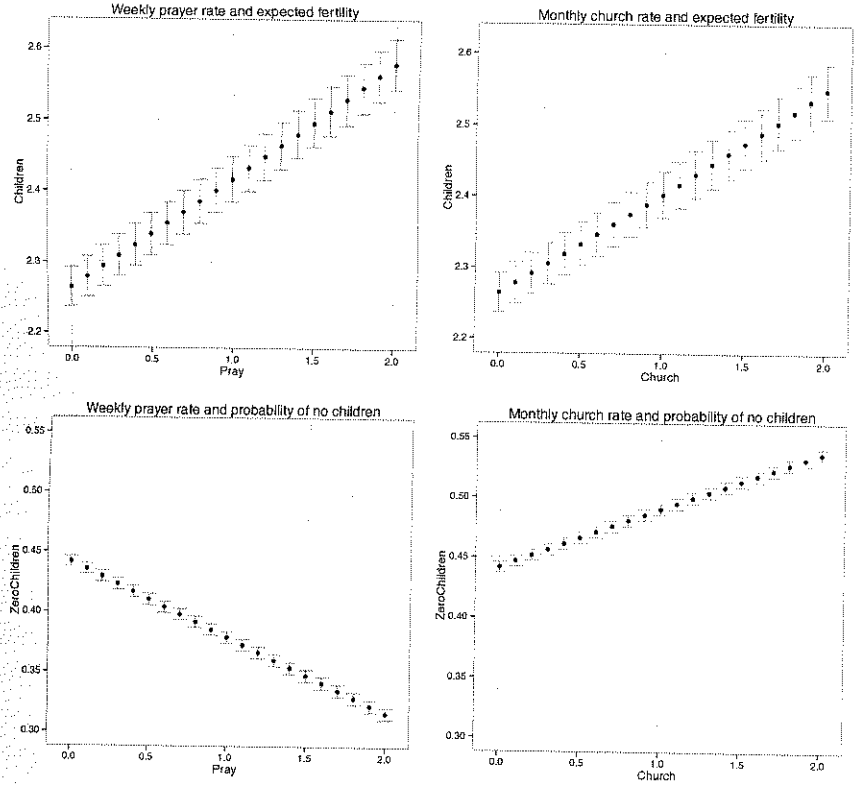

Figure 2.1 Expected fertility effects associated with prayer rate and church attendance.

attendance increases is consistent with Slone, who argues that church is a public forum for signaling mate-worthiness.

Though church attendance results imply a mixed population of high-fertility frequent church-goers and zero-inflated church-attenders, we can say little more than that this finding is consistent with Slone's model. Our cross-sectional data do not enable us to identify whether this zero-inflation is the result of mate-seeking behavior. It is possible that for some people, church attendance decreases fertility. It is possible that the mixed population of fertile and childless church-going types results from some other variable. Because the NZAVS is currently repeatedly surveying the same participants each year, such questions will be better clarified from future longitudinal data.

Discussion

Summary of findings

Commitment signaling models of religion claim that religious expressions and behaviors demonstrate traits relevant to predicting the likelihood of successful cooperation. Though sexual reproduction is a universal and fundamental cooperation problem, the relationship between religious signaling and mating decisions has to date received limited attention.

The purpose of this study was to evaluate the predictions of Slone's sexual signaling theory (2008), which claims that religion facilitates mate selection. Our first task was to assess how religious behaviors are linked to mate-quality traits. We called this task: "signal identification". Our next series of tasks related to evaluating the predictions of sexual signaling theory. This involved: (1) investigating whether men and women differed in their rates of expressing signals associated with mate-quality; (2) evaluating whether religious people were, overall, more fertile than nonreligious people; and (3) assessing whether signal frequencies associated with signaling mate-quality were associated with greater fertility for religiously identified individuals.

Our findings were as follows:

1. Signal assessment: prayer is linked to belief in God. Consistent with theoretical predictions, we found that prayer is strongly associated with belief in God. Because belief in God, when recollected, has been found to restrain anti-cooperative behavior, we propose that the display of prayer may function as a signal of fidelity.
2. Signal assessment: church attendance is linked to religious ingroup entitlement values. Consistent with previous studies, we found that church attendance is strongly associated with prestige gradients. The present study reveals a basis for higher social prestige from church attendance through a novel measure of religious ingroup entitlement values. It identifies a social value—religious ingroup entitlement—clarifying why the frequency of church attendance may be associated with greater commitment to a group; it is such commitment that we postulate underpins social capital.
3. Model assessment: women pray more than men pray. Consistent with the predictions of sexual signaling theory, we find that religiously identified

women tend to pray more frequently than religiously identified men, holding all else equal.

4. Model assessment: men attend church more than women attend church. Consistent with the predictions of sexual signaling theory, we find that religiously identified men attended church more frequently than do religiously identified women, again holding all else equal.
5. Model assessment: religious people exhibit higher fertility than nonreligious people, and among religious people, prayer and church attendance frequencies are positively associated with fertility. Consistent with the predictions of sexual signaling theory, we find that prayer is associated with greater fertility and being more likely to pray among both men and women. We also find that church attendance was associated with greater fertility among those who had offspring. Notably, religious people without children were more likely to go to church frequently. Slone predicts a mixture of high-fertility and zero-fertility frequent church attendees, and our results support his assertion.

Methodological contribution

Methodologically our study is important for three reasons:

1. We use social-psychological measures to assess the predictions of an important biological theory of religion, using a large and diverse sample of religiously identified New Zealanders (n = 1,647).
2. We introduce a novel measure of religious ingroup entitlement, and use this to clarify the relationship between social reputation, church attendance and cooperative commitments observed in previous studies. We hope that this measure will be adopted for wider use.
3. We apply appropriate and rigorous statistical models to handle zero-inflation and correlated data. We hope such models, which are widely used in the biological sciences, become more commonplace in the human sciences.

Theoretical contribution

Theoretically our study is important for two reasons:

1. We clarify how religious signaling might facilitate mate selection and retention. Reproduction poses biology's most fundamental cooperation problem. Our study adds credence to the theory that religious behavior facilitates the cooperation of parents and identifies traits relevant to predicting parental success among potential mates. Though others have proposed this idea, our study is among the first to quantify sex differences in religious piety, and to observe predicted associations with fertility.
2. Our analysis suggests that religious signals for commitment may be more intricate than previous research has suggested. Some religious expressions appear to signal traits associated with fidelity while other religious expressions appear to signal traits associated with religious ingroup commitments. And of course, these are not mutually exclusive categories; some religious expressions serve as both signals of fidelity and ingroup commitment. Religious expressions might function to identify unique and potentially diverse traits relevant to cooperative predictions.

Limitations and future research

There are three limitations of our research:

1. We neither claim nor show that religion evolved for mate discrimination alone. Elsewhere we argue that belief in God underpins cooperative commitments outside of sexual fidelity, and indeed, most of our research on religion and signaling has focused on cooperation in broader social networks (Bulbulia & Mahoney, 2008; Sosis, 2005; Sosis & Bressler, 2003; Sosis & Ruffle, 2003; Xygalatas et al., 2013). Elsewhere we have claimed that belief in supernatural powers is a core psychological trait that facilitates such cooperation (Bulbulia, 2004) and have tested this claim empirically (Purzycki et al., 2012). Relatedly, we did not suppose that the functional benefits of prayer would be restricted to mate signaling. Elsewhere we have suggested that prayer functions to allay anxiety (Sosis

& Handwerker, 2011) as well as support social acceptance (Sibley & Bulbulia, 2012).

2. Our data are cross-sectional and thus we cannot assess the direction of the associations we have discovered. That is, our analysis does not rule out the possibility that having children causes religious people to pray more frequently and to attend church more frequently. Nor do we rule out that church attendance invites a greater risk for lower fertility. Excitingly, the NZAVS is collecting data relevant to assessing causal questions.[5]
3. We have not assessed how cultural gender norms and biases inform the associations we observed in this study. However, we acknowledge that gender biases operate widely, even within modern democracies such as New Zealand. One of the core motivations in the initial design of the NZAVS was to understand how gender biases affect people over time. Longitudinal investigation of gender biases is fundamental both to appropriate statistical inference and to sensible practical inferences, and future studies must assess these processes in connection with gender differences and religion.

With due consideration to the limitations of the present study, the correlations we observed offer some initial support for the sexual signaling model of religion. We infer that sexual signaling deserves more attention in the evolutionary literature on religion and cooperation. Religion appears exquisitely adapted for supporting the cooperation of parents. Such biological functionality persists, even in a largely secular country.

Appendix

Model equations

Models 1a/b. Our signal identification task was to assess the relationship between these outcomes (inner beliefs and values) and the outward religious behaviors theorized to identify them (i.e., prayer and church attendance. Where y^{L} denotes the level of belief in God vector and y^{I} denotes the level of religious ingroup commitment vector (stacked in the multivariate model). The model equation assessing predicted associations can be written:

Equation 2.1

$$y^{L} \sim N\left(v_B^{1L} + v_B^{Pr_I^L} + v_B^{Ch_I^L} + v_B^{Men_I^L} + v_B^{Age_I^L} + v_B^{Eth_I^L} + v_B^{Csrv_I^L} + v_B^{Dep_I^L} + v_B^{Urb_I^L} + v_{G=\,L/I\,I}^{Dmn\,L\,I/L},\ v_{R=\,L/I\,I}^{L\,I/L}\right)$$

Where it is assumed that belief and religious ingroup entitlement values are normally distributed, conditional on the modeled predictors.

Model 2a. A key challenge is to account for the abundance of zeroes for prayer, church attendance, and offspring (see Figure 2.2).

To handle zero-inflation we modeled effects assuming zero-altered Poisson distributions. Where η^{P} denotes the weekly prayer rate outcome vector and η^{C} denotes the zero-outcome vector for weekly prayer (stacked in the multivariate model), the model equation comparing church attendance among male and female religiously identified New Zealanders can be written:

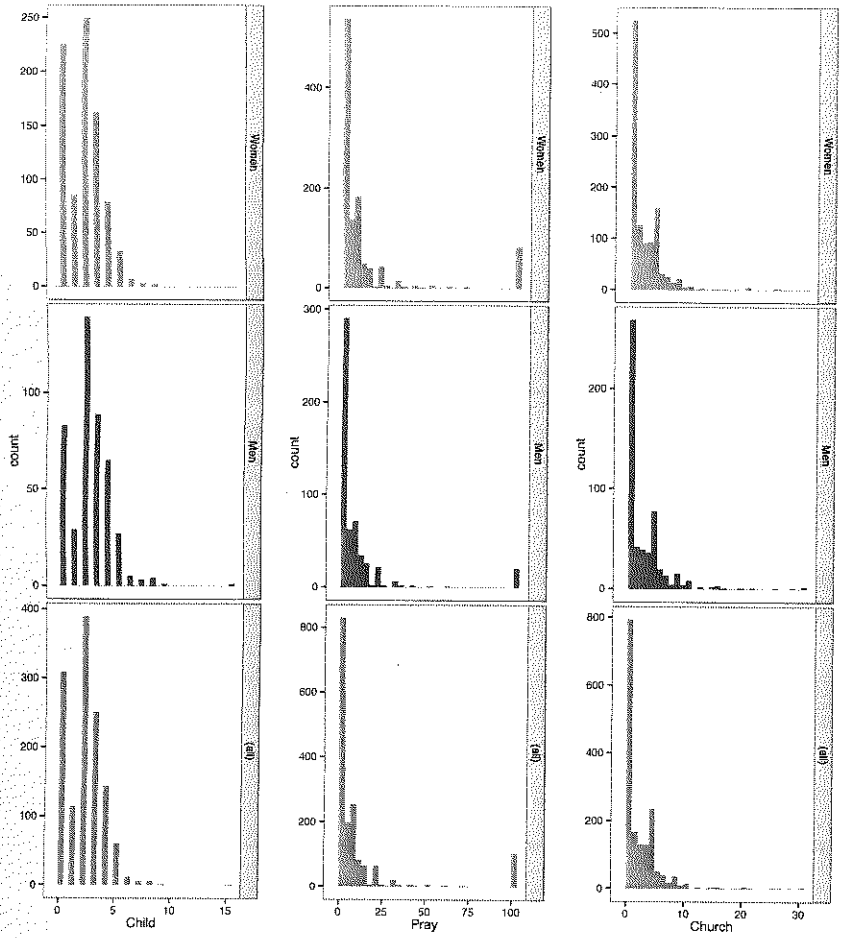

Figure 2.2 Histograms showing frequencies of children, prayer, and church attendance for women, men, and the combined sample of religious respondents.

Equation 2.2

$$\eta^{\mathrm{P}}_{\mathrm{Z}} = \mathrm{v}^{\mathrm{1P}}_{\mathrm{B}} + \mathrm{v}^{\mathrm{MenP}}_{\mathrm{B}} + \mathrm{v}^{\mathrm{BlfP}}_{\mathrm{B}} + \mathrm{v}^{\mathrm{AgeP}}_{\mathrm{B}} + \mathrm{v}^{\mathrm{EthP}}_{\mathrm{B}} + \mathrm{v}^{\mathrm{CsrvP}}_{\mathrm{B}} + \mathrm{v}^{\mathrm{DepP}}_{\mathrm{B}} + \mathrm{v}^{\mathrm{UrbP}}_{\mathrm{B}} + \mathrm{v}^{\mathrm{DnmP}}_{\mathrm{G}=\begin{smallmatrix}1&1\\1&1\end{smallmatrix}} + \mathrm{v}^{\mathrm{ChildHomeP}}_{\mathrm{G}=\begin{smallmatrix}1&1\\1&1\end{smallmatrix}} + \mathrm{v}^{\mathrm{P}}_{\mathrm{R}=\begin{smallmatrix}1&1\\1&1\end{smallmatrix}}$$

Where the outcomes are assumed to draw from a zero-inflated Poisson-(over) dispersed rate parameter. The Poisson process was assessed using the log-link function, and zero-inflation/deflation was assessed used the complimentary log/log link function and constraining over-dispersion to be equal:

Equation 2.3

$$\eta_{\mathrm{pz}} \sim \mathbf{ZAPois}\left(\lambda = \exp(\eta_{\mathrm{pz}}, p = exp(-exp(\eta_z))\right)$$

Model 2b. Another key model evaluation task was to assess the relationship between church attendance and gender. If church attendance were to signal social reputation, and it might be more important for men to signal high social standing than it would be important for women to signal high social standing, we would expect religious men to attend church more frequently than religious women. Assuming that religious signals are honest, as signaling theory does, we would expect signaling rates to remain relatively constant (rather than show susceptibility to opportunism). Where η^{H} denotes the monthly church attendance vector and η^{Z} denotes the zero-outcome vector for monthly church attendance (stacked in the multivariate model), the model equation comparing church attendance among male and female religiously identified New Zealanders can be written:

Equation 2.4

$$\eta^{\mathrm{H}}_{\mathrm{Z}} = \mathrm{v}^{\mathrm{1H}}_{\mathrm{B}} + \mathrm{v}^{\mathrm{MenH}}_{\mathrm{B}} + \mathrm{v}^{\mathrm{RGrpH}}_{\mathrm{B}} + \mathrm{v}^{\mathrm{AgeH}}_{\mathrm{B}} + \mathrm{v}^{\mathrm{EthH}}_{\mathrm{B}} + \mathrm{v}^{\mathrm{CsrvH}}_{\mathrm{B}} + \mathrm{v}^{\mathrm{DepH}}_{\mathrm{B}} + \mathrm{v}^{\mathrm{UrbH}}_{\mathrm{B}} + \mathrm{v}^{\mathrm{DnmH}}_{\mathrm{G}=\begin{smallmatrix}1&1\\1&1\end{smallmatrix}} + \mathrm{v}^{\mathrm{ChildHomeH}}_{\mathrm{G}=\begin{smallmatrix}1&1\\1&1\end{smallmatrix}} + \mathrm{v}^{\mathrm{H}}_{\mathrm{R}=\begin{smallmatrix}1&1\\1&1\end{smallmatrix}}$$

Where the outcomes are assumed to draw from a zero-inflated Poisson-(over) dispersed rate parameter. The Poisson process was assessed using the log-link function, and zero-inflation/deflation was assessed used the complimentary log/log link function and constraining over-dispersion to be equal:

Equation 2.5

$$\eta_{\mathrm{hz}} \sim \mathbf{ZAPois}\left(\lambda = \exp(\eta_{\mathrm{hz}}, p = exp(-exp(\eta_z))\right)$$

Model 3a. If religious behaviors were to signal qualities important to mate-selection, we would expect religious people to have more offspring, on average, than nonreligious people. A key theoretical test of sexual signaling theory was to assess this predicted increase in fertility among religiously identified New Zealanders. Where η^{C} denotes the child outcome vector and η^{Z} denotes the zero-outcome vector (stacked) in the multivariate model, the model equation comparing (zero-inflated) fertility among religious and nonreligious New Zealanders can be written:

Equation 2.6

$$\eta_Z^C = v_B^{1C} + v_B^{RelC} + v_B^{MenC} + v_B^{AgeC} + v_B^{EthC} + v_B^{PrtnrC} + v_B^{CsrvC} + v_B^{DepC} + v_B^{UrbC} + v_{R=\begin{smallmatrix}1&1\\1&1\end{smallmatrix}}^C$$

Where the outcomes are assumed to draw from a zero-inflated Poisson-(over) dispersed rate parameter. The Poisson process was assessed using the log-link function, and zero-inflation/deflation was assessed used the complimentary log/log link function and constraining over-dispersion to be equal:

Equation 2.7

$$\eta_{CZ} \sim \mathbf{ZAPois}\left(\lambda = \exp(\eta_{CZ}, p = exp(-exp(\eta_Z))\right)$$

Model 3b. If religious behaviors were to signal qualities important to parent-selection, we would expect that within the religion-identified group, those who signaled more would tend to have more children than those who signaled less. A key theoretical test of sexual signaling theory was to assess this predicted increase in fertility by assessing the relationship between weekly prayer and monthly church attendance and offspring in religiously identified New Zealanders. Where η^C denotes the child outcome vector and η^Z denotes the zero-outcome vector (stacked) in the multivariate model, the model equation comparing (zero-inflated) fertility among religious New Zealanders by weekly prayer and monthly church attendance can be written:

Equation 2.8

$$\eta_Z^C = v_B^{1C} + v_B^{PrC} + v_B^{ChC} + v_B^{MenC} + v_B^{AgeC} + v_B^{EthC} + v_B^{PrtnrC} + v_B^{CsrvC} + v_B^{DepC} + v_B^{UrbC} + v_{G=\begin{smallmatrix}1&1\\1&1\end{smallmatrix}}^{DumC} + v_{R=\begin{smallmatrix}1&1\\1&1\end{smallmatrix}}^C$$

Where the outcomes are assumed to draw from a zero-inflated Poisson-(over) dispersed rate parameter. The Poisson process was assessed using the log-link function, and zero-inflation/deflation was assessed used the complimentary log/log link function and constraining over-dispersion to be equal:

Equation 2.9

$$\eta_{CZ} \sim \mathbf{ZAPois}\left(\lambda = \exp(\eta_{CZ}, p = exp(-exp(\eta_Z))\right)$$

Sampling procedure

The sample was obtained from the Time 3.5 (2012 mid-year wave) New Zealand Attitudes and Values Study (NZAVS), which contained responses from 4,515 participants who completed an online-only questionnaire administered roughly six months following the full Time 3 (2011/12) NZAVS questionnaire. The Time 3.5 sample was supplementary to the full Time 3 (2011/12) NZAVS. The sample frame included those participants who had provided an email address when completing the full Time 3 questionnaire earlier that year, as well as approximately 400–500 Pacific participants who were recruited informally via Pacifika networks. The sample included 1,972 retained participants from the initial Time 1 (2009/10) NZAVS random electoral roll sample, 2,164 participants from the non-random online newspaper website sample collected as part of the Time 3 (2011/12) NZAVS, 202 participants who self-selected into the study or who were unable to be matched to a sample frame, and 177 additional Pacific participants recruited via Pacifika networks.

Because the Time 3.5 wave did not contain information about key demographic variables including fertility rates, participants were matched to the Time 3 (2011/12) NZAVS wave which contained responses from 6,886 participants (3,914 retained from previous years, 2,972 new participants for the 2011/12 NZAVS). Missing data were imputed using the mice package in R (van Buuren & Groothuis-Oudshoorn, 2014). We did not impute missing values for religious affiliation (yes/no) and gender (male/female), resulting in a subset of 1,647 religiously identified participants in the T3.5 wave and 4,377 participants for the T3.0 wave. Responses for number of children were used only as outcome variables; here missing data were estimated using a multivariate (latent) normal distribution during McMC. Number of children living at home was used in the church attendance model (given previous research indicating that children at home affects the gender representation at church attendance); here we modeled children living at home as a random effect, and the McMC algorithm estimated missing values on a multivariate (latent) normal distribution.

Participant details and survey measures

Religious affiliation. This was assessed using the same method of the New Zealand Census, by asking "Do you identify with a religion and/or spiritual group?" (yes/no response). Those who answered "yes" were then asked to complete an open-ended field specifying their religious denomination or group membership. Denominational affiliations were coded using the New Zealand 2006 Census categories, which included 40 denominations. The number of participants in the full T3.5 wave who included information about both their gender and religious identification was n = 4,377. Of these, 2,730 did not affiliate as religious, while 1,647 did. Those identifying as religious were coded as 1 and those identifying as nonreligious were coded as 0. These zeroes were converted to -1 and we used sum contrast coding in the fertility prediction model when estimating the effects of religion on offspring.

Gender. In the full sample there were 1,566 (.358) men and 2,811 women (.642); in the religious sub-sample there were 1,108 women (.673) and 539 men (.327). Those identifying as female were coded as 1 and those identifying as male were originally coded as 0. These zeroes were converted to -1 and the 1's were retained: that is, we used sum contrast coding for this variable in all regression models so that the intercept is interpreted as the expected effect for population average.

Age. Average age in the full sample was 48.82 years old (SD = 15.71) and in the religious sub-sample 50.15 years old (SD = 16.14). Age was centered in all regression models.

Ethnicity. Ethnicity was assessed using European ancestry (yes/no). In the full sample there were 1,990 people who identified as non-European (.455) and 2,387 who identified as European (.545); in the religious sub-sample there were 792 people who identified as non-European (.481) and 855 who identified as European (.519).

Romantic partnership. Participants were asked to indicate their relationship status. They could choose from several options ("single," "dating," "living together/de facto," or "married"); they could also select to fill in an open-ended "other" box. In the inclusive religious/nonreligious sample, 1,326 participants (.303) reported not having romantic partners and 3,051 (.697) reported having romantic partners; in the religious sub-sample, 493 (.299) reported not having romantic partners and 1,154 (.701) reported having romantic partners.

Number of children. Average number of children in the inclusive sample was 1.81 (SD = .52). Nonreligious people averaged 1.65 children (SD = 1.43) and religious people averaged 2.09 (SD = 1.64).

Number of children at home. Number of children living at home was used only in the religious sub-sample to predict church attendance and prayer, based on past evidence that children at home may affect church attendance in women. This variable was modeled and missing values were imputed directly during McMC. 1,079 religious participants reported zero children living at home and 568 reported at least one child living at home.

Deprivation (NZDep). Participant addresses from the 2011/12 questionnaire were coded by neighborhood. Statistics New Zealand codes each neighborhood for deprivation on the NZDep scale (see Salmond et al., 2007). The NZDep is a principal components analysis of nine variables that indicate socioeconomic status. These are (in weighted order): proportion of adults receiving a means-tested government supplied benefit, household income, proportion not owning own home, proportion single-parent families, proportion unemployed, proportion lacking qualifications, proportion living under crowded household conditions, proportion with no telephone access, and proportion with no car access. We used the percentile deprivation index, which places neighborhoods on a scale from 1 (least deprived) to 10 (most deprived). The overall average NZDep in the inclusive sample was 4.37 (SD = 2.64) and in the religion sub-sample it was 4.48 (SD = 2.65).

Urban/rural. Participant addresses from the 2011/12 questionnaire were also coded according to territorial authority. New Zealand is divided into 73 territorial authorities, which are larger area units classified as one of either 16 city councils or 57 rural district councils. In the inclusive sample, 1,297 participants (.296) were from rural areas and 3,080 (.704) were from urban areas; in the religious sub-sample, 496 (.301) participants were from rural areas and 1,151 (.699) were from urban areas.

Political conservatism. This was measured using a single item which asked participants to indicate how conservative they viewed themselves on a 7-point scale (1 = extremely conservative; 7 = extremely liberal). This item was recoded so that higher values represent higher levels of political conservatism. Average political conservatism in the inclusive sample was 3.56 (SD = 1.38) and in the religion sub-sample was 3.89 (SD = 1.35).

Prayer. Participants who affiliated as religious were asked how often they prayed each week. Average weekly prayer was 11.30 (SD = 24.08). Women prayed on average 12.59 times per week (SD = 25.97) and men prayed on average 8.65 times per week (SD = 19.36).

Church attendance. Participants who affiliated as religious were asked how often they attended church each month. Average monthly church attendance was 2.08 (SD = 3.32). Breaking this down by gender, women attended church on average 1.97 times per week (SD = 3.06) and men attended church on average 2.30 times per week (SD = 3.80). When used as a predictor variable, church attendance was standardized except in the fertility model, where it was centered to facilitate interpretation.

Religious ingroup commitment. We assessed religious ingroup commitment by assessing judgments that one's group is owed special entitlements. We used three items adapted from the measure of collective narcissism developed in other research by de Zavala, Cichocka, Eidelson, & Jayawickreme (2009). These items were: "I insist upon my religious group/denomination getting the respect that is due to it," "If my religious group/denomination had a major say in the world, the world would be a much better place," and "The true worth of my religious group/denomination is often misunderstood." The Cronbach's alpha for this scale was .69. Item scores for religious group entitlement were averaged to form a composite score. Average religious ingroup entitlement was 3.66 (SD = 1.40). Breaking this down by gender, women scored on average 3.62 (SD = 1.40) and men scored on average 3.73 (SD = 1.41).

Bayesian regression

We evaluated model predictions using Bayesian regression, which has many advantages over frequentist estimators. For our purposes, the most important

of these advantages is pooling of information across all components of the model when estimating uncertainty around parameters of theoretical interest (Gelman et al., 2013). In Bayesian regression, there is little distinction between fixed and random effects (Gelman & Hill, 2007; Hadfield, 2012); however, the convention helps to identify model features.

Priors for the fixed components of the model were improper, assuming a mean of zero and variance of, 10-8. Hence, information in the data conditioned on the assumption of near-infinite population-level variance when estimating marginal distributions for parameters modeled as fixed. Effects modeled as fixed were the variables of core theoretical interest.

A core assumption of linear regression is conditional independence of outcomes given all predictors (i.e., independence of errors). Previous work has suggested that religious signaling may vary across denominations with some denominations being more demanding than others (Chen, 2010; Iannaccone, 1992; Wuthnow, 1994). We therefore modeled denominational variances as random effects, within a multi-level modeling framework. For random model components priors we used the inverse-Wishart distribution, permitting a variance of one-hundred times that of the data, with a shape (belief) scale set as one greater than the dimension of the random effects co/variance matrix. This is the lowest degree of belief possible to maintain a proper joint distribution. A nice feature of Bayesian estimation is that it enables stricter standards for data when the evidence warrants greater doubt (Gelman, 2006).

When used as predictors: age, belief in God, conservatism, NZDep, religious identification, religious ingroup entitlement and all were standardized in all models. Contrast coding was used for all factors: females were coded -1, males were coded 1, non-Europeans were coded -1 and Europeans were coded 1, no-romantic-partner was coded -1 and partner was coded 1, rural was coded -1 and urban was coded 1. The intercepts are interpretable in all models as the expected outcomes when continuous variables and factors are set to the sample mean. Standardizing the predictor variables facilitated both McMC mixing and model interpretations. The default number of McMC cycles in MCMCglmm is 13,000, with a burnin of 3,000 cycles and a thin interval of 10 (Hadfield, 2010). We ran models for at least 50,000 cycles with a burnin of 5,000 cycles and a thin interval of 10. Evidence from plots of the

posterior distributions for all models and effective sample sizes all greater than 1,000 indicated McMC chains mixed well.

Software

The following packages in R (R Core Team, 2012) were used: Auguie, 2012; Bates & Maechler, 2014; Bolker & Su, 2011; Bolker et al., 2013; Dahl, 2014; Eddelbuettel & Francois, 2014; Hadfield, 2014; Harrell, 2014; Paradis et al., 2014; Plummer et al., 2012; Ripley, 2014; Sarkar, 2014; Skaug et al., 2013; Therneau, 2014; van Buuren & Groothuis-Oudshoorn, 2014; Wickham & Chang, 2013; Xie, 2013; Zeileis & Croissant, 2013.

Acknowledgements

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Author contribution

CS designed the NZAVS. CS and LG collected NZAVS data for Wave 3 and 3.5. JB conducted the analysis. All authors contributed to the writing of this manuscript.

3

How Is't With Thy Religion, Pray? Selection of Religiosity Among Individuals and Groups

Michael Blume

The perspectives of all human beings, including those of us who specialized as scientists, are inevitably and unconsciously shaped by the culture(s) we grew up in. And as most of those of us contributing to evolutionary studies are used to an individualized, "Westernized" lifestyle, we tend to assume that human mate choices "naturally" took place among free individuals checking out potential partners for their very personal qualities in a kind of open "marriage market." Contemporary and valuable theories of religion and sexual selection (as in Slone, 2008; Li et al., 2010) are situated within these yet-to-be-reflected frames.

In contrast, Johann Wolfgang von Goethe sketched a mate-selection scene in his eminent *Faust* (1808/2005). Therein, the "hero" spontaneously falls in love with Margarethe, as he watches her leaving a church (!). He then tries to win her over for a game of sexual cooperation. Although Margarethe, fondly called "Gretchen," is inclined to give in to his advances, she is testing his reliability with a question about his faith (all quotes Goethe 1808/2005, Ch. XVI):

> How is't with thy religion, pray?
> Thou art a dear, good-hearted man,
> And yet, I think, dost not incline that way.

Instantly understanding her question as one probing his reliability, Faust tries to dodge the topic by "individualizing" it:

> FAUST
> Leave that, my child! Thou know'st my love is tender;