



# Common genetic influences underpin religiosity, community integration, and existential uncertainty

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## ABSTRACT

Although genetic factors underpin individual differences in religiosity, the psychological mechanisms through which such influences are manifested are presently unknown. Religiosity is associated with concerns for community integration and existential certainty, suggesting that heritable influences underlying such sentiments may overlap with heritable influences underpinning religiosity. Here we tested this hypothesis within a genetically informative design, using a large, nationally-representative twin sample. As predicted, heritable effects underlying community integration and existential uncertainty were strongly overlapping with the heritable influences on religiosity. These findings are consistent with the position that individual differences in religiosity are mediated through biological systems involved in meeting both social and existential needs, although further work is required to determine directions of causal action.

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## 1. Introduction

Religious beliefs and values appear in all human societies recorded to date (Bulbulia, 2004; Swatos, 1998), although individual levels of religiosity also differ significantly (e.g. Lewis, Ritchie, & Bates, 2011; Norenzayan & Gervais, 2013; Saroglou, 2010). As such, the origins of variation in religious belief have been of enduring interest to social and behavioral scientists (c.f. Dennett, 2006). Genetically-informative studies of religiosity have indicated that the strength of religious belief is moderately heritable ( $h^2 = .30-.45$ ; Bouchard, 2004; Bouchard, McGue, Lykken, & Tellegen, 1999; D'Onofrio et al., 1999; Kendler et al., 2003). This observation, however, gives rise to the important question of what psychological mechanisms mediate this biological influence on religiosity. Currently, little is known of the mechanism(s) through which genetic factors exert their effects on religious belief; however, in psychological research, two broad and relevant accounts have been proposed concerning needs for community and existential certainty, and this research can be used to guide predictions at the genetic level. Below we introduce these perspectives, followed by a multivariate twin-study examining whether measures derived from these two perspectives share common heritable influences with

religiosity. First, however, we outline work establishing a genetic component to religiosity.

## 2. Genetic bases of religiosity

Religiosity is commonly viewed as the product of environmental influences designed to transmit and reinforce prevailing cultural values (Batson, Schoenrade, & Ventis, 1993; Dudley & Dudley, 1986). This assertion has been challenged, however, by studies utilizing genetically-informative designs. Such designs utilize a naturally occurring phenomenon – human twinning – to decompose behavioral variation into genetic and environmental components (Neale & Cardon, 1992). In short, if monozygotic, or identical, twins are more similar to each other than are dizygotic, or fraternal, twins, despite both kinds of twin sharing environmental factors – such as their age, their parents, and schools – this greater similarity between the monozygotic twin pairs is evidence for the influence of genetic, or heritable, factors.

Utilizing this approach, Martin et al. (1986), in the first genetic analysis of religiosity, reported significant heritable effects on beliefs regarding such matters as the importance of observing the Sabbath and truthfulness of the Bible. This work was replicated and extended by Waller, Kojetin, Bouchard, Lykken, and Tellegen (1990) showing that individual differences in religious attitudes, the importance of religion, and interests in religion were all significantly influenced by genes. Subsequent work across numerous studies has corroborated these earlier positive findings indicating that religious beliefs and practices contain moderate heritable influences (Bouchard

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et al., 1999; Bradshaw & Ellison, 2008; D'Onofrio et al., 1999; Koenig, McGue, Krueger, & Bouchard, 2005; Vance, Maes, & Kendler, 2010).

### 3. Community and existential needs: links with religiosity

While the twin studies detailed above provide strong evidence that genetic factors influence individual differences in religious sentiment, such work does not provide evidence that such heritable factors reflect genes specifically “for” religion. One alternative position would posit that such genetic factors operate at more basic, and non-theological, psychological levels. These influences, in turn, would give rise to individual differences in religiosity, such as would be the case if religion exists to meet basic human needs (Graham & Haidt, 2010; Kay, Shepherd, Blatz, Chua, & Galinsky, 2010). Little is currently known, however, of the mechanism(s) through which genetic factors exert their effects on religious belief, although two candidates – concerns regarding (1) community integration and (2) existential certainty – are prominent in the behavioral literature, and are detailed further below.

The first account of religiosity is perhaps best understood by adopting what Graham and Haidt (2010) call a “relentlessly social” (p. 140) approach, arguing that religion exists to facilitate cooperative community binding (also see Norenzayan & Shariff, 2008). This focus on social and community functions of religion has a long history in the literature. For instance, Durkheim (1915) argued that, “[t]he idea of society is the soul of religion” (p. 433). The social binding function of religion is also supported by research showing that community integration is significantly associated with higher levels of religious belief (Cavendish, Welch, & Leege, 1998). Work on factors influencing church membership dropouts provides additional support for religious belief as a manifestation of social needs. For example, Hartman (1976) asked former Methodist church members why they decided to leave their church and found the most frequent response entailed “their failure to feel . . . accepted, loved, or wanted” by others in the congregation (p. 40).

Experimental work also supports links from social binding to religiosity: For instance, Birgegard and Granqvist (2004) report that subliminal primes reflecting a separation threat (e.g. “mother is gone”) induced significant subsequent increases in the desire to be close to God. Similar work found that individuals who were exposed to science vignettes purporting to prove the existence of God reported significantly higher belief in God, although only if God was perceived as accepting and loving (vs. rejecting; Gebauer & Maio, 2012). Of interest, this interaction was attenuated if participants underwent an attachment prime, a brief visualization of a significant other (vs. a stranger), indicating that the observed increased belief in God may reflect a more generalized need to belong (Gebauer & Maio, 2012). With these findings in mind, religious individuals may be predisposed towards group life in general rather than to religious belief strictly conceived. This model, then, would locate specific religions within the set of group structures meeting this need, rather than as a unique phenomenon per se.

The second account of religiosity which we draw on here suggests that religiosity emerges as a source of existential certainty, generating a sense of agency and control, and thus serving to reduce feelings of anxiety (Inzlicht, McGregor, Hirsh, & Nash, 2009; Kay, Shepherd, et al., 2010; Peterson, 1999). Supporting this idea, religiosity has been shown to increase when perceived control is threatened. For example, Kay, Shepherd et al. (2010) found that just prior to an election, when government stability was low, individuals were more likely to believe in a controlling God, compared with immediately after an election (when a sense of governmental stability had returned). These authors also

observed that experimentally manipulating perceived control through the presentation of vignettes describing high/low levels of governmental stability also resulted in lower/higher levels of belief in a controlling God. Independent work supporting this conclusion has demonstrated that when perceived personal control is undermined (by recalling an unpleasant life event where one lacked control), belief in God is enhanced (Rutjens, van der Pligt, & van Harreveld, 2010). Interestingly, in the Rutjens et al. (2010) study, this increased belief in God was only observed in the absence of other belief frameworks that helped to create order in the world: individuals primed to understand Darwinism as an orderly process with inevitable outcomes did not show enhanced belief in God when personal control was threatened, although enhanced belief in (the orderly form of) Darwinism was observed for these individuals.

Work stemming from the terror management literature (Greenberg, Pyszczynski, & Solomon, 1986) – which stresses that human psychological concerns are strongly influenced by the awareness of death – has also lent support to the notion that religious belief serves a role in reducing existential angst (cf. Vail et al., 2010). For instance, Norenzayan and Hansen (2006) found that manipulating mortality salience led individuals to report greater levels of religiosity and a stronger belief in God. Furthermore, Jonas and Fischer (2006) reported that affirming intrinsic religiosity reduced death thought accessibility following mortality salience. Religiosity, then, can be seen as a response to activity in a general existential certainty system, serving to enhance personal control and providing an epistemic buffer from a range of factors such as unpredictability, instability, and concerns over mortality that exist in this world.

### 4. The current study

In line with the work detailed above, the literature is now at a point where extensive psychological research has provided testable hypotheses regarding the origins of the heritable influences underlying religiosity. The demonstration that manipulating community integration or existential uncertainty gives rise to change in religiosity, is consistent with these psychological processes showing links with the heritable influences on religiosity; that is, it is plausible that these sensitivities to social and existential needs being met are themselves, in part, heritable. In support of this position, while these constructs have not received genetically informative study per se, analogous variables to these constructs have been observed to contain heritable variation, further strengthening the position that common genetic effects may be present between these constructs and religiosity. For example, social warmth and gregariousness (i.e. elements of extraversion) have shown genetic influences (e.g. Eid, Riemann, Angleitner, & Borkenau, 2003); and a range of traits reflecting anxiety (e.g. Mackintosh, Gatz, Wetherell, & Pedersen, 2006), have also shown heritable effects. Of note, much previous behavioral work linking community and existential needs has implied or directly argued for causal links to religiosity; in the current study we are unable to test causal predictions: rather we are limited here to tests of genetic and environmental correlations. Accordingly, in the current study we tested whether measures of community integration and existential uncertainty showed overlapping heritable effects with religiosity by utilizing a large, nationally representative sample of identical, or monozygotic, and fraternal, or dizygotic, twins. In line with the correlational and experimental work linking both community integration and existential uncertainty with religiosity, we predicted that genetic factors underlying individual differences in these constructs would be significantly correlated.

## 5. Method

### 5.1. Participants

Phenotypic data were available for 993 pairs of twins assessed for religiosity, community integration, and existential uncertainty following contact by the MacArthur Foundation Survey of Midlife Development in the United States (MIDUS I; Brim, Ryff, & Kessler, 2004). Of the monozygotic (MZ) pairs, 178 were male (mean age = 44.47, SD = 11.53) and 192 were female (mean age = 43.56, SD = 12.28). Of the dizygotic (DZ) pairs, 143 were male (mean age = 44.25, SD = 12.35), 214 were female (mean age = 45.90, SD = 12.53), and 266 were opposite-sex pairs (mean age = 45.77, SD = 11.85). By race, 93.2% of the sample was comprised of White individuals, 3.3% of Black individuals, 1.7% of Native American/Es-kimo individuals, and 1.8% of individuals who reported their race as “other”. By religion, 85.1% participants identified themselves as belonging to a Christian religion, 1.3% reported belonging to a Jewish denomination, 1.7% reported belonging to a Buddhist, Hindu, or “other” denomination, 2.2% self-reported as atheist or agnostic, and a further 9.7% reported “no religious preference”. By (highest level of) education, 7.9% had not completed high school, 28.2% were high school graduates, 31% had completed some college/university education, 18.2% had a college degree, 2.9% had completed some graduate school education, and 11.8% had completed a graduate-level degree.

### 5.2. Measures

Religiosity was measured with the following items: “How religious are you?”; “How important is religion in your life?”; “How important is it for you – or would it be if you had children now – to send your children for religious or spiritual services or instruction?” (1: Not at all, to 4: Very). These items were highly correlated (.54–.81, all  $p$  values <.01; Cronbach’s alpha = .85) and were thus summed into a composite religiosity score. Although additional indicators of religious belief/commitment were available, we selected only those items that did not make explicit reference to social manifestations of religiosity (e.g. attendance at a place of worship, identification with a religious group), or to items where religiosity was related to existential certainty (e.g. coping, divine support). This omission of such items served to avoid confounding the test of our core hypotheses through content overlap, and thus (specifically) provides a more conservative test of our hypotheses.

Community integration was measured with the following three items: “I don’t feel I belong to anything I’d call a community” (reverse-scored); “I feel close to other people in my community”; “My community is a source of comfort” (1: Disagree strongly, to 7: Agree strongly). These items were significantly correlated (.41–.57, all  $p$  values <.01; Cronbach’s alpha = .74) and were thus summed into a composite score.

Existential uncertainty was measured with the following two items: “The world is too complex for me”; “I cannot make sense of what’s going on in the world” (1: Disagree strongly, to 7: Agree strongly). These items were significantly correlated (.44,  $p$  <.01; Cronbach’s alpha = .61) and were thus summed into a composite score.

### 5.3. Analysis

The classical twin design partitions observed variation into three latent components: Additive genetic influences (A), shared-environmental influences (C; environmental influences fostering similarities within twin pairs), and unique-environmental influences (E; environmental influences serving to make individuals

within a twin pair less similar). Genetic effects are inferred when monozygotic (MZ) twins are more similar than dizygotic (DZ) twins, whereas shared-environment effects are inferred when MZ twin correlations are less than twice that of the DZ twins. Unique-environment effects are inferred when MZ twins are correlated less than at unity for a given trait, and this variance component thus also contains measurement error. While these heuristics provide an instructive guide to the pattern of relative genetic and environmental effects, modern approaches typically utilize a multi-group structural equation modeling framework, which facilitates formal tests of parameter significance, as well as for the estimation of parameters in multivariate models (Neale, 2003).

Prior to conducting the analyses, we controlled for the effects of age and sex, and standardized residuals were used in all subsequent analyses in line with standard practice (McGue & Bouchard, 1984). The models were estimated by full-information maximum-likelihood analysis using OpenMx (Boker et al., 2010a, 2010b) and R (R Development Core Team, 2009).

The hypothesis that genetic variance in religiosity is associated with the genetic influences underlying community integration and existential uncertainty was tested in a multivariate Cholesky decomposition (Neale & Cardon, 1992) of additive genetic, shared-environment, and unique-environment covariance between the measures. This model specifies as many latent factors as there are variables for each source of variance (i.e. A, C, and E), with each subsequent factor having one fewer pathways than the preceding factor (see Fig. 1). In other words, for additive genetic effects (A) the first latent factor loads on all of the  $n$  measured variables: The subsequent latent factors load on  $n - 1$ ,  $n - 2$ , ...,  $n - j$  variables. In this way, each factor accounts for as much of the remaining variance as possible, until the last factor accounts for just the remaining variance in the last measured variable. This is repeated for shared-environmental (C) and unique-environmental factors (E). Neatly for the present purpose, this arrangement of factors means that entering a measured variable to the right of other variables tests the degree to which this variable is reflected in the genetic and/or environmental latent factors that primarily account for variance in the preceding measured variables. The model also

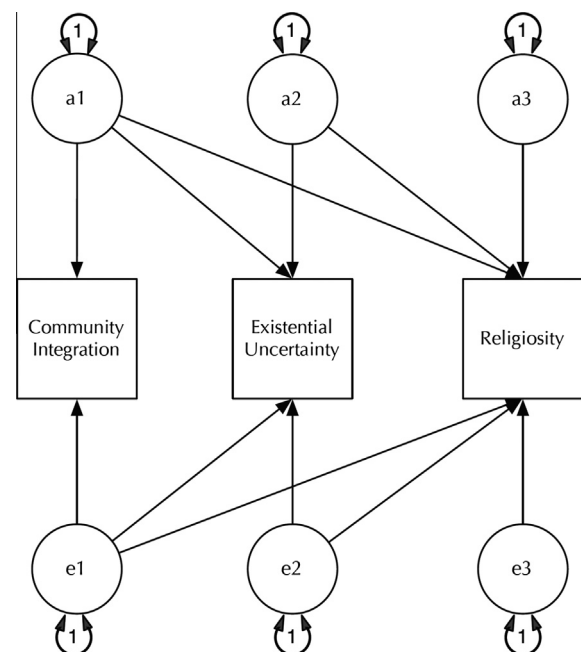


Fig. 1. Graphical representation of the Cholesky decomposition. Note: Shared-environment (C) effects were also modeled but are omitted here for clarity of illustration.

reveals if genetic and/or environmental covariance between measures is present.

For current purposes, the critical test concerns whether heritable variance in religiosity is overlapping with genetic effects on community integration and existential uncertainty. If this is the case, then the specific genetic effects on religiosity (i.e. those genetic influences on religiosity that do not co-vary with either community integration and/or existential uncertainty) will be able to be removed from the model without significantly worsening fit.

## 6. Results

The phenotypic correlations between study variables are detailed in Table 1. These indicate that at the phenotypic level, individuals high on community integration are lower in existential uncertainty, and somewhat more likely to be religious. Furthermore, existential uncertainty and religiosity appear unrelated at this observational level. This null association between existential uncertainty and religiosity runs contrary to our predictions; however, it is noteworthy that the strength of the genetically informed approach adopted here is that it allows the decomposition of these summary behavioral measures into multiple, potentially distinct and complex components of influence. In other words, genetic and environmental correlations need not reflect phenotypic correlations (Purcell, 2008). Accordingly, we included existential uncertainty in our biometric analyses.

### 6.1. Univariate analyses

We next examined the univariate heritability for each of our measures. MZ correlations were notably higher than for DZ pairs on all measures, implying the presence of genetic influences on variation in each measure (see Table 2). Assumption testing in univariate and multivariate models suggested that neither scalar nor general sex-limitation effects were significant (male and female DZ pairs, and same and opposite-sex groups could be equated without significant loss of model fit for any of the variables), although it is worth briefly noting that the current sample possessed limited power to detect such effects and thus should be interpreted tentatively. Accordingly, males and females were pooled for subsequent analyses.

Both community integration and existential uncertainty were best explained by models containing additive genetic and unique-environment effects (shared-environment effects could be removed without significantly worsening model fit:  $\Delta\chi^2 = 0$ ,  $p = 1$ ; and  $\Delta\chi^2 = 0$ ,  $p = 1$ , respectively): Additive genetic and unique-environment effects explained 31% and 69% of the variance in community integration, and 36% and 64% of the variance in existential uncertainty. For religiosity, additive genetic, shared-environment, and unique-environment effects were all significant, explaining 26%, 26%, and 48% of the variance, respectively. Full results of the univariate modeling are detailed in Table 2.

**Table 1**  
Phenotypic correlations among the study measures.

	Community integration	Existential uncertainty
Existential uncertainty	-.24*	-
Religiosity	.27*	.01

\*  $p < .01$ .

### 6.2. Multivariate analyses

We next moved to a test of our core hypotheses. We built a multivariate model comprised of community integration, existential uncertainty, and religiosity (also see Appendix A). In this model, the genetic effects specific to religiosity were estimated at just .10. This value is considerably reduced from the genetic path estimate of .51 for religiosity in the univariate model (i.e. the square root of the univariate heritability estimate for religiosity). This suggests, then, that community integration and existential uncertainty to this model share most of the genetic variation in our measure of religiosity. This is supported by the relatively high genetic correlations of community integration and existential uncertainty with religiosity in this model – .67 and .33, respectively – again indicating shared genetic influences from community integration and existential uncertainty to religiosity. The genetic correlation between community integration and existential uncertainty was -.46.

To explicitly test whether the heritable element of religiosity could be understood entirely in terms of shared genetic links to community integration and existential uncertainty, we examined whether the specific genetic effect to religiosity could be removed from the model without significantly worsening fit. As predicted, removing this specific genetic effect for religiosity incurred no significant loss of fit ( $\Delta\chi^2(1) = 0.002$ ,  $p = .96$ ), indicating that genetic effects underlying community integration and existential uncertainty were sufficient to explain the heritable bases underpinning religiosity.

We then examined whether genetic effects underlying religiosity were shared solely by either community integration or existential uncertainty: Neither of these effects, however, could be removed without significant loss of fit. Removing the path from existential uncertainty (a2) to religiosity (and so forcing the model to explain heritable effects on religiosity solely through community integration), significantly worsened fit ( $\Delta\chi^2(1) = 6.09$ ,  $p = .01$ ), indicating significant common genetic effects between existential uncertainty and religiosity. Similarly, removing the path from community integration (a1) to religiosity, forcing the model to explain heritable effects on religiosity solely through existential uncertainty, also significantly worsened fit ( $\Delta\chi^2(1) = 4.33$ ,  $p = .04$ ). These results indicated that both community integration and existential uncertainty were required to account for the genetic bases underpinning religiosity. Moreover, this modeling shows how significant genetic effects between existential uncertainty and religiosity, in spite of a non-significant behavioral association, could arise: Heritable effects raising both community integration and religiosity (a1) acted to decrease existential uncertainty; simultaneously, heritable effects on existential uncertainty acted to increase religiosity (a2). In sum, these countervailing effects serve to cancel each other out leading to a greatly reduced correlation at the phenotypic level. This observation can be understood with the following real-world example: Let's first posit a theoretical model of automobile performance using two latent factors; firstly, that the more cylinders a car has, (a) the more horsepower it can generate, (b) the worse its miles per gallon (mpg) will be, and (c) the more it will cost to buy; secondly, that streamlining (a) increases fuel efficiency, but also (b) increases the cost to buy. In this example, one should be able to see how mpg and cost will likely be unrelated, despite sharing an underlying common basis: this arises because greater streamlining both drives up cost and mpg, whereas greater number of cylinders drives up cost but drives down mpg. This finding is commented on in greater detail in Section 7.

We next examined the significance of environmental influences in the model. All shared-environment paths except to religiosity

**Table 2**

Univariate modeling results, across zygosity twin pair correlations, and phenotypic correlations for community integration, existential uncertainty, and religiosity.

	A	C	E	MZm	MZf	DZm	DZf	DZos
Community integration	.31 (.13–.41)	.00 (.00–.13)	.69 (.61–.80)	.26	.46	.12	.22	.12
Existential uncertainty	.36 (.11–.46)	.00 (.00–.19)	.64 (.56–.74)	.32	.41	.22	.11	.23
Religiosity	.26 (.05–.48)	.26 (.07–.43)	.48 (.41–.56)	.54	.58	.36	.39	.39

Note: A = additive genetic effects; C = shared-environment effects; E = unique-environment effects; 95% confidence intervals shown in brackets; MZm = MZ male pairs; MZf = MZ female pairs; DZm = DZ male pairs; DZf = DZ female pairs; DZos = DZ opposite sex pairs; CI = community integration; EU = existential uncertainty.

could be removed without significantly worsening model fit ( $\Delta\chi^2(5) = 2.03, p = .85$ ); however, shared-environments effects to religiosity were significant ( $\Delta\chi^2(1) = 15.76, p < .001$ ) and so were retained. Finally, we examined unique-environment effects. Removing those unique-environment effects that were common between the measures significantly worsened fit ( $\Delta\chi^2(3) = 17.67, p < .001$ ); however, this effect was exclusively driven by the unique-environment effects common to community integration and existential uncertainty ( $\Delta\chi^2(1) = 17.08, p < .001$ ) and so only this path was retained. The final model is detailed in Fig. 2.

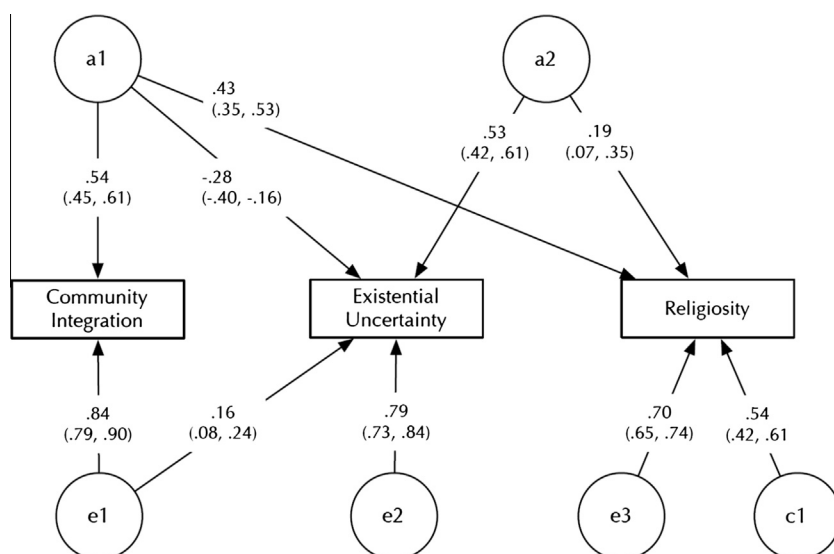
## 7. Discussion

The first finding of the present study was to confirm a moderate heritability for religiosity: genetic factors accounted for 26% of the variance. This is comparable, though somewhat smaller than values reported previously, which ranged from 30% to 45% (Bouchard, 2004). Additionally, religiosity possessed a significant shared-environment influence (perhaps reflecting parental culture or other family-level effects), a finding that also confirms prior work (Bouchard, 2004). Existential uncertainty and community integration also contained moderate genetic influences, with approximately a third of the variance in each case accounted for by heritable factors. Most importantly, and in line with our hypotheses, the genetic effects on religiosity were overlapping with the genetic effects on community integration and existential uncertainty.

Community integration showed a strong relationship with religiosity, with a genetic correlation of .67 (indicating that, of the total genetic influence on these traits, almost 45% of this influence (i.e.,  $.67^2$ ) is shared by both traits). By contrast, existential uncertainty and religiosity showed a more moderate genetic correlation of .33. This indicates that, at least for the measure of religious belief used in the current study, social needs appear to be the predominant correlate, supporting the theorizing of Graham and Haidt (2010).

These findings demonstrate that religiosity is a biologically complex construct, with distinct heritable components, which in turn suggests that attempts to locate specific genetic variants – which has become possible and popular in recent years among social psychologists (Ebstein, Salomon, Chew, Zhong, & Knafo, 2010) – will need to account for this heterogeneity at the genic level. Specifically, gene association studies seeking to delineate the molecular bases of religiosity would be wise to include in their analyses measures reflecting these underlying foundations of religiosity; namely, community integration and existential uncertainty. This approach will, however, need to hold in mind the likely modest effect size for any given gene variant and the highly polygenic architecture of a complex trait such as religiosity (e.g. Munafò & Flint, 2011).

Interestingly, and deserving of further comment, was the significant genetic overlap between existential uncertainty and religiosity which sat in contrast to a null phenotypic correlation for these variables. Our modeling allows us to understand how



**Fig. 2.** Final model of additive genetic, shared-, and unique-environment effects on community integration, existential uncertainty, and religiosity. Note: Circles represent latent additive genetic, shared-, and unique-environment variables. Path values are standardized path coefficients (squaring the path loading indicates the proportion of variance accounted for in the measured variable by the latent factor).

this arises: The two sources of genetic influence on religiosity had distinct relationships to existential uncertainty: Factor a1 loaded *negatively* on existential uncertainty but *positively* on religiosity. Factor a2 loaded *positively* on both. This observation specifically sheds light on why existential uncertainty and religiosity are correlated weakly ( $r = .01$ ): On average, these two roughly equal genetic influences cancel out leading to a greatly reduced correlation at the phenotypic level. These findings can also be understood from the perspective of regression modeling: For instance, at the behavioral, or phenotypic, level it is not uncommon to find that a given predictor variable is not significantly associated with a given outcome variable, although to find the beta coefficient between the first predictor and the outcome variable to be significantly different from zero after controlling for the effect of a second predictor. The classical twin design, as employed in the current study, allows us to examine these patterns of effects at the level of variance components (i.e. A, C, and E) rather than solely at the phenotypic level: but the principle remains fundamentally the same as is the case in the standard regression framework. As such, here we find that the genetic effects primarily accounting for variation in existential uncertainty (Factor a2) are significantly and positively (albeit modestly) associated with religiosity when controlling for the heritable effects underlying community integration. These findings, then, suggest that psychological theories of religion must expect, and account for, multiple, possibly countervailing causes at the biological level.

Additionally, in the full Cholesky model (see Appendix A) we observed additional countervailing effects such that in addition to genetic effects acting positively on both existential uncertainty and religiosity, we also observed shared-environment effects on these two variables that acted positively on religiosity but acted to decrease existential uncertainty: Thus environmental influences may also serve to decrease phenotypic associations. This observation again reiterates the likely complexities that underlie higher-order psychological traits and illustrates the value of the twin design in elucidating the nature of such effects.

Speculatively, the current findings are consistent with a position positing that religion *per-se* may not be the sole organization or system able to fill the niche created by human needs for community and existential meaning. The succession, displacement, and evolution of religions can be viewed in this light as the shaping of religious systems by their adherents to maximize the extent to which their needs are met. It might be predicted, then, that under certain conditions, even a secular apparatus, should it be able to meet the community and existential needs of people, may be attributed the same importance in people's lives as religion often occupies (e.g. Kay, Shepherd et al., 2010). Graham and Haidt (2010), however, suggest this "exchangeable goods" notion of religion may fail to acknowledge the tight fit between religious belief and human psychology: "*religious practices and rituals co-evolved with religiously inclined minds, so that they now fit together extremely well... because of our biological and cultural-evolutionary history, it's hard to come up with anything that "fits" or satisfies as many people as does religion*" (p. 147). The extent to which religion is a wholly exchangeable good thus remains an open question.

The principle limitation of the present study is its use of a single measure of religious belief focused on religiosity. Religious belief is a multidimensional construct (Hill & Hood, 1999; Kendler et al., 2003). As such, while the strength and importance of religious belief is a major component of religiosity, other aspects of religious life may not similarly be accounted for by community and existential factors. Religious fundamentalism

(Altemeyer & Hunsberger, 2005) and spirituality (Zinnbauer & Pargament, 2005), for instance, show significant (opposite) associations with openness to experience (Saroglou, 2010), with openness in turn not obviously reflecting community interests or existential concerns (McCrae & John, 1992). A full account of religious faith, then, will no doubt be more complex than that presented here, likely including additional factors such as openness to experience.

Secondly, our measures of community integration and existential uncertainty were necessarily brief with subsequent restrictions in construct range and reliability. Accordingly, future work is recommended to further delineate the precise nature of the genetic relations between these non-theological traits and religiosity with broader and more powerful measures. However, it is worth highlighting that the relatively short scales used here were nevertheless able to be modeled as wholly overlapping with the genetic component of religiosity.

Thirdly, while we report results here that indicate community integration and existential uncertainty wholly mediated the genetic influences on religiosity, this is not to say that alternative accounts are not plausible. For example, an unmeasured variable highly linked to community integration may be the ultimate cause of this phenotypic and genetic association with religiosity. One question this possibility raises is whether these additional variables would explain additional heritable variation in religiosity, or show overlaps with the genetic effects common with community integration and existential uncertainty. Future work is recommended to further delineate the genetic covariates of religiosity.

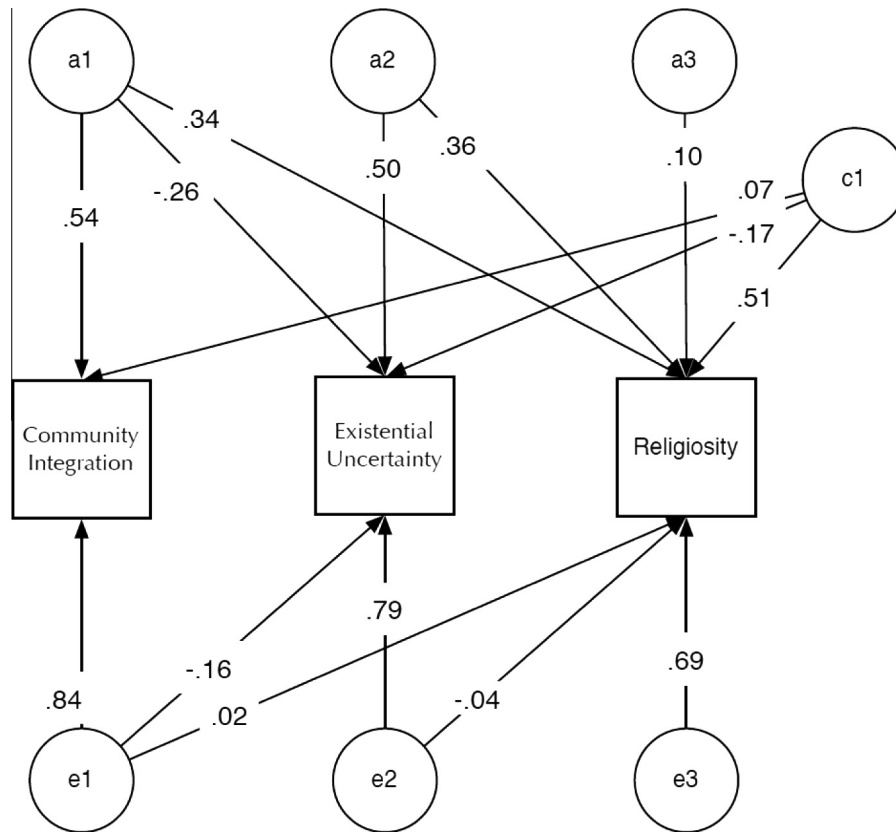
Fourthly, the current study design does not permit causal inferences to be made from what is, in essence, correlational data. While the current findings are consistent with a model of religiosity emerging from more basic social and existential needs, it will be of some value to determine whether this direction of causality is correctly positioned. Longitudinal study designs that measure such social and existential sentiment before religious views have emerged, such as in childhood, may shed light on this issue.

Finally, it is possible that participants responded to the items concerning community integration with their religious community in mind. If so, this would potentially have the effect of generating a degree of content overlap between our measures of religiosity and community integration (in spite of our efforts to avoid such a scenario). With this in mind, future research could explicitly distinguish the religious and secular components of community orientation.

In summary, our results indicate that the genetic influences from both community integration and existential uncertainty are shared with the genetic effects underlying a measure of religiosity reflecting the strength and importance of religion in one's life. Additional familial influences were observed for religiosity, in line with previous work. These findings are supportive of theories regarding the role of religion as a system for meeting basic social and existential needs, and for the additional role of cultural transmission in shaping the strength of religious beliefs. Future work should seek to examine whether the current findings generalize to additional aspects of religious belief, such as religious fundamentalism and spirituality, as well as to establish the causal directions of these associations.

## Appendix A.

The full (unreduced) Cholesky decomposition model with standardized parameter estimates.



Note: Shared-environment effects C2 and C3 were estimated at zero and so are omitted here for clarity of illustration.

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