

Familial Resemblance in Religiousness in a Secular Society: A Twin Study

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It is well known that human behavior and individual psychological traits are moderately to substantially heritable. Over the past decade, an increasing number of studies have explored the genetic and environmental influence on religiousness. These studies originate predominantly from countries generally considered more religious than the very secular northern European countries. Comparisons of the results are complicated by diverse definitions of religiousness, but several studies indicate that the influence of the family environment is most predominant in early life, whereas genetic influences increase with age. We performed a population-based twin study of religiousness in a secular society using data from a Web-based survey sent to 6,707 Danish twins born 1970–1989, who were identified in the Danish Twin Registry. We applied Fishman's three conceptual dimensions of religiousness: cognition, practice, and importance. In all polygenic models and biometric analyses, we controlled for gender and age. The study sample comprised 2,237 same sex twins, a response rate of 45%. We found high correlations within both monozygotic and dizygotic twin pairs in most items of religiousness, indicating a large influence from shared environmental factors. Personal religiousness such as praying to God, believing in God, and finding strength and comfort in religion were more influenced by genetic factors than were social forms of religiousness such as church attendance. We found a small tendency for increasing genetic influence with increasing age for some religious items, but not for all.

■ **Keywords:** religiousness, secular society

There are many elements in our lives that form the lives we end up living and the values (beliefs, existential concerns, atheism) that are important to us. But where do these choices and fundamental values come from? And how are they formed and how do they gradually transform our lives? It is well known that human behavior and individual psychological traits are moderately to substantially heritable (Bouchard & McGue, 2003). In other words, to some degree we are as we are in our behavior and personality because we have inherited genes that make us that way. Over the past decade, an increasing number of studies have explored the genetic and environmental influences on a rather new and perhaps provocative realm: religiousness, often using the twin study design to facilitate assessment of the impact of genetic, shared environmental and unique environmental factors (Kendler et al., 1997; Kendler & Myers, 2009; Kirk et al., 1999a, 1999b; Koenig et al., 2005, 2008; Tsuang et al., 2002; Vance et al., 2010). The twin study design takes advantage of the fact that twins are reared in the same environment, but while monozygotic (MZ) twins share all of their

genes, dizygotic (DZ) twins share on average half of their genes and hence differences in intrapair similarity between the two may indicate the presence of a positive heritability. Accordingly, in twin studies we can assess how alike twin couples are regarding religiousness and if a similarity stems from being raised in the same family or from genetic factors. We also assess the impact of unique environmental factors such as personal experiences, for example, having a child or losing a close relative.

Comparisons of the results in twin studies are, however, complicated by diverse definitions of religiousness. Some

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studies apply only one single item measure, often an affiliation to a religious denomination or church attendance (Kendler & Myers, 2009; Kirk et al., 1999a, 1999b; Koenig et al., 2008), which may not be an adequate approach as religiosity is a multidimensional construct involving beliefs, practices, and perceptions of God (Hill & Pargament, 2003). Other studies compose different religious constructs categorized from factor analysis of several items relating to religious acts and beliefs or to spirituality, and often divided into intrinsic/personal and extrinsic/social religiosity (Kendler et al., 1997; Kirk et al., 1999a; Koenig et al., 2005, 2008; Tsuang et al., 2002; Vance et al., 2010)

Most studies suggest that religiosity and religious behavior in childhood and adolescence are largely influenced by shared environmental factors — children are much influenced by the environment in which they grow up — (Winter et al., 1999), but as the twins age the picture changes and in adulthood genetic factors and unique environmental factors become increasingly influential (Kendler & Myers 2009; Koenig, 2011; Koenig et al., 2005, 2008). This shift is shown in American follow-up studies of religiosity and the importance of religion (Koenig et al., 2008) and frequency of church attendance (Kendler & Myers, 2009), and can possibly be explained by a decreasing social influence from the families as the twins age and an increasing influence from unique environmental factors such as individual experiences, for example, a personal crisis. As much as 50% of the variance in church attendance in childhood and adolescence derives from shared environmental factors. These factors become less dominant over time and in adulthood they account for close to zero of the variance in frequency of church attendance, while genetic factors and unique environmental factors become progressively more important, accounting for respectively about 60% and 40% of the variance between MZ and DZ twins in adulthood (Kendler & Myers, 2009). The same tendency is seen in a study of two cohorts of young American female twins, with a statistically significant change between the impact of genetics and shared environmental factors on religiosity from 14 to 18 years of age, and a comparable change from 20 to 25 years of age, although not statistically significant (Koenig et al., 2008). Results presented in an American study, using retrospective assessment of religiosity in early life, also indicate that the influence of genetic factors on religiosity increases from adolescence to adulthood (Koenig et al., 2005). Shared environmental factors account for approximately 50%, unique environmental factors for 30%, and genetic factors for 10% of the variance in childhood, as opposed to adulthood where shared environmental factors account for approximately 20%, unique environmental factors for 40%, and genetic factors for 40% of the variance. However, when religiosity was divided into internal and external aspects, the shift in explaining factors only remained statistically significant for the external aspects of religiosity (Koenig et al., 2005).

In agreement with these findings, Kirk et al. (1999b) not only show considerable influence from genetic factors but also find effects from shared environmental factors in a large study of church attendance among American and Australian adults. Conversely, in a solely Australian study, Kirk et al. (1999a) show no effect of genetic factors and find that shared environmental factors have the largest effect in adulthood, accounting for about 60% of the variance in church attendance in twins over 50 years of age. Kirk et al. (1999a) also study self-transcendence in this sample of older Australian twins and show that genetic factors contribute approximately 40%, while unique environmental factors contribute 50%, and shared environmental factors contribute 10% of the variance.

Bouchard et al. (1999) employ a construct of intrinsic and extrinsic religiosity in an American study and demonstrate significant heritability for both measures. Vance et al. (2010) measure seven religiosity factors in an American population and find that the predisposition to become religious is affected by genetic factors, whereas the specificity of how religiosity phenotypes are expressed is shaped by unique environmental factors.

Kendler et al. (1997) divide religiosity into three dimensions — personal devotion, personal conservatism, and institutional conservatism — and find no statistically significant difference in intrapair similarity between MZ and DZ twins in any of these dimensions in an American female population. Still, they do show a tendency for an important contribution from shared environmental factors on institutional conservatism, approximately 50% of the variance, while genetic factors account for about 10% and unique environmental factors for about 40%. For personal devotion, unique environmental factors account for the larger part with approximately 50%, while genetic factors account for about 30% and shared environmental factors for about 20% (Kendler et al., 1997).

Tsuang et al. (2002) assess spirituality as divided into well-being (sense of relationship with God) and involvement (religious practices) in a sample of American male twins who were Vietnam War veterans. Spiritual well-being was accounted for by genetic factors (40%), unique environmental factors (50%), and shared environmental factors (10%), while spiritual involvement was accounted for by genetic factors (20%), unique environmental factors (30%), and shared environmental factors (50%) (Tsuang et al., 2002). Bradshaw and Ellison (2008) examined church attendance, personal religiosity and spirituality, conservative ideologies, and commitment and found that genetic factors and unique environmental factors statistically significantly influence all measures in an American national sample, while shared environmental factors influence only church attendance and one item within personal religiosity, namely religious salience.

Conclusively, results are not easily compared, but religiosity seems to be influenced by both genetic, shared

environmental and unique environmental factors. However, in some studies there seems to be a tendency toward personal religiousness as self-transcendence (Kirk et al., 1999a), personal devotion (Kendler et al., 1997), and spiritual well-being (Tsuang et al., 2002) being influenced more by genetic factors; and social religiousness, such as church attendance (Bradshaw & Ellison, 2008; Kirk et al., 1999b), institutional conservatism (Kendler et al., 1997), and spiritual involvement (Tsuang et al., 2002) being influenced more by shared environmental factors. Furthermore, studies consistently show an increasing influence of genetic factors on religiousness from childhood to adulthood.

Nearly all the studies mentioned above originate from countries generally considered more religious than the very secular northern European countries, and only one study from a secular society was identified (Winter et al., 1999). Despite very low rates of church attendance in Denmark, 82% of the Danish population are still members of the Danish National Evangelical Lutheran Church (Folkekirken, n.d.), and the majority still call on the church to perform rites of passage such as baptism, weddings, and funerals (Iversen, 2005). It has been argued that the relationship to the church in Denmark is not so much an expression of Christianity and religiousness as a marker of social and cultural identity (Zuckerman, 2008). One can perhaps say that most Danes are passive members, but this passivity may transform into something more active during crisis, and active religiousness in Denmark is to some degree 'crisis religiosity' (la Cour, 2008). In a survey from 2008 assessing the use of religious coping, Danish hospital patients reported intensified beliefs and religious practices during hospitalization (Ausker, 2008). Denmark has been characterized as one of the world's most secular countries (Zuckerman, 2008) and therefore Danish research in religious behavior can make a considerable contribution as there is only limited knowledge about the scope and application of religion in secular societies.

Many twin studies have employed the Religious Orientation Scale of Allport and Ross (1967) to distinguish between intrinsic and extrinsic religiousness where intrinsic was considered authentic, driven by man's inner desires, and extrinsic was driven by family expectations or tradition. However, the existing terminology in research of religiousness might not be applicable to a Danish population, and Danish researchers in this field have made comprehensive efforts to make meaningful religious constructs in a secular society (la Cour & Hvidt, 2010). On the basis of a literature review, they propose the application of three conceptual dimensions: cognition, practice, and importance, dimensions with theoretical and practical support in the literature. The three dimensions represent the essential areas of the psychology of religion identified by Wulff, namely (1) questions of supernatural principles; (2) activities according to this; and (3) the feeling present in the individual (Wulff, 1997). These dimensions correspond with the intu-

itive sociological dimensions of Fishman: knowing, doing, and being (Fishman, 1980), dimensions that are known to have good explanatory power (Gundelach et al., 2008). In this twin study based on a questionnaire from a Danish Views and Value Survey, we aimed to assess how different aspects of religiousness are influenced by genetic and environmental factors in a secular society, applying Fishman's three conceptual dimensions of religiousness: cognition, practice, and importance (Gundelach et al., 2008).

Methods and Materials

On October 1, 2009, an invitation to participate in a Web-based survey was sent to 6,707 Danish twins born 1970–1989, identified in the Danish Twin Registry. If preferred, the participants could request and return a printed questionnaire. One reminder was sent to non-responders.

The Danish Twin Registry was established in 1953 (Skytthe et al., 2006, 2011). The twins in this study were included in 1990–1991 for birth cohorts 1970–1982 and in 2003 for birth cohorts 1983–1989. The zygosity status of same-sexed twin pairs was assessed at inclusion time with four questions about the similarity of the twins; the parents or the twins themselves answered the questions. Zygosity status is obtained by questionnaire; parents respond to questionnaire items dealing with twin similarity in physical characteristics and frequency of mistaking one twin for another by parents, relatives, and strangers. This method has been shown to give at least 95% agreement with zygosity based on genetic markers (Christiansen et al., 2003). Written informed consent was obtained from all subjects.

The survey encompassed questions about health, smoking, alcohol intake, socio-economic status in childhood, educational level and connection to the labor market, marital status, political and ethical principles, experiences with a life crisis, religious beliefs, and existential values; some questions about religious beliefs in general were obtained from the European Values Survey (EVS; Gundelach, 2006), and other questions about religiousness, existential values, and coping were constructed for this study. The six core questions analyzed in this study were chosen for their representativeness for the three conceptual dimensions and were a priori classified in the construct: cognition, practice, and importance (Gundelach et al., 2008). Belief in God and life after death were categorized as cognition; frequency of church attendance and prayer were categorized as practice; the importance of God and finding comfort and strength in religion were categorized as importance. The six core questions were assessed as single item. Belief in God was dichotomized from the answers 'Yes, and I always did' and 'Yes, but I didn't always do' into *Yes*, and the answers 'No, and I never did' and 'No, but I used to' into *No*; respondents who answered 'I do not know' were counted as missing. Belief in life after death had the response options *Yes*, *No*, and *Do not know*, the last counting as missing in the analyses. The

question about church attendance was phrased ‘How often you go to church, apart from weddings, funerals, and baptisms?’ and had eight response options from *More than once a week* to *Never*. We dichotomized the answers at *Once a month or more* and the next response option ‘At special occasions as Easter or Christmas’ to identify people who attend church regularly. The question on prayer was phrased ‘How often do you pray to God apart from at religious services?’ with choices from *Every day* to *Never* and was dichotomized between *Seldom* and *Never* to distinguish between ever and never praying. Finding comfort and strength in religion had the response options *Yes*, *No*, and *Do not know*, the last counting as missing in the analyses. The question ‘How important is God in your life?’ had response options on a 10-point Likert scale from *Not at all* to *Very much* and was dichotomized at the five point.

The survey also included a question about church attendance at the age of 12 years, enabling analyses of difference across ages.

Statistical Analyses

Similarities in twins originate from two factors: genetic factors and shared environmental factors. Additive genetic factors (symbolized by the letter A) contribute twice as much to the MZ as to the DZ twin correlation because MZ twins share all of their genes while DZ twins share, on average, half of their genes. The second source of twin resemblance included in our models is shared environment (symbolized by the letter C), which contributes equally to the correlation in MZ and DZ twins and reflects environmental experiences in the home, community, or school. In addition to this shared environment, the model also contains unique environmental factors (symbolized by the letter E), which reflects those true environmental experiences that make members of a twin pair differ, as well as errors of measurement. Non-additive genetic effects are symbolized by the letter D. The dominant genetic effects derive from an interaction between alleles at the same locus, which contribute four times as much to the intrapair correlation in MZ twins as in DZ twins. We compared the full ACE and ADE models with entirely saturated models and used Akaike’s information criterion (AIC) for selecting the best fitting of the two. Then we tested the AE/CE/E or AE/DE/E submodels. In tetrachoric correlations and biometric analyses, we controlled for gender. Furthermore, to explore if the influence from shared environmental factors would decrease with increasing age, as shown in many other studies, we made subanalyses stratified in age groups from 20–30 years and 31–40 years. Adjustment for the effects of age and gender was achieved by letting the threshold, hence the prevalence, being a regression function of these covariates. All models were implemented as age- and sex-adjusted liability threshold models, assuming that the underlying distribution of the outcome variables follows a bivariate normal distribu-

tion. All analyses are carried out using the Mx software (Neale et al., 2003).

Results

Of the 6,707 twins invited to participate in the survey, 3,686 twins answered, resulting in a response rate of 55%. The section of the questionnaire regarding beliefs and religiosity was completed by 3,000 twins, resulting in a response rate of 45%; for this part of the survey, 60% of the respondents were women. The younger age group (20–30 years) comprised 1,474 twins, and the older age group (31–40 years) comprised 1,526 twins. The mean age was 29.1 (*SD* 6.2); 82.6% were members of the Danish National Evangelical Lutheran Church. The electronic version of the questionnaire was used by 3,652 twins while only 34 twins used the paper version of the questionnaire. The study sample comprised 2,237 same-sex twins (Table 1).

Table 1 shows the number and percentages of male and female MZ and DZ twins answering *Yes* to the six core questions about religiosity categorized in the three dimensions: cognition, practice, and importance. Except for church attendance, a higher percentage of women answered *Yes* in all items. Table 2 shows the concordance rates and the tetrachoric correlations for male and female twins answering *Yes* to the six core questions about religiosity categorized in the three dimensions: cognition, practice, and importance. Table 2 shows that twins are very similar on most religious items — regardless whether they are MZ or DZ — which generally indicates that shared environment more than genetic factors is the source of their similarity.

Table 3 shows the model-fit analyses and the parameter estimates of the variance in the three dimensions: cognition, practice, and importance. We used the AIC to select the best-fitting model. However, the models with the lowest AIC were not statistically significantly different from the ACE model and hence we only present the ACE estimates in the combined variables. Table 4 shows the differences between the younger and the older part of the cohort with tetrachoric correlations and estimates of variance, the ACE model.

Only 5.6% of the twins reported church attendance once a month or more. Asked about their church attendance at the age of 12 years, 12.1% reported going to church monthly. The concordance rates and the tetrachoric correlations for current and childhood church attendance are shown in Table 2. The ACE model fitted data best in the analyses of church attendance at age 12 years, and shared environmental factors accounted for 55% (0.19–0.82) of the variance, genetic factors for 31% (0.00–0.69), and unique environmental factors accounted for 14% (0.07–0.24) (Table 3).

In Table 4, age-stratified analyses reveal a tendency for genetic factors having an increasing influence in the older part of the cohort for some items: belief in life after death, praying to God, importance of God, and finding strength and comfort in religion.

TABLE 1
Demographics and Numbers of Twins Answering Yes to Questions About Religiousness

	MZ female	DZ female	MZ male	DZ male
Demographics				
Invited	1,316	1,405	962	1,228
Participated ^a	709 (54)	672 (48)	401 (42)	455 (37)
Age (mean)	30.4	28.5	29.6	28.6
Member of the national church ^{b,c}	618 (87.2)	551 (82.0)	313 (78.5)	358 (78.7)
Member of other churches ^{b,d}	25 (3.5)	26 (3.9)	2 (0.6)	7 (1.5)
Not a member ^b	66 (9.3)	95 (14.1)	83 (20.9)	90 (19.8)
Cognition ^e				
I believe in God	290 (53.2)	218 (43.6)	116 (34.3)	117 (30.4)
I believe in life after death	276 (53.5)	246 (49.1)	92 (28.8)	115 (31.6)
Practice ^e				
I go to church monthly	40 (5.6)	38 (5.6)	23 (5.8)	27 (5.9)
I pray to God	403 (57.7)	344 (52.0)	150 (38.4)	168 (36.9)
Importance ^e				
God is important in my life	167 (24.0)	143 (21.8)	58 (14.8)	68 (18.7)
I find strength and comfort in religion	211 (34.3)	153 (26.5)	68 (15.1)	83 (19.5)

Note: ^aPercentages of invited within specific zygosity and gender; ^bpercentages of participating within specific zygosity and gender; ^cthe Danish National Evangelical Lutheran Church; ^dCatholic, Muslim, Jew, Jehovah's witnesses, Hindu, Buddhist, and so on; ^epercentages saying Yes of those answering this specific question within specific zygosity and gender. DZ = dizygotic; MZ = monozygotic.

TABLE 2
Concordance Rates by Gender and Polygenic Model Adjusted for Age and Gender With 95% CI for Questions on Religiousness, Classified as Cognition, Practice, and Importance

	Zygosity	Concordance rates (95% CI)	Zygosity	Tetrachoric correlation (95% CI) ^a
Cognition				
Belief in God	MZ female	0.79 (0.71–0.86)	MZ	0.80 (0.69–0.88)
	DZ female	0.69 (0.58–0.77)	DZ	
	MZ male	0.71 (0.55–0.83)		
	DZ male	0.41 (0.19–0.58)		
Belief in life after death	MZ female	0.79 (0.72–0.87)	MZ	0.72 (0.57–0.83)
	DZ female	0.70 (0.58–0.78)	DZ	
	MZ male	0.52 (0.26–0.64)		
	DZ male	0.44 (0.17–0.59)		
Practice				
Church attendance monthly	MZ female	0.56 (0.37–0.74)	MZ	0.82 (0.65–0.92)
	DZ female	0.61 (0.22–0.83)	DZ	
	MZ male	0.46 (0.00–0.75)		
	DZ male	0.40 (0.00–0.70)		
Pray to God	MZ female	0.76 (0.70–0.81)	MZ	0.66 (0.54–0.76)
	DZ female	0.63 (0.54–0.68)	DZ	
	MZ male	0.66 (0.50–0.77)		
	DZ male	0.43 (0.24–0.54)		
Church attendance monthly at age 12	MZ female	0.69 (0.57–0.77)	MZ	0.86 (0.76–0.93)
	DZ female	0.53 (0.38–0.72)	DZ	
	MZ male	0.62 (0.31–0.76)		
	DZ male	0.43 (0.24–0.67)		
Importance				
Importance of God	MZ female	0.50 (0.42–0.61)	MZ	0.61 (0.45–0.73)
	DZ female	0.47 (0.35–0.59)	DZ	
	MZ male	0.55 (0.29–0.71)		
	DZ male	0.40 (0.10–0.59)		
Comfort in religion	MZ female	0.65 (0.55–0.74)	MZ	0.65 (0.51–0.77)
	DZ female	0.43 (0.28–0.59)	DZ	
	MZ male	0.49 (0.20–0.65)		
	DZ male	0.39 (0.14–0.57)		

Note: ^aAdjusted for age and gender. DZ = dizygotic; MZ = monozygotic.

Discussion

In this population-based twin study of religiousness in a secular society, we found high correlations within both MZ and DZ twin pairs in most items of religiousness, except the items praying to God and finding strength and comfort in religion. This indicates a large influence from growing up together. Twin couples are very alike regarding religiousness and this similarity stems largely from being raised in the

same family. To enable comparison across age strata, we held onto the ACE model.

Within the *cognition dimension*, the tetrachoric correlations were high for both MZ and DZ twins, with the highest correlation for MZ twins, but the difference was only statistically significant with regard to belief in God (Table 2). Biometric analyses showed that belief in God was influenced equally by shared environmental factors and genetic

TABLE 3
Biometric Analyses

	Model	-2 lnI	Degrees of freedom	Parameter estimates (95% CI)				AIC	p
				a2	c2	d2	e2		
Cognition									
Belief in God	Saturated	2,219.509	1,760						
	ACE	2,227.831	1,763	0.39 (0.02–0.79)	0.41 (0.03–0.72)	—	0.20 (0.12–0.31)	-1,298.169	.040
	ADE	2,232.372	1,736	0.82 (0.72–0.89)	—	0.00	0.18 (0.10–0.28)	-1,293.628	.005
	AE (submodel of ACE)	2,232.372	1,764	0.82 (0.72–0.89)	—	—	0.18 (0.11–0.28)	-1,295.628	.033
	CE (submodel of ACE)	2,232.168	1,764	—	0.72 (0.63–0.80)	—	0.28 (0.20–0.38)	-1,295.832	.037
	E (submodel of AE)	2,348.094	1,765	—	—	—	1	-1,181.906	<.001
Belief in life after death	Saturated	2,152.923	1,692						
	ACE	2,154.665	1,695	0.21 (0.00–0.64)	0.51 (0.12–0.75)	—	0.28 (0.17–0.42)	-1,235.335	.628
	ADE	2,161.071	1,695	0.76 (0.64–0.85)	—	0.00	0.24 (0.15–0.36)	-1,228.929	.043
	AE (submodel of ACE)	2,161.071	1,696	0.76 (0.64–0.85)	—	—	0.24 (0.15–0.36)	-1,230.929	.011
	CE (submodel of ACE)	2,155.689	1,696	—	0.67 (0.56–0.76)	—	0.33 (0.24–0.44)	-1,236.311	.311
	E (submodel of AE)	2,244.341	1,696	—	—	—	1	-1,149.659	<.001
Practice									
Church attendance monthly	Saturated	896.070	2,227						
	ACE	897.948	2,230	0.0001 (0.00–0.38)	0.83 (0.48–0.91)	—	0.17 (0.08–0.29)	-3,562.052	.598
	ADE	910.926	2,230	0.86 (0.73–0.94)	—	0.00	0.14 (0.06–0.27)	-3,549.074	.002
	AE (submodel of ACE)	910.926	2,231	0.86 (0.73–0.94)	—	—	0.14 (0.06–0.27)	-3,551.074	<.001
	CE (submodel of ACE)	897.948	2,231	—	0.83 (0.71–0.91)	—	0.17 (0.09–0.29)	-3,564.052	>.99
	E (submodel of AE)	980.219	2,232	—	—	—	1	-3,483.781	<.001
Church attendance monthly (at 12 years of age)	Saturated	952.047	1,403						
	ACE	952.047	1,403	0.31 (0.00–0.69)	0.55 (0.19–0.82)	—	0.14 (0.07–0.24)	-1,853.953	.99
	ADE	960.052	1,403	0.88 (0.80–0.94)	—	—	0.12 (0.06–0.20)	-1,845.948	.99
	AE (submodel of ACE)	960.052	1,404	0.88 (0.80–0.94)	—	—	0.12 (0.06–0.20)	-1,847.948	.005
	CE (submodel of ACE)	955.664	1,404	—	0.80 (0.71–0.87)	—	0.20 (0.13–0.29)	-1,852.336	.057
	E (submodel of AE)	1,097.029	1,405	—	—	—	1	-1,712.971	.001
Pray to God	Saturated	2,890.318	2,198						
	ACE	2,894.339	2,201	0.54 (0.16–0.76)	0.12 (0.00–0.44)	—	0.34 (0.24–0.46)	-1,507.661	.259
	ADE	2,894.843	2,201	0.67 (0.56–0.76)	—	0.00	0.33 (0.24–0.44)	-1,507.157	.210
	AE (submodel of ACE)	2,894.842	2,202	0.67 (0.56–0.76)	—	—	0.33 (0.24–0.44)	-1,509.158	.478
	CE (submodel of ACE)	2,902.075	2,202	—	0.54 (0.44–0.63)	—	0.46 (0.37–0.56)	-1,501.925	.005
	E (submodel of AE)	2,992.115	2,203	—	—	—	1	-1,413.885	<.001
Importance									
Importance of God	Saturated	2,087.704	2,188						
	ACE	2,087.704	2,188	0.001 (0.001–0.001)	0.61 (0.49–0.70)	—	0.39 (0.30–0.51)	-2,288.296	>.99
	ADE	2,095.915	2,188	0.66 (0.54–0.76)	—	0.00	0.34 (0.24–0.46)	-2,280.085	>.99
	AE (submodel of ACE)	2,095.915	2,189	0.66 (0.54–0.68)	—	—	0.34 (0.24–0.46)	-2,282.085	.004
	CE (submodel of ACE)	2,087.704	2,189	—	0.61 (0.49–0.70)	—	0.39 (0.30–0.51)	-2,290.296	>.99
	E (submodel of AE)	2,163.611	2,190	—	—	—	1	-2,216.389	.000
Strength and comfort in religion	Saturated	2,165.055	1,981						
	ACE	2,168.420	1,984	0.34 (0.00–0.75)	0.31 (0.01–0.31)	—	0.35 (0.23–0.49)	-1,799.580	.339
	ADE	2,170.426	1,984	0.86	—	0.00	0.32	-1,797.574	.147
	AE (submodel of ACE)	2,170.426	1,985	0.68 (0.55–0.78)	—	—	0.32 (0.22–0.45)	-1,799.574	.157
	CE (submodel of ACE)	2,170.538	1,985	—	0.59 (0.47–0.69)	—	0.41 (0.31–0.53)	-1,799.462	.146
	E (submodel of AE)	2,242.176	1,986	—	—	—	1	-1,729.824	<.001

Note: ACE = additive common unique; ADE = additive dominant unique; AE = additive unique; AIC = Akaike's information criterion; CE = common unique; a2 = additive genetic effects; c2 = shared environmental effects; d2 = dominant genetic effects; e2 = unique environmental effects.

TABLE 4
Tetrachoric Correlations and Biometric Analyses in Age Strata, the ACE Model

	Zygosity	Tetrachoric correlations (95% CI)	Parameter estimates (95% CI)		
			a ²	c ²	e ²
Cognition					
Belief in God					
20–29 years	MZ	0.85 (0.69–0.94)	0.69 (0.15–0.94)	0.16 (0.00–0.62)	0.15 (0.06–0.31)
	DZ	0.51 (0.22–0.72)			
30–40 years	MZ	0.76 (0.59–0.86)	0.11 (0.00–0.66)	0.65 (0.14–0.83)	0.24 (0.12–0.39)
	DZ	0.71 (0.46–0.87)			
Belief in life after death					
20–29 years	MZ	0.77 (0.55–0.90)	0.20 (0.00–0.76)	0.56 (0.06–0.82)	0.23 (0.10–0.42)
	DZ	0.67 (0.42–0.83)			
30–40 years	MZ	0.68 (0.46–0.83)	0.27 (0.00–0.81)	0.41 (0.00–0.75)	0.32 (0.17–0.53)
	DZ	0.54 (0.24–0.76)			
Practice					
Church attendance monthly					
20–29 years	MZ	0.93 (0.74–0.99)	0.06 (0.00–0.53)	0.87 (0.41–0.97)	0.07 (0.01–0.21)
	DZ	0.90 (0.67–0.98)			
30–40 years	MZ	0.69 (0.37–0.88)	0.00 (0.00–0.81)	0.72 (0.00–0.87)	0.28 (0.11–0.53)
	DZ	0.75 (0.33–0.94)			
Pray to God					
20–29 years	MZ	0.69 (0.51–0.83)	0.45 (0.00–0.82)	0.24 (0.00–0.64)	0.31 (0.17–0.49)
	DZ	0.47 (0.25–0.65)			
30–40 years	MZ	0.63 (0.47–0.76)	0.63 (0.12–0.75)	0.00 (0.00–0.00)	0.37 (0.25–0.53)
	DZ	0.29 (0.03–0.52)			
Importance					
Importance of God					
20–29 years	MZ	0.59 (0.33–0.78)	0.00 (0.00–0.00)	0.61 (0.12–0.75)	0.39 (0.22–0.56)
	DZ	0.63 (0.38–0.81)			
30–40 years	MZ	0.61 (0.41–0.78)	0.08 (0.00–0.73)	0.53 (0.00–0.73)	0.39 (0.23–0.56)
	DZ	0.57 (0.26–0.79)			
Strength and comfort in religion					
20–29 years	MZ	0.62 (0.38–0.79)	0.66 (0.56–0.81)	0.00 (0.00–0.00)	0.34 (0.19–0.54)
	DZ	0.52 (0.23–0.73)			
30–40 years	MZ	0.68 (0.49–0.82)	0.69 (0.52–0.82)	0.00 (0.00–0.00)	0.31 (0.18–0.48)
	DZ	0.45 (0.10–0.70)			

Note: a² = additive genetic effects; c² = shared environmental effects; DZ = dizygotic; e² = unique environmental effects; MZ = monozygotic.

factors. Unique environmental factors such as crisis experiences accounted for only 20%. With regard to belief in life after death, the shared environmental factors were even more pronounced, accounting for half of the variance and the genetic factor for only 20% (Table 3). Only 43% of the twins believed in life after death. This is among the lowest percentages in the Nordic countries and in Western Europe (Haraldsson, 2006) and far from the percentages of people believing in life after death in the United States (82%; Gallup & Lindsay, 1999). We identified only one other twin study assessing belief in life after death, a Finnish study assessing religiousness in adolescent boys and girls in rural and urban areas (Winter et al., 1999). In the Finnish study, approximately 51% of the boys and 65% of the girls believed in life after death, and their religiosity was largely influenced by shared environmental factors, in agreement with other studies on religiousness in adolescence (Koenig, 2011). The phenotype 'not believing in life after death' is a much less 'extreme' phenotype in Denmark than in the United States. However, it is difficult to predict how this will translate into changing the genetic and environmental components. One possibility is that in a setting where not believing in life after death is common and well accepted, your genetic predisposition is more likely to be expressed;

that is the genetic contribution will be larger in Denmark than in the United States.

The two items in the *practice dimension* (Table 2) showed very dissimilar patterns. Church attendance had the highest tetrachoric correlation, approximately 84% for both MZ and DZ twins, and there was a very low genetic influence, while shared environmental factors accounted for 80% of the variance (Table 3). In Denmark, less than 6% of the population goes to church monthly and in this study only 128 twins attended church once a month or more. Going to church frequently is uncommon in Denmark and may be closely linked to family tradition in more religious families and might have an entirely different etiology than church attendance in, for example, the United States, where some studies find influence from genetic factors (Kirk et al., 1999b). Praying, on the other hand, was largely influenced by genetic factors, with approximately 50% of the variance, rising to over 60% in the older part of the cohort (Tables 3 and 4). There was a statistically significantly higher tetrachoric correlation in the MZ twins than in the DZ twins (Table 2). The question was phrased 'How often do you pray to God other than at religious services?', and as Denmark is such a secular society praying to God is possibly a truly personal deed. In our data,

1,065 twins answered that they prayed to God (all frequencies from daily to once a year). No other studies assessed prayer as a single item, but seen in the framework of earlier studies using the intrinsic/personal and extrinsic/social terminology, personal prayer belongs to intrinsic religiosity, and in agreement with others (Bouchard et al., 1999; Vance et al., 2010), we found large influence from genetic factors on the more personal religiosity.

In the *importance dimension*, the tetrachoric correlations did not differ statistically significantly between MZ and DZ twins. Importance of God was predominantly influenced by shared environmental factors (60%), and finding strength and comfort in religion was equally influenced by genetic factors, shared and unique environmental factors.

Only one of the six core questions — church attendance — expresses social religiosity, and had the highest influence from shared environmental factors. The other five items express personal religiosity.

In the age-stratified analyses, there was a tendency for genetic factors to have an increasing influence in the older part of the cohort for some items: belief in life after death, praying to God, importance of God, and finding strength and comfort in religion (Table 4). This is in clear accordance with several American studies (Kendler & Myers, 2009; Koenig, 2011; Koenig et al., 2005, 2008). In other words, the more you age, the more you disentangle yourself from the influences of the beliefs of the family, leaving more room for individual spiritual and religious characteristics. The shift in influence was less pronounced than in the American studies, most likely as we assessed early adulthood (20–29 years) with mature adulthood (30–40 years), not including children or adolescents.

However, we were not able to replicate the consistent findings from studies in the United States when we focused on church attendance. The US studies show that shared environmental factors become less dominant over time, whereas in adulthood genetic factors and unique environmental factors become progressively more important (Kendler & Myers, 2009; Koenig et al., 2005, 2008). On the contrary, we found larger influence from shared environmental factors on church attendance in adulthood than in childhood at 12 years of age, and also in the age strata analyses there was a decrease in the influence of genetic factors in the older cohort. For church attendances in childhood and also in adult life, the correlations were very high for both MZ and DZ twins, indicating a large influence from shared environmental factors. In other words, in Denmark, people to a higher degree than in the United States continue going to church, as did their parents. This may be partly explained by the fact that the frequency of church attendance is much lower in Denmark than in the United States, where as many as 50% go to church every month (Gallup & Lindsay, 1999). The frequency of church attendance might therefore not express the same kind of religiosity in Denmark and in the United States. Going to church simply is a minority phe-

nomenon in Denmark much more than in the United States, and we know from other studies that minority groups tend to take their religious practice very seriously and are more likely to remain within the group across generations (Finke, 1998). Furthermore, as our respondents were asked retrospectively about their church attendance at the age of 12 years, recall bias might introduce some misclassification.

This study was based on data from a population-based national register that includes all twins in Denmark. The response rate was 45%. The proportion of respondents answering positively to religious questions in our study was smaller than the proportion of Danes in the EVS from 2008, even when we compared the same age groups (Gundelach et al., 2008). In the practice and importance dimensions small and moderate differences were seen, but in the cognition dimension a large discrepancy was seen in the question ‘Do you believe in God?’ (*Yes/No/Don't know*), where 62% of the women and 43% of the men in the EVS answered *Yes* compared with 37% of the women and 27% of the men in our data. We found no obvious explanation for this divergence. Still, respondents in Web-based questionnaires might be a selected group and the EVS interviews were carried out face to face.

Other twin studies on religiosity do not report a discrepancy between twins and singletons in regard to religiosity (Koenig, 2011). Conclusions from twin studies assume that twins are representative for the population at large and that they do not differ systematically from singletons with respect to personality. Studies assessing individual psychological traits conclude that twins are just ordinary people with respect to personality (Johnson et al., 2002) and that they show similar academic performance in adolescence to that of singletons (Christensen et al., 2006). Being a twin, on the other hand, decreases the risk of committing suicide (Tomassini et al. 2003); and also, twins tend to marry slightly later and have slightly fewer divorces (Petersen et al., 2011). Hence, twins might differ from singletons in that twins have a unique and secure attachment to each other. As other studies have shown, the lack of secure attachments to other people, especially during childhood, may enhance belief in God in adulthood due to the need for a substitute attachment figure (Kirkpatrick, 1997). Evidently it needs to be explored whether this could influence twins' inclination to believe in God.

Constructive replication of findings requires the existence of adequate measuring instruments and presently no generally accepted consensus exists on how to assess religiosity. Studies on religiosity use a broad variety of measures. Furthermore, comparisons of the findings are difficult as the current evidence of heritability in religiosity stems from studies of diverse populations. In our study, we included Danish men and women between 20 and 40 years of age. In the Australian studies, twins older than 50 years of age were included and three studies focused on the development from childhood and adolescence to

adulthood (Kendler & Myers, 2009; Koenig et al., 2005, 2008). Two studies comprised only women (Kendler et al., 1997; Koenig et al., 2008) and three comprised men (Kendler & Myers, 2009; Koenig et al., 2005; Tsuang et al., 2002). The vast majority of studies were based on American populations (Bouchard et al., 1999; Kendler & Myers, 2009; Kendler et al., 1997; Kirk et al., 1999a; Koenig et al., 2005, 2008; Vance et al., 2010), two included Australian twins (Kirk et al., 1999a, 1999b), and one was from Finland (Winter et al., 1999). In religiousness, considerable discrepancies between gender (Francis, 1997; Gallup & Lindsay, 1999) and across ages are well known (Warburg, 2007), and the public manifestation of religiousness as seen in US society is unfamiliar to the more secularized Danish society. Despite these differences, a tendency appears: the personal elements of religiousness (such as private prayer) are to a larger extent explained by genetic factors and unique environmental factors (i.e., crisis experiences), while social elements of religiousness more often are explained by shared environmental factors (such as parents' influence). Further studies are needed to confirm this trend.

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