Genetic and Environmental Contributions to Childhood Temperament in South Korean Twins

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Although genetic basis of childhood temperament has been well documented in western populations, little is known about whether genes play an important role in childhood temperament in East Asians. The present study examined mother's ratings of Emotionality, Activity, and Sociability (EAS) in 894 pairs of 2- to 9-year-old South Korean twins. The best-fitting model indicated that 34 to 47% of the variances of the EAS were attributable to genetic factors, with the remaining variances being due to the effects of environmental experiences unique to each child. Common family environmental factors were negligible. Genetic variances for Activity and Sociability were primarily nonadditive, whereas those for Emotionality were additive. In spite of well known cultural differences in child rearing practices, social values, and the mean levels of temperament between East Asian and western populations, the pattern of additive vs. nonadditive gene actions and heritability estimates found in the present sample were remarkably similar to those reported in western twin samples. There were no significant age or sex differences in genetic or environmental influences. Overall, these results corroborate cross cultural generality of genetic influences on childhood temperament.

Keywords: childhood temperament, genetics, environment, twins, culture

Temperament is defined as biologically based individual differences in emotional and physiological reactivity and regulation that are expressed through children's negative and positive emotionality, activity level, and sociability (Buss & Plomin, 1984). Taiwanese, Chinese, and Japanese children have been shown to be lower on approach, less active, expressing higher negative affect, and more inhibited than did Canadian or American children (Chen et al., 1998). Although twin studies conducted in Western countries have consistently documented evidence of genetic influences on childhood temperament, little is known whether genetic factors are an important source of individual differences in temperament in East Asian children. Genetic variances for childhood temperament found in western twins generally fall within the range of 20% to 60%, with the remaining variance being attributable to nonshared environmental factors, that is, the effects of environmental experiences unique to each individual. Family environmental influences on temperament have been reported to be near zero in most Western twin studies (Goldsmith et al., 1997; Plomin et al., 2001; Saudino, 2005).

A cross-cultural comparison of child rearing style found that American mothers displayed higher levels of social stimulation and responsiveness than did Japanese mothers (Bornstein, Tal, & Tamis-LeMonda, 1991). There is also evidence for cultural differences in parental soothing efforts. For example, American parents frequently induced soothing by orienting their infants to external events, and spent more time stimulating their infants into positive expressions of emotion, whereas Japanese parents used rocking and soothing by contact more frequently, perhaps directing attention toward internal events (Caudill & Frost, 1972). Temperament is valued differently between East Asian and Western societies. For instance, whereas behavioral inhibition is positively valued and encouraged in China, it is often regarded as maladaptive behavior and a deficit in social skills in the US (Chen et al., 1998; Ho & Kang, 1984).

Because heritability is a function of genes and environmental factors of the population under study, these cultural differences in child-rearing practices and social values as well as differences in frequencies of genes between Caucasians and East Asians can produce different heritability for childhood temperament between the two populations. Twin studies of childhood temperament have very rarely been undertaken in East Asians. In 44 monozygotic (MZ) and 18 dizygotic (DZ) pairs of Taiwanese infant twins, Chen et al. (1990) found that heritability ranged from 39% for Quality of Mood to 74% for Intensity of Reaction,

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with a mean of 56%. However, the sample used in the Chen et al. study (1990) was too small to make substantial conclusions on genetic influences on temperament in East Asian children. The current study, therefore, explored genetic and environmental contributions to childhood temperament in a relatively large sample of South Korean twins (*N* = 894 pairs). Age and sex differences in genetic and environmental influences on temperament during childhood were also examined.

Materials and Methods

Sample

The present sample was drawn from the South Korean Twin Registry (Hur et al., 2006). As part of a scheduled telephone interview, a Korean version of the Emotionality, Activity, and Sociability Scale (EAS; Buss & Plomin, 1984) was given to mothers of 2- to 9-year-old twins (Mean = 4.3 years; *SD* = 1.7 years). Zygosity was determined from mothers' responses to questions about physical similarity (Ooki et al., 1993). As the questionnaire method is less accurate than DNA analysis, however, we excluded twins whose zygosity was ambiguous from data analyses.

The final sample included 894 twin pairs consisting of 154 monozygotic male (MZM), 123 monozygotic female (MZF), 162 dizygotic male (DZM), 146 dizygotic female (DZF), and 309 opposite-sex dizygotic (OSDZ) twin pairs. Higher number of DZ than MZ twins in the preset sample reflected a recent sharp increase of DZ twin births in South Korea (Hur & Song, 2009).

Measure

The Korean version of the EAS scale used in the present study included 20 items rated on a 5-point Likert scale (1 = *not at all true*, 5 = *certainly true*) (Cheon, 2002). Emotionality refers to distress, the tendency to become upset easily and intensely. Sociability refers to gregariousness and preferences to be with others. Activity represents the tempo, energy, and vigor with which the child behaves (Buss & Plomin, 1984). Internal consistency reliabilities in the present sample were .73 for Emotionality and Activity, and .85 for Sociability.

Table 1

Correlations with Age, Means, and Standard Deviations for the EAS Scales for Males (*N* = 941) and Females (*N* = 847)

Scale	Correlation with age	Mean	SD
Emotionality			
M	–.09**	14.4	3.5
F	–.10**	14.3	3.6
Activity			
M	.02	18.9†	3.4
F	–.07*	17.8†	3.5
Sociability			
M	.06	30.9	5.7
F	.08*	30.5	6.0

Note: M = males, F = females. * p <.05, ** p <.01.
† Means are significantly different between males and females at p < .01.

Statistical Analyses

A general sex-limitation model incorporating age as a moderator was applied to the raw data (Purcell, 2002). First, for each of the EAS scales, a saturated model where all variances and covariances were allowed to vary was fit to the data. Then, to determine the importance of shared environmental factors, the fit of the two full models were compared. The first full model (ACE) included additive genetic (A) and shared (C) and nonshared (E) environmental factors that were allowed to differ as a function of sex and age (M). The second full model (ADE) replaced C with nonadditive genetic factors (D) in the first full model, while holding all other parameters to be the same. The extent to which age moderates A, C (or D), and E was represented in the terms $\beta_{a,}$ β_c (or β_d), and $\beta_{e,}$ respectively. On the basis of the degree of genetic relatedness, the correlations for A were set at 1.0 for MZ, 0.50 for same-sex DZ (SSDZ), and less than 0.50 for OSDZ twins. Because of power constraints, the model included only one nonadditive genetic correlation for DZ twins. Thus, the correlations for D were set at 1.0 for MZ and 0.25 for both SSDZ and OSDZ twins. The correlation for C was set at 1.0 for all types of twins because they were raised together. The correlation for E was set at 0.0 because this variance is unique to each member of a twin pair. E included measurement error.

Model-fitting analyses were performed using Mx (Neale et al., 2003), which calculated twice the negative log-likelihood (–2LL) of the data. Because the difference in –2LL between the full and the nested model is distributed as a chi-square, it allows for a test of the difference in model-fit. A significant change in chi-square suggests that constraining the parameter in the nested model caused a significant decrease in fit of the model, whereas a nonsignificant change indicates that constraining the parameter is acceptable. When alternative models are not nested, Akaike Information Criteria (AIC = –2LL–2df) was used to evaluate superiority among competing models. Generally, models with lower AIC values are considered to represent better and more parsimonious fits to the data than are models with higher AIC values (Loehlin, 1992).

Results

Descriptive Statistics

Means, standard deviations and correlations with age for the EAS scales are presented in Table 1. Although the correlations with age for the EAS scales were statistically significant for four of the six observations, the magnitudes of the correlations were negligible (–.10 < *r* < .06). Sex differences in variance were not significant for any of the EAS scales. Except for Activity, no significant sex differences in mean were observed. In Activity, the mean was higher in males than in females.

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Table 2

Monozyotic and Dizygotic Twin Correlations and Their 95% CI by Sex and Age Group for the EAS Scales

Scale	Age	MZM	DZM	MZF	DZF	OSDZ
Emotionality	Young	.25 (.04–.43)	.26 (.08–.43)	.43 (.21–.61)	.22 (.02–.40)	.18 (.05–.31)
	Old	.38 (.16–.57)	.09 (–.18–.35)	.44 (.22–.63)	.18 (–.09–.42)	.17 (-.03–.35)
	Total	.32 (.17–.45)	.20 (.05–.35)	.43 (.28–.57)	.22 (.06–.36)	.18 (.07–.29)
Activity	Young	.48 (.30–.63)	–.12 (–.30–.07)	.62 (.45–.75)	–.50 (–.63–.33)	–.07 (–.21–.06)
	Old	.44 (.23–.62)	–.05 (–.32–.22)	.53 (.32–.69)	–.04 (–.30–.23)	.01 (–.18–.20)
	Total	.46 (.33–.58)	–.10 (–.25–.05)	.59 (.47–.70)	–.32 (–.46- -.17)	–.04 (–.16–.07)
Sociability	Young	.35 (.15–.52)	–.03 (–.21–.16)	.46 (.25–.63)	–.05 (–.25-.15)	.05 (–.08–.19)
	Old	.32 (.08–.52)	–.09 (–.35–.19)	.34 (.09–.55)	–.30 (–.52–.04)	.10 (–.09–.29)
	Total	.34 (.19–.47)	–.04 (–.19–.11)	.41 (.25–.54)	–.11 (–.27–.05)	.07 (–.04–.18)

Note: Young = 2–4 years; Old = 5–9 years; MZM = monozygotic male twins (young = 88 pairs; old = 66 pairs),
DZM = dizygotic male twins (young = 111 pairs, old = 51 pairs), MZF = monozygotic female twins (young = 65 pairs, old = 58 pairs)
DZF = dizygotic female twins (young = 93 pairs, old =5 3 pairs), OSDZ = opposite-sex dizygotic twins (young = 208 pairs, old=101 pairs).

Twin Correlations

Prior to model-fitting analyses, we divided the total sample into the young (2 to 4 years) and old age group (5 to 9 years) by sex and examined twin correlations for the EAS scale for each group (Table 2). For Emotionality, MZ twin correlations were consistently higher than DZ twin correlations in both sexes in the old age group, suggesting significant genetic influences on this scale. In the young age group, however, MZ twin correlation was higher than DZ twin correlation only in females, indicating some hint of sex differences in the magnitude of genetic and environmental influences on Emotionality.

For Activity, MZ twin correlations were substantially larger than DZ twin correlations in both age groups and in both sexes. Especially, DZ twin correlations were much less than MZ twin correlations, pointing the importance of nonadditive genetic influences on Activity. Twin correlations were not significantly different between the two sexes or between the two age groups in any of the five zygosity groups, suggesting that genetic and environmental influences on Activity are relatively stable during childhood and that sex differences in these influences are minimal. The patterns of twin correlations for Sociability were similar to those found in Activity: There was evidence for nonadditive genetic influences, genetic and environmental factors were similar in magnitude between males and females and between the two age groups.

For all EAS scales, OSDZ twin correlations were not significantly lower as compared to the same-sex DZ twin correlations, suggesting that sex-specific genes are not operating in any of the EAS scales during childhood. Overall, the twin correlations in Table 2 suggest that genetic and environental factors are relatively stable in the preschooler years, and that there are no appreciable sex differences in genetic and environmental influences on temperament measured by the EAS scales. For Activity and Sociability, the importance of genetic nonadditivity was indicated.

Model-Fitting Analyses

Table 3 gives the results of model-fitting analyses. Because the ADE and ACE models were not nested, their relative fits were judged by AIC values for each model. Except for Emotionality, AIC values were lower in the ADE than in the ACE model. However, because the estimate of C in the ACE model for Emotionality was zero and because the difference in AIC between the ADE and ACE model for Emotionality was very small, in order to keep consistency in model, the ADE model was chosen as the baseline full model for all three scales. Variations of the ADE model were made to determine the best-fitting model. For all three scales, elimination of moderating effects of age yielded no significant change in chi-square, indicating stability of genetic and environmental influences on temperament during childhood (Model 3). The genetic weights were fixed to be the same for SSDZ and OSDZ twins (Model 4), suggesting that the same set of genes may be operating in males and females. These results were consistent with those found in correlational analyses. Next, genetic and environmental parameters were equated across two sexes without a significant loss of fit (Model 5), suggesting that the magnitudes of genetic and environmental factors for childhood temperament are similar in males and females. Thus, Model 5 was chosen as the best-fitting one for all three scales. The best-fitting models showed that additive genetic and nonshared environmental factors were, respectively, .37 and .63 for Emotionality, and that nonadditive genetic and nonshared environmental factors were, respectively, .47 and .53 for Activity, .and 34 and .66 for Sociability.

Discussion

Although child rearing practices, social values, the mean level of temperament characteristics in East

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Table 3

Model-Fitting Results

Model	Description	Emotionality					Activity					Sociability				
		–2LL	AIC	df	ΔX^2	*p*	–2LL	AIC	df	ΔX^2	*p*	–2LL	AIC	df	ΔX^2	*p*
1	Full (ADE)	9495.7	5953.7	1771			9380.2	5838.2	1771			11338.3	7796.3	1771		
2	Full (ACE)	9495.4	5953.4	1771			9401.0	5859.0	1771			11347.1	7805.1	1771		
3	$\beta_a = 0, \beta_d = 0, \beta_e = 0$	9504.0	5950.0	1777	8.3	.22	9388.6	5834.6	1777	8.4	.21	11340.2	7786.2	1777	1.9	.93
4	$r_g = 0.5$, $\beta_a = 0, \beta_d = 0, \beta_e = 0$	9504.2	5948.2	1778	8.7	.29	9388.6	5832.6	1778	17.6	.30	11340.4	7784.4	1778	2.1	.96
5	$r_g = 0.5$, & $\beta_a = 0, \beta_d = 0, \beta_e = 0$ $A_m = A_f, D_m = D_f, E_m = E_f$	*9505.1*	*5943.1*	*1781*	*9.4*	*.49*	*9390.3*	*5828.3*	*1781*	*10.2*	*.43*	*11341.6*	*7779.6*	*1781*	*3.3*	*.97*

Note: A = additive genetic effects, C = shared environmental effects, D = nonadditive genetic effects, E = nonshared environmental effects including measurement error. Subscripts m and f refer to male and female, respectively; r_g = genetic correlation for opposite-sex dizygotic twins; β_a = the age moderator effects on additive genetic factors, β_d = the age moderator effects on nonadditive genetic factors, β_e = the age moderator effects on nonshared environmental factors; –2LL = –2 log likelihood. The best-fitting model is in italics.

Asian populations are vastly different from those in western populations (Garstein et al., 2006), estimates of genetic and environmental influences on EAS temperament found in South Korean twins were largely within the range of those reported from western twin studies. Consistent with those found in western twin studies, environmental factors important for temperament in South Korean children were primarily those experiences unique to each child rather than those shared by family members.

In the present study, while genetic factors for Emotionality were primarily additive, those for Activity and Sociability were predominantly nonadditive ones. These results were also in line with those found in western twin studies (Saudino, 2005). Activity and Sociability in childhood are known to be foundations of extraversion in adulthood. Many studies of personality on the basis of Western adult twins consistently demonstrated that nonadditive genetic factors were an important source of variation in extraversion in adulthood. South Korean adolescent and young adult twin studies also showed that nonadditive genetic factors exerted significant influences on personality traits (Hur, 2006; Hur, 2007). Taken together, these results indicate that genetic factors for temperament, especially those nonadditive ones emerge early in childhood and persist into adolescence and young adulthood in the South Korean population, as they do in Western populations.

Studies conducted with young children generally find that individual differences in temperament appear early in life and demonstrate increasing stability from infancy to the preschool years (Rothbart & Bates, 1998). Twin studies of temperament have shown that if heritability estimates of temperament change from infancy to early childhood, they tend to increase. For example, Goldsmith et al. (1997) detected moderate to large genetic contributions only for two indices of negative emotionality, activity level, and interest/persistence during the toddler period. However, during the late preschool years, they found moderate genetic contributions (heritability estimates ranged from .41 to .58) consistently for all temperament dimensions. Both model-fitting and correlational results in the present study suggest that except for Emotionality, genetic and environmental influences on temperament are stable throughout the preschool years. For Emotionality, genetic factors increased, while shared environmental factors decreased although these effects did not attain statistical significance in the current sample. Longitudinal studies with larger sample, therefore, are necessary to determine whether genetic and environmental factors in temperament in the South Korean population change significantly during the preschooler years.

It has been suggested that sex differences in some temperament characteristics begin to emerge by the preschool years (Rothbart, 1989). In the present sample, sex differences in genetic and environmental influences were not significant in any of the EAS scales. These results agreed with some western twin studies (Saudino & Cherny, 2001; Silberg et al., 2005) but not with others (Stevenson & Fielding, 1985). Sex and age differences in genetic and environmental factors could not be detected in the present sample because the sample size was not sufficiently large to separate these effects. Future studies should employ a larger sample to make firm conclusions about sex effects in genetic and environmental influences on childhood temperament.

Significant genetic effects (34% to 47%) found for the EAS scales in the present study suggest that childhood temperament in the South Korean population can be targeted for association analyses to identify specific genes. The DRD4 and 5-HTTLPR polymorphisms known to be involved in adult personality traits have been reported to be associated with negative emotionality in infants as well (Auerbach et al., 1999). A significant association between DRD4 genotypes and intensity of reaction has been also found in 3-year-old children (De Luca et al., 2003). Interestingly, Sheese et al. (2007) noted that children with the DRD4 7-repeat allele were influenced by parenting quality, with lower quality parenting associated with higher levels of sensation seeking; whereas children without the DRD4 7-repeat allele were not influenced by parenting quality. The Sheese et al. study is important in that it points out a significant role of the gene-environment interaction in the temperament development. More recently, Schmidt et al., (2009) found that the DRD4 gene moderated the relation between resting frontal EEG asymmetry at 9 months and temperament at 48 months such that children who exhibited left frontal EEG asymmetry at 9 months and who possessed the DRD4 long allele were significantly more soothable at 48 months than other children, whereas those with right frontal EEG asymmetry at 9 months had significantly more difficulties focusing attention at 48 moths even if they had DRD4 long alleles. Although these results are interesting, they should be interpreted with caution until they have been replicated in various samples.

Limitations of the present study include the use of a single measure of parental rating. Parents have been reported to exaggerate dissimilarity of DZ twins (sibling-contrast effects), which may have caused overestimation of genetic contributions and underestimations of shared environmental contributions to temperament (Saudino et al., 2000). Sibling-contrast effects are difficult to detect in a classical twin design. However, the male DZ twins in the present sample had slightly but significantly larger variance than did MZ twins for Activity, providing suggestive evidence for sibling-contrast effects. Hints of sibling-contrast effects have also been indicated in several negative DZ twin correlations, especially in Activity (See Table 2). Future studies, therefore, should use multiple raters of temperament as well as nontwin family members to investigate the extent to which sibling contrast effects affected the estimates of genetic influences on temperament found in the present study.

Although the importance of nonadditive genetic factors in Activity and Sociability found in the present study largely support previous studies, the estimates should be viewed with caution. It has been argued that classical twin studies typically do not have sufficient power to discriminate between additive and nonadditive genetic effects (Eaves, 1988; Martin et al., 1978). Thus, estimates of genetic nonadditvity for Sociaiblity and Activity found in the present study are likely to be a sum of both additive and nonadditive genetic effects.

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