
Early Childhood Temperament and the Covariation Between Internalizing and Externalizing Behavior in School-Aged Children

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There is significant covariation between internalizing and externalizing behavior, although there is also evidence that internalizing behavior is a protective factor against externalizing behavior. Several researchers have posited that the examination of the relationship between temperament or personality and behavior problems may help explain these seemingly contradictory results. Specifically, negative emotionality or neuroticism has been cited as a temperament characteristic that internalizing and externalizing behavior share in common, whereas behavioral inhibition may be related only to internalizing behavior. We examined the degree to which the covariation between internalizing and externalizing behavior assessed from age 4 to 12 years can be explained by temperament characteristics assessed from age 14 to 36 months. Additionally, we assessed the extent to which this relationship is due to genetic or environmental factors, analyzing data from 225 monozygotic and 185 dizygotic twin pairs assessed by the Colorado Longitudinal Twin Study. In males, a portion of the covariation between internalizing and externalizing behavior was explained by shared environmental influences in common with emotionality and shared environmental influences in common with shyness. In females, most of the covariation between internalizing and externalizing behavior was explained by shared environmental influences in common with emotionality. A possible limitation of this study is that the covariation between temperament and behavior problems may be due to shared measurement variance, as parent ratings were used to assess both temperament and behavior problems.

There is significant covariation between internalizing and externalizing behavior and between internalizing and externalizing disorders (Lilienfeld, 2003; Loeber & Keenan, 1994). Also, socially withdrawn children are more at risk for conduct problems (e.g., Serbin et al., 1991). On the other hand, shyness or anxiety that occurs in childhood without co-occurring early

conduct problems is a protective factor against later conduct problems (e.g., Sanson et al., 1996), and delinquents with higher levels of anxiety have a lower risk of recidivism (e.g., Quay & Love, 1977). Therefore, it is unclear whether internalizing behavior is a protective factor or a risk factor for externalizing behavior.

Several researchers have posited that the examination of the relation between temperament/personality and behavior problems may help explain these seemingly contradictory results. Specifically, negative emotionality (i.e., the increased tendency to experience negative emotions such as guilt, anxiety, mistrust, and irritability or the tendency to experience negative emotions frequently, intensely, and with little provocation) has been cited as a temperament characteristic that internalizing and externalizing behavior or disorders share in common (e.g., Lahey & Waldman, 2003; Lilienfeld, 2003). Other terms referring to the same construct include neuroticism and negative affectivity. In contrast, daring (i.e., adventurousness and enjoyment of loud, rough, and risky activities) may be a temperament characteristic related only to externalizing behavior, and may be a trait that differentiates internalizing and externalizing behavior (e.g., Lahey & Waldman, 2003). It is similar to several other constructs, including sensation seeking (Zuckerman, 1996) or novelty seeking (e.g., Cloninger, 1987) and extraversion/surgency (e.g., Rothbart et al., 2001), and inversely related to the constructs of behavioral inhibition (e.g., Kagan et al., 1988), harm avoidance (Cloninger, 1987), constraint (e.g., Tellegen, 1982), and shyness (Rowe & Plomin, 1977).

Lahey and Waldman (2003) propose that internalizing behavior that reflects negative emotionality is a risk factor for the development of externalizing

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behavior, whereas internalizing behavior that reflects low daring is a protective factor against the development of externalizing behavior. Moffitt et al. (2002) found support for Lahey and Waldman's (2003) hypothesis in their age 26 follow-up of the Dunedin Longitudinal Study. Males who were not antisocial from childhood to age 26 were high in constraint (inverse of daring) and low in negative emotionality during adolescence, whereas males who had life-course-persistent conduct problems were low in constraint and high in negative emotionality during adolescence. Keiley et al. (2003) found that difficulty (i.e., negative emotionality) was related to the covariance between internalizing and externalizing symptoms. Resistance to control (i.e., daring) was related to externalizing symptoms and the covariance between internalizing and externalizing symptoms. Although statistically nonsignificant, resistance to control was negatively related to internalizing symptoms. Unadaptability (i.e., behavioral inhibition or the inverse of daring) was positively related to internalizing symptoms and negatively related to externalizing symptoms. Krueger et al. (2001) conducted factor analyses of personality measures and eight common psychiatric disorders. In contrast to Lahey and Waldman's predictions, Krueger et al. found that negative emotionality was positively correlated with internalizing disorders, but not with externalizing disorders. As predicted by Lahey and Waldman, however, constraint (i.e., low daring) was negatively correlated with externalizing disorders and uncorrelated with internalizing disorders.

A prospective study examining temperament in early childhood and behavior problems in middle childhood also lends support to Lahey and Waldman's (2003) hypothesis. Schmitz et al. (1999) examined the relationship between temperament (measured by the Colorado Childhood Temperament Inventory [CCTI]) and behavior problems (measured by the Child Behavior Checklist [CBCL]) in the Colorado Longitudinal Twin Study. Supporting Lahey and Waldman's hypotheses, they found that the emotionality scale of the CCTI was correlated significantly with both the internalizing and externalizing broadband scales of the CBCL, whereas the shyness scale of the CCTI was correlated significantly only with the internalizing broadband scales of the CBCL.

In the present study, we conducted an extension of the Schmitz et al. (1999) study, examining the degree to which internalizing behavior, externalizing behavior, and the covariation between internalizing and externalizing behavior can be explained by emotionality and shyness assessed in early childhood, and the degree to which the relationship between temperament and behavior problems is due to common genetic, shared environmental, and nonshared environmental influences. Temperament assessed in early childhood before the appearance of behavior problems was examined. If Lahey and Waldman's (2003) hypotheses are correct,

genetic and environmental influences on emotionality should be positively correlated with those influencing both internalizing and externalizing behavior. Genetic and environmental influences on shyness, however, should be positively correlated with those influencing internalizing behavior but negatively correlated with those influencing externalizing behavior.

Method

Participants

The Colorado Longitudinal Twin Study (LTS) is a sample of same-sex twin pairs recruited through the Colorado Department of Health born between 1986 and 1991 in Colorado. Of the parents initially contacted, more than 50% of the families who mainly lived within a 2-hour drive of Boulder, Colorado enrolled in the study. A total of 108 monozygotic (MZ) male, 96 dizygotic (DZ) male, 117 MZ female, and 89 DZ female pairs were included in the present study. Only same-sex twin pairs are included in the present study because the Colorado Longitudinal Twin Study recruited same-sex twin pairs only. Data on emotionality and shyness were available for 103 MZ male, 94 DZ male, 114 MZ female, and 82 DZ female pairs, and data on internalizing and externalizing behavior were available for 96 MZ male, 90 DZ male, 100 MZ female, and 79 DZ female pairs. The ethnic distribution of the LTS sample examined here (i.e., 87.0% Caucasian, 8.6% Hispanic, 0.2% African American, 1.3% Asian, and 2.9% other) corresponds well to that reported for Boulder County, Colorado in the 1990 United States Census (89.5% Caucasian, 3.8% Hispanic, 0.9% African American, 2.4% Asian, and 3.4% other; US Census Bureau, 1990). The mean number of years of education for the LTS sample was 14.29 years for mothers and 14.42 years for fathers, and of all parents, 5% did not complete high school, 29% completed high school without post-secondary education, 49% had some post-secondary education, and 17% had some graduate-level education. In comparison, for adults aged 25 years and over in Boulder County, Colorado as reported in the 1990 United States Census, 9% did not complete high school; 20% completed high school; 55% completed some college, an associate degree, or a bachelor's degree; and 16% completed a graduate or professional degree (<http://www.census.gov>).

Zygosity of the twin pairs was determined using ratings from the testers across the ages. Twin similarity on 10 physical characteristics (e.g., eye color, hair color, shape of the ears; Nichols & Bilbro, 1966) was rated by the testers each time the twins were seen in person. Twins who were rated highly similar (1 or 2 on a 5-point similarity scale) across the ages were rated as MZ, and twins who had two or more features rated as only somewhat similar (3 on the similarity scale) or one feature rated as not at all similar (4 or 5 on the similarity scale) were rated as DZ. Twin pairs were considered unambiguously MZ or DZ if 85% of the raters agreed

on their zygosity, and blood testing was used to resolve ambiguity in nine twin pairs. Zygosity ratings were later confirmed for continuing participants using 11 polymorphic microsatellite markers.

Measures

The CCTI (Rowe & Plomin, 1977) assesses emotionality, activity, persistence, soothability, shyness, and sociability. Of these scales, the emotionality and shyness scales are the most similar to the constructs of negative emotionality and the inverse of daring described by Lahey and Waldman (2003). The emotionality scale assesses five items regarding children's general emotionality (i.e., child cries easily, child tends to be somewhat emotional, child often fusses and cries, child gets upset easily, child reacts intensely when upset), and the shyness scale assesses five items regarding a child's shyness (i.e., child tends to be shy, child makes friends easily, child is very sociable, child takes a long time to warm up to strangers, child is very friendly with strangers). The CCTI data from parental reports at ages 14 months, 20 months, 24 months, and 36 months (prior to the assessment of behavior problems) were used in this study. The CBCL (Achenbach, 1991) is a parent questionnaire designed to assess eight behavior problem scales and two broadband scales, internalizing and externalizing. The CBCL was administered to the twins' parents at ages 4, 5, 7, 9, 10, 11, and 12.

There are two items in the CBCL internalizing scale that resemble items in the CCTI. The item 'cries a lot' in the CBCL resembles 'child cries easily' and 'child often fusses and cries' in the CCTI emotionality scale, and the item 'shy or timid' in the CBCL resembles 'child tends to be shy' in the CCTI shyness scale. After these items were removed from the CBCL internalizing scale, the correlation between the CBCL internalizing scale and the CCTI emotionality and shyness scales were statistically significant and only slightly lower than the correlations between the original CBCL internalizing scale and the CCTI emotionality and shyness scale (r shyness-internalizing = .13 in males and .16 in females, cf. .16 in males and .18 in females with the original scale; r emotionality-internalizing = .22 in males and .25 in females, cf. .24 in males and .25 in females with the original scale).

Analyses

The phenotypic age-to-age correlations range from .45 (between 14 months and 36 months) to .60 (between 20 months and 24 months) for emotionality, from .43 (between 14 months to 36 months) to .68 (between 20 months and 24 months) for shyness, from .34 (between 4 years and 12 years) to .72 (between 9 years and 11 years) for internalizing behavior, and from .44 (between 4 years and 12 years) to .82 (between 9 years and 10 years) for externalizing behavior. The average temperament and behavior problem scores across the ages were examined in order to examine the most reliable phenotypes

possible and given evidence of age-to-age stability and genetic contributions to the phenotypic age-to-age correlations for emotionality and shyness (Saudino & Cherny, 2001) and internalizing and externalizing behavior (Haberstick et al., 2005, 2006). The average temperament scores are the mean of the emotionality and shyness scores across ages 14 months, 20 months, 24 months, and 36 months, and the average behavior problem scores are the mean of the internalizing and externalizing scores across ages 4, 5, 7, 9, 10, 11, and 12 years.

All data were square root transformed given that behavior problem data were positively skewed. The square root transformed scores were z -scored within the sexes to control for sex differences. The descriptive statistics for each sex and zygosity group are presented in Table 1. Although the data were z -scored within the sexes, the means are not zero, given that they were not z -scored within MZ and DZ twin pairs and there were unequal numbers of MZ and DZ twin pairs. In general, the variances are larger in the DZ twin pairs than in the MZ twin pairs for all variables. Given missing data, analyses were conducted on raw data.

Phenotypic correlations, within-trait/cross-twin correlations, and cross-trait/cross-twin correlations were calculated and univariate and multivariate genetic analyses were conducted using Mx. Alternative univariate models including additive genetic influences (A), nonadditive genetic influences (D), shared environmental influences (C), nonshared environmental

Table 1
Descriptive Statistics

	Mean	Variance	Minimum	Maximum
Internalizing				
MZ males	-0.12	0.97	-2.11	2.80
DZ males	0.12	1.00	-2.11	2.49
MZ females	0.00	0.85	-2.14	2.58
DZ females	0.00	1.20	-2.14	4.04
Externalizing				
MZ males	-0.07	0.94	-2.49	3.13
DZ males	0.08	1.06	-2.49	2.56
MZ females	0.05	0.95	-2.19	2.71
DZ females	-0.06	1.06	-2.19	4.32
Shyness				
MZ males	-0.04	0.97	-2.20	2.21
DZ males	0.05	1.04	-2.20	2.07
MZ females	0.09	0.87	-2.48	2.05
DZ females	-0.13	1.16	-2.48	2.29
Emotionality				
MZ males	-0.14	0.94	-3.39	2.00
DZ males	0.16	1.02	-2.93	2.34
MZ females	0.00	0.99	-3.31	2.52
DZ females	0.01	1.02	-2.43	2.37

Note: MZ = monozygotic; DZ = dizygotic.

Table 2

Phenotypic Correlations (Confidence Intervals)

	Males	Females
Internalizing–externalizing	.66 (.61, .71)	.69 (.63, .73)
Shyness–emotionality	.28 (.18, .37)	.32 (.23, .41)
Shyness–internalizing	.16 (.05, .26)	.18 (.07, .29)
Shyness–externalizing	.02 (–.09, .12)	.01 (–.11, .13)
Emotionality–internalizing	.24 (.13, .34)	.25 (.13, .35)
Emotionality–externalizing	.17 (.06, .28)	.32 (.20, .42)

influences (E), and sibling contrast effects (i.e., one sibling's phenotype having a negative influence on the other sibling's phenotype; B) were tested. These alternative models were the ACE, ADE, AE, CE, ACE-B, and AE-B models. First, heterogeneity models allowing separate parameters for males and females were tested to evaluate the possibility of sex differences in the magnitude of genetic and environmental influences, and the best fitting heterogeneity model (i.e., that with the lowest χ^2 relative to its degrees of freedom and Akaike's information criterion [AIC; Akaike, 1987]) was compared to a homogeneity model fixing the parameters to be equal between males and females.

Cholesky models examining two sets of variables — (1) those that examine the covariance among emotionality, internalizing behavior, and externalizing behavior, and (2) those that examine the covariance among shyness, internalizing behavior, and externalizing behavior — were conducted (see Figure 1). These models include additive genetic, shared environmental, and nonshared environmental influences that are (1) common to temperament, internalizing behavior, and externalizing behavior; (2) common to internalizing behavior and externalizing behavior (but do not influence temperament); and (3) unique to externalizing behavior. The multivariate Cholesky models partition the covariance between temperament and

behavior problems into those due to common genetic and environmental influences, and partition the covariance between internalizing and externalizing behavior into those due to genetic and environmental influences shared with temperament.

Results

Table 2 presents the phenotypic correlations between internalizing and externalizing behavior, between shyness and emotionality, and between temperament and behavior problems. Results were similar in males and females. There was a large correlation between internalizing behavior and externalizing behavior and a moderate correlation between shyness and emotionality. Emotionality was moderately correlated with both internalizing and externalizing behavior. Shyness was moderately correlated with internalizing behavior, but uncorrelated with externalizing behavior.

Table 3 presents the within-trait/cross-twin correlations and the cross-twin/cross-trait correlations between MZ and DZ twin pairs in males and females. The within-trait/cross-twin correlations suggest that there are both additive genetic and shared environmental influences on internalizing and externalizing behavior, given higher MZ than DZ correlations and DZ correlations that are higher than half the MZ correlations. They suggest additive genetic influences and possible contrast effects or nonadditive genetic influences on emotionality and shyness, given moderate MZ correlations and low or negative DZ correlations. The cross-twin/cross-trait correlations do not suggest consistent evidence of common genetic influences between temperament and behavior problems, as the MZ cross-twin/cross-trait correlations are higher than the DZ cross-twin/cross-trait correlations for some traits (e.g., emotionality and internalizing behavior in males) and the DZ cross-twin/cross-trait correlations are higher than the MZ cross-twin/cross-trait correlations for some traits (e.g., shyness and externalizing behavior in males).

Table 3

Within-Trait/Cross-Twin Correlations and Cross-Twin/Cross-Trait Correlations

	MZ males	DZ males	MZ females	DZ females
Internalizing	.83 (.77, .87)	.52 (.35, .63)	.83 (.77, .87)	.75 (.66, .81)
Externalizing	.89 (.85, .91)	.56 (.42, .66)	.88 (.83, .91)	.57 (.43, .67)
Shyness	.55 (.41, .65)	–.08 (–.26, .11)	.62 (.50, .70)	.00 (–.18, .18)
Emotionality	.59 (.45, .68)	–.06 (–.25, .13)	.56 (.43, .65)	.18 (–.03, .36)
Internalizing–externalizing	.62 (.56, .68)	.52 (.41, .61)	.69 (.63, .74)	.67 (.60, .73)
Shyness–emotionality	.19 (.07, .30)	.08 (–.07, .22)	.26 (.15, .37)	.09 (–.06, .23)
Shyness–internalizing	.11 (–.01, .22)	.12 (–.02, .25)	.19 (.06, .30)	.01 (–.12, .14)
Shyness–externalizing	.02 (–.10, .13)	.18 (.05, .30)	.03 (–.09, .15)	.16 (.01, .30)
Emotionality–internalizing	.23 (.11, .34)	.13 (–.01, .25)	.22 (.09, .33)	.26 (.13, .38)
Emotionality–externalizing	.23 (.11, .34)	.14 (.01, .26)	.27 (.15, .38)	.20 (.04, .34)

Note. MZ = monozygotic; DZ = dizygotic.

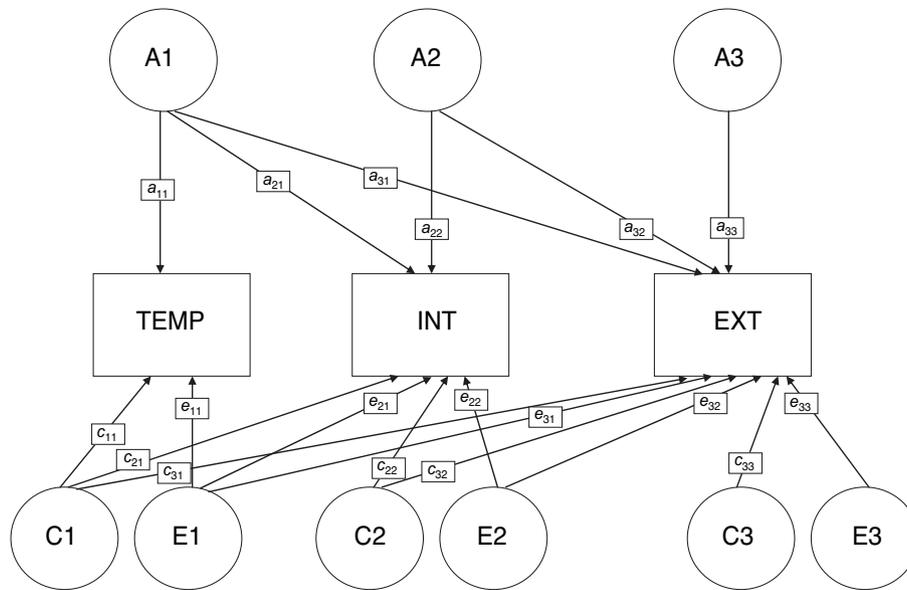


Figure 1

Multivariate model examining the covariance among temperament, internalizing behavior, and externalizing behavior. A1/C1/E1 = additive genetic influences/shared environmental influences/nonshared environmental influences common to temperament, internalizing behavior, and externalizing behavior; A2/C2/E2 = additive genetic influences/shared environmental influences/nonshared environmental influences common to internalizing and externalizing behavior (but not temperament); A3/C3/E3 = additive genetic influences/shared environmental influences/nonshared environmental influences unique to externalizing behavior; TEMP = temperament; INT = internalizing behavior; EXT = externalizing behavior.

The low or negative within-trait/cross-twin DZ correlations for emotionality and shyness suggest possible contrast effects or nonadditive genetic influences. However, most of the cross-twin/cross-trait DZ correlations between temperament and behavior problems are positive and moderate. These results suggest that there are no contrast effects between one twin's temperament and the other twin's behavior problems, and that there may be common shared environmental influences such as rater bias effects between temperament and behavior problems.

Table 4 presents the univariate model fitting results. First, the results of heterogeneity models with separate parameters for males and females are shown. Alternative models (i.e., ADE, ACE, AE, CE, ACE-B, and AE-B) were tested, but only the best fitting heterogeneity model is shown. Second, the results of the homogeneity model fixing the parameters to be equal between males and females are shown. Among the heterogeneity models, the ACE model fit best for internalizing and externalizing behavior problems, whereas the AE-B model fit best for shyness and emotionality. For externalizing behavior, shyness, and emotionality, fixing the parameters to be equal in males and females did not result in a significant decrement in fit; the homogeneity model clearly fit better than the heterogeneity model, and the parameter estimates were very similar for males and females. For internalizing behavior, although the homogeneity model did not fit significantly worse than the heterogeneity model, the fit of the homogeneity and

heterogeneity models are similar by the AIC. Also, the results suggest that the magnitude of genetic influences is higher in males and the magnitude of shared environmental influences is higher in females, and these differences may have been statistically significant in a larger sample. Therefore, all subsequent analyses were conducted for males and females separately. Also, given the univariate results, subsequent multivariate analyses included additive genetic influences, shared environmental influences, and nonshared environmental influences on all variables and a sibling contrast effect for shyness and emotionality.

Table 5 shows the results of the multivariate models examining the covariance among emotionality, internalizing behavior, and externalizing behavior, and among shyness, internalizing behavior, and externalizing behavior. See Figure 1 for definitions of the path loadings. Path loadings that are statistically significant are in bold. The sibling contrast effects for shyness and emotionality, although included in the multivariate models, are not in Table 5. The sibling contrast effect was $-.22$ for emotionality and $-.25$ for shyness in males and $-.12$ for emotionality and $-.78$ for shyness in females. (The sibling contrast effect from the multivariate model is sometimes higher than that from the univariate model given the need to compensate for moderate DZ cross-twin/cross-trait correlations.)

For males, additive genetic influences and shared environmental influences on emotionality do not contribute significantly to internalizing or externaliz-

Table 5

Path Loadings (95% Confidence Intervals) in the Full Model

	Emotionality–Internalizing–Externalizing		Shyness–Internalizing–Externalizing	
	Males	Females	Males	Females
Genetic influences				
a11 (A1-temperament)	0.92 (0.001, 1.05)	0.79 (0.03, 0.96)	0.87 (0.23, 1.01)	0.27 (0.002, 0.87)
a21 (A1-internalizing)	0.16 (–0.06, 0.38)	–0.08 (–0.34, 0.19)	–0.10 (–0.34, 0.12)	0.24 (0.04, 0.42)
a31 (A1-externalizing)	0.15 (–0.06, 0.37)	0.07 (–0.18, 0.36)	–0.24 (–0.46, –0.02)	–0.18 (–0.41, 0.08)
a22 (A2-internalizing)	0.68 (0.50, 0.84)	0.29 (0.07, 0.52)	0.69 (0.50, 0.85)	0.30 (0.13, 0.48)
a32 (A2-externalizing)	0.40 (0.18, 0.60)	0.52 (0.17, 0.75)	0.39 (0.17, 0.59)	0.60 (0.33, 0.74)
a33 (A3-externalizing)	0.63 (0.52, 0.72)	–0.37 (–0.59, 0.59)	0.61 (0.49, 0.70)	0.00 (–0.49, 0.49)
Shared environmental influences				
c11 (C1-temperament)	0.24 (–2.60, 2.60)	0.38 (0.11, 24.50)	0.41 (0.07, 1.39)	1.41 (0.60, 2.21)
c21 (C1-internalizing)	0.58 (–0.77, 0.77)	0.85 (0.20, 0.98)	0.58 (0.10, 0.76)	0.12 (–0.13, 0.32)
c31 (C1-externalizing)	0.57 (–0.76, 0.76)	0.69 (0.14, 0.84)	0.57 (0.08, 0.76)	0.12 (–0.03, 0.34)
c22 (C2-internalizing)	0.00 (–0.69, 0.69)	0.00 (–0.88, 0.88)	0.00 (–0.67, 0.67)	0.81 (0.71, 0.94)
c32 (C2-externalizing)	0.00 (–0.69, 0.69)	0.00 (–0.74, 0.74)	0.00 (–0.68, 0.68)	0.69 (0.53, 0.83)
c33 (C3-externalizing)	0.00 (–0.28, 0.28)	0.00 (–0.24, 0.24)	0.00 (–0.28, 0.28)	0.00 (–0.22, 0.22)
Nonshared environmental influences				
e11 (E1-temperament)	0.49 (*, 0.62)	0.58 (*, 0.75)	0.50 (0.17, 0.63)	0.13 (*, 0.45)
e21 (E1-internalizing)	0.02 (–0.08, 0.11)	0.04 (–0.05, 0.13)	0.08 (–0.01, 0.18)	0.01 (–0.07, 0.10)
e31 (E1-externalizing)	–0.09 (–0.17, –0.01)	0.07 (–0.003, 0.15)	0.00 (–0.07, 0.08)	–0.04 (–0.12, 0.04)
e22 (E2-internalizing)	0.43 (0.37, 0.49)	0.44 (0.38, 0.50)	0.42 (0.36, 0.49)	0.42 (0.37, 0.48)
e32 (E2-externalizing)	0.09 (0.03, 0.16)	–0.06 (–0.14, 0.01)	0.09 (0.02, 0.16)	–0.04 (–0.11, 0.03)
e33 (E3-externalizing)	0.32 (0.27, 0.37)	0.36 (0.31, 0.42)	0.33 (0.28, 0.38)	0.37 (0.32, 0.43)

Note: See Figure 1 for definition of path loadings. Statistically significant path loadings are in bold. A1/C1/E1 = additive genetic influences/shared environmental influences/nonshared environmental influences common to temperament, internalizing behavior, and externalizing behavior; A2/C2/E2 = additive genetic influences/shared environmental influences/nonshared environmental influences common to internalizing and externalizing behavior (but not temperament); A3/C3/E3 = additive genetic influences/shared environmental influences/nonshared environmental influences unique to externalizing behavior.

* = The confidence interval could not be determined. When confidence intervals are symmetric, the other parameter estimates in the model are the same for the lower and upper confidence interval, but may have opposite signs.

Table 6Correlations Between Genetic (r_G), Shared Environmental (r_C), and Nonshared Environmental (r_E) Influences Shared by Temperament and Behavior Problems

	Males			Females		
	r_G	r_C	r_E	r_G	r_C	r_E
Emotionality–internalizing	.23	1.00	.04	–.25	1.00	.09
Emotionality–externalizing	.20	1.00	–.27	.11	1.00	.20
Shyness–internalizing	–.14	1.00	.19	.61	.15	.03
Shyness–externalizing	–.31	1.00	.01	–.29	.18	–.09

ing behavior. Nonshared environmental influences on emotionality have a significant but inverse influence on externalizing behavior. For females, additive genetic influences and nonshared environmental influences on emotionality do not influence internalizing or externalizing behavior, but there is evidence of significant common shared environmental influences among emotionality, internalizing behavior, and externalizing behavior.

For males, additive genetic influences on shyness do not influence internalizing behavior, but have a

significant, inverse influence on externalizing behavior. There is evidence of significant common shared environmental influences among shyness, internalizing behavior, and externalizing behavior, and no evidence of common nonshared environmental influences among shyness, internalizing behavior, and externalizing behavior. For females, there is evidence of significant common additive genetic influences between shyness and internalizing behavior, but not between shyness and externalizing behavior, and no evidence of either common shared environmental or

nonshared environmental influences among shyness, internalizing behavior, and externalizing behavior.

Given the small sample size and concerns regarding lack of power, the results were interpreted in two other ways. First, one can examine the correlations between the genetic (r_G), shared environmental (r_C), and nonshared environmental (r_E) influences on temperament and behavior problems. The r_G , r_C , and r_E estimates are shown in Table 7. Second, the covariance between temperament and behavior problems can be divided into those attributable to common genetic, shared environmental, and nonshared environmental influences using parameters in the full model. Table 7 shows the phenotypic correlations between emotionality and internalizing/externalizing behavior, the phenotypic correlation between shyness and internalizing/externalizing behavior, and the phenotypic correlation between temperament and behavior problems attributable to common genetic, shared environmental, and nonshared environmental influences.

It is possible to use the models illustrated in Figure 1 to decompose the covariance among temperament, internalizing behavior, and externalizing behavior into genetic, shared environmental, and nonshared environmental influences. For example, the covariance between emotionality and internalizing behaviors due to common genetic influences is ($a_{11} \times a_{12}$), the covariance due to shared environmental influences is

($c_{11} \times c_{12}$), and the covariance due to nonshared environmental influences is ($e_{11} \times e_{12}$).

Given that there is a significant sibling contrast effect for emotionality and shyness, the variances of these variables and the phenotypic correlations between temperament and behavior problems are different for MZ and DZ twins. Neale and Maes (2004) explain how a sibling contrast effect has consequences for the variation and covariation between MZs and DZs (see Table 8.3 on p. 159). Therefore, in Table 7, results are presented separately for MZ and DZ twins. The overall conclusions are very similar for MZ and DZ twins, however.

For males, the covariance between emotionality and internalizing behavior and between emotionality and externalizing behavior were due to both common additive genetic and shared environmental influences. The covariance between shyness and internalizing behavior was due mostly to common shared environmental influences. The covariance between shyness and externalizing behavior was very low. For females, the results suggest that the covariance between emotionality and internalizing, between emotionality and externalizing, and between shyness and internalizing are due mostly to common shared environmental influences. Again, the covariance between shyness and externalizing behavior was very low.

Table 8 shows the phenotypic correlation between internalizing and externalizing behavior, the degree to

Table 7
Covariation between Temperament and Behavior Problems

	Phenotypic Correlation	Phenotypic Correlation Attributable to		
		A	C	E
MZ males				
Emotionality–internalizing	.26	.13	.12	.01
Emotionality–externalizing	.19	.12	.12	–.05
Shyness–internalizing	.17	–.07	.20	.04
Shyness–externalizing	.03	–.19	.22	.00
DZ males				
Emotionality–internalizing	.25	.13	.11	.01
Emotionality–externalizing	.19	.13	.11	–.05
Shyness–internalizing	.14	–.08	.18	.04
Shyness–externalizing	.00	.00	.00	.00
MZ females				
Emotionality–internalizing	.26	–.05	.29	.02
Emotionality–externalizing	.33	.05	.24	.04
Shyness–internalizing	.15	.04	.11	.00
Shyness–externalizing	.06	–.03	.10	–.01
DZ females				
Emotionality–internalizing	.25	–.05	.28	.02
Emotionality–externalizing	.32	.05	.23	.04
Shyness–internalizing	.18	.09	.09	.00
Shyness–externalizing	.01	–.09	.11	–.01

Note. MZ = monozygotic; DZ = dizygotic; A = additive genetic influences; C = shared environmental influences; E = nonshared environmental influences

Table 8
Covariation Between Internalizing and Externalizing Behavior Explained by Temperament

$r_{\text{Internalizing-Externalizing}}$	Attributable to Emotionality	Attributable to Emotionality			Attributable to Shyness	A_{Shyness}	C_{Shyness}	E_{Shyness}
		$A_{\text{Emotionality}}$	$C_{\text{Emotionality}}$	$E_{\text{Emotionality}}$				
Males								
.66	.36	.03	.33	.00	.36	.03	.33	.00
Males (effect of shyness controlled for covariation with emotionality)								
.66	.24	.02	.22	.00	.14	.04	.10	.00
Females								
.69	.57	.00	.57	.00	.00	—	—	—

Note. A = additive genetic influences; C = shared environmental influences; E = nonshared environmental influences.

which the correlation between internalizing and externalizing behavior is attributable to emotionality and shyness, and the degree to which the correlation between internalizing and externalizing behavior is attributable to genetic, shared environmental, and nonshared environmental influences common to those for emotionality and shyness. For example, in Figure 1, the covariation between internalizing and externalizing behaviors due to genetic influences in common with emotionality is $(a_{12} \times a_{13}) / [(a_{12} \times a_{13}) + (a_{21} \times a_{22})]$, due to shared environmental influences in common with emotionality is $(c_{12} \times c_{13}) / [(c_{12} \times c_{13}) + (c_{21} \times c_{23})]$, and due to nonshared environmental influences in common with emotionality is $(e_{12} \times e_{13}) / [(e_{12} \times e_{13}) + (e_{21} \times e_{23})]$. The results in Table 8 are derived from the results of trivariate analyses examining the covariance among emotionality, internalizing behavior, and externalizing behavior, and the trivariate analyses examining the covariance among shyness, internalizing behavior, and externalizing behavior.

For males, approximately half of the covariance between internalizing and externalizing behavior was attributable to shared environmental influences common with those on emotionality. Similar results were found for shyness. However, shyness may explain some of the covariance between internalizing and externalizing behavior because of its covariance with emotionality. Therefore, we also conducted quadrivariate analyses examining emotionality, shyness, internalizing behavior, and externalizing behavior, examining the degree to which the covariation between internalizing behavior and externalizing behavior is due to emotionality and the unique effects of shyness after controlling for emotionality (shown on the second results line of Table 8). Results were similar, suggesting that a moderate degree of the covariance between internalizing and externalizing behavior is due to shared environmental influences common with those on emotionality and shyness. For females, a substantial amount of the covariance between internalizing and externalizing behavior was attributable to shared environmental influences common with those on emotionality. None of the covariance between internalizing and externalizing behavior was attributable to shyness.

Discussion

Lahey and Waldman (2003) defined temperament as ‘substantially heritable and relatively persistent individual differences in global aspects of socio-emotional responding that emerge early in childhood and constitute the foundation for many personality traits later in life’, and psychopathology as ‘more specific behaviors with serious consequences for adaptive functioning (pp. 80–81). They hypothesize that different temperament dimensions, such as shyness and emotionality, are influenced by unique genetic influences, and that genes influence behavior problems indirectly via temperament. If their hypothesis is correct, the identification of specific genes influencing behavior problems should be facilitated by examining the association between temperament and behavior problems, given that it should be easier to find genes influencing distinct temperament dimensions rather than overlapping genes that indirectly influence behavior problems.

Few genetically informative, longitudinal studies have examined the association between temperament and behavior problems (Saudino, 2005). Schmitz et al. (1999) examined the association between shyness and internalizing behavior, emotionality and internalizing behavior, and emotionality and externalizing behavior for temperament assessed from 14 to 36 months and behavior problems assessed at age 4 years in the LTS sample. They found evidence of significant common genetic influences between shyness and internalizing behavior, emotionality and internalizing behavior, and emotionality and externalizing behavior. Schmitz and Saudino (2003) examined the association between emotionality assessed during the grade school years and behavior problems assessed at age 12 in the Colorado Adoption Project and found different results for teacher and parent ratings. There was evidence of common genetic influences between emotionality and internalizing behavior and emotionality and externalizing behavior for teacher ratings, but no evidence of genetic influences on emotionality or common genetic influences between emotionality and behavior problems for parent ratings. Gjone and Stevenson (1997) examined the association between temperament and more specific scales from the CBCL in Norwegian

twins aged 7 to 17. There were no common genetic or shared environmental influences between any temperament scale and anxious/depressed or delinquent behavior. However, there were significant common genetic influences between emotionality and attention problems and emotionality and aggressive behavior.

Using multivariate analyses, the present study examined the relationship between temperament assessed in early childhood and behavior problems assessed in middle childhood. The main goal of these analyses was to test Lahey and Waldman's (2003) hypothesis that internalizing behavior reflecting negative emotionality is a risk factor for the development of externalizing behavior, whereas internalizing behavior reflecting low daring is a protective factor against the development of externalizing behavior. This hypothesis explains the seemingly contradictory results from the literature suggesting that internalizing behavior is both a risk factor for (e.g., Loeber & Keenan, 1994) and a protective factor against (e.g., Sanson et al., 1996) externalizing behavior. If Lahey and Waldman's (2003) hypothesis is correct, genetic and environmental influences on emotionality should be positively correlated with those influencing both internalizing and externalizing behavior. Genetic and environmental influences on shyness (i.e., low daring), however, should be positively correlated with those influencing internalizing behavior but negatively correlated with those influencing externalizing behavior.

The phenotypic correlation between internalizing and externalizing behavior was .66 to .69. As reported in Schmitz et al. (1999), there was a moderate correlation between emotionality and both internalizing and externalizing behavior and between shyness and internalizing behavior, but not a statistically significant correlation between shyness and externalizing behavior, suggesting support for Lahey and Waldman's (2003) hypothesis. The within-trait/cross-twin correlations suggest additive genetic and shared environmental influences on internalizing and externalizing behavior, and additive genetic influences and possible contrast effects on emotionality and shyness. In general, the cross-twin/cross-trait correlations do not suggest consistent evidence of common genetic influences between temperament and behavior problems, as the DZ cross-twin/cross-trait correlations are higher than the MZ cross-twin/cross-trait correlations for some of the traits (e.g., shyness and externalizing behavior in males). These higher DZ than MZ cross-twin/cross-trait correlations suggest that there may be common shared environmental influences such as rater bias effects between temperament and behavior problems.

Given concerns regarding the small size of the current sample and power, we examined the phenotypic correlations between temperament and behavior problems and the degree to which they are due to common genetic, shared environmental, and nonshared environmental influences in the full model. In males, the covariation between emotionality and internalizing

behavior and between emotionality and externalizing behavior were explained by both common genetic influences and shared environmental influences. The covariation between shyness and internalizing behavior was explained mostly by common shared environmental influences, and the covariation between shyness and externalizing behavior was nonsignificant. In females, the covariation between emotionality and internalizing behavior, emotionality and externalizing behavior, and shyness and internalizing behavior were explained mostly by common shared environmental influences. Again, the covariation between shyness and externalizing behavior was nonsignificant.

The covariation between internalizing and externalizing behavior was explained by both shared environmental influences in common with emotionality and shared environmental influences in common with shyness in males. The covariation between internalizing and externalizing behavior was explained only by shared environmental influences in common with emotionality in females.

Some support was found for Lahey and Waldman's (2003) hypothesis that emotionality shares common variance with both internalizing and externalizing behavior and shyness shares common variance only with internalizing behavior. The shared environmental influences on emotionality were positively correlated with those on both internalizing and externalizing behavior in males and females. Also, the genetic influences on shyness in females were positively correlated with those on internalizing behavior and negatively correlated with those on externalizing behavior. However, the results do not provide straightforward support for Lahey and Waldman's (2003) hypotheses. The nonshared environmental influences on emotionality were negatively correlated with those on externalizing behavior in males, and the genetic influences on emotionality were negatively correlated with those on internalizing behavior in females. In males, the genetic influences on shyness were negatively correlated with those on both internalizing and externalizing behavior. In both males and females, the shared environmental influences on shyness were positively correlated with those on both internalizing and externalizing behavior.

A strength of this study includes measurement of temperament at very early ages before the appearance of behavior problems. Additionally, the study's repeated measurements of temperament and behavior problems led to a more reliable assessment of both constructs. Weaknesses include small sample size and low power, twin methodology commonly used at the study's commencement (e.g., assessment of only same-sex twin pairs and inability to test general sex-limitation models), and difficulties in measuring the same constructs in a wide age range.

The results of the present study, which suggests evidence of common shared environmental influences on temperament and behavior problems, are inconsistent

with those of earlier longitudinal twin studies, which found stronger evidence of common genetic influences on temperament and behavior problems in general. A potential limitation in the present study is the possibility that the covariation between temperament and behavior problems may be due to shared measurement variance; that is, some of the positive correlations between temperament and behavior problems may have occurred because parent ratings were used to assess both temperament and behavior problems. We plan to address this limitation in a future study by using a multi-trait multi-method approach, using observational measures, mother ratings, father ratings, and observer ratings of temperament in early childhood and mother ratings, father ratings, teacher ratings, and self ratings of behavior problems in middle childhood.

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