Genetic and Environmental Influences on Multiple Dimensions of Religiosity

A Twin Study

Todd Vance, PhD,* Hermine H. Maes, PhD,† and Kenneth S. Kendler, MD†

Abstract: In recent years there has been a renewed scientific interest in the study of religiosity, including research on genetic and environmental contributions to religiosity. In this article, we investigate genetic and environmental effects on 7 religiosity factors and explore how genetic and environmental effects covary across these factors. Seven religiosity factors estimated from 78 items were examined in a sample of adult male and female twins. The 7 religiosity factors were largely influenced by additive genetic and unique environmental effects, with relatively little influence from common environmental effects. Multivariate genetic analyses found the 7 religiosity factors were influenced by 1 common additive genetic factor, 3 common unique environmental factors, and unique environmental effects specific to each religiosity factor. The results suggest that for the population studied, additive genetic and unique environmental effects largely account for the variance across the religiosity construct.

Key Words: Religiosity, twin studies, multivariate analysis.

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In recent years, the medical and scientific community has shown a renewed interest in religiosity, especially as this trait relates to mental and physical health (Koenig et al., 2005; Mills, 2002). Several studies have explored the role of genetic and environmental effects on religiosity (Kendler et al., 1997; Kirk et al., 1999a,b; Koenig et al., 2005; Tsuang et al., 2002).

At first, it may seem unlikely that an attribute like religiosity would be influenced by genes. However, behavior genetic studies have shown that nearly all individual psychological traits are heritable (Bouchard and McGue, 2003). In studies to date, at least a moderate genetic influence on individual differences in religiosity has been generally found, as well as common and unique environmental effects (Kendler et al., 1997; Kirk et al., 1999a,b; Koenig et al., 2005; Tsuang et al., 2002).

One of the limitations of research on religiosity has been incomplete measurement of the religiosity construct (Cacioppo and Brandon, 2002; Kendler et al., 2003; Stefanek et al., 2004). Single-item measures of religiosity such as Religious Affiliation (Protestant, Catholic, Jewish, etc.) and Church Attendance have been used in behavior genetics studies. As noted in previous reviews (Bouchard and McGue, 2003; D'Onofrio et al., 1999a,b) almost no additive genetic effects are observed for Religious Affiliation, although a small genetic contribution may be present in females (D'Onofrio et al., 1999a; Eaves et al., 1990). Church Attendance, on the other hand, appears to be moderately influenced by additive genetic effects (Kirk et al., 1999b; Maes et al., 1999). Despite these interesting findings, there are significant problems with single-item measures. They are likely to underestimate the complexity of the religiosity construct and are psychometrically less reliable than scales using related, multiple items (Bouchard and McGue, 2003; Hill and Pargament, 2003).

A few behavior genetic studies have used multiple-item scales to measure religiosity. Bouchard et al. (1999) studied Intrinsic Religiousness and Extrinsic Religiousness in male and female Minnesota twins reared apart. Additive genetic effects accounted for 43% of the variance for Intrinsic Religiousness and 39% of the variance in Extrinsic Religiousness, with unique environmental effects accounting for the remainder of the variance. Tsuang et al. (2002) examined spirituality in male twins, using the Spiritual Well-Being Scale and an Index of Spiritual Involvement. The authors found that additive genetic effects were similar in the Religious Well-Being and Existential Well-Being subscales of the Spiritual Well-Being Scale, accounting for 37% and 36% of the variance, respectively. No common environmental effects were found for Existential Well-Being, but common environmental effects accounted for 10% of the variance in Religious Well-Being. Genetic effects accounted for 23% of the variance in Spiritual Involvement, with common environmental effects accounting for 45% of the variance.

Kendler et al. (1997) studied 3 factors—Personal Devotion, Personal Conservatism, and Institutional Conservatism in adult female twins, finding additive genetic effects for Personal Devotion (29%) and Institutional Conservatism (12%), but not for Personal Conservatism. Common and unique environmental effects were observed on all 3 dimensions of religiosity. Common environmental effects accounted for 24% of the variance in Personal Devotion and 51% of the variance in Institutional Conservatism. Variance in the factor Personal Conservatism was accounted for entirely by common (45%) and unique (55%) environmental effects. Religiosity is likely a multidimensional construct and its expression takes many forms (Pargament, 2002). To date, there are no universally agreed-on measures of religiosity. Therefore, studies that use multiple measures to maximize heterogeneity are more likely to yield insights into the nature of the religiosity construct.

In a 2003 study, Kendler et al. examined different dimensions of religiosity, conducting factor analysis on 78 items. These analyses yielded 7 religiosity factors, which they called General Religiosity, Social Religiosity, Involved God, Forgiveness, God as Judge, Unvengefulness, and Thankfulness (Kendler et al., 2003). The General Religiosity factor included items reflecting concern and involvement with spiritual issues and with God. Social Religiosity was comprised of items tapping the social aspects of religiosity. Involved God included items reflecting belief in God and in God's active involvement in human affairs. Forgiveness was made up of items reflecting a loving, caring, and forgiving approach to the world. God as Judge

*Department of Psychology, Virginia Commonwealth University, Richmond, VA; and †Department of Psychiatry and Human Genetics, Virginia Institute for Psychiatric and Behavioral Genetics, Virginia Commonwealth University, Richmond, VA.

Send reprint requests to Kenneth S. Kendler, MD, Department of Psychiatry and Human Genetics, Virginia Institute for Psychiatric and Behavioral Genetics, Virginia Commonwealth University, Box 980126, Richmond, VA 23298. E-mail: kendler@vcu.edu.

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included items indicating a view of a judgmental and punitive deity. The sixth factor, called Unvengefulness, was comprised of items reflecting an attitude opposed to taking personal retaliation. The final factor, called Thankfulness, included items reflecting an attitude of thankfulness. The study of Kendler et al. used the largest set of items yet studied for religiosity, spirituality, and related attitudes and behaviors in behavior genetics research.

In the present study, using the same data and the same sample, we recreated the 7 factors reported by Kendler et al. (2003) and sought to answer the following research questions: What is the magnitude of genetic and environmental effects on multiple dimensions of religiosity? and How do genetic and environmental effects covary across these different dimensions of religiosity? By using a large set of items that broadly measure religiosity and related constructs, our goal was to contribute to a more comprehensive understanding of genetic and environmental effects on religiosity.

METHODS

Participants and Sample Characteristics

As described previously by Kendler et al. (2003), the sample came from 2 related projects that recruited participants from the population-based Virginia Twin Registry. Questionnaires were mailed out to all former participants in these projects ($N = 7230$). Limited resources were available for follow-up with nonresponders and 2621 questionnaires were returned, for a response rate of 36.3%. From this sample, 1106 monozygotic (MZ) twins and 1501 dizygotic (DZ) twins were used in univariate and multivariate genetic analyses. The sample included 244 MZ female twin, 156 DZ female twin, 118 MZ male twin, 46 DZ male twin, and 150 DZ male-female twins. All participants were White and 58% were female. The average age was 43.06 years ($SD = 8.61$, range = 27–63 years). More than 3 quarters (77%) were Protestant and the most common denominational preference was Baptist.

Measures

The measures and rationale used to assess religiosity have been described previously (Kendler et al., 2003). Briefly, after a review of the literature, 78 items were selected to broadly measure religiosity, spirituality, and related attitudes and behaviors. These included the Religious Attitudes and Practices Inventory (D'Onofrio et al., 1999a,b), items from Pargament's Religious/Spiritual Coping Scale and Underwood's Daily Spiritual Experiences Scale (Fetzer Institute/NIA Work Group, 1999), and other items concerning the nature of God and God images used previously by Kendler et al. (2003).

Statistical Analysis

Kendler et al. (2003) performed an exploratory factor analysis with a VARIMAX rotation on the 78 religiosity items. This analysis yielded 7 factors, which the authors called General Religiosity, Social Religiosity, Involved God, Forgiveness, God as Judge, Unvengefulness, and Thankfulness, which have already been described.

In the present study, the 7-factor structure reported by Kendler et al. (2003) was recreated using confirmatory factor analysis techniques. Raw, ordinal-level data collected from the sample for the 78 religiosity items were entered into a confirmatory factor analysis using the Mplus program (Mplus Version 3.0; Muthen and Muthen, 1998–2004). A 7-factor model was specified based on Kendler et al. (2003) prior study results. A weighted least square means and variance adjusted estimator was used to obtain estimates of factor loadings and interfactor correlations for this factor structure. The weighted least square means and variance estimator has been recommended as a robust estimator for ordinal-level data (Flora and Curran, 2004). Correlated, continuous-level factor scores were estimated in Mplus based on the results of the confirmatory factor analysis. These factor scores were used for further analysis of the religiosity factors in the present study.

To determine how closely the new factor scores replicated the original factor-derived composite scores from the original study (Kendler et al., 2003), correlations between the original factor scores and the new factor scores were examined. Correlations were generally high, ranging from 0.98 to 0.77.

Univariate Analysis

Genetic and environmental contributions to variance were estimated for each religiosity factor. Table 1 shows sample sizes and correlations by zygosity group. A good first step prior to univariate analysis is to examine original MZ and DZ correlations for the phenotypes being studied to get a preliminary indication of the portions of variance contributed by genes and the environment (Kendler and Eaves, 2005; Neale, 2003).

Likelihood ratio tests and Akaike Information Criterion (AIC) were used to determine the best fitting models, with lower values of the AIC indicating models with a better balance of explanatory power and complexity (Kendler et al., 1993). Parameter estimates (a^2, c^2, and e^2) and 95% confidence intervals were estimated. Where appropriate, both full ACE models and best-fitting submodels were estimated, along with 95% confidence intervals for each parameter in each model.

Multivariate Analysis

Multivariate analysis estimates the contribution of genes and environment to the correlation between multiple variables, which in the present study are the 7 religiosity factors. An exploratory approach was used, as there was no previous literature to draw on to suggest a likely multivariate structure, and we had no strong a priori hypotheses about a multivariate structure. A combination of Cholesky decompositions and Confirmatory Independent Pathway Models were used to estimate the additive genetic and environmental factors shared by the 7 religiosity factors.

TABLE 1. Correlations for 7 Religiosity Factors by Zygosity Group

Zygosity	Total N	Twin Pairs	General Religiosity	Social Religiosity	Involved God	Forgiveness/Love	God as Judge	Unvengefulness	Thankfulness
MZF	612	244	0.68	0.71	0.67	0.47	0.57	0.18	0.41
DZF	408	156	0.32	0.41	0.28	0.30	0.40	0.15	0.15
MZM	494	118	0.62	0.65	0.6	0.55	0.64	0.23	0.41
DZM	296	46	0.47	0.41	0.45	−0.05	0.37	0.07	0.16
DZMF	797	150	0.35	0.37	0.34	0.11	0.38	0.03	0.08

MZF indicates monozygotic female; DZF, dizygotic female; MZM, monozygotic male; DZM, dizygotic male; DZMF, dizygotic male-female twins.

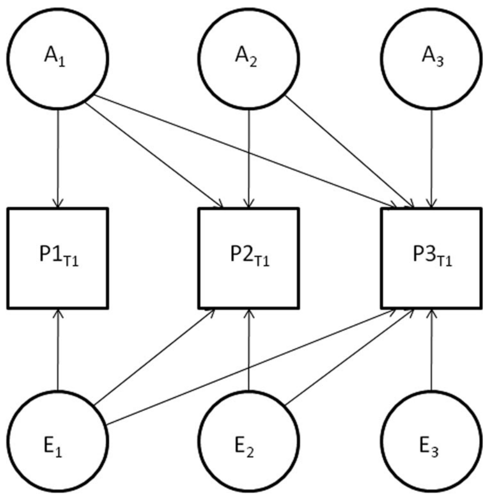

FIGURE 1. Figure represents a simplified example of Cholesky decomposition with 3 phenotypes (P) and additive genetic factors (A) and unique environmental factors (E). Phenotypes from the first twin (T1) are correlated with phenotypes of second twin (not shown).

A Cholesky decomposition uses a triangular matrix and its transpose to provide positive definite estimates of component covariance matrices. In Cholesky decomposition, the number of common genetic factors, common shared environment factors, and common environmental factors are equal to the number of phenotypes, which in the present study is the 7 religiosity factors. The first common factor loads on each of the 7 phenotypes, the second common factor loads on 6, the third on 5, and so on as each subsequent factor loads on 1 less phenotype. See Figure 1 for a simplified, 3-phenotype representation of Cholesky decomposition.

The Independent Pathway Model allows multiple common factors for each phenotype as well as estimates of residual variance that are specific to each phenotype. The Independent Pathway Model assumes that genetic and environmental factors act independently, allowing for different patterns of genetic versus environmental covariance. For example, genes may create the disposition for a certain trait or behavior, whereas environmental effects, acting independently, may shape how that trait or behavior is ultimately expressed (Hettema et al., 1999). Therefore, when used in multivariate analysis, the Independent Pathway Model can elucidate shared and unique genetic and environmental influences across different variables of interest (Rijsdijk, 2005).

RESULTS

Univariate Analysis

To estimate the genetic and environmental contributions to variance, univariate analyses were conducted for each of the 7 religiosity factors, using the Mx program (Neale et al., 2005). A saturated model with free variances and covariances was first estimated to yield expected means and covariance matrices. The variance was then partitioned into the latent variables A (additive genetic effects), C (common environmental effects), and E (unique environmental effects) and submodels (e.g., AE, CE, and E) were fitted, with goodness-of-fit indices used to evaluate each submodel's fit compared with the full saturated model. Table 2 shows the full ACE models and the best fitting models from the univariate analyses of the religiosity factors.

For 5 of the 7 factors, an AE model provided the best fit, indicating the variance in these factors could be accounted for by additive genetic and unique environmental effects. Two of the 7 factors (Factor 2, Social Religiosity and Factor 5, God as Judge) had moderate contributions from the common environment. Based on the likelihood ratio test, the goodness-of-fit statistics show that an AE model represents the best fit for these 2 factors. However, the AIC fit statistics favor the ACE model as the more parsimonious model, although including shared environment does not result in a significant improvement of fit. Furthermore, in the presence of low power, reduced models may bias parameter estimates for genetic effects upward. An ACE model may more accurately represent true parameter estimates (Sullivan and Eaves, 2002).

Multivariate Analysis

Multivariate analyses were conducted for the 7 religiosity factors, using the Mx program (Neale et al., 2005). A 2-step exploratory approach was used to determine the multivariate structure of the 7 religiosity factors.

To yield an initial indication of a multivariate structure, the first step was to submit the 7 factors to a Cholesky decomposition. After the full Cholesky was fit, factor loadings were examined, and loadings approaching zero were tested to determine whether removing these factors would result in a worse model fit.

The initial Cholesky decomposition found that an AE model with all common environmental factors dropped did not result in a significantly worse fit compared with the full ACE Cholesky. Because retaining even one shared common environmental factor ("C") did not differ significantly from the full ACE Cholesky, and therefore, provided a worse AIC score, shared common environmental factors were dropped from further analysis. Table 3 shows that models dropping common additive genetic factors and common unique environmental factors were also compared with the full ACE Cholesky, with results showing that these factors could not be dropped without a significant loss of fit in the model. Therefore, additive genetic and unique environmental factors were retained for further analysis.

Models retaining additive genetic factors ("A") and unique environmental factors ("E") were then tested to determine the optimal model fit for the data. Table 4 presents an AE model and submodel comparisons. An AE Cholesky model was estimated and tests were conducted to determine whether any common additive genetic factors could be dropped. Results showed that all but one additive genetic factor shared by the 7 religiosity factors could be dropped without affecting model fit. However, additive genetic factors could not be dropped entirely, as this resulted in a significantly worse model fit.

The second step in this exploratory multivariate analysis was to test the results observed in the Cholesky Decompositions by fitting Independent Pathway models. An AE model was fit, and factor loadings for common and specific additive genetic factors and common and specific unique environmental factors were examined. Examination of factor loadings indicated that a model with 1 common additive genetic factor and 3 common unique environmental factors best fit the data. Genetic factors specific to each of the 7 religiosity factors were not significant and could be dropped; however, 1 additive genetic factor common to all 7 religiosity factors could not be dropped. Three AE Independent Pathway models were tested based on examination of factor loadings.

Figure 2 presents a graphic representation of the final multivariate structure. Table 5 presents factor loadings from the best-fitting model. The best-fitting model included 1 common additive genetic factor, 1 common unique environmental factor that loaded on all 7 religiosity factors, and 2 other common unique environmental factors, one that loaded on religiosity factors 1 to 4 and another

TABLE 2. Univariate Analysis of Religiosity Factors Best-Fitting Models

Factor	Model	−2 lnl	*df*	A^2	C^2	E^2	$\delta\chi^2$	AIC	*p*
General religiosity	Saturated	6788.75	2572						
	ACE	6800.10	2584	0.56 (0.36–0.70)	0.09 (0–0.26)	0.35 (0.30–0.40)	11.34	−12.66	0.50
	[a]AE	6800.98	2585	0.66 (0.60–0.70)	—	0.34 (0.30–0.40)	12.22	−13.78	0.51
	CE	6833.31	2585	—	0.52 (0.47–0.57)	0.48 (0.43–0.53)	44.55	18.55	0
Social religiosity	Saturated	6624.28	2572						
	ACE	6637.63	2584	0.50 (0.32–0.70)	0.17 (0–0.33)	0.33 (0.28–0.38)	13.35	−10.65	0.34
	[a]AE	6640.91	2585	0.68 (0.63–0.72)	—	0.32 (0.28–0.37)	16.51	−9.49	0.22
	CE	6667.46	2585	—	0.56 (0.50–0.60)	0.44 (0.40–0.50)	43.18	17.18	0
Involved God	Saturated	6647.40	2572						
	ACE	6661.05	2584	0.60 (0.39–0.69)	0.04 (0–0.22)	0.36 (0.31–0.42)	13.64	−10.36	0.32
	[a]AE	6661.27	2585	0.64 (0.59–0.69)	—	0.36 (0.31–0.41)	13.86	−12.13	0.38
	CE	6696.46	2585	—	0.50 (0.44–0.55)	0.50 (0.45–0.56)	49.06	23.06	0
Forgiveness	Saturated	6825.69	2572						
	ACE	6851.89	2584	0.47 (0.34–0.54)	0 (0–0.10)	0.53 (0.46–0.60)	26.20	2.20	0.01
	[a]AE	6851.89	2585	0.47 (0.40–0.54)	—	0.53 (0.46–0.60)	26.20	0.20	0.02
	CE	6876.23	2585	—	0.34 (0.27–0.40)	0.66 (0.60–0.73)	50.54	24.54	0
God as judge	Saturated	6350.67	2572						
	ACE	6358.46	2584	0.43 (0.23–0.63)	0.17 (0–0.34)	0.40 (0.35–0.47)	7.79	−16.21	0.80
	[a]AE	6361.69	2585	0.61 (0.55–0.66)	—	0.39 (0.34–0.45)	11.02	−14.98	0.61
	CE	6376.11	2585	—	0.49 (0.44–0.54)	0.51(0.46–0.56)	25.45	−0.55	0
Unvengefulness	Saturated	6367.12	2572						
	ACE	6388.08	2584	0.20 (0–0.30)	—	0.80 (0.70–0.90)	20.96	−3.04	0.05
	[a]AE	6388.08	2585	0.20 (0.11–0.30)	—	0.80 (0.70–0.89)	20.96	−5.04	0.07
	CE	6390.58	2585	—	0.15 (0.07–0.22)	0.85 (0.78–0.93)	23.46	−2.54	0.04
Thankfulness	Saturated	6373.41	2572						
	ACE	6386.05	2584	0.38 (0.24–0.46)	—	0.62 (0.54–0.70)	12.64	−11.36	0.40
	[a]AE	6386.05	2585	0.38 (0.30–0.46)	—	0.62 (0.54–0.70)	12.64	−13.36	0.48
	CE	6401.14	2585	—	0.27 (0.21–0.34)	0.73 (0.66–0.79)	27.73	1.73	0.01

[a]Best-fitting model.
AIC indicates Akaike's Information Criterion; A, additive genetic effects; C, common environmental effects; E, unique environmental effects.

TABLE 3. Comparisons of Cholesky ACE Model and Submodels

Model	−2 lnl	$\delta\chi^2$ (*df*)	AIC	*p*
Full ACE	30234.29			
CE (drop A)	30278.98	44.69 (28)	−11.30	0.02
AC, E (keep 1 E)	34156.10	3921.81 (21)	3879.81	0
AE (drop C)	30235.79	1.50 (28)	−54.49	1.00
AE, 1 C (keep 1 C)	30234.29	0 (21)	−42.00	Incalc.

All sub-models compared to full ACE model. Significant *p* values indicate parameters tested cannot be dropped from the model without a worse model fit.
A indicates additive genetic effects; C, common environmental effects; E, unique environmental effects shared by religiosity factors.

TABLE 4. Comparison of Cholesky AE Model and Submodels, Dropping Additive Genetic Factors

Model	−2 lnl	$\delta\chi^2$ (*df*)	AIC	*p*
Full AE	30235.79			
Drop factors 4–7	30235.79	0 (4)	−8.00	Incalc
Drop factors 3–7	30237.95	2.16 (5)	−7.84	0.827
Drop factors 2–7	30244.58	6.62 (6)	−5.38	0.357
Drop A	30487.77	251.98 (28)	195.98	0

All sub-models compared to full AE model. Significant *p* values indicate parameters tested cannot be dropped from the model without a worse model fit.
AIC indicates Akaike's Information Criterion; A, additive genetic effects; E, unique environmental effects shared by religiosity factors.

that loaded on factors 5–7. Unique environmental factors specific to each of the religiosity factors were also included in the final model.

DISCUSSION

The present study examined genetic and environmental effects on 7 dimensions of religiosity and estimated how genetic and environmental factors account for covariation between different dimensions of religiosity. The univariate findings in the present study, in which additive genetic and unique environmental effects accounted for the variance in the best-fitting models for 5 of the 7 religiosity factors, are in contrast to several previous studies that have reported significant and substantial contributions to variance from common environmental effects on certain aspects of religiosity (Kendler et al., 1997; Kirk et al., 1999a,b; Koenig et al., 2005; Truett et al., 1992). However, there have been exceptions. Kirk et al. (1999a) found no common environmental effects for the variable Self Transcendence in a study of older Australian twins. Tsuang et al. (2002) studied 3 spirituality measures and found no common environmental effects for Existential Well-Being in a study of males from the Vietnam Era Twin Registry. Olson et al. (2001) reported no common environmental effects for attitude toward organized reli-

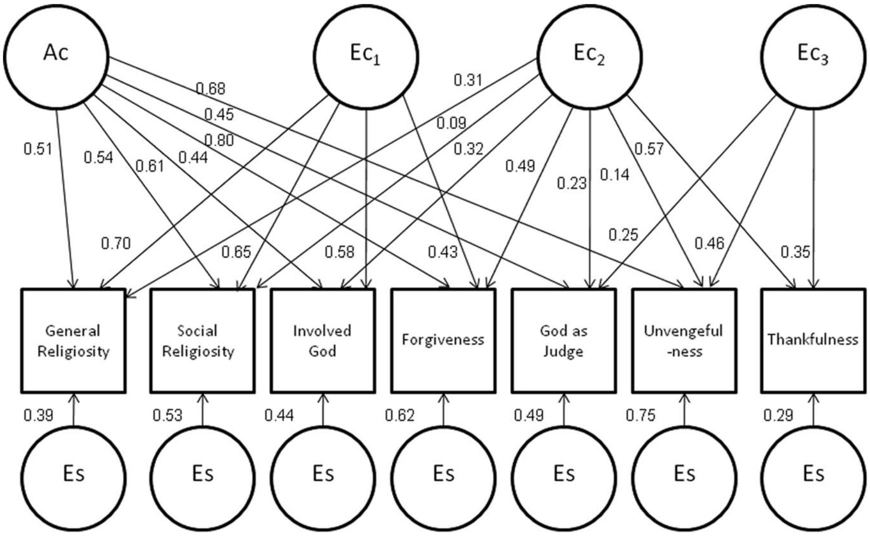

FIGURE 2. Multivariate structure, 7 religiosity factors. Ac indicates common additive genetic factor; Ec_1, first common unique environmental factor; Ec_2, second common unique environmental factor; Ec_3, third common unique environmental factor; Es, specific unique environmental effects.

TABLE 5. Factor Loadings, Best-Fitting Independent Pathway Model, 7 Religiosity Factors

Religiosity Factor	Ac	Ec_1	Ec_2	Ec_3	Es
Factor 1					
General religiosity	0.51	0.70	0.31	—	0.39
Factor 2					
Social religiosity	0.54	0.65	0.09	—	0.53
Factor 3					
Involved God	0.61	0.58	0.32	—	0.44
Factor 4					
Forgiveness	0.44	0.43	0.49	—	0.62
Factor 5					
God as judge	0.80	—	0.23	0.25	0.49
Factor 6					
Unvengefulness	0.45	—	0.14	0.46	0.75
Factor 7					
Thankfulness	0.68	—	0.57	0.35	0.29

Ac indicates common additive genetic factor; Ec_1, first common unique environment factor; Ec_2, second common unique environment factor; Ec_3, third common unique environment factor; Es, unique environment effects specific to each religiosity factor.

gion in a study of adult males and female twins. Additionally, Waller et al. (1990) reported that common environmental effects for religious leisure time interests and religious occupational interests were nonsignificant in a sample of 1642 male and female twins. The results of the present study provide another example in which genetic and unique environmental effects accounted for most of the variance in measures of religiosity, whereas common environmental effects were relatively less influential.

The present study used the most comprehensive set of religiosity measures known to exist for behavior genetics studies. A set of 78 items measuring religiosity, spirituality, and related attitudes and behaviors yielded 7 distinct factors. Our results suggest that when a relatively ill-defined construct such as religiosity is saturated with items intended to create maximum heterogeneity and sophisticated measurement techniques are applied, additive genetic effects and unique environmental effects account for most of the observed variance, with common environmental effects accounting for a smaller portion of the estimated variance. As others have noted, the predominance of additive genetic effects and unique environmental effects makes the expression of religiosity similar to other traits such as personality and temperament (Waller et al., 1990). Replication is needed to have confidence in the findings of the present study.

Multivariate Findings

Exploratory multivariate analyses using Cholesky decompositions and Independent Pathway Models found that the 7 religiosity factors were influenced by 1 common additive genetic factor, 3 common unique environmental factors, and unique environmental effects that were specific to each religiosity factor. Common environmental factors were not statistically significant and could be dropped without resulting in a worse model fit.

Our interpretation of these results is that for the population represented by this sample, one common additive genetic factor affects the predisposition to become religious, whereas unique environmental factors shape the specificity of how religiosity phenotypes are expressed. That is, the predisposition to become religious is due in part to additive genetic effects, whereas the manner in which religiosity is expressed is shaped by unique environmental effects.

All 7 religiosity factors were influenced by 1 unique environmental factor. However, the religiosity factors General Religiosity, Social Religiosity, Involved God, and Forgiveness/Love were influenced by a second unique environmental factor, whereas the factors God as Judge, Unvengefulness, and Thankfulness were influenced by a third unique environmental factor. We interpret this to mean that there are unique environmental experiences that influence some aspects of religiosity (factors 1–4) and another set of unique environmental experiences that influences other aspects of religiosity (factors 5–7), in addition to unique environmental experiences that affect all 7 dimensions of religiosity. There is no clear evidence for what types of unique environmental experiences would influence some aspects of religiosity and not others. However, some forms of religiosity are less commonly reported than others (Pargament et al., 2000; Philips and Stein, 2007). For example, "Punishing God Reappraisals" (redefining a stressor as a punishment from God) appear to be less common than more benevolent forms of religious meaning making (Philips and Stein, 2007). Forms of punishing God reappraisals (e.g., "I feel that stressful situations are God's way of punishing me for my sins or lack of spirituality") loaded highly on the present study's "God as Judge" factor. Punishing God reappraisals can persist over time and are associated with poor mental and physical health outcomes (Pargament et al., 2000; Philips and Stein, 2007), leaving open the question of whether there are certain environmental events unique to individuals that influence the development of these less common dimensions of religiosity.

The present findings yield surprising insights into the nature of religiosity. The common environment is often assumed to play a large role in determining mental well-being or mental illness (Kendler, 1995, 2005, Kendler et al., 2000) and in passing on traits such as attitudes. However, twin studies have shown that the common environment has little or no detectable effect on most psychiatric disorders and personality and only limited contributions to other psychological differences such as social attitudes (Bouchard and McGue, 2003; Kendler, 2001, 1995). Illicit drug use/dependence is a typical exception where significant common environmental effects are commonly found (Button et al., 2007; Tsuang et al., 1996).

The present results should be interpreted in the context of the limitations of classical twin studies. In twin studies, common or "family" environment is defined as those environmental experiences that make twins similar. Unique environmental effects are defined as those environmental experiences that make members of the twin different. Two twins may experience the same objective environment but respond differently to an event. This type of event would be reflected in a twin study as a unique environmental effect, even though it was experienced by both twins in the family environment (Kendler, 2001). Another consideration is that the power limitations of classical twin studies require samples with tens of thousands of twin pairs to detect relatively small common environmental effects particularly in the presence of additive genetic effects (Kendler, 2001; Kendler et al., 2000). The present study is limited by a small number of twins, resulting in low power. Studies that have been able to address this methodological issue have shown that common or family environmental effects do play a role in the development of traits and disorders, but the magnitude of the effects is far below the power of most studies to detect (Kendler, 2001; Kendler et al., 2000).

For a range of traits, there is evidence that the influence of the common environment is stronger in childhood but attenuates in adulthood (Eaves et al., 1997; Kendler, 1995). This pattern has been indicated in behavior genetics studies of religiosity. For example, in a study of adult male twins, Koenig et al. (2005) found a larger influence from the common environment in retrospective adolescence religiosity compared with religiosity in adulthood. In a study of Dutch adolescent and young adult twins with an average age of 17.8 years, Boomsma et al. (1999) found that common environmental factors had the greatest influence on phenotypic variance in religiosity variables. D'Onofrio et al. (1999a,b) studied adolescent twins with an average age of 14.6 years and found that common environmental effects had the largest influence on all measures of religiosity in females.

The sample used in the present study is comprised entirely of adults, leaving open the possibility that the common environment is important in the development of religiosity, although earlier in the lifespan. Therefore, the results of the present study do not rule out the importance of the family environment in passing on religious values, as found in previous studies (Boomsma et al., 1999; D'Onofrio et al., 1999a,b; Koenig et al., 2005), but do suggest that factors that influence both twins in a similar way in the development of their religious behaviors and attitudes are likely of moderate importance in adulthood.

CONCLUSIONS

In conclusion, this study expanded on what is known about genetic and environmental effects on religiosity. Using the most comprehensive set of religiosity items known to exist for behavior genetics studies, univariate and multivariate analyses showed that for the population represented by this study, the expression of religiosity was largely influenced by additive genetic effects and unique environmental experiences. In contrast to several previous studies, we found that common environmental effects, those factors that influence twins in a similar way in the development of their religious attitudes and behaviors, are likely of little importance in adulthood. Further behavior genetics studies using multiple items to tap the complexity of the religiosity construct are needed to increase confidence in findings of this study.

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