Stability of Genetic and Environmental Effects from Adolescence to Young Adulthood: Results of Croatian Longitudinal Twin Study of Personality

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The primary aim of this study was to conduct a bivariate genetic analysis investigating the extent to which genetic and environmental factors contribute to stability and change in personality factors in the period from adolescence to young adulthood on a sample of Croatian twins. The sample used in this research was formed in 1992 based on a register of citizens of Zagreb and data was collected for 160 twin pairs (75 monozygotic and 85 dizygotic twin pairs). Twins were tested twice, 4 years apart with the Eysenck Personality Questionnaire (mean age at first time point was 17 years). Univariate analyses indicate that the best fitting model for extraversion, neuroticism, psychoticism and lie scale at both time points includes additive genetic (A) and nonshared environmental (E) influences, with heritability estimates in the .40 to .50 range. Longitudinal analyses using AE correlated factors model indicate that genetic factors contribute mainly to stability, while environmental factors contribute mainly to change in personality during that 4-year period of transition from adolescence to young adulthood.

Studies exploring stability and change of personality can give us useful information about the development of specific personality traits or dimensions over the course of life. There are several types of stability and change of personality that have been explored in those studies. Roberts and DelVecchio (2000) provide a review of longitudinal studies of differential stability and change that shows that rank-order stability of personality traits is moderate in magnitude from childhood to early adulthood, that it increases with age and peaks some time after age 50, decreases as the time interval increases and does not vary across Big Five traits, assessment methods or gender. Roberts et al. (2006) provide a review of longitudinal studies of mean-level stability and change that shows that people increase in measures of social dominance (a facet of extraversion), conscientiousness and emotional stability especially in young adulthood, and in measures of social vitality (facet of extraversion) and openness in adolescence but then decrease in both those measures in old age. Agreeableness increases only in old age. These patterns were the same for both men and women. This review shows that personality traits have a pattern of normative change across the life course and that the change appears more often in young adulthood than any other life period.

These studies, however, only deal with the description of the phenomenon and do not tell us anything about the etiology, that is, which factors contribute to stability or change in personality in certain periods of life span. Behavioral genetics research offers a way to uncover factors contributing to stability and change in personality. Twin studies have suggested that heritability estimates for broad personality traits like Eysenck's three factors or the Big Five fall into .40 to 60 range (Bouchard & Loehlin, 2001). Although lay people may think that stability and heritability of a certain trait are closely linked, it is possible to have longitudinally stable characteristics which are not heritable, and, vice versa, heritable characteristics which are changing during development. For example, it has been shown that height, which constantly changes during development, has a heritability of around .90 in different age groups (Plomin, 1990). So, one type of developmental change that can be explored using a behavioral genetics research design is a relative contribution of genetic and environmental factors to individual differences in personality or change in the heritability of a personality trait in different time points. Temporal stability of the genetic and environmental factors or the question do the same or different genetic and environmental factors contribute to individual differences in personality at different time points can also be explored using a behavioral

Received 18 July, 2006; accepted 5 December, 2006.

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genetics design. Genetic and environmental correlations are a convenient approach for studying temporal stability of genetic and environmental effects. For example, a high genetic correlation would imply that the same genes are contributing to individual differences in a certain personality trait at different time points, while a low genetic correlation would imply that different genes are contributing to individual differences in that personality trait at different time points. At the same time heritability of this personality trait can be either high or low. Also, the magnitude of the genetic and environmental influences on the covariance between the two ages can be estimated. Estimate of the magnitude of the genetic influences on the covariance is called bivariate heritability and it is a function of heritabilities at each age and the genetic correlation. Bivariate heritability is distinct from the genetic correlation and it gives information about which portion of the phenotypic correlation between two time points can be attributed to genetic influences.

It is difficult to draw a general conclusion regarding change in heritability during personality development because there are many personality traits and because ways of measuring personality differ greatly depending on the age of the subjects. In general, heritability of personality appears to increase during infancy (Goldsmith, 1983; Loehlin, 1992; Plomin, 1986). Throughout the rest of the life span, different studies suggest different conclusions, either that heritability does not change (Martin & Jardine, 1986; McCartney et al., 1990) or that it decreases (Pedersen, 1996; Pedersen et al., 1991) or even increases (see e.g., Plomin & Nesselroade, 1990). This implies that the pattern of heritability change during development might be different for different personality traits and therefore has to be examined separately for each personality trait.

Furthermore, longitudinal behavioral genetic studies of personality can help us establish whether genetic or environmental influences contribute to stability or change in personality. Results of the three studies that used components of variance approach and had shorter time intervals (2–12 years) indicate that there is significant stability in genetic influences across time (Dworkin et al., 1976; Eaves & Eysenck, 1976; Pogue-Geile & Rose, 1985). One of the largest longitudinal studies of personality was conducted in Finland by Viken et al. (1994). They collected data on extraversion and neuroticism from a national sample of twins aged between 18 and 59 years across two time points 6 years apart. The sample was divided into six cohorts and data were analyzed as a function of time and cohort. Results have suggested that heritabilities decrease with age and that genetic effects contribute to stability, because there were no new genetic influences after 29 years of age, while there were new environmental influences at each age and time point. Pedersen and Reynolds (1998) collected data on neuroticism, extraversion and openness to experience from Swedish twins (mean age at the first time point was 60 years of age) across four time points 3 years apart. Results from this study also demonstrate mean stability in personality in the second half of the life span with high genetic stability observed across time and nonshared environmental effects accounting for majority of phenotypic variance. Loehlin and Martin (2001) report results of the analysis of Eysenck personality scales from the Australian Twin Registry. There were several twin samples of different age, ranging from 23 to 62 years of age, and also a different number of time points, ranging from one to three time points. Results of this study indicate that psychoticism, extraversion and neuroticism decline with age in adulthood, while conformity measured by Lie scale increases. Individual differences in extraversion, neuroticism and psychoticism appear to be substantially influenced by genes and that influence is stable during adulthood. Individual differences in conformity (lie) showed the effect of both genes and shared environment which dropped off in late adulthood. In sum, all longitudinal studies done so far indicate that genetic factors mainly contribute to stability in personality over time.

The aim of the present study was to explore the etiology of the Eysenckian personality traits as well as the genetic and environmental contribution to the stability of personality traits using the sample of Croatian twins tested at two time points 4 years apart. The strength of our study is that twins were tested during their transition from adolescence to young adulthood. This is a period of personality development when the most intensive changes in personality take place and a period that has not been much explored yet. We hypothesized that, based on the results from previous studies, our data will also show moderate heritabilities of all four personality traits and that genetic influences will contribute to stability in personality, while nonshared environmental influences will contribute to change in personality during that period.

Materials and Methods

The sample used in this research was formed in 1992 based on a register of citizens of Zagreb from which twin pairs born between 1973 and 1977 were identified. Only same-sex twin pairs were included in the sample. All twin pairs were living at the time in Zagreb area with their parents. A letter asking them to participate in the study was mailed to their addresses and then they were contacted by telephone or personally, if possible, by an examiner and data collection time was arranged. From 220 contacted pairs 160 (73%) agreed to participate in the study. Exactly 4 years later the same procedure was repeated. Twin pairs were informed about the continuation of the study by letter and asked to participate again. Data were collected for 131 twin pairs (82%). Analyses presented here are carried out on all twins participating in the study (75 monozygotic [MZ] twin pairs and 85 dizygotic [DZ] twin pairs). Their age varied between 15 and 19 years (M = 17.3; SD = 1.34) at first time point.

Zygosity was determined by questionnaire used at the first time point, with items from questionnaires by

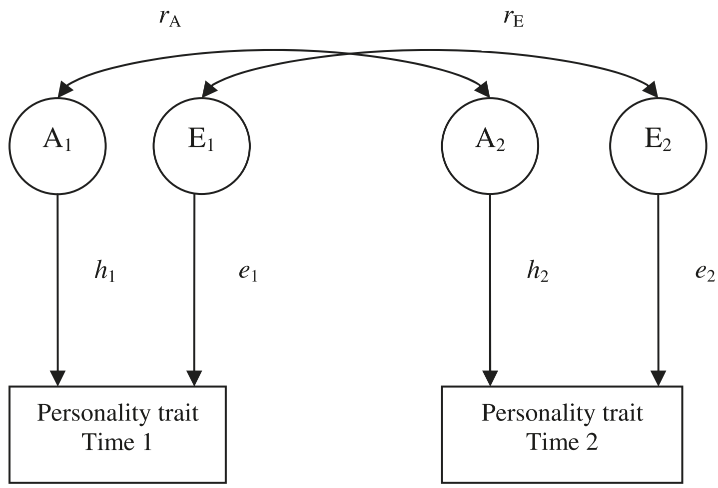

Figure 1

Bivariate genetic model for one twin in the pair: correlated factors model. A_1 and E_1 are genetic and nonshared environmental influences at the first time point; A_2 and E_2 are genetic and nonshared environmental influences at the second time point; r_A and r_E are genetic and environmental correlations between two time points. The effects of A_1 and E_1 are represented by parameters h_1 and e_1, and effects of A_2 and E_2 are represented by parameters h_2 and e_2.

Nichols and Bilbro (1966) and Cohen et al. (1973, 1975), and classification procedures based on criteria suggested by Nichols and Bilbro (1966). The use of questionnaires for zygosity determination has been shown to be around 95% accurate in number of studies (Nichols & Bilbro, 1966; Reed et al., 2005; Segal, 1984; Spitz et al., 1996).

Personality dimensions were measured using the Eysenck Personality Questionnaire (EPQ; Eysenck & Eysenck, 1975), which measures three personality factors — extraversion (E), neuroticism (N) and psychoticism (P), and also has a lie scale (L). Croatian translation of a standard version of EPQ was used (Lojk, 1986). The data collection procedure differed slightly at the two time points. At the first time point data was collected at the Faculty of Philosophy in Zagreb in small groups consisting of two pairs of twins. At second time point data was, for most participants, collected at their homes. Cronbach alpha reliability coefficients were .79, .86, .64 and .79 at first time point and .82, .83, .68 and .77 at second time point for extraversion, neuroticism, psychoticism and lie scale, respectively.

Genetic Model Fitting

Genetic model fitting of twin data aims to estimate the contribution of genetic and environmental influences to individual differences in a trait. The difference in correlations between MZ and DZ twin pairs gives an indication of the relative importance of the different sources of variance: additive genetic influences (A), nonadditive genetic influences (D), shared environmental influences (C) and nonshared environmental influences (E), because MZ and DZ twins have different degrees of correlation for the genetic components A and D, but the same degree of correlation for the environmental components C and E.

The structural equation model-fitting program Mx (Neale et al., 2003) was used for genetic model fitting analyses. Because of its greater flexibility and automatic handling of missing data problems, raw data was used in the analyses. The goodness-of-fit of each genetic model is measured relative to a perfect fitting phenotypic (saturated) model, in which the maximum number of parameters is estimated to describe the covariance structure between variables. After fitting a full model, for example, ACE model, a series of nested models can be run to test if any of the parameters could be dropped from the model without significant worsening of fit. Differences in fit function between submodels are distributed as χ^2 and therefore the fit of nested submodels can be evaluated by changes in χ^2. A nonsignificant χ^2 value suggests that the model is consistent with the data, whereas a significant χ^2 value ($p < .05$) suggests that the model poorly fits the data and can be rejected.

To test which influences contribute to stability and change in personality we ran a series of bivariate genetic models, one for each personality trait. We started with bivariate Cholesky decomposition which was then transformed into a correlated factors model to enable easier interpretation (Loehlin, 1996). This correlated factors model is presented in Figure 1 and, as can be seen, it includes, based on the results from univariate analyses, only additive genetic and nonshared environmental influences. Also, before fitting genetic models we ran saturated models for each variable.

Results

Preliminary Analyses

A series of preliminary analyses were carried out to test different assumptions about the data. First the selective attrition of participants from the second time point was checked. Using MANOVA it was tested if there was a significant difference in E, P, N and L scores between participants who participated in the second time point and those who did not. Results showed that the two groups do not differ significantly (F = 1.335; df = 4; p = .257). Normality of the data was tested using Kolmogorov-Smirnov Test, separately for MZ and DZ pairs. All tests were nonsignificant and showed that our data are normally distributed. Since MANOVA showed that there are some sex and age effects in our sample, age and sex were regressed from the scores before genetic model fitting using an adjustment procedure proposed by McGue and Bouchard (1984). Twin intraclass correlations for the two time points were also calculated and they are presented in Table 1.

Univariate Analyses

Before fitting any genetic models we ran saturated models for each variable in both time points. Using different nested models means and variance differences between MZ and DZ twins were tested. Probably due to small sample sizes, there were variance differences between MZ and DZ twins for neuroticism and psychoticism at the second time point which are reflected in the relative poor fit of the full genetic model compared to the full saturated model.

Based on the obtained pattern of MZ-DZ correlations shown in Table 1, the first tested model included A, D or C and E. The results of the univariate analyses indicated that the best fitting model for all four scales in both time points was the one that included A and E. Obtained heritability estimates are in line with previous findings and range between .43 and .52.

Longitudinal Analyses

Results of the bivariate analyses are presented in Table 2. As can be seen from Table 2, heritability estimates obtained from the bivariate analyses are similar to the ones from the univariate analyses and range between .40 and .52. More interesting are the estimates of genetic and environmental correlations for each personality factor which reveal if genetic or environmental influences contribute to stability or change in personality in the period from adolescence to young adulthood. For extraversion, neuroticism and psychoticism, those estimates are very similar — genetic correlations are around .80 and environmental correlations around .35. Those estimates indicate that genetic influences mainly contribute to stability in personality between two time points, while nonshared

Table 1

Twin Correlations for Four Personality Factors and Two Time Points

Factor		Time 1 Twin 1	Time 2 Twin 1	Time 1 Twin 2
MZ extraversion	Time 2 Twin 1	.69 (.53–.81)		
	Time 1 Twin 2	**.46 (.26–.62)**	.49 (.27–.66)	
	Time 2 Twin 2	.31 (.06–.52)	**.43 (.20–.62)**	.54 (.33–.70)
DZ extraversion	Time 2 Twin 1	.59 (.42–.72)		
	Time 1 Twin 2	**.29 (.08–.47)**	.11 (–.12–.33)	
	Time 2 Twin 2	.26 (.03–.46)	**.12 (–.12–.34)**	.51 (.32–.67)
MZ neuroticism	Time 2 Twin 1	.65 (.47–.78)		
	Time 1 Twin 2	**.49 (.30–.65)**	.37 (.13–.57)	
	Time 2 Twin 2	.33 (.08–.54)	**.40 (.17–.60)**	.60 (.41–.74)
DZ neuroticism	Time 2 Twin 1	.48 (.28–.64)		
	Time 1 Twin 2	**.19 (–.03–.38)**	.14 (–.09–.36)	
	Time 2 Twin 2	.28 (.05–.48)	**.19 (–.04–.40)**	.61 (.44–.74)
MZ psychoticism	Time 2 Twin 1	.50 (.29–.67)		
	Time 1 Twin 2	**.46 (.26–.62)**	.26 (.01–.48)	
	Time 2 Twin 2	.37 (.13–.57)	**.43 (.20–.62)**	.46 (.24–.64)
DZ psychoticism	Time 2 Twin 1	.59 (.41–.72)		
	Time 1 Twin 2	**.18 (–.04–.38)**	.30 (.07–.49)	
	Time 2 Twin 2	.09 (–.14–.32)	**.24 (.01–.44)**	.46 (.26–.63)
MZ Lie scale	Time 2 Twin 1	.55 (.35–.71)		
	Time 1 Twin 2	**.39 (.19–.57)**	.52 (.30–.68)	
	Time 2 Twin 2	.46 (.24–.64)	**.52 (.31–.68)**	.57 (.37–.72)
DZ Lie scale	Time 2 Twin 1	.44 (.24–.61)		
	Time 1 Twin 2	**.18 (–.03–.38)**	.08 (–.16–.30)	
	Time 2 Twin 2	.24 (.01–.45)	**.26 (.03–.46)**	.51 (.32–.66)

Note: 95% confidence intervals shown in parentheses. MZ = monozygotic twins, DZ = dizygotic twins. Univariate twin correlations presented in bold.

https://doi.org/10.1375/twin.10.1.151 Published online by Cambridge University Press

Table 2

Bivariate Model-Fitting Results: Fit Statistics for the Saturated and Correlated Factors Model and Parameter Estimates for Correlated Factors Model

Factor	Model	–2LL	*df*	$\chi^2(df)$	*p* value	Parameter estimates
						A_1 = .48 (.31–.62)
Extraversion	Full saturated	3047.587	554			E_1 = .52 (.38–.69)
	Correlated factors	3076.009	574	28.422 (20)	.10	A_2 = .41 (.17–.61)
						E_2 = .59 (.39–.83)
						r_A = .87 (.62–1.0)
						r_E = .36 (.14–.54)
						A_1 = .46 (.29–.61)
Neuroticism	Full saturated	3228.108	554			E_1 = .54 (.39–.71)
	Correlated factors	3253.101	574	24.993 (20)	.20	A_2 = .43 (.20–.61)
						E_2 = .57 (.39–.80)
						r_A = .83 (.57–1.0)
						r_E = .38 (.17–.56)
						A_1 = .46 (.28–.60)
Psychoticism	Full saturated	2693.154	554			E_1 = .54 (.40–.72)
	Correlated factors	2714.370	574	21.216 (20)	.39	A_2 = .46 (.26–.62)
						E_2 = .54 (.38–.74)
						r_A = .75 (.50–.98)
						r_E = .29 (.09–.47)
						A_1 = .40 (.23–.56)
Lie scale	Full saturated	3146.776	554			E_1 = .60 (.44–.77)
	Correlated factors	3166.036	574	19.260 (20)	.51	A_2 = .52 (.34–.66)
						E_2 = .48 (.34–.66)
						r_A = 1.00 (.75–1.0)
						r_E = .10 (-.09-.31)

Note: –2LL = minus twice the Log-likelihood of the data, *df* = degrees of freedom, $\chi^2(df)$ = –2LL (and *df*) difference between saturated and correlated factors model, A_1 = genetic variance at first time point, E_1 = environmental variance at first time point, A_2 = genetic variance at second time point, E_2 = environmental variance at second time point, r_A = genetic correlation between two time points, r_E = environmental correlation between two time points, 95% confidence intervals shown in parentheses.

environmental influences mainly contribute to change in personality between two time points. For the lie scale, the estimate of the environmental correlation included zero in the confidence interval and therefore we tested if it could be dropped from the model. Results showed that environmental correlation for the lie scale could be dropped from the model without significant worsening of fit ($\Delta\chi^2[1] = .99$, $p = .32$). Therefore, it seems that for the lie scale genetic influences completely contribute to stability, while environmental influences, which include measurement error, contribute to change.

Also, bivariate heritabilities have been calculated as product of the square root of each univariate heritability and genetic correlation for each trait. These were .39 for extraversion, .37 for neuroticism, .35 for psychoticism and .46 for lie scale. Since phenotypic correlations between two time points for these traits were .57 for extraversion, .60 for neuroticism, .51 for psychoticism and .51 for lie scale, this indicated that 68%, 62%, 67% and 90% of phenotypic correlations of these traits could be attributed to shared genetic influences at two time points.

Discussion

The primary aim of this study was to conduct a bivariate genetic analysis investigating the extent to which genetic and environmental factors contribute to stability and change in personality factors in the period from adolescence to young adulthood on a sample of Croatian twins. The results of our analyses showed that individual differences in personality are moderately heritable (40%–52%) and that genetic influences mainly contribute to stability in personality (75%–100%), while environmental influences mainly contribute to change in personality (62%–100%) during that period. Also, estimates of bivariate heritability indicated that between 62% and 90% of phenotypic correlations between two time points could be attributed to shared genetic influences, again indicating that genetic influences contribute to stability in personality.

https://doi.org/10.1375/twin.10.1.151 Published online by Cambridge University Press

These findings are consistent with previous research on different samples, as moderate heritability of Eysenck's personality factors has been found based on data from Australian (Loehlin & Martin, 2001; Martin & Jardine, 1986), British (Eaves et al., 1989), Swedish (Floderus-Myrhed et al., 1980; Pedersen et al., 1988), American (Loehlin & Nichols, 1976), Finish (Rose et al., 1988) and Russian twins (Saudino et al., 1999). Even more so, heritability estimates in our study are very similar for different personality factors. Although there are number of studies establishing moderate heritability of Eysenck's personality factors, mainly extraversion and neuroticism, in different samples, there are only few studies on Australian twins reporting heritability of the lie scale, a measure of socially desirable responding (Gillespie et al., 2001; Loehlin & Martin, 2001). Our finding of moderate heritability of the lie scale in a sample of Croatian twins indicates that this control scale behaves like a personality trait.

Analyses of the factors contributing to stability and change in personality also yielded results similar to previous studies. As in longitudinal analyses of data from Finnish (Viken et al., 1994), Swedish (Pedersen & Reynolds, 1998) and Australian (Gillespie et al., 2004) twins, genetic factors contributed mainly to stability in personality, while environmental factors contributed mainly to change in personality. Generally this finding has been obtained when the retest interval was shorter (2–4 years), while in studies that had longer retest intervals (10–12 years), it was found that genetic factors also contribute to change in personality (Dworkin et al., 1976; McGue et al., 1993). As in the case of heritability estimates, values of genetic and environmental correlations indicating stability of genetic and environmental influences obtained in our study are very similar for extraversion, neuroticism and pyschoticism. Values of genetic correlation are around .80 indicating that large proportions of the additive genetic variance observed in young adulthood can be explained by genetic effects present in adolescence. Values of environmental correlations are around .35 indicating that about a third of environmental influences present in adolescence remain stable during the transition to young adulthood. The only exception was the lie scale for which the results indicate that complete additive genetic variance observed in young adulthood can be explained by genetic effects present in adolescence, while there was no environmental correlation between adolescence and young adulthood.

The limitation of our own study is the small number of twin pairs, which had an impact on the power of the study and precision of obtained estimates. This is apparent in the wide confidence intervals associated with each parameter estimate. But it seems from our own and from previous studies of stability and change in personality that nonshared environmental influences contribute mainly to change in personality. However, it is important to keep in mind that estimates of nonshared environmental influences include error of measurement and are therefore probably attenuated. Also, environmental influences in all those studies were not measured, but conclusions about their contribution were reached based on the results of model fitting procedures. Therefore, the next step in the research of etiology of stability and change in personality should be the identification and measurement of specific environmental factors, which contribute to stability and change in personality.

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