Evidence for Nonadditive Genetic Effects on Eysenck Personality Scales in South Korean Twins

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While evidence supporting for nonadditive genetic influences on personality traits in Caucasian populations has been growing in recent years, twin studies that explored the existence of genetic nonadditivity in personality variation in Asian populations are still lacking. Seven hundred and sixty-five pairs of adolescent and young adult twins registered with the South Korean Twin Registry completed the 7 scales of the Eysenck Personality Scales through a mail survey. Maximum likelihood twin correlations were computed and model-fitting analyses were conducted. Monozygotic twin correlations were consistently higher than twice the dizygotic twin correlations for all 7 scales, suggesting pervasive influences of nonadditive genetic effects on personality traits in the South Korean population. Model-fitting analyses indicated that genetic nonadditivity is particularly important for the variation of Impulsivity, Venturesomeness, Empathy, Lie, and Psychoticism. According to the best fitting models, nonadditive genetic effects ranged from 34 to 49% for these scales. For Neuroticism and Extraversion, models that included an additive genetic component fit better than those including a nonadditive genetic variance component.

There has been a plethora of twin studies of personality conducted in Western countries. These studies converge on a conclusion that 30% to 50% of the variance of personality traits is due to genetic factors (Loehlin, 1992). More recently, studies using adoption and extended twin–family design have demonstrated that nonadditive genetic effects significantly contribute to the genetic factors found for various personality traits (Keller et al., 2005; Plomin et al., 1998).

Although twin studies have been increasing in Asian countries in recent years, studies that explored genetic influences on personality using Asian twins are still very rare. To the author's knowledge, to date, only two twin studies (Ando et al., 2002, 2004) investigated genetic influences on personality in Asians. Both studies examined Cloninger's Temperament and Character Inventory (TCI) among Japanese twins. In the first study, which was based on 296 pairs of twins, only one of the seven scales yielded a dizygotic (DZ) twin correlation lower than half the monozygotic (MZ) twin correlation. On the basis of these results, the authors concluded that genetic influences on personality in Japanese twins are predominantly additive in nature (18 to 49%). However, the second study, which was based on an increased sample ($N = 617$ pairs) suggested some evidence of nonadditive genetic effects: DZ twin correlations were lower than half the MZ twins for four of the seven scales. When model-fitting analyses were applied to the data, however, nonadditive genetic effects were statistically significant for only one (Persistence) of the seven scales. In both studies, shared environmental influences were minimal.

It appears that the failure to detect genetic nonadditivity for the scales of TCI in Japanese twin studies is largely due to sampling error associated with small samples (especially, DZ twins) and a lack of statistical power to detect nonadditive genetic influences. Recently, Hur (2006) examined genetic influences on hostility in 719 pairs of South Korean twins and found that 34% of the variance was attributable to genetic nonadditivity, providing a support for the existence of nonadditive genetic influence on personality in Asian population.

The major goal of the present study was to examine whether there is evidence for nonadditive genetic effects on personality traits in South Korean population. The present study is unique in that it includes the largest sample of Asian twins ever reported in the literature of personality.

Materials and Methods

Sample

The present sample was composed of 765 twin pairs drawn from ongoing South Korean Twin Registry (SKTR). The SKTR is a nationwide volunteer registry

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of South Korean twins and their families, and is described in detail elsewhere (Hur et al., 2006).

In early 2006, a package of questionnaires including seven scales of a Korean version of the Eysenck Personality Scale (EPS: Eysenck & Eysenck, 1991) was mailed to adolescent and young adult twins registered with the SKTR. The overall response rate of the mail survey in 2006 was somewhat over 30%.

Twins' zygosity in the SKTR was determined by the questionnaire method (Ooki et al., 1993). Although the questionnaire method is less accurate than DNA analysis, we have used stringent criteria to exclude twins whose zygosity is ambiguous. For the present analyses, 44 twin pairs were excluded because their zygosity could not be classified according to the selection criteria used in the SKTR. The total 765 pairs of twins used in the present analyses consisted of 531 pairs of MZ twins (188 male and 343 female pairs) and 234 pairs of DZ twins (62 male, 67 female, and 105 opposite-sex pairs).

The number of MZ twins was much greater than that of DZ twins in the present sample. These rates of MZ and DZ twins generally reflect the low DZ twin birth rates in the South Korean population for the birth cohorts in the present study (Hur & Kwon, 2005). As in most volunteer twin samples (Heath et al., 2001), however, the present sample has an overrepresentation of female twins. An overrepresentation of females appears due in part to the fact that some of the male twins were in the military service at the time of the mail survey as army service is mandatory for young adult males in South Korea.

Measure

The Korean version of the EPS used in the present analyses includes 88 yes-no items that measure Neuroticism, Extraversion, Psychoticism, Lie, Impulsiveness, Venturesomeness, and Empathy. The Eysenckian personality dimensions have been extensively investigated in genetic studies of personality (e.g., Heath et al., 1989, 1994). Cross-cultural studies of personality have demonstrated the remarkable similarity of the factor structure and the generality of the constructs of the Eysenckian personality dimensions across many different countries (Barrett & Eysenck, 1984; Lynn & Martin, 1995). Validity and reliabilities of the Korean version of the EPS have been well established and the factor structure of the Eysenckian personality dimensions has been replicated among Koreans also (Lee, 1997). The internal consistency reliabilities of the seven scales in the present sample ranged from .62 to .81, with a mean of .73.

Statistical Analyses

To investigate genetic and environmental influences on the seven scales of the EPS, MZ and DZ maximum likelihood twin correlations were computed and univariate model-fitting analyses were performed using the raw data option of Mx (Neale et al., 2003). Data analyses were carried out on the basis of the combined sample of males and females to increase the statistical power to detect nonadditive genetic effects. In the analyses, sex and age variables were treated as covariates to control their main effects.

Univariate genetic model included additive genetic (A), shared environmental (C), dominance genetic (D), and nonshared environmental (E) effects. Because it was not possible to estimate D and C in the same model, two full models, that is, the ADE and the ACE model, were fit to the data separately.

Two criteria were used to select the best fitting, most parsimonious model: the chi-square difference test and the Akaike Information Criterion (AIC; AIC = $\chi^2 - 2df$). When the raw data are used in model-fitting analyses, Mx computes minus twice the log-likelihood of the data (–2LL), with an arbitrary constant that is a function of the data. If two models are nested, differences in –2LL between nested models are distributed as a chi-square, with degrees of freedom as follows: $df_{k+1} - df_k$, where k is number of degrees of freedom (Bollen, 1989). A significant increase in chi-square in the reduced model as compared to the full model would suggest that the reduced model fit the data less well than the full model. A nonsignificant change in chi-square would indicate that the full model and the restricted model are equally acceptable. AIC quantifies the information content of a model in terms of the joint criterion of fit and parsimony. In general, small chi-square values from models with few free parameters lead to small AlCs representing maximum parsimony. Therefore, if competing models are not nested, the model that produces the lowest AIC is considered the best fitting model.

In the present analyses, two steps were taken to choose the best fitting, most parsimonious model to explain the data. First, for each of the seven scales of the EPS, AIC values were compared to choose between ADE and ACE. Second, the reduced models of either ADE or ACE were tested for each scale using both AIC and the chi-square difference test.

Results

Maximum Likelihood Twin Correlations

Table 1 provides MZ and DZ twin correlations for the seven scales of the EPS separately. Also presented in the table are the results of statistical comparisons of the correlation between the two zygosity groups. MZ twin correlations were consistently higher than twice the DZ twin correlations for all seven scales, suggesting the pervasive influences of nonadditive genetic effects on personality traits in South Korean adolescents and young adults. When the MZ and DZ twin correlations were equated for the seven scales, the change in –2LL was significant at $p < .01$ for all scales but Neuroticism.

Model-Fitting

Table 2 presents the results of model-fitting analyses for the seven scales of the EPS. For all seven scales, AIC values were lower in ADE than in ACE,

Table 1

Maximum Likelihood MZ and DZ Twin Correlations

Scale	MZ	DZ	Δ –2LL
Impulsivity	.38	.10	14.75**
Venturesomeness	.49	.17	21.08**
Empathy	.35	.03	17.31**
Lie	.47	.15	20.47**
Psychoticism	.36	.08	14.00**
Extraversion	.51	.25	15.74**
Neuroticism	.38	.16	8.78

Note: $^{**}p < .01$.

suggesting that genetic dominance is more important than shared environmental effects in explaining individual differences in personality in South Korean twins. Therefore, the ADE model was chosen as the full model, and subsequent models entailed a reduction of A, D, or both parameters from the ADE model.

When A was removed from the ADE model (ADE vs. DE), none of the change in –2LL was significant. Similar results were obtained when D was eliminated from the ADE model (ADE vs. AE). However, dropping both A and D parameters from the ADE model resulted in a significant change in –2LL for all seven scales, suggesting that genetics play a critical role in variations of the seven scales of the EPS.

To evaluate superiority between the AE and DE model, AIC values for these two models were compared. For five of the seven scales, that is, Impulsivity, Venturesomeness, Empathy, Lie, and Psychoticism, AIC was lower in DE than in AE, indicating the importance of nonadditive genetic effects on these scales. For the remaining two scales, Extraversion and Neuroticism, however, the AE model yielded lower AIC than the DE model. Taken together, these results suggest that in general, nonadditive genetic effects are more important than additive genetic effects for the EPS scales.

Table 3 provides parameter estimates for the ADE model and the best fitting, most parsimonious models for each of the seven EPS scales. For Impulsivity, Venturesomeness, Empathy, Lie, and Psychoticism, genetic effects explained 34 to 49% of the variance, and these genetic effects were primarily of the nonadditive kind (28 -39%). For Extraversion and Neuroticism, broad heritability estimates were 51% and 38%, respectively. The proportion of variance attributable to nonadditive genetic effects was 6% for Extraversion and 14% for Neuroticism.

Discussion

In recent years, there has been growing evidence for nonadditive genetic influences on personality traits in Caucasian populations. Little is known, however, about the significance of genetic nonadditivity in personality traits in Asian populations. The present South Korean twin sample, similar to other twin studies conducted in Western countries, provides strong evidence that the genetic effects on most personality traits are operating in a nonadditive fashion. Nonadditive genetic effects were notable especially for Impulsivity, Venturesomeness, Empathy, Lie, and Psychoticism. According to the best fitting models, nonadditive genetic effects on these scales ranged from 34 to 49%.

Table 2

Results of Model-Fitting Analyses

Model		Impulsivity	Venturesomeness	Empathy	Lie	Psychoticism	Extraversion	Neuroticism
ADE	Δ 2LL	7899.75	8102.56	6852.53	6779.91	6484.98	7596.02	7783.34
	AIC	4851.75	5056.56	3806.53	3735.91	3442.98	4550.02	4739.34
ACE	Δ 2LL	7902.46	8103.77	6855.77	6781.04	6489.49	7596.09	7783.67
	AIC	4854.46	5057.77	3809.77	3737.04	3447.49	4550.09	4739.67
AE	Δ 2LL	7902.46	8103.77	6855.77	6781.0	6489.49	7596.09	7783.67
	AIC	4852.46	5055.77	3807.77	3735.04	3445.49	**4548.09**	**4737.67**
DE	Δ 2LL	7899.75	8103.19	6852.53	6780.34	6484.98	7599.49	7784.28
	AIC	**4849.75**	**5055.19**	**3804.53**	**3734.34**	**3440.98**	4551.49	4738.28
E	Δ 2LL	7983.03	8255.11	6919.53	6917.94	6559.55	7768.95	7871.77
	AIC	4931.03	5205.11	3869.53	3869.94	3513.55	4718.95	4823.77
ADE vs. AE	Δ –2LL	2.70	1.21	3.24	1.13	4.51*	0.07	0.33
	Δ*df*	1	1	1	1	1	1	1
ADE vs. DE	Δ –2LL	0	0.63	0	0.43	0	3.47	0.94
	Δ*df*	1	1	1	1	1	1	1
ADE vs. E	Δ –2LL	83.28**	152.55**	67.00**	138.03**	74.57**	172.93**	88.43**
	Δ*df*	2	2	2	2	2	2	2

Note: AIC values for the best fitting, most parsimonious model were indicated in boldface. $^{*}p < .01$, $^{**}p < .01$.

A = additive genetic effects, D = dominance genetic effects, E = nonshared environmental effects and measurement error.

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Table 3

Parameter Estimates (95% CI) for the ADE Model and the Best Fitting, Most Parsimonious Model for the EPS Scales

	Full model			The best-fitting, most parsimonious model		
	Parameter estimates (95% CI)			Parameter estimates (95% CI)		
Scale	A	D	E	A	D	E
Impulsivity	.00 (.00–.40)	.38 (.00-.45)	.62 (.55–.69)	—	.38 (.31–.45)	.62 (.55–.69)
Venturesomeness	.21 (.00–.53)	.28 (.00–.54)	.51 (.45–.58)	—	.49 (.42–.55)	.51 (.45–.58)
Empathy	.00 (.00–.35)	.34 (.00–.41)	.66 (.59–.74)	—	.34 (.26–.41)	.66 (.59–.74)
Lie	.18 (.00–.51)	.28 (.00–.52)	.54 (.48–.60)	—	.46 (.40–.53)	.54 (.48–.60)
Psychoticism	.00 (.00–.34)	.39 (.03–.46)	.61 (.54–.69)	—	.39 (.31–.46)	.61 (.54–.69)
Extraversion	.45 (.00–.57)	.06 (.00–.54)	.49 (.43–.55)	.51 (.45–.57)	—	.49 (.43–.55)
Neuroticism	.24 (.00–.44)	.14 (.00–.45)	.62 (.55-.69)	.38 (.31–.45)	—	.62 (.55–.69)

Note: A = additive genetic effects, D = dominance genetic effects, E = nonshared environmental effects and measurement error.
— = Fixed to be zero.

The seven EPS scales used in the present study yielded broad sense heritability estimates of 34 to 51%, which were also remarkably consistent with reports from twin studies of personality carried out in Western countries (Loehlin, 1992) and Japan (Ando et al., 2002, 2004). In the present study, additive genetic effects were stronger than nonadditive genetic effects only for two of the seven scales, Neuroticism and Extraversion. While evidence for the significance of nonadditive genetic effects on Neuroticism has been inconsistent in the literature of personality, there is a general agreement on the importance of nonadditive genetic influences on extraversion among studies on the basis of Caucasian twins (Loehlin, 1992; Pedersen et al., 1988). It is difficult to determine the reason for the discrepancy between previous findings and the results of the present study. However, one should note that the MZ twin correlation of .51 for the Extraversion scale found in the present study is very close to the MZ correlations for various measures of extraversion reported in the literature of personality, while the DZ twin correlation of .25 in the present study is somewhat higher than those reported in the literature (Loehlin, 1992; Keller et al., 2005). These twin correlations suggest that a lack of evidence for nonadditive genetic effects on Extraversion in the present sample may be due to a random sampling error associated with the relatively small sample size of DZ twins in the present study.

Models that included a nonadditive component fit better than those that contained a shared environmental variance component for all seven scales of the EPS, suggesting that being reared in the same family hardly impacts on individual differences in personality traits in South Korean adolescent and young adults. These results were also congruent with findings from Western twin samples. East Asian culture traditionally has been considered to be collectivistic in nature, whereas Western cultures are considered to be individualistic. East Asian societies, in general, place more importance on dependence on the family, and obligation to bind to the family and family common values, and less emphasis on the independence and autonomy of individuals (Markus & Kitayama, 1991). Youths in East Asian societies have been reported to spend more time with the family and be more involved in family obligations as compared to their peers in Western societies (Fuligni & Stevenson, 1995; Fuligni et al., 2002). But, nevertheless, along with Japanese twin studies (Ando et al., 2002, 2004), the present sample clearly demonstrates that family environmental factors exert little influence and do not suppress expression of genetic factors in personality traits in adolescents and young adults in East Asian populations. As one can see from the twin correlations, the estimates of shared family environmental influences for the ACE model were zero for all seven scales.

There are a few limitations of the present study that need to be addressed. First, the estimates of nonadditive genetic influences reported in the present study should be interpreted with caution, as a very large sample is needed to detect nonadditive genetic influences (Martin et al., 1978). Power calculations using Mx (Neale et al., 2003) revealed that when true estimates of additive and nonadditive genetic effects in the population are 20% and 10%, respectively, the sample size required to detect nonadditive genetic effects with an 80% power was 28,555 pairs of MZ and DZ twins. When true estimates of additive and nonadditive genetic effects are 30% and 15%, respectively, we need 11,310 pairs to detect nonadditive genetic effects with an equal level of power.

Second, the estimates of nonadditive genetic effects modeled in the present study include both dominance genetic effects and the effects of higher order epistatic interaction. If the effects of higher order epistatic interactions are significant, then the D parameter could have been overestimated and the A parameter, underestimated in the present design. A detailed discussion of parameter indeterminacy in the classical twin design can be found in Keller and Coventry (2005). The importance of epistatic interactions is implicated when the DZ correlation is lower than a quarter of the MZ correlation. The DZ correlations of lower than a quarter of the MZ correlations found for Impulsivity, Empathy, and Psychoticism suggest that epistatic interactions might be active in these scales. For Venturesomeness and Lie, although the DZ correlation was not as low as a quarter of the MZ correlation, on the basis of the statistical criteria, the DE model was selected as the most parsimonious model among the competing models. However, as dominance genetic effects alone are unlikely to explain the total genetic effects (Eaves, 1988), the estimates of additive and nonadditive genetic effects found for the ADE model may be close to reality for Venturesomeness and Lie.

If nonadditive genetic effects are important, it may be very difficult to identify individual genes for the trait because even if the individual gene effects may be small, interactions among alleles can make a substantial contribution to the final manifestation of the trait and often mask the effects of the individual genes. For this reason, researchers who search genes for personality traits may need to identify polymorphisms known to be functional within a single neurotransmitter system to elucidate complex interactions of multiple loci (Lesch et al., 2002).

The results of the present study provide a support for the importance of genetic nonadditivity in personality traits found in Caucasian twin samples and show their cross-cultural generality. Although proportions of genetic and environmental influences on variations of personality traits are similar between East Asians and Caucasians, it is possible that the distribution of genetic variations of personality traits may differ between two groups. It would be interesting to examine in future research whether the genetic variances of personality traits vary between East Asians and Caucasians, as well as the origin of these differences.

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