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A religious upbringing reduces the influence of genetic factors on disinhibition: Evidence for interaction between genotype and environment on personality

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Information on personality, on anxiety and depression and on several aspects of religion was collected in 1974 Dutch families consisting of adolescent and young adult twins and their parents. Analyses of these data showed that differences between individuals in religious upbringing, in religious affiliation and in participation in church activities are not influenced by genetic factors. The familial resemblance for different aspects of religion is high, but can be explained entirely by environmental influences common to family members. Shared genes do not contribute to familial resemblances in religion. The absence of genetic influences on variation in several dimensions of religion is in contrast to findings of genetic influences on a large number of other traits that were studied in these twin families. Differences in religious background are associated with differences in personality, especially in Sensation Seeking. Subjects with a religious upbringing, who are currently religious and who engage in church activities score lower on the scales of the Sensation Seeking Questionnaire. The most pronounced effect is on the Disinhibition scale. The resemblances between twins for the Disinhibition scale differ according to their religious upbringing. Receiving a religious upbringing seems to reduce the influence of genetic factors on Disinhibition, especially in males.

Keywords: genotype × environment (G × E) interaction, twins, religion, personality, sensation seeking

Introduction

A frequently observed finding from behavioural genetics research is that resemblances between family members for a wide range of human characteristics are mainly due to shared genes and not to shared environment. We have studied variables related to personality, psychopathology, life style, cardiovascular disease, brain function, cognition and intelligence in twins of different ages. These twins, and sometimes their family members such as parents and siblings, participate in research projects that require them to come to the laboratory for electrophysiological assessment of brain function, for example, or they are visited at home for assessment of IQ or for 24-hour ambulant registration of heart rate and blood pressure. Other twin families participate in large scale surveys that are conducted by mailed questionnaires.

In Figures 1 and 2 a summary is presented, separately for males and females, of the main results from these studies in Dutch twins, who are registered with the Netherlands Twin Registry.[30] The dark bars represent heritabilities, the shaded bars give estimates for the influence of shared environment and the light bars show the influence of unique environmental effects (including any effect of age). In these figures, the variables have been grouped into four domains: cardiovascular parameters and life style factors influencing risk for cardiovascular disease and health, information processing and memory and biological parameters related to information processing, personality and psychopathology and intelligence. Several main findings are obvious from these figures: there are few systematic differences in heritabilities across the different domains; within each domain there are large differences in heritabilities (with the possible exception of the personality domain); there is very little difference in the genetic architecture of individual differences between males and females; the largest part of the resemblances between family members can be attributed to shared genes and only a few traits show an important contribution of shared family environment.

Birth weight is one of the traits that is influenced to a relatively large extent by shared environment (though we do not know whether this shared environment for twins represents the influence of maternal genes), and IQ at an early age also shows a

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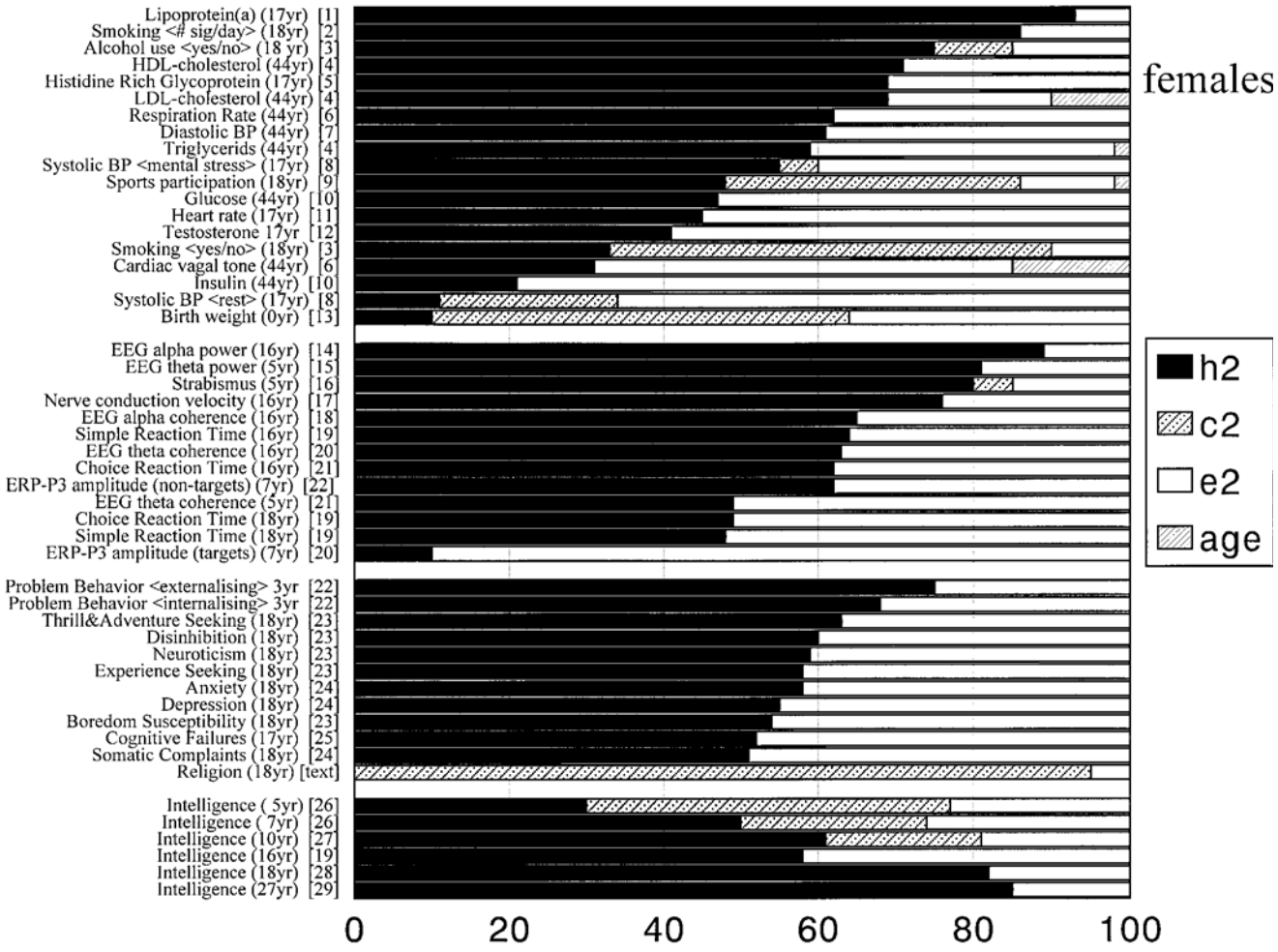

Figure 1 Estimates of heritability (h2) and the contributions of shared (c2) and unique environmental (e2) factors and age to phenotypic variance for a number of traits in females. Average age of the subjects is given in parentheses. Traits are cardiovascular risk parameters (Lipoprotein(a) to birth weight), behavioural and electrophysiological indices of neural speed and brain function (EEG alpha power to ERP-P3 amplitude), personality (Sensation Seeking to Religion) and intelligence (at 6 different ages). Estimates were obtained from the best fitting models (usually AE without sex differences)[1–29]

significant contribution of the environment that is common to 5-year-olds who grow up in the same family. During adolescence and young adulthood, initiation of smoking and drinking is for a large part due to environmental influences shared by twins living in the same household (analysing smoking and drinking data from the twins simultaneously with similar data from their parents, suggested that these shared environmental influences do not consist of any direct influence of parental smoking or drinking behaviour on smoking or drinking behaviour in their offspring). Of the large number of variables that have been studied in the past 10 years, religion is the only trait that does not seem to be influenced by genotype. The familial resemblance for different aspects of religion – upbringing, religious affiliation and active participation – is very large. In contrast to the other variables summarised in Figures 1 and 2, however, genetic factors do not contribute to this familial resemblance.

For this paper we explored the influence of religion on a number of personality traits in Dutch adolescent and young adult twins and their parents. We first looked at the influence of different aspects of religion on average scores for personality characteristics such as neuroticism, extraversion and sensation seeking and on depression and anxiety. Analysing average personality scores in religious and non-religious groups, we found that several traits are significantly associated with religion in both sexes and both generations. The association between religion and personality was found to be especially strong for the Disinhibition scale of the Sensation Seeking Questionnaire. We therefore selected this scale to look at the genetic architecture of Disinhibition in male and female twins with and without a

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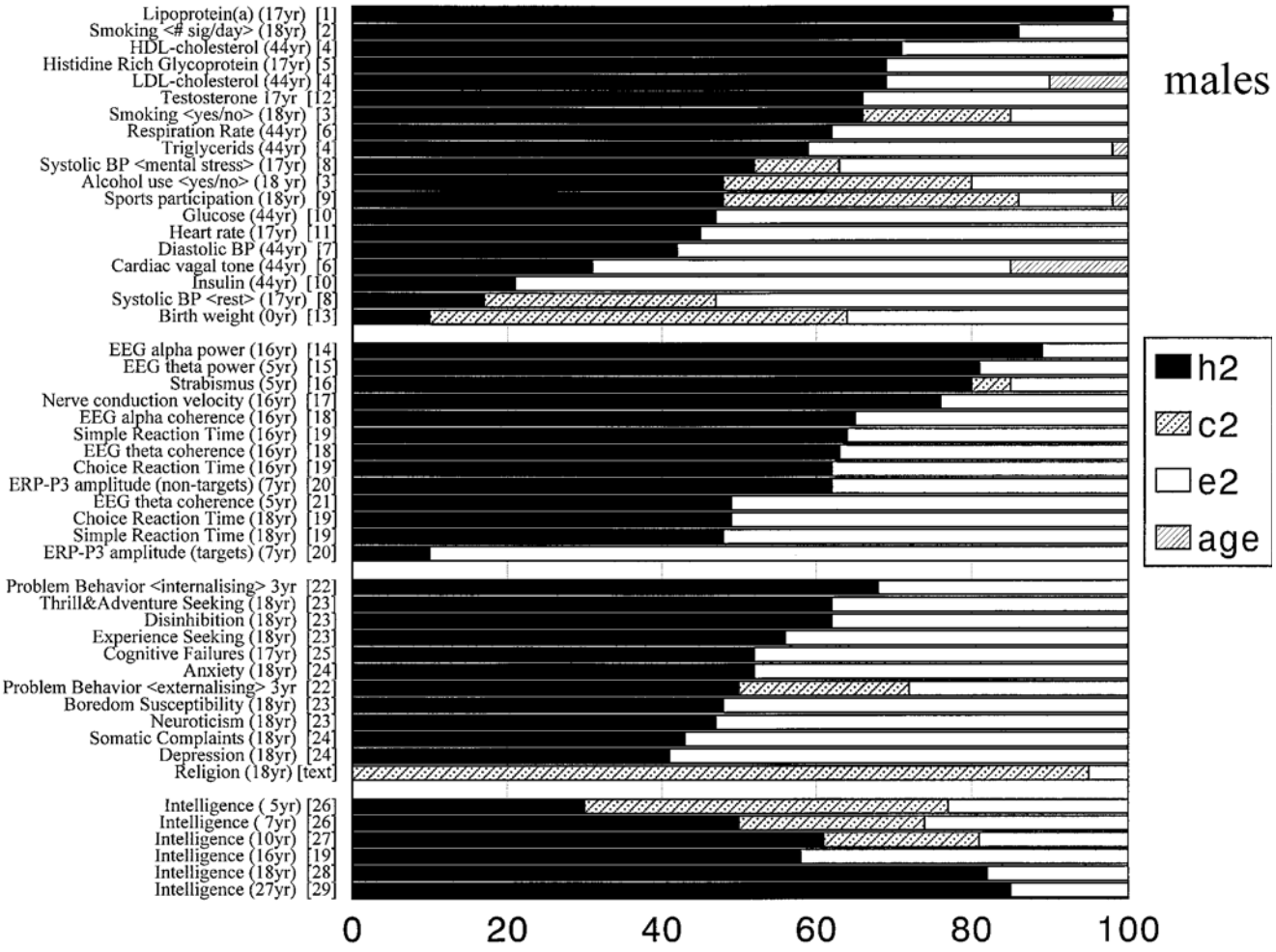

Figure 2 Estimates of heritability (h2) and the contributions of shared (c2) and unique environmental (e2) factors and age to phenotypic variance for a number of traits in males. Average age of the subjects is given in parentheses. Traits are cardiovascular risk parameters (Lipoprotein(a) to birth weight), behavioural and electrophysiological indices of neural speed and brain function (EEG alpha power to ERP-P3 amplitude), personality (Sensation Seeking to Religion) and intelligence (at 6 different ages). Estimates were obtained from the best fitting models (usually AE without sex differences)[1–29]

religious upbringing. More specifically, we tested whether, in addition to an effect on means, there was any evidence for an interaction between genotype and environment (G × E) on disinhibition scores.

The approach suggested by Eaves[31] to test for the presence of G × E interaction involving a dichotomous environmental variable (eg presence or absence of a religious upbringing) was followed. In this approach the influences of genotype and environment on disinhibition scores are estimated conditional upon environmental exposure. When there is no interaction, the influence of genetic and environmental factors should not differ between twins with and without a religious upbringing. If genetic effects are modified by religious upbringing (differ significantly between the religious and non-religious groups), then this constitutes evidence for G × E interaction; see also Heath et al[32] for an application of this model to alcohol consumption and Heath et al[33] for an application to symptoms of depression in married and unmarried female Australian twins.

Subjects and methods

This study is part of a longitudinal questionnaire study, that assesses families with adolescent and young adult twins every two years since 1991. The data presented in this paper come from the 1993 survey, which was sent both to families who had also participated in the study in 1991 (49% of the sample) and to newly recruited families. Addresses

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of twins were obtained from City Council registries.[34,35]

In 1993, subjects received an 18-page booklet which contained a large number of personality inventories, items about religion, zygosity, schooling, socio-economic status, family structure, health, and questions about physical exercise habits, use of tobacco, use of soft and hard drugs, use of alcohol and alcohol problems. There were three items about religion: religious upbringing (no/yes), religious affiliation (seven categories: none; Roman Catholic; Reformed; Calvinist; Islamic; Hindu and other) and active participation in religious activities (three categories: none, I am not religious; religious but do not participate; yes, active member of a church). For most analyses the question about religious affiliation was recoded into five (none; Roman Catholic; Reformed, Calvinist; other) or into two categories (no/yes).

The total number of participating families was 1974. There were 1768 fathers (average age 48 years), 1918 mothers (46 years) and 1967 twin pairs (17.8 years) who completed the questionnaires. For the majority of the twin pairs zygosity was determined from questions about physical similarity and confusion of the twins by family members, friends and strangers. For 161 same-sex twin pairs information on their zygosity was available from blood group and/or DNA polymorphisms. The agreement between zygosity diagnosis from questionnaire and DNA data was 90% (in a larger group of 405 same-sex twin pairs of the same age who participated in other research projects the agreement between DNA/blood group polymorphisms and questionnaire data on zygosity was 95%). The zygosity of the twins was 40% MZ and 60% DZ, with a nearly equal participation of male and female twins (MZM = 327 (17%), MZF = 457 (23%), DZM = 284 (14%), DZF = 356 (18%), DOS = 543 pairs (28%)).

Statistical analyses

Resemblances between members of a twin pair (monozygotic male and female pairs, dizygotic same-sex and opposite-sex pairs) for different aspects of religious behaviour were summarised into tetrachoric correlations (for dichotomous variables) and polychoric correlations (for the religious participation item). The 2×2 contingency tables of data from the first and second born twins (or male and female twins of opposite-sex pairs) were used to obtain these correlations in Mx.[36]

The influence of religion on personality was first tested simultaneously for all 11 personality/psychopathology traits by Multivariate Analysis of Variance (MANOVA), separately for both sexes and both generations. Observations on twin pairs are not statistically independent. The bias that will arise when this complication is ignored, however, is minimal with sample sizes as large as in the present study.[32] The MANOVAs were followed by univariate ANOVAs for each variable, again separately for both sexes and both generations.

The genetic analysis of individual differences in Disinhibition scores employed a Structural Equation Modelling (SEM) approach. SEM provides a general way to analyse the causes of variation in data gathered in genetically informative samples such as MZ and DZ twins.[37] In applying SEM to these data, genetic and environmental effects are modelled as the contribution of latent (unmeasured) variables to the phenotypic individual differences. These latent factors represent the effects of many unidentified influences. In the case of a genetic factor, these effects are due to a possibly large, but unknown, number of genes. Environmental factors are usually divided into common environmental influences that cause resemblance between family members living together and unique environmental influences that cause family members to be different (unique environmental influences also include any effects of measurement error). The contributions of the latent genetic and environmental variables are estimated as regression coefficients (path coefficients) in the linear regression of the observed variables on the latent variables. If the latent variables are standardised to have unit variance, the square of these coefficients gives the amount of genetic, common and unique environmental variance. Identification of these models is achieved because MZ twins are genetically identical, whilst DZ twins share on average 50% of their segregating genes. If MZ twins resemble each other more than DZ twins, this is evidence for the importance of genetic influences on the trait under consideration.

To test for $G \times E$ interaction the sample was divided into pairs in which both twins reported a religious upbringing (945 pairs) and pairs in which both twins replied that they received a non-religious upbringing (837 pairs). The pairs (131) who did not agree on the answer on the question about religious upbringing and the pairs in which only one of twins (42) or neither twin (19) answered the question about religious upbringing were omitted from the analyses.

Genetic analyses were carried out simultaneously on the data from male and female MZ and DZ and opposite-sex DZ twin pairs, with and without a religious upbringing (10 groups). Additive genetic effects (A), environmental effects common to offspring growing up together in the same family (C) and unique environmental effects (E) were estimated

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conditional upon sex and religious upbringing. When there is no G × E interaction, the estimates for the genetic and environmental effects should not vary between groups with and without a religious upbringing. Evidence for G × E interaction obtains when the estimates for the proportion of genetic variance differ between groups. Different estimates between groups with and without a religious upbringing for the amount of variance in Disinhibition scores that can be explained by genetic factors, implies that religious upbringing acts as a modifier of genetic effects on Disinhibition. If mean differences between subjects with and without a religious upbringing are associated with different error variances in the two groups (heteroscedasticity), this would lead to different estimates for the proportion of unique environmental variance. Heteroscedasticity would thus also lead to differences in heritabilities between the groups, without any G × E interaction effects. Heteroscedasticity was tested for by comparing the fit of a model with different estimates for unique environmental variances in religious and non-religious groups to a model in which the two estimates were constrained to be equal. In addition, before any models were fitted to the data we also inspected in MZ twin pairs the association between absolute pair differences and pair sums for Disinhibition.[38,39] No systematic heteroscedasticity was found in the data using this test (the correlation between sums and absolute differences was –0.04 in MZM and 0.03 in MZF pairs).

Model fitting was done directly on the raw data, instead of first summarising the data into covariance matrices. By using this approach it was possible to include those twin pairs (35) into the analysis, who had both answered the question about religious upbringing, but who had missing data for either the first or the second-born twin on the Disinhibition scale of the Sensation Seeking Questionnaire.

In the most general model the following parameters were estimated for males and females: a mean disinhibition score depending on religious upbringing, and three variance components (genetic, shared and unique environmental variances). Next, the estimates for the three variance components were constrained to be equal for females with and without a religious upbringing and for males with and without a religious upbringing.

Parameters were estimated by maximum-likelihood methods in Mx.[36] The likelihoods obtained for different methods were compared with χ^2 difference tests where $\chi^2 = 2(L_1 - L_0)$. L_1 and L_0 denote the log likelihoods of the general (H_1) and a constrained (H_0) hypothesis. The degrees of freedom (df) for this test are equal to the number of constrained parameters between H_1 and H_0.

Results

The sample of twin families was fairly representative of the Dutch population with respect to religious affiliation. Table 1 gives information on religious affiliation for the Dutch population,[40] for parents of twins, and for twins themselves (according to sex and zygosity). The largest difference between census data and data from twin families was in the parental generation, in which the number of people reporting no religious affiliation was smaller and the number reporting a Roman Catholic affiliation was somewhat larger for parents of twins than for the general population. One likely explanation for this finding is that being religious is associated with having children and that the census sample and the sample of parents of twins differ with respect to having had children. Table 1 also shows a substantial difference between generations for self-reported religious affiliation: whereas only 28% of fathers and 24% of mothers reported no religious affiliation, around 40% of their offspring chose this answer.

Part of the sample that participated in the 1993 survey also took part in the 1991 survey, so it was possible to look at the stability of religious affiliation (questions about upbringing and participation in church activities were not included in the 1991 survey). In the older generation, 86% of parents and in the offspring generation 83% of twins reported the same religious affiliation in 1991 and 1993. This high stability suggests a sufficient reliability for the religious affiliation item.

In Table 2 the data from MZ and DZ twins are presented for the questions about religious upbringing, on whether or not they are currently religious (the religious affiliation item was dichotomised into no/yes for these analyses) and on their participation in religious activities (three response categories). Table 2 first gives the percentage of yes answers and next the percentage of twin pairs who gave the same answer (concordant pairs) to these questions. The

Table 1 Religion of twins and their parents

	None	R.C.	Reformed	Calvinist	Other
Census	37%	34%	17%	8%	5%
Father	28%	39%	19%	9%	5%
Mother	24%	42%	19%	10%	5%
MZM	41%	35%	10%	9%	5%
DZM	42%	35%	12%	6%	5%
MZF	37%	37%	14%	9%	4%
DZF	37%	35%	13%	10%	5%
DOS	38%	31%	17%	8%	6%

Census data collected in 1991 in subjects age 18 years and older, twin family data collected in 1993.
MZM: monozygotic males; DZM: dizygotic males; MZF: monozygotic females; DZF: dizygotic females; DOS: dizygotic opposite sex twins

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Table 2 Religion in adolescent and young adult twins, prevalence, % concordant and tetrachoric correlation

	Yes	% Concord.	Correlation
Religious upbringing			
MZM (313)	52	96	0.99
DZM (276)	50	91	0.96
MZF (450)	54	94	0.98
DZF (347)	52	96	0.98
DOS (527)	54	92	0.97
Currently religious			
MZM (312)	59	96	0.99
DZM (265)	58	91	0.96
MZF (437)	63	96	0.99
DZF (336)	63	95	0.99
DOS (527)	62	92	0.96

Participation in religious activities	% No/O/Yes*	% Concord.	Correlation
MZM (313)	50 24 26	85	0.94
DZM (272)	55 25 20	82	0.92
MZF (439)	46 27 27	88	0.96
DZF (339)	44 31 25	82	0.91
DOS (512)	49 24 27	81	0.92

*No: not religious; O: religious, but not actively participating; Yes: active

last column in Table2 gives the tetrachoric (or polychoric) correlation between members of a twin pair as estimated from the 2×2 (or 3×3) contigency tables. As can probably be expected, there is a high agreement between members of twin pairs on whether or not they had a religious upbringing. Correlations in all zygosity groups are above 0.9. For the answers on the questions about current religion and religious practice, however, the agreement between members of a twin pair is as high as for the question on religious upbringing. There is no difference in the correlations for MZ and DZ twins. Fitting a genetic vs a shared environmental model to these data, showed that a model that specified only shared environmental influences and left out the influence of genetic factors fitted the data as well as a full ACE model, confirming that genetic influences do not contribute to variation in any of the different aspects of religion.

Differences in personality and in anxiety and depression between religious groups were tested by MANOVA, separately for fathers and mothers of twins and for male and female twins. In all four groups MANOVA showed significant influences of being currently religious and of participation in religious activities. In all groups, except in the mothers of twins, MANOVA also showed a significant effect of religious upbringing on personality and anxiety and depression. Table3 summarises the results from the univariate analyses of variance, for Anxiety, Depression and Neuroticism, for the four Sensation Seeking scales, and for Extraversion, Anger and Test Attitude. For all scales (except Test Attitude) that show a significant effect of religion, this effect was always in the same direction: religious subjects, subjects with a religious upbringing and subjects who were actively involved in religious activities scored lower on all scales. The only exception was the Test Attitude ('Lie') Scale on which they scored higher.

Clearly, the most consistent effect of religion was on the four scales of the Sensation Seeking Questionnaire. In both fathers and mothers as well as in their offspring, the most significant influence of religion was on the Disinhibition scale. This scale measures 'the desire to find release through social disinhibition, drinking, going to parties and having a variety of sexual partners' and consists of items such as 'I like wild uninhibited parties', 'I feel best after taking a couple of drinks', 'I like to have new and exciting experiences and sensations even if they are a little unconventional or illegal' and 'a person should have considerable sexual experiences before marriage'.[41]

Because self-reported religious upbringing of twins divided the sample into two groups of roughly equal size, we chose this variable to explore whether there was any evidence for an interaction between Genotype and Environment on Disinhibition scores.

Table 3 Religion (upbringing, currently religious and religious practice) and personality in twin families (father, mother, son, daughter)

	Religious upbringing				Religious yes/no				Religious practice			
	Fa	Mo	So	Da	Fa	Mo	So	Da	Fa	Mo	So	Da
Anxiety[49,50]	–	–	–	–	?	–	?	?	–	?	–	?
Depression[51]	–	–	–	?	?	?	Y	?	?	–	?	?
Neuroticism[52]	Y	–	–	–	Y	–	–	–	Y	–	–	Y
Somatic complaints[52]	–	–	–	Y	–	–	–	?	–	–	–	Y
Thrill and adventure seeking[53–55]	–	–	–	Y	Y	–	–	Y	Y	?	–	Y
Experience seeking[53–55]	?	–	?	Y	Y	Y	Y	Y	?	Y	Y	Y
Boredom susceptibility[53–55]	–	–	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Disinhibition[53–55]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Extraversion[52]	–	–	–	?	–	–	–	–	Y	Y	–	Y
Anger[56,57]	–	–	–	?	–	–	–	–	–	–	–	–
Test attitude[52]	–	–	–	–	–	Y	Y	–	Y	Y	Y	–

Y = P<0.05, ? = P<0.10, – = P>0.10

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Religious upbringing, however, is closely associated with the two other aspects of religion, current affiliation and active participation, as can be seen in Table 4. Nearly 80% of twins without a religious upbringing report that they have no religious affiliation, whereas only 5% of twins with a religious upbringing report no religious affiliation. Also, less than 1% of twins who received no religious upbringing answer that they are active in church activities. For twins with a religious upbringing this percentage is 51%.

In Figure 3, mean Disinhibition scores are given for subjects with and without a religious upbringing, for both generations and both sexes. In both sexes and both generations, individuals with a religious upbringing score lower than those without a religious upbringing. (F ratios for the effect of religious upbringing were $F(1,1736) = 6.43$ in fathers; $F(1,1888) = 5.02$ in mothers; $F(1,1700) = 38.03$ in sons and $F(1,2114) = 58.52$ in daughters). In addition, Figure 3 shows the well-known effects of sex and generation on Disinhibition: older individuals score lower than younger ones and within each generation females score lower than males.[42]

Table 5a gives the correlations between twins for Disinhibition, for MZ and DZ twins conditional upon religious upbringing. Next, Table 5b presents the maximum likelihood estimates for the mean scores in the religious and non-religious group, separately for males and females, and the ML estimates of the percentages of variance explained by genetic, common environmental and unique environmental influences. The pattern of twin correlations strongly suggests that environment common to twins from the same family plays an important role in explaining individual differences in Disinhibition scores in the religious group. For males, the MZ and DZ twin correlations are the same (both 0.62). For females, the MZ correlation (0.61) is slightly higher than the DZ correlation (0.50). In contrast, the pattern of correlations in twins without a religious upbringing is suggestive of genetic influences on individual differences in Disinhibition scores: MZ correlations in male and female twins are still around 0.6, but DZ correlations are lower (0.35). Twins of opposite sex resemble each other less than DZ same-sex twins, but the differences in correlations are not very large.

Table 5b gives the parameter estimates from the most general model in which all estimates for variance components (A, C and E) were allowed to differ between the sexes and between religious and non-religious groups. The log-likelihood for this general model is given in Table 6. We also fitted this general model to the data with one additional parameter, that estimated either the correlation between the common environmental factors or the correlation between the genetic factors in opposite-sex twin pairs (instead of constraining these correlations at 1 and 0.5, respectively). In none of these analyses did we see a significant better fit of the model to the data. This indicates that the same genetic and shared environmental factors influence Disinhibition in male and female twins.

The log-likelihood of the general model (all parameters different in males and females and in religious and non-religious groups) was used as a baseline to test for G × E interaction. For females, there was no significant decrease in the goodness-of-fit of the model if parameter estimates for the genetic and environmental variances were constrained to be the same in the religious and non-religious groups ($\chi^2 = 1.05$ with 3 degrees of freedom). In males, however, constraining the estimates for variance components to be equal led to a significant decrease in the goodness-of-fit of the model ($\chi^2 = 10.84$ with 3 degrees of freedom). The significant χ^2 was not due to differences between the two groups in the amount of variance explained by

Table 4 Current religion and religious practice in twins without and with a religious upbringing

	Current religious affiliation					
	None	RC	Reformed	Calvinist	Other	Total
No religious upbringing						
Not religious, not practising	1263	128	39	0	17	1447
Religious, not practising	25	104	25	2	13	169
Practising	0	4	4	0	3	11
Total	1288	236	68	2	33	1627
	79.2%	14.5%	4.2%	0.1%	2.0%	100%
Religious upbringing						
Not religious, not practising	92	97	22	7	5	223
Religious, not practising	8	423	144	65	46	686
Practising	0	377	234	227	91	929
Total	100	897	400	299	142	1838
	5.4%	48.8%	21.8%	16.3%	7.7%	100%

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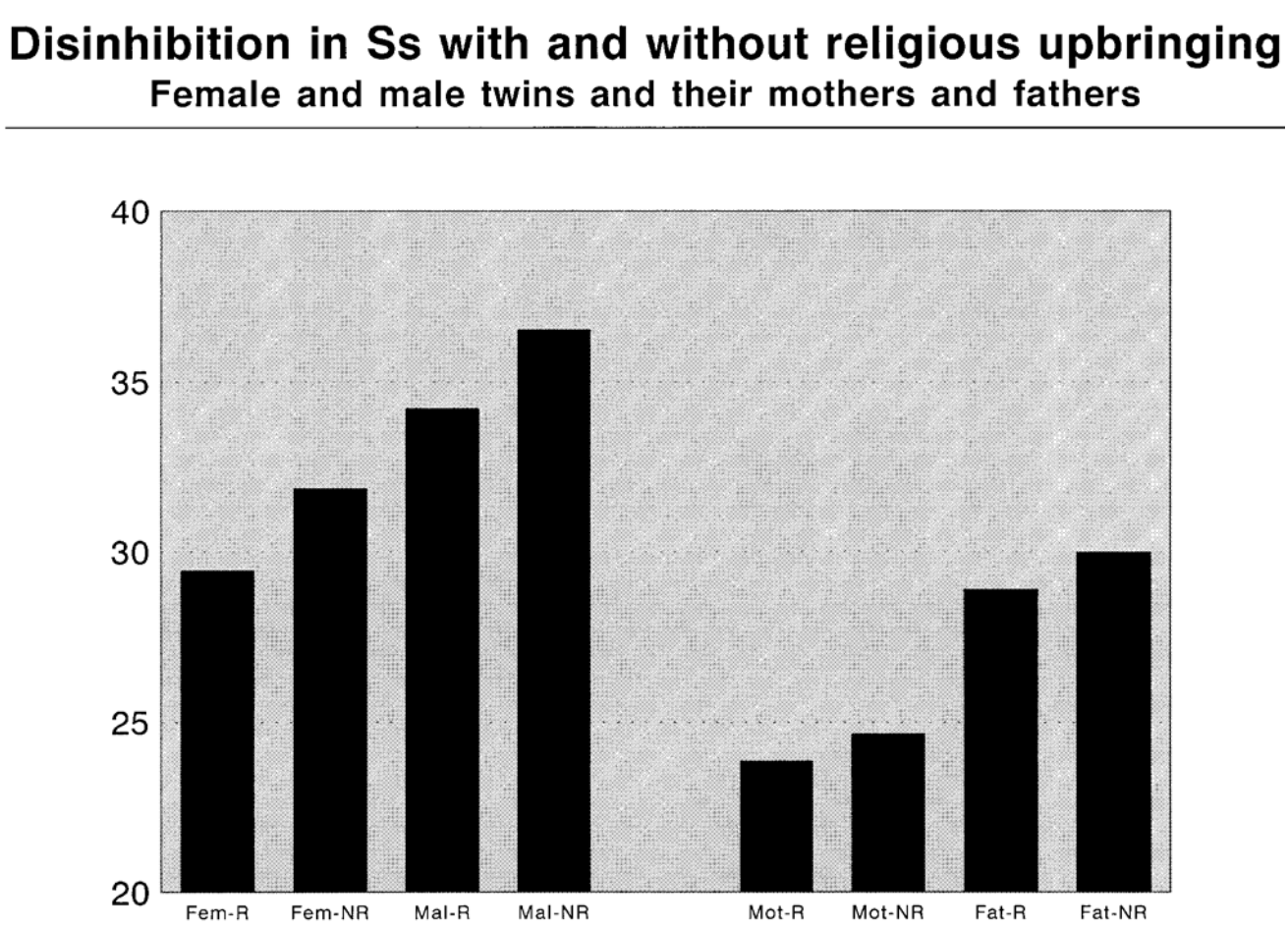

Figure 3 Scores on the Disinhibition scale of the Sensation Seeking Questionnaire for fathers and mothers of twins and for male and female adolescent and young adult twins as a function of religious upbringing

Table 5A Twin resemblances (correlations) for Disinhibition as a function of religious upbringing

	MZM	DZM	MZF	DZF	DOS
Religious	0.62	0.62	0.61	0.50	0.38
Non-religious	0.62	0.35	0.58	0.35	0.30

Religious: MZM = 149, DZM = 124, MZF = 227, DZF = 169, DOS = 259 pairs
Non-religious: MZM = 143, DZM = 123, MZF = 188, DZF = 151, DOS = 214 pairs

Table 5B Percentage of variance in Disinhibition explained by additive genetic factors (A), common (C) and unique environment (E) for males and females as a function of religious upbringing; parameter estimates with 95% confidence intervals in parentheses

	Mean	A	C	E
Fem, religious	29.45	37 (22–55)	25 (09–37)	38 (32–46)
Fem, non-religious	31.86	61 (07–67)	00 (00–48)	39 (32–51)
Male, religious	34.21	00 (00–22)	62 (43–69)	38 (31–45)
Male, non-religious	36.53	49 (14–69)	11 (00–40)	40 (32–51)

Table 6 Tests of genotype × religion interaction for Disinhibition

	–2*log-likelihood	χ^2	df
All parameters different:	23101.91	–	–
Females: all parameters equal:	23102.96	1.05	3
Males: all parameters equal:	23112.75	10.84	3
estimates for E equal:	23102.17	0.26	1
estimates for A equal:	23108.01	6.10	1
estimates for C equal:	23111.36	9.45	1

unique environmental factors, but to different contributions of additive genetic and common environmental factors (last two lines of Table 6). Thus, there seems to be a significant G × E interaction in males on Disinhibition scores. For subjects without a religious upbringing, a large part of the variation in Disinhibition is explained by genetic influences, and the influence of shared environment is small. In the group with a religious upbringing, there is no contribution of genetic factors on individual differences in Disinhibition scores and all familial resemblance can be attributed to shared environment. This

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last finding raises the question of which shared environmental influences contribute to variance in Disinhibition in this group.

Table 4 showed that religious upbringing is closely related to current religious affiliation. In individuals without a religious upbringing there is little variation in religious affiliation (80% have no affiliation), whereas in the group of individuals with a religious upbringing, there is substantial variation in affiliation. We looked at whether (within this group) current affiliation had an effect on Disinhibition scores. The results are given in Table 7, which shows the mean Disinhibition scores for males and females as a function of religious affiliation. In both sexes there was a significant effect of affiliation (F ratios on Disinhibition: all males $F(4,1674) = 16.97$; only religious males $F(3,993) = 11.26$; all females $F(4,2082) = 22.73$; only religious females $F(3,1311) = 11.14$), but, as can be seen in Table 7, the differences in Disinhibition scores between the different affiliations were somewhat greater in males than in females. This finding is consistent with a larger contribution of shared environmental influences on variation in Disinhibition scores of religious males than of religious females.

Discussion

We have studied the causes of variation in several dimensions of religion, ie upbringing, affiliation and practice, and the influence of these aspects of religion on personality, anxiety and depression in a large sample of Dutch twins and their parents.

Adolescent and young adult twins closely resemble each other in religious upbringing, religious affiliation and participation in church activities. In contrast to most other traits that have been studied in humans, the familial resemblance for religious behaviour in this age group cannot be attributed to shared genes, but seems solely due to shared environment. We observed high twin correlations (above 0.9) for all these aspects of religion in both mono- and dizygotic-twins. The high correlations suggest that the relatively crude measures that were used to assess religious behaviour are reliable and also that the twins have a strong sense of their religious upbringing and affiliation.

Table 7 Mean Disinhibition scores for males and females as a function of religious affiliation

	Males			Females		
	N	Mean	SD	N	Mean	SD
No religion	682	36.73	7.48	772	32.06	6.84
Religious	997	34.57	7.39	1315	29.77	6.48
R.C.	569	35.72	6.71	724	30.65	6.09
Reformed	209	33.15	8.07	303	29.08	6.64
Calvinist	132	33.18	7.46	187	27.98	6.78
Other	87	32.55	8.52	101	28.92	7.15

The finding of a significant contribution of shared environmental influences to religious behaviour is consistent with findings reported by Eaves et al[43] and Kendler et al[44] and the few other investigators who studied religiosity in twins and their families.[44,45] These other studies looked at adult American and Australian twins. In addition to shared environmental influences, some studies report small genetic effects on some aspects of religion. Truett et al,[46] for example, find a heritability of 25% for church attendance and Kendler et al[44] find heritabilities of 29% and 12%, respectively, for personal devotion and institutional conservatism (a measure based on religious affiliation). The absence of any genetic influence on variation in religious behaviour in the Dutch sample may reflect differences between the measures that were employed to assess religious behaviour in the various studies. Another possibility is, of course, that age differences between the samples explain the differences in genetic architecture for religiosity. The Dutch twins are relatively young and it may be that genetic influences on their religious behaviour come to expression when they grow older. Because the twins and their families are participating in a longitudinal research project, we intend to address this issue in the future.

Alternatively, the absence of any genetic influences and the large effect of shared environment on religious behaviour in Dutch twins may reflect a true difference between Dutch and American/Australian society. The number of individuals in our study who report no religious affiliation is higher than in the other studies. On the other hand, the degree of denominational segregation is probably much larger in Dutch society than it is in the USA or in Australia. For example, children from age 4 onwards go to schools that are segregated according to religious denomination. At present 35% of primary schools are non-religious, public, schools, 30% are Roman Catholic, 30% are Protestant and 5% are private non-denominational schools. All 'private' schools are fully financed by state funds.[47] This denominational segregation continues through high school and even university. Other aspects of public life also show a similar division along religious lines, which involves youth organisations, sport and cultural clubs, media, insurance companies, health institutions and hospitals, old-age homes, and housing associations. The high degree of shared environmental influences in the twin data seems to capture this system of 'voluntary apartheid' in Dutch society.[47]

Religion influences the way individuals respond to personality questionnaires. The influence of religion was evident on several personality dimensions,

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but was most pronounced for the scales of the Sensation Seeking Questionnaire. Individuals with a religious background scored lower on the neuroticism, anxiety and depression scales. This finding is consistent with most of the literature on religion and psychopathology.[44,48] Religious subjects also scored lower on the scales of the Sensation Seeking Questionnaire. Especially the Disinhibition scale showed large effects of religiosity. Zuckerman[42] reports one other study that found religion to be a significant source of variation in Sensation Seeking. Both men and women with a religious affiliation or who frequently attended church scored low on Sensation Seeking.

In addition to a large effect on mean Disinhibition scores, religious upbringing influences the genetic architecture of Disinhibition: in adolescent and young adult twins who report a religious upbringing, the influence of genetic factors on variation in Disinhibition is lower in females (although statistically not significant) and in religious males heritability for Disinhibition is zero. In religious males (and to a lesser extent in religious females) the familial resemblance for Disinhibition is due to common environmental factors shared by family members. As was shown in Table 7, within the group of twins with a religious upbringing there is still a significant effect of denomination on Disinhibition scores. Roman Catholic males and females score higher on Disinhibition than Protestants and other denominations. These results constitute evidence of Genotype $\times$ Environment interaction on Disinhibition scores and suggest that religious upbringing and/or other aspects of religiosity that are associated with a religious upbringing tend reduce the impact of the genotype on Disinhibition.

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