Genetic and Environmental Effects on Openness to Experience, Agreeableness, and Conscientiousness: An Adoption/Twin Study

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ABSTRACT Previous research has indicated that extraversion and neuroticism are substantially affected both by genotype and environment. This study assesses genetic and environmental influences on the other three components of the five-factor model of personality: Openness to Experience, Agreeableness, and Conscientiousness. An abbreviated version of the NEO Personality Inventory (NEO-PI) was administered to 82 pairs of identical twins and 171 pairs of fraternal twins reared apart and 132 pairs of identical twins and 167 pairs of fraternal twins reared together. Estimates of genetic and environmental effects for Openness and Conscientiousness were similar to those found in other studies of personality: Genetic influence was substantial and there was little evidence of shared rearing environment. Results for Agreeableness were different: Genetic influence accounted for only 12% of the variance and shared rearing environment accounted for 21% of the variance. Few significant gender or age differences for genetic and environmental parameters were found in model-fitting analyses.

Research on the five-factor model of personality has given us a useful set of very broad dimensions that characterize individual differences in personality structure (see Digman, 1990), and many well-known self-report inventories actually reflect various aspects of the five-factor model (Digman, 1979). Subsequent research has broadened the basis for this claim by showing that the same factor structure is found both in self-report inventories and in ratings (McCrae & Costa, 1985a, 1987), and that similar factors can also be found cross-culturally (Amelang & Borkenau, 1982; Bond, Nakazato, & Shiraishi, 1975; Borkenau & Ostendorf, 1990).

Although there is a converging consensus for the *number* of broad dimensions, the *meaning* of the factors varies from one system to another. In general, there is overwhelming agreement concerning Eysenck's (1947) and Cattell's (1957) dimensions of Extraversion/Exvia and Neuroticism/Anxiety. The other three dimensions, however, involve varied nomenclature, as well as somewhat different conceptualizations. It is these dimensions of personality that are the focus of the present study.

The five-factor NEO Personality Inventory model of personality (NEO-PI; Costa & McCrae, 1985; McCrae & Costa, 1985a, 1987) labels the other three dimensions Openness to Experience, Agreeableness, and Conscientiousness. McCrae and Costa (1985b) describe the Openness domain as assessing proactive seeking and appreciation of experience for its own sake, based on characteristics such as openness to feelings, new ideas, flexibility of thought, and readiness to indulge in fantasy. The Openness factor is also interpreted as Intellect (Cattell,

1957; Digman & Inouye, 1986; Goldberg, 1981), Intelligence (Borgatta, 1964), and Culture (Norman, 1963; Tupes & Cristal, 1961). Hogan (1986) includes educational aptitude as well as cultural and creative interests under the name "Intellectance".

The second of the three domains is often referred to as Agreeableness (Goldberg, 1981; Norman, 1963; Tupes & Cristal, 1961), contrasting such characteristics as altruism, nurturance, caring, sympathy, and cooperation with hostility, cynicism, callousness, antagonism, and indifference to others (for a review of the Agreeableness dimension, see Graziano & Eisenberg, in press). Other labels for this factor are Conformity (Fiske, 1949), Likeability (Borgatta, 1964; Hogan, 1986), Friendliness (Guilford & Zimmerman, 1949), and Friendly Compliance versus Hostility (Digman & Takemoto-Chock, 1981).

The essence of the third domain has been difficult to capture, but in most cases represents the individual's degree of organization, persistence, and motivation in goal-directed behavior. Many schemata are consistent with the Costa and McCrae label of Conscientiousness (Botwin & Buss, 1989; Costa & McCrae, 1985; Noller, Law, & Comrey, 1987; Norman, 1963), but this dimension has also been characterized as Dependability (Tupes & Cristal, 1961), Superego Strength (Cattell, 1957; Meyer, Heath, Eaves, Mosteller, & Schieken, 1988), Impulsive Sensation Seeking (Zuckerman, Kuhlman, & Camac, 1988); Impulsivity (Buss & Plomin, 1984), Constraint (Tellegen, 1985), and Self-Control (Lorr, 1986). It has also been suggested that Will to Achieve or Will may more closely reflect the core characteristics of this dimension (Digman & Takemoto-Chock, 1981).

The relative contributions of genetic and environmental influences on individual differences in extraversion and neuroticism have been extensively explored (Goldsmith, 1983; Henderson, 1982; Loehlin, Willerman, & Horn, 1988). Recently, genetic and environmental influences on neuroticism and extraversion were estimated in the Swedish Adoption/Twin Study of Aging (SATSA), which compares identical and fraternal twins reared apart and matched twins reared together (Pedersen, Plomin, McClearn, & Friberg, 1988). Estimates indicated that 31% of the variance in neuroticism and 41% of the variance in extraversion is due to genetic differences between individuals. Shared rearing environment accounted for 10% and 7% of the variance of neuroticism and extraversion, respectively. Nonshared environment accounted for the largest portion of variance for both traits.

To our knowledge, no research has specifically addressed the etiology

of individual differences in Openness to Experience, Agreeableness, and Conscientiousness, although a few studies have included scales related to these domains. One study addressed individual differences in measures which are components of Agreeableness (Rushton, Fulker, Neale, Nias, & Eysenck, 1986). Based on quantitative genetic model-fitting analyses, heritability estimates were 51%, 51%, 43%, 39%, and 53% for altruism, empathy, nurturance, aggressiveness, and assertiveness, respectively. Virtually none of the variance was attributed to the effects of shared environment, with the remaining variance ascribed to the influences of nonshared environment. When parameters were estimated separately by gender and age, the fit of the models improved. Results of this type indicate that there may be age and gender differences in the contributions of genetic and environmental influences for these variables.

Another example is a study of high-school twins from the National Merit twin sample, which employed the California Psychological Inventory (CPI; Loehlin, 1987a). Using a factor-analytic approach to estimate genetic and environmental influences on personality, evidence for four genetic factors was interpreted in terms of Norman's model: Shyness versus Social Dominance (Extraversion); Emotional Maladjustment (Neuroticism); Intellectual Interests (Openness); and Achievement Motivation (Conscientiousness). Five environmental factors also emerged. Two of these factors represented shared rearing environment, and were labeled "masculinity/femininity" (which may have been an artifact of using only same-gender twin pairs) and "problems with family" (reflecting family conflict or discord). The other three environmental factors represented nonshared environmental factors, and corresponded to the genetic factors previously mentioned—emotional maladjustment, shyness, and, to a lesser degree, orderliness.

Two recent reports by Tellegen and colleagues also provide insight into genetic and environmental influences on the five-factor model of personality. The first provides an empirical basis for linking the Multidimensional Personality Questionnaire (MPQ) to the five-factor model (Tellegen & Waller, in press). Table 1 indicates the correlation between the five factors as measured by adjective descriptors and the scales of the MPQ which are most closely related. For example, Neuroticism correlates .73 with the MPQ Stress Reaction scale, and Extraversion corresponds to MPQ Social Closeness (.61). For the other three dimensions, Openness, Agreeableness, and Conscientiousness, the correlations are .40, −.50, and .52 with MPQ Absorption, Aggression, and Control, respectively.

Table 1
Correlations between the Multidimensional Personality Questionnaire (MPQ) and Adjective Factors with Heritability Estimates for the MPQ Scales

Adjective factors	MPQ scale	Correlation[a]	MPQ scale heritability[b]
Neuroticism	Stress Reaction	.73	.53
	Negative Well-Being	−.39	.48
Extraversion	Social Closeness	.61	.40
	Social Potency	.42	.54
Openness	Absorption	.40	.50
Agreeableness	Aggression	−.50	.44
Conscientiousness	Achievement	.42	.39
	Control	.52	.44

a. Tellegen & Waller, in press.
b. Tellegen, Lykken, Bouchard, Wilcox, Segal, & Rich (1988).

Heritability estimates for the MPQ scales (Tellegen et al., 1988) are also provided in Table 1. Results of model-fitting analyses from a twin design indicate that genetic influences are important for all of these aspects of personality, ranging from .39 to .54. In addition, results indicated that there was little influence of shared rearing environment, with the only significant estimate for the Social Closeness scale, accounting for 19% of the variance (Tellegen et al., 1988). Nonshared environmental influences accounted for the remainder of the variance.

Based on previous research in personality, we would predict that openness, agreeableness, and conscientiousness—like other personality dimensions—will show substantial genetic variance and little effects of shared rearing environment.

The present report also tests for age and gender differences in parameters of genetic and environmental influence for these measures, using a model that incorporates separate estimates of genetic and environmental parameters for males and females, and for young and old (Eaves, 1977; Eaves & Eysenck, 1976; Eaves, Last, Young, & Martin, 1978; Martin & Jardine, 1986). Previous results suggest (Eaves & Young, 1981) that both age and gender affected the expression of genetic and environmental differences in both extraversion and neuroticism using the Swedish Twin Registry (Floderus-Myhred, Pedersen, & Rasmuson, 1980). The three additional facets of the five-factor model have not previously been studied in relation to gender or age differences, except as discussed above. Because so little is known about age and gender

differences in genetic and environmental influence on personality in general, no a priori predictions about the outcome of these analyses can be made.

METHOD

Sample

The SATSA sample of twins separated early in life and reared apart, and matched twins reared together, has been identified in the Swedish Twin Registry, which includes nearly 25,000 pairs of same-gender twins born in Sweden between 1886 and 1958 (Cederlöf & Lorich, 1978). The history of the identification of the SATSA sample has been described elsewhere (McClearn, Pedersen, Plomin, Nesselroade, & Friberg, 1989).

In the fall of 1984, shortened versions of the Openness to Experience, Agreeableness, and Conscientiousness scales (described later) from the NEO-PI (Costa & McCrae, 1985) were included in the second part of a two-part battery of questionnaires sent to the SATSA twins. Responses from 552 intact pairs of twins were used: 82 pairs of identical twins reared apart (monozygotic-apart; MZA), 132 pairs of identical twins reared together (monozygotic-together; MZT), 171 pairs of fraternal twins reared apart (dizygotic-apart; DZA), and 167 pairs of fraternal twins reared together (dizygotic-together; DZT). Zygosity of the twins was determined using physical similarity criteria (i.e., adult eye color, hair color, hair texture, hair curliness, and questions concerning overall physical similarity—e.g., strangers confuse twins, friends confuse twins, family members confuse twins, and twins are as similar as peas in a pod); these criteria are described elsewhere (Bergeman, Plomin, McClearn, Pedersen, & Friberg, 1988). Physical similarity criteria indices consistently show greater than 90% accuracy when validated against analyses of single-gene markers in blood (Plomin, DeFries, & McClearn, 1990).

The average age of the twins at the time of testing was 58.6 years (SD = 13.16; range, 26 to 87 years); 72% of the twins are age 50 or older. Sixty percent of the twins are female, which conforms to the increased proportion of females in an older population (U.S. Bureau of the Census, 1983). In general, the SATSA twins are representative of twins in the Swedish Twin Registry except that they are older because most of the reared-apart twins were born in the early 1900s when economic depression and epidemics increased the likelihood of separation. The average age of separation for the entire sample was 2.8 years; 48% of the pairs were separated during the first year of life and 82% were separated by age 5. The reasons for separation are varied; however, the most common reasons were economic hardship or illness/death of one or both of the parents. In the SATSA sample, separation involves multiple factors—age at separation, age at reunion, frequency of contact (in person, telephone, letter), attendance at same or different schools, and the biological

relatedness of the rearing parents. This variation in degree of separation can be evaluated parametrically; analyses of this type, however, suggested little effect of degree of separation on twin similarity for the Openness, Conscientiousness, and Agreeableness measures (Pedersen, McClearn, Plomin, & Nesselroade, in press).

Measures

Personality traits were measured by short versions of the Openness, Agreeableness, and Conscientiousness scales of the NEO-PI. The NEO-PI itself is a standardized measure of the five-factor model; reviews are provided by Hogan (1989) and Leong and Dollinger (1990).

The present study employed a shortened version of the Openness scale (25 of 48 original items) and 10-item preliminary versions of the Agreeableness and Conscientiousness scales. Only 8 of the 10 Agreeableness items were retained in the published instrument; all of the Conscientiousness items were retained. Items were selected by item-total correlations and regressions using data from the Baltimore Longitudinal Study of Aging (McCrae & Costa, 1983, 1987). Validity of the resulting scales in the original sample was demonstrated by correlations with adjective checklist measures of the five factors (McCrae & Costa, 1985a). Correlations of the shortened Openness, Agreeableness, and Conscientiousness scales with the corresponding adjective factors were .54, .49, and .60, respectively (Baltimore sample: Ns = 430 to 475, $p < .001$); none of the discriminant correlations exceeded .18 in absolute magnitude.

Items were translated into Swedish by a professional translator and back-translated to English to assure that the meaning of the original items was retained. Factor analysis provided reasonable confirmation of the Swedish version of the NEO-PI scales. Items were scored according to the traditional NEO-PI scoring to increase comparability to other studies using these scales. Internal consistency (Cronbach's alpha) was .77 for the Openness to Experience items, .52 for the Agreeableness items, and .69 for the Conscientiousness items. The relatively low homogeneity of the Agreeableness scale may be due to the breadth of the construct and the limited number of items used to assess it.

Analyses

The biometrical model used in the SATSA design has been described in detail elsewhere (Pedersen et al., 1988; Plomin, Pedersen, McClearn, Nesselroade, & Bergeman, 1988). In brief, the analyses fit a model of five parameters: (*a*) additive genetic variance (G_a)—genetic deviations which add up linearly in their effect on the phenotype; (*b*) nonadditive genetic variance (G_d)—the effects of dominance; (*c*) shared rearing environment (E_s)—similarity for twins reared together versus twins reared apart; (*d*) nonshared environment (E_n)—

environmental influences which make twins different from each other, which includes error variance; and (*e*) correlated environment (E_c)—similarity for twins beyond resemblance due to heredity and shared rearing environment (adult contact, or the effects of selective placement). Because the model's expectations for G_a, G_d, and E_c create a linear dependency, separate model-fitting analyses are conducted in which E_c is excluded when G_a and G_d are included, and either G_a or G_d is excluded when E_c is included.

Model-fitting analyses are useful because they estimate multiple parameters simultaneously, they make the assumptions underlying the estimation explicit, and they permit tests of the relative fit of different models (e.g. Loehlin, 1987b). For example, a reduced model, in which a genetic or an environmental parameter is dropped, can be tested against a full model in which the parameter is included. When the reduced models are nested within the full model, the change in chi square is itself distributed as a chi square which permits evaluation of the significance of the dropped parameter. Three reduced models that assess the significance of total genetic variance, shared rearing environment, and correlated environments were tested.

To assess gender and age differences in genetic and environmental influences, the approach is much the same: Parameters are estimated separately for males and females (or young and old), and then the results are compared to models in which the parameters are restrained to be equal. For simplicity, the gender and age models were conducted using three parameters: Genetic variance (G), shared rearing environment (E_s), and nonshared environment (E_n). Previous model-fitting designs (Eaves, 1977) specified separate latent variables for males and females. LISREL VI (Jöreskog & Sörbom, 1985), however, allows for the use of three latent variables while providing separate parameter estimates by gender or age.

The relative fit of reduced models can also be tested for gender and age differences. That is, for gender and age models, differences in genetic and environmental influences for males versus females, or for young versus old, are tested by systematically setting the parameters equal across gender (age) with each of the parameters (G, E_s, and E_n) tested separately. The goodness-of-fit is determined by comparing the change in chi square from the full model (parameters estimated separately by gender or age groups) to reduced models (gender or age groups constrained to be equal for the parameter of interest).

RESULTS

Descriptive Statistics

Means and standard deviations (irrespective of twinness) by gender and age are provided in Table 2. A significant mean difference by gender was found for Agreeableness, with females scoring higher than males. Two

Table 2
Means and Standard Deviations by Gender and Age for the Openness to Experience, Agreeableness, and Conscientiousness Scales

	Males		Females		Young		Old	
Scale	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
Openness	74.17	10.47	75.32	11.76	77.36[a]	11.33	72.41	10.64
	(N = 402)		(N = 567)		(N = 474)		(N = 495)	
Agreeableness	37.54[b]	3.65	39.85	3.92	38.44[a]	3.89	39.32	4.01
	(N = 418)		(N = 593)		(N = 491)		(N = 520)	
Conscientiousness	37.50	4.74	37.67	4.66	37.55	4.82	37.67	4.56
	(N = 417)		(N = 585)		(N = 498)		(N = 504)	

Note. Young = age < 60; old = age ≥ 60.

a. Mean differences for young and old are significantly different for Openness, $F(1, 965) = 47.23$, $p < .01$, and Agreeableness, $F(1, 1007) = 11.81$, $p < .01$.

b. Mean scores for males and females are significantly different, $F(1, 1007) = 88.28$, $p < .01$.

significant mean differences by age were found when the sample was divided into younger (age < 60) and older (age ≥ 60): Younger individuals scored higher on Openness and lower on Agreeableness than the older age group. There were no significant Age $\times$ Gender interactions. Prior to model-fitting analyses, scale scores were standardized using a regression technique to correct for any possible main effects of gender and age which would inflate twin correlations (McGue & Bouchard, 1984). Analyses to detect mean differences by zygosity, rearing status, and their interaction resulted in no significant differences for Openness, Agreeableness, or Conscientiousness.

Twin Correlations

Genetic and environmental influences can be gauged by the comparison of intraclass correlations for the four twin groups (Table 3). In general, the twin correlations suggest genetic influence because monozygotic (MZ) correlations are higher than dizygotic (DZ) correlations. On this criterion, the greatest genetic influence is shown for Openness. Openness also shows the greatest genetic influence in terms of its correlations for twins reared apart. In cases where DZ correlations are on average

Table 3
Intraclass Correlations for Identical (MZ) and Fraternal (DZ) Twins Reared Apart (A) or Reared Together (T)

Scale	MZA	MZT	DZA	DZT
Openness	.43	.51	.23	.14
Agreeableness	.15	.41	−.03	.23
Conscientiousness	.19	.47	.10	.11

Note. Correlations are based on pairwise responses of 552 pairs of twins: 82 MZA, 132 MZT, 171 DZA, and 167 DZT.

less than half of the MZ correlations, the presence of nonadditive genetic variance is suggested; Openness and Conscientiousness show this pattern of correlations. However, this nonadditive pattern of correlations occurs only for the MZT and DZT correlations, which suggests that the effects could be due to a violation of the equal environments assumption of the twin method.

The equal environments assumption refers to presumed equal environmental similarity for MZ and DZ twins. A violation of this assumption could yield DZT correlations less than half the MZT correlation because environmental factors raise MZT similarity relative to DZT similarity or lower DZT similarity relative to MZT similarity. These two types of violations of the equal environments assumption have been called assimilation and contrast, respectively (Loehlin & Nichols, 1976). The SATSA design of twins reared together and apart provides a unique opportunity to differentiate effects of this type from nonadditive genetic variance: For twins reared apart, such assimilation and contrast effects are likely to be less important than for twins reared together. Because some of the nonadditive genetic pattern of twin correlations for Openness and Conscientiousness appears to be due to effects of this type, the model-fitting analyses will include separate tests of the MZT assimilation effect.

In comparing the MZT/DZT correlations for Agreeableness (the standard twin comparison), additive genetic variance is indicated. If the information from the twins reared apart (MZA/DZA) is included, a different picture emerges: The twins reared together showed higher correlations than the twins reared apart, which indicates the importance of shared rearing environment for this aspect of personality.

Twin correlations for male and female twins and for younger and older twins yield similar results. Only one of the 24 (age/gender) differ-

Table 4
Maximum-Likelihood Model Fitting: Parameter Estimates, Standard Errors, and Chi Squares for the Full Model

	Parameter estimates ± standard errors (% variance)					
Scale	G_a	G_d	E_s	E_n	χ^2	p
Openness	.63 ± .22 (38%)	.14 ± .97 (2%)	.25 ± .17 (6%)	.75 ± .03 (54%)	10.30[a]	.04
Agreeableness	—	.35 ± .13 (12%)	.46 ± .09 (21%)	.82 ± .04 (67%)	1.05[b]	.90
Conscientiousness	—	.54 ± .08 (29%)	.33 ± .12 (11%)	.77 ± .04 (60%)	2.15[b]	.71

Note. Dash means parameter estimate is zero. G_a = additive genetic variance; G_d = nonadditive genetic variance; E_s = shared environmental variance; and E_n = nonshared environmental variance.
a. χ^2 (4df).
b. χ^2 (5df).

ences is statistically significant ($p < .05$, two-tailed), which is expected on the basis of chance alone. The average absolute difference in correlations for male and female twins and for younger and older twins is .16, which indicates the degree of chance fluctuations in twin correlations when the sample size is halved. Such quantitative genetic parameters and comparisons between males and females and young and old can be estimated much more powerfully using a model-fitting approach.

Model Fitting

Maximum-likelihood parameter estimates and standard errors were obtained using LISREL VI (Jöreskog & Sörbom, 1985). Results of model-fitting analyses are depicted in Table 4, which indicates the relative percentages of variance explained by heredity, shared rearing environment, and nonshared environment; parameter estimates with standard errors are also provided. Genetic influences account for 40%, 12%, and 29% of the variance in Openness to Experience, Agreeableness, and Conscientiousness, respectively. As indicated in Table 4, Openness to Experience was consistent with a model assessing additive genetic variance, whereas a model with a parameter for nonadditive genetic variance fit the data best for Conscientiousness and Agreeableness. All

subsequent analyses will use the additive genetic parameter for Openness and the nonadditive parameter for the other two scales, although for simplicity of discussion the variance will be referred to as genetic variance regardless of the type.

Estimates of shared rearing environment were modest for Openness to Experience and Conscientiousness (6% and 11%, respectively). However, for Agreeableness, shared rearing environment accounts for 21% of the variance. When the model was fit with the correlated environments parameter, the effects of correlated environments are negligible for all three variables. In all cases, the effects of nonshared environment are large and important, accounting for 54% to 67% of the variance.

Reduced models. Comparisons of reduced models provide a strong test of significance for the various parameters. The first reduced model tested the significance of genetic influence. Results indicate that genetic influence is significant for Openness to Experience, change in $\chi^2(1) = 25.43$, $p < .01$, and Conscientiousness, change in $\chi^2(1) = 8.50$, $p < .01$, but not for Agreeableness, change in $\chi^2(1) = 1.00$, $p > .05$.

A second reduced model tests the effects of shared rearing environment. For Openness to Experience and Conscientiousness there is no significant change in chi square when the shared environment parameter is removed from the model. The change in chi square was significant for Agreeableness when the shared rearing environment parameter was removed, change in $\chi^2(1) = 6.19$, $p < .05$. In other words, the influence of shared rearing environment is significant for Agreeableness, but not for Openness to Experience or Conscientiousness.

Model-fitting analyses including a parameter to assess an MZT assimilation effect were also conducted. For Conscientiousness, adding a parameter to represent MZT assimilation improved the fit of the model. A significant chi square change between the two models could not be expected, however, due to the good fit of the base model. Openness and Agreeableness, on the other hand, showed little effect when an additional parameter was added to assess the influence of MZT assimilation.

Gender and age models. Models assessing the effects of gender and age differences in genetic and environmental influences were also tested. The genetic and environmental parameters were first estimated sepa-

rately for males and females (young/old). Figure 1 depicts the relative influence of heredity, shared rearing environment, and nonshared environment for males/females and young/old. Reduced models set the various parameters equal for the genders (age groups), and the goodness-of-fit was tested by the change in chi square. As expected on the basis of the correlations, no more than a chance number of significant differences for gender and age were found. Although variations in parameter estimates exist (Figure 1), the only significantly different parameter estimate was a gender difference for the genetic parameter for Conscientiousness, change in $\chi^2(1) = 5.63$, $p < .02$. This finding indicates that males show greater genetic influence than females (41% vs. 11%, respectively).

DISCUSSION

Recent research suggests that five broad factors account for most of the common variance in personality traits. Two of the factors—Neuroticism and Extraversion—have been the object of extensive behavior genetics research, and have consistently shown evidence of moderate to strong genetic influences and little or no shared environmental influence (Pedersen et al., 1988). This fact is consistent with the long-standing interpretation of these two as dimensions of temperament (e.g., Eysenck, 1947). As Caspi and Bem (1990) noted, the remaining three factors—Openness, Agreeableness, and Conscientiousness—have rarely been measured in twin studies, and there are theoretical reasons to suppose that they would show little genetic influence. Openness is an experiential and attitudinal dimension that might be shaped by early childhood experiences (Rogers, 1961) or by other life events such as a liberal education. Agreeableness and Conscientiousness can be considered aspects of character that might be shaped primarily by socialization processes, including parental love and discipline (McCrae & Costa, 1988).

In fact, however, the present analysis supports the view that at least two of these factors, Openness and Conscientiousness, also show moderately high heritability and little evidence of shared rearing environment effects. These findings are consistent with those of Tellegen and colleagues (1988), who found similar levels of heritability for scales measuring the related traits of Absorption and Control.

The present study found no evidence of a significant genetic effect on Agreeableness, but support was found for the importance of shared rearing environmental influences. The low estimate of heritability for

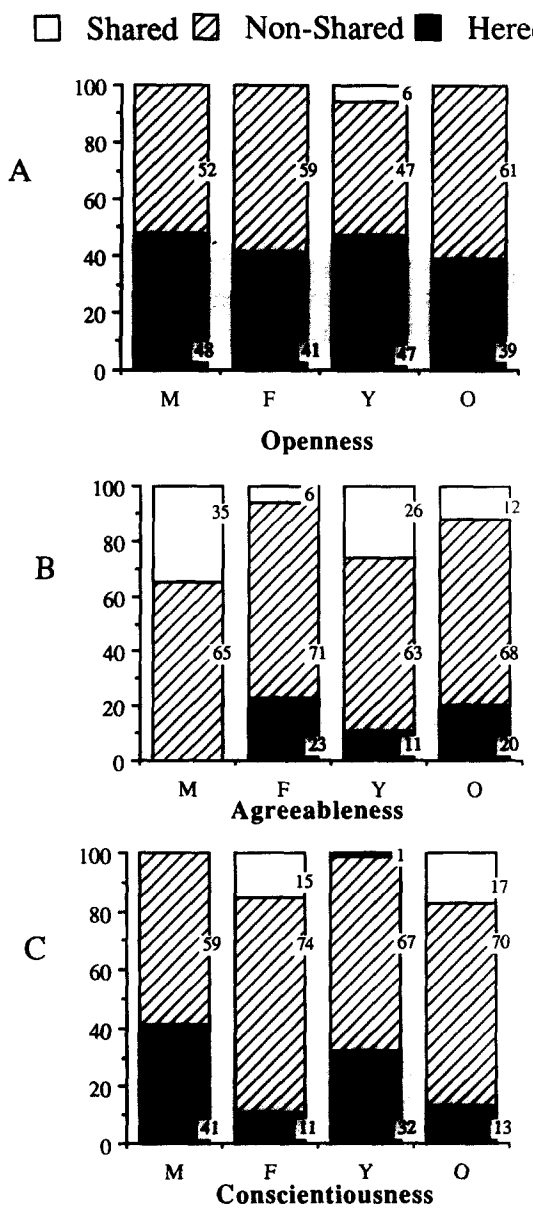

Figure 1
Graph Representing the Relative Variance for Openness to Experience (A), Agreeableness (B), and Conscientiousness (C) Explained by Heredity, Shared Rearing Environment, and Nonshared Environment Separately by Gender and Age

Note. M = male; F = female; Y = < 60 years old; O = ≥ 60 years old.

Agreeableness emerges from several methods of estimating heritability. For example, Agreeableness shows the lowest MZA and DZA correlations and the smallest MZT versus DZT difference. Similarly, the comparisons between twins reared together consistently point to substantial influence of shared rearing environment for Agreeableness. That is, Agreeableness shows the largest difference between MZT and MZA and between DZT and DZA. The evidence for the importance of influences of being reared in the same family is consistent with the work of Koestner, Franz, and Weinberger (1990), who reported that parental behavior in early childhood predicted empathic concern at age 31.

The significant influence of shared rearing environment and the absence of genetic effects, however, is inconsistent with the studies of Tellegen and colleagues (1988) and Rushton and colleagues (1986), who found substantial heritabilities for traits related to Agreeableness. In evaluating these conflicting results, it is reasonable to believe that parents are likely to socialize heavily for traits that are part of the Agreeableness domain, such as aggression, altruism, compliance, and conflict. In other words, parents who are aggressive or altruistic are more likely to reinforce, model, and otherwise provide environments that may enhance these characteristics (Bandura, 1977; Rushton, 1980). This same argument could hold for many personality dimensions, however, and few show a significant influence of shared environment. The results of the present study may be due to the psychometric limitations of the brief scale used or to peculiarities of the Swedish sample. It is clear that additional studies, using better measures of the full domain of Agreeableness, are needed to resolve this issue.

In general, behavior genetic studies provide a consistent picture in which a very broad range of personality traits have been shown to be substantially influenced by genetic factors, and relatively unaffected by shared environmental factors. When it is recalled that "shared rearing environmental factors" include such influences as parents' style of child-rearing, socioeconomic status, religious training, educational opportunities, and neighborhood peer groups, this is an astounding fact. Some recent articles (Hoffman, 1991; McCrae & Costa, 1988; Plomin & Daniels, 1987) have addressed this issue, concluding that these influences, often thought to contribute to sibling similarity, may in fact make siblings (in this case, twins) different from one another. This surprising lack of shared environmental influences has important implications for theories of personality development.

Of equal interest is an explanation for the heritability of personality

traits: Why are characteristics such as tenseness or calmness, curiosity or conventionality, diligence or laziness passed on biologically? Current thinking in evolutionary personality psychology (Buss, 1990; Tooby & Cosmides, 1990) is not that there is some adaptive significance in having or not having these traits. On the contrary, they are likely to be genetic noise, retained over time even though they have no impact on survival. If there were an adaptive advantage to being, for example, high in Openness, human beings would presumably have evolved toward uniformly high Openness, and it would not emerge as a major dimension of individual differences (Tooby & Cosmides, 1990). The significance of personality is personal, social, and cultural, even if the origin may be biological.

In contrast to most previous behavioral genetic research, the present study examined men and women across a wide adult age range and explicitly examined the effects of age and gender. Testing gender and age models is potentially important to the study of personality because genetic and environmental influences might differ for males and females, or across the life span. Results of gender and age analyses of genetic and environmental influences on the measures of Openness to Experience, Agreeableness, and Conscientiousness yielded only one significant result: Gender differences in genetic influence were found for Conscientiousness, with males having greater genetic influence than females. However, caution is warranted in interpreting this finding because no more than a chance number of significant gender and age effects emerged.

It is noteworthy that no significant differences in genetic or environmental parameters were found for the Openness, Agreeableness, and Conscientiousness scales when model-fitting comparisons were made for the younger and older twins. Life-span models have suggested that the influence of heredity might decrease as individual experiences play an increasingly greater role as time goes by (Baltes, Reese, & Lipsitt, 1980). Results of personality research in adulthood, however, have shown that personality trait measurements manifest considerable stability despite the accumulated experience and the changes in health, social roles, and status that age brings (Costa & McCrae, 1980, in press; McCrae & Costa, 1984). It has been speculated that genetic influences may contribute to the stability of adult personality, and our results are consistent with this idea. It should be noted, however, that these age comparisons are based on a cross-sectional analysis, which can only approximate the results of longitudinal analyses. Such analyses will be

forthcoming as the SATSA sample is tested longitudinally at 3-year intervals.

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