

# **A Behavioral Genetic Analysis of the Relationship Between the Socialization Scale and Self-Reported Delinquency**

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**ABSTRACT** This investigation examined the genetic (A), and shared (C) and nonshared (E) environmental variance contributions to the relationship of self-reported delinquency (as measured by the “Delinquent Behavior Inventory” [DBI; Gibson, 1967]) to the Socialization (So) scale of the California Psychological Inventory using univariate and bivariate structural equation models. The scales were administered to 222 male (145 monozygotic; 77 dizygotic) and 159 female (107 monozygotic; 52 dizygotic) 16- to 18-year-old same-sex twin pairs. Principal components analysis with varimax rotation revealed three interpretable So factors representing family/home environment, self-concept, and behavioral control. Univariate modeling suggested sex differences in etiological

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influences associated with individual differences in most scales. The bivariate ACE model fit the data, suggesting that the covariance between the So scale and self-reported delinquency owes in part to shared etiological factors.

The Socialization (So) scale of the California Psychological Inventory (CPI) was developed by identifying items that discriminated between delinquent and nondelinquent boys and girls (Gough, 1957), and it is moderately correlated with various measures of antisocial behavior (Gough, 1994). Gough (1994) asserted that the So scale (as a whole) offers psychologists an index of the extent to which individuals have internalized prosocial values, systems of control, and other adaptive mechanisms required for norm-abiding behavior. Given the strategy of test construction, it is tempting to assume that the So scale is simply another delinquency measure. The So scale, however, is factorially complex: It is an aggregation of items that tap delinquency (e.g., stealing when younger), home/family environment (e.g., home life was pleasant), and interpersonal functioning (e.g., concerns about how one is viewed by others). What are the broad etiological influences on individual differences in So scale scores? Are different subscales of the So scale influenced by the same etiological factors to a similar degree? Finally, what (if any) etiological factors contribute to the covariance of the So scale and its common behavioral correlate, delinquency? The purpose of the present investigation was to examine the etiological influences on the So scale, its empirically derived subscales, and self-reported delinquency. Additionally, we examined the possibility that the covariance between the So scale and delinquency owes to common etiological factors influencing both phenotypes.

Examining subscales of the So scale is not a new idea. The literature on the factor structure of the So scale consistently reveals three interpretable item clusters corresponding to a dimension of home/school adjustment and satisfaction, a dimension of trust/distrust and self-concept, and a dimension of conventionality of attitude and behavioral control. This factor structure has been demonstrated using the 54-item So scale (Stein, Gough, & Sarbin, 1966) and later versions (Butt, 1973; De Francesco & Taylor, 1986; Rosen, 1976). According to a recent review by Gough (1994), unpublished factor analytic work with the (newest) 46-item version generally yielded results similar to those found with earlier versions of the So scale. The literature thus supports the notion that the

So scale (in its various forms) contains three subscales related to behavioral self-control, home/family environment, and self-concept and trust.

The utility of a behavioral genetic analysis is in its ability to tell us something about the broad etiological factors that are associated with individual differences in a trait or a behavior. This method makes use of biometrical (structural equation) models that decompose the total variance in a phenotype into the portions of variance accounted for by (a) additive genetic factors (A), which serve to increase phenotypic similarity among biologically related family members; (b) shared environmental factors (C), which also serve to increase phenotypic similarity among family members; and (c) non-shared environmental factors (E), which are unique experiences that serve to decrease phenotypic similarity among family members. Biometrical models are tested using genetically informative data sets such as those derived from samples of monozygotic (MZ) and dizygotic (DZ) twins, or parents and offspring, or other sets of relatives. Biometrical models can be used to examine single variables (univariate models), two variables (bivariate models), or several variables (multivariate models). Bivariate and multivariate models are used to investigate the nature of the covariance between variables and these models provide evidence of common and unique etiological influences between variables.

Although ours is the first investigation of the etiological influences associated with the covariance of the So scale and delinquency, others demonstrated that genetic and environmental factors are associated with both the So scale and delinquency. Roughly one third of the variance in the full So scale is associated with additive genetic factors, while the remaining variance is associated with unique environmental factors (Gottesman, 1966; Horn, Plomin, & Rosenman, 1976). Bouchard and McGue (1990) used data from adult twins reared apart to show that genetic and environmental factors may be differentially associated with So subscales. They did not, however, use empirically derived subscales and they did not examine the relationship of the So scale to delinquency. Several twin studies reveal evidence for influence of additive genetic and nonshared environmental factors on juvenile delinquency or conduct problems in childhood (Edelbrock, Rende, Plomin, & Thompson, 1995; Eley, 1997; Rowe, 1983, 1986; Rushton, 1996; Slutske et al., 1997). Additionally, antisocial behavior in childhood may be influenced by shared environmental factors (Edelbrock et al., 1995; Eley, 1997; Lyons et al., 1995; Rushton, 1996). Thus, previous work suggests that individual

differences in So scores are associated with additive genetic and unique environmental influences, while delinquency also may be influenced by shared environmental factors.

Delinquency can be ascertained in a number of ways, including official police or court records, juvenile self-report, or reports from other individuals (e.g., parents or schools). Official police or court records of juvenile delinquency can be difficult to obtain given the privacy afforded to juvenile offenders. Additionally, official police reports likely underestimate delinquency because many crimes go undetected. For these reasons, researchers often use self-report delinquency questionnaires with juvenile samples. For example, Gibson (1967) introduced a 36-item self-report scale of delinquent acts, which has been used extensively in studies of delinquency (e.g., Farrington & West, 1971). Gibson's (1967) scale items reflect minor (e.g., skipping school; riding a bike recklessly), moderate (e.g., shoplifting; gang activity; destroying property; breaking and entering), and more serious behaviors (e.g., using a weapon in a fight; attacking a police officer; burglary). The scale includes many arrestable behaviors; however, it lacks items that reflect serious violent crime (e.g., rape and murder).

In sum, previous research suggests that the So scale is comprised of three factors that tap aspects of the family/home environment, level of behavioral control, and self-concept. Additionally, research shows that individual differences in So scale scores are associated with genetic and non-shared environmental factors, while individual differences in self-reported delinquency are associated with these factors as well as shared environmental influences. What is not clear from previous research is whether the etiological factors associated with individual differences in the So scores are the *same* as those associated with individual differences in delinquency. That is, what contribution do common genetic and environmental factors make to the association between the So scale and self-reported delinquency? Moreover, are the magnitudes of genetic and environmental influences similar across So subscales?

There were three specific aims of this investigation. First, we examined the factor structure of the 46-item So scale and derived its subscales. Second, we estimated the contribution of additive genetic (A), shared environmental (C), and nonshared environmental (E) influences on the So scale, the So subscales, and Gibson's (1967) delinquency scale (which we have labeled the Delinquent Behavior Inventory, or DBI). Third, we sought to clarify the relationship between the So scale and delinquency

by assessing the magnitude of genetic and environmental influences on the covariance between the DBI and the So scale.

## METHOD

### Participants

Male and female 16- to 18-year-old (same-sex) reared-together twins participating in the Minnesota Twin Family Study (MTFS) served as subjects. The MTFS is a community-based longitudinal study of the etiology of substance use and related disorders among twins and their families. Twin pairs were identified through Minnesota state birth records for the years 1972 through 1977 (male adolescent cohort) and 1975 through 1979 (female adolescent cohort). Families were excluded from participating if the twins were adopted, or if the family lived farther than a day's drive from Minneapolis, or if the twins had a physical or intellectual disability that precluded their completion of the day-long intake assessment. Consistent with demographics of Minnesota during the birth years sampled, nearly all of the twins are Caucasian.

Zygoty of the twins was established using the following three methods: (a) parents completed a zygoty questionnaire regarding the twins' physical similarity and the frequency with which people confused them; (b) staff rated the zygoty of the twins based on various points of physical similarity (e.g., eye color and ear shape); and (c) zygoty was determined using an algorithm based on ponderal index, cephalic index, and fingerprint ridge count. Any discrepancy in the three methods was resolved through a serological examination of 12 blood group antigens and protein polymorphisms.

The principal components analysis of the So scale was conducted using 881 adolescent twins (492 boys; 389 girls) from the MTFS. The behavioral genetic analyses were based on twin pairs in which both members had a complete set of scores for the So scale, the So subscales, and the DBI. The behavioral genetic analyses were conducted using 222 male twin pairs (145 MZ; 77 DZ) and 159 female twin pairs (107 MZ; 52 DZ). Of the 492 available boys, 48 were excluded from the twin analyses (7 for missing data on one or more of the scales; 1 twin pair for whom zygoty was as yet undetermined; 39 because their cotwins' data were unavailable at the time of the analysis). Of the 389 available girls, 71 were excluded from the twin analyses (7 for missing data on one or more of the scales; 6 twin pairs for whom zygoty was as yet undetermined; 52 because their cotwins' data were unavailable at the time of the analysis).

## Measures

As part of the MTFS intake assessment, twins were administered a self-ratings booklet which contained a slightly altered version of the 46-item So scale and the 36-item DBI (with one item replaced and minor changes in wording to reflect the current American culture). Reflecting our interest in substance abuse, the MTFS version of the So scale contained two items related to alcohol use (items 393 and 323 on the 462-item CPI) in place of two items related to a propensity for getting into “trouble” (items 223 and 345 on the 462-item CPI). An unpublished analysis using a sample of adult men showed a very high correlation (above .99) between the actual So scale and the slightly altered version (administered to MTFS twins). We are confident that our slightly altered version is comparable to the actual So scale in terms of its validity and we hereafter refer to it simply as the So scale.

Preliminary analyses using the sample of 881 MTFS adolescents showed that the DBI has a unitary factor structure and high internal-consistency reliability ( $\alpha = .96$  for boys and  $.97$  for girls). Both the So scale and the DBI are composed of items scored dichotomously (i.e., true/false and yes/no).

## Analyses

The So scale was submitted to a linear principal components analysis with varimax rotation using the sample of 881 boys and girls.<sup>1</sup> A scoring algorithm was derived for each of the So subscales based on the factor loadings (items with a negative factor loading were reverse-scored) and on the overall interpretability of the final solution. The So scale and its subscales were scored in the traditional prosocial direction such that high scores indicated “more” socialization. The DBI score was derived by summing the “yes” responses, and high scores indicated a greater variety of delinquent acts committed.

Once the So subscales were derived, Pearson product-moment correlations were computed to index the phenotypic association among the scales. Twin intraclass correlations were calculated for each scale using the 222 male and 159 female twin pairs.

Biometrical models were used to examine the relative contribution of genetic and environmental influences on individual differences in a single trait and on

1. In order to examine difficulty factors that may arise when conducting a linear principal components analysis on dichotomously scored items, we performed an iterated principal factor analysis on the smoothed tetrachoric correlation matrix derived from So scale data from 811 adolescents. Four factors were extracted and submitted to varimax rotation. The factor analysis results were consistent with those of the linear principal components analysis suggesting the two models were relatively interchangeable. As such, only results from the principal component analyses were reported.

the individual differences in the covariance between the So scale and the DBI. We specified a model that decomposed the total phenotypic variance ( $V_P$ ) into the three aforementioned etiological components (A, C, and E). The biometrical models were specified by the following equation:

$$(1) \quad V_P = V_A + V_C + V_E$$

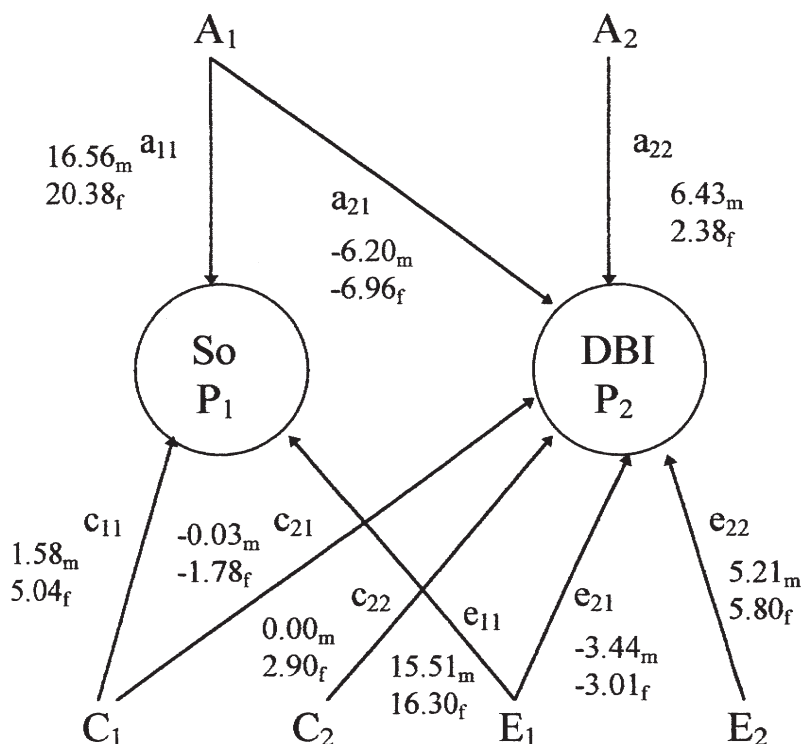
Each model was further specified by supplying the expected covariance among twins. The expected covariances were simply a function of the expected overlap in shared genetic and environmental covariance within twin pairs. For each model, the expected covariances were specified as follows:

$$(2) \quad \text{MZ covariance} = a^2 + c^2$$

$$(3) \quad \text{DZ covariance} = .5a^2 + c^2$$

Univariate and bivariate models were estimated by maximum-likelihood using the Mx software program (Neale, 1997; interested readers are referred to Neale & Cardon, 1992, for a discussion of biometrical modeling using LISREL). Separate parameter estimates for boys and girls were obtained for each univariate model. A bivariate Cholesky decomposition model was used to examine the relationship between the So scale and delinquency.

The typical univariate biometrical model as given by equation 1 reflects a relationship between latent variables (A, C, and E) and observed variables (So, DBI, etc.) such that each latent variable accounts for some portion of the total variance in an observed trait. In the univariate model, we can test the contribution of only one latent genetic factor (A), one shared environmental factor (C), and one nonshared environmental factor (E) to the variance in a single trait. The Cholesky model allows us to examine the contribution of more than one latent genetic and environmental factor to the covariance of two or more observed traits. Figure 1 depicts the bivariate Cholesky model used in this analysis. In essence, the paths represent the loadings of each latent factor on the observed variables. In the bivariate Cholesky model, the first latent factors ( $A_1$ ,  $C_1$ , and  $E_1$ ) represent that portion of the variance in the DBI that is attributable to the factors underlying variation in the So scale and are thus allowed to load onto both observed traits. The second latent factors ( $A_2$ ,  $C_2$ , and  $E_2$ ) represent residual variance and are thus allowed to load onto just one observed trait. The  $a_{21}$ ,  $c_{21}$  and  $e_{21}$  paths in the bivariate model represent the contribution of etiological factors to both the So scale and the DBI. These paths can be omitted from the model to test the significance of the contribution of common etiological factors to the covariance between the So scale and delinquency.



**Figure 1**

The ACE Cholesky model fit to the data for the Socialization scale ("So") with the log DBI (Delinquent Behavior Inventory) as the delinquency indicator. A = additive genetic effects; C = shared environmental effects; E = nonshared environmental effects. The model is constructed such that the total genetic and environmental influences on the DBI are decomposed into a portion in common with the So scale components (subscript 1) and a portion unique to the DBI (subscript 2). Parameter estimates are provided and denoted with a subscript of m or f to denote male and female estimates, respectively.

We also used the Cholesky model to estimate (a) the proportion of the phenotypic correlation that is attributable to genetic and environmental influences, (b) the genetic correlation ( $r_{axy}$ , the association of genetic factors contributing to two traits), and (c) environmental correlations ( $r_{cxy}$ , the association of shared environmental factors contributing to two traits;  $r_{exy}$ , the association of unique environmental factors contributing to two traits).

## RESULTS

The principal components analysis of the So scale yielded four factors. Following a varimax rotation of all four factors, three interpretable and internally consistent factors remained. We included on a subscale those items that (a) had a factor loading with an absolute value of at least .3 and (b) did not load higher on another factor. (One item with a .28 factor loading was included on one subscale because it contributed to the scale's internal consistency reliability.) Table 1 contains the So scale items (briefly described and listed by item number from the 462-item CPI [Gough, 1986])<sup>2</sup> and their factor loadings on the three subscales as well as the internal consistency reliability estimates for each subscale. The derived subscales were Optimism (a dimension of self-concept related to one's capacity for trust and optimism about the world), Family (a family/home environment dimension), and Control (a dimension of behavioral control). Scale names were adopted from previous research (Butt, 1973; Stein et al., 1966).

Table 2 presents the means and standard deviations for the So scale, the So subscales, and the DBI for boys and girls. The male MZ and DZ means for the full So scale were only slightly higher than those reported by Gough (1994; Table 1, p. 679) for a sample of male high school students ( $M = 30.8$ ,  $SD = 5.7$ ). The female MZ and DZ means for the full So scale also were quite similar to those reported by Gough (1994; Table 2, p. 684) for a sample of female high school students ( $M = 32.9$ ,  $SD = 5.8$ ). These comparisons are useful in evaluating whether twins are representative of the general population (a major assumption in twin research). The DBI data were transformed ( $\log_{10} [x + 1]$ ) prior to analyses due to the substantial positive skew of the data. Descriptive data for both the raw and the log-transformed DBI are reported in Table 2; results from the biometrical analyses are reported only for the transformed DBI scores.

Another major assumption of twin research is that MZ and DZ twins have equally similar environments and, as such, that any greater similarity

2. We requested permission from Consulting Psychologists Press, Inc., to print So scale items and were informed via their standard request form that CPP, Inc. "DOES NOT permit the inclusion of any whole or partial tests" for publication. In order to provide readers with the complete results of the principal components analysis without violating copyright laws, we elected to present items by their CPI item number with a one- or two-word descriptor of the tabled items.

**Table 1**  
Factor Loadings for Each Socialization Scale Item From the Four Factor Principal Components Analysis

<u>Optimism (Alpha = .73)</u>					<u>Family (Alpha = .78)</u>					<u>Control (Alpha = .72)</u>				
Item	F1	F2	F3	F4	Item	F1	F2	F3	F4	Item	F1	F2	F3	F4
416 unhappy	.61	.29	.01	.12	168 happy home	-.06	-.76	-.07	.10	393 use alcohol	.06	.04	.63	.15
369 regretful	.56	.04	.09	.16	367 pleasant home	-.05	-.76	-.05	.02	323 don't drink	.04	-.21	-.57	-.08
94 hopeless	.53	-.00	.09	-.08	439 close family	-.04	-.66	-.02	.06	214 troublesome	.22	-.04	.56	-.13
398 get raw deal	.51	.16	.18	.02	444 misunderstood	.35	.57	.17	.02	36 skip school	.07	.06	.55	-.02
405 talk about me	.50	.17	.03	.14	336 want to leave	.26	.47	.24	.05	212 no legal prob	-.12	-.01	-.52	.04
457 untrusting	.47	.07	.12	-.14	396 want to run	.30	.44	.28	.05	420 steal	.14	.08	.50	.01
257 have wronged	.46	.10	.24	.09	180 may decide	-.08	-.43	.06	.04	431 bad in school	.25	-.06	.47	-.20
245 feel happy	-.44	-.20	-.07	-.01	164 bad peers	.26	.41	.24	-.06	302 defy parents	.23	.38	.41	.08
12 wrong job	.41	.00	.13	.03	184 worried	.31	.37	.13	.07	409 no poker	.11	.01	-.40	-.09

**Table 1 (cont.)**

<u>Optimism (Alpha = .73)</u>					<u>Family (Alpha = .78)</u>					<u>Control (Alpha = .72)</u>				
Item	F1	F2	F3	F4	Item	F1	F2	F3	F4	Item	F1	F2	F3	F4
436	.40	.07	.25	-.18	428	.14	.28	.15	-.19	170	.19	.19	.40	-.05
dislike school					chaotic home					impulsive				
327	.39	.06	.12	-.05						93	.10	.12	.36	-.20
drop friends										daring				
182	.37	.12	-.10	-.03						123	-.03	-.14	-.30	.19
do without										strict morals				

*Note.* F = factor; Item refers to the 462-item California Psychological Inventory item number; text is a paraphrase of item content. Reliability analyses were conducted using the sample of 881 boys and girls; internal consistency reliability estimates are given parenthetically in column headings. Items answered “false” were scored 1; items answered “true” were scored 0. Items with a negative factor loading were reverse-scored. Items that loaded highest on the fourth (nonscored) factor included 317, 338, 192, 334, 144, 198 and 389. Items that did not load .30 or better on any factor included 385, 435, 62, 386 and 373.

**Table 2**  
Scale Means (and Standard Deviations) for Boys and Girls

Scale	Boys		Girls	
	MZ ( <i>N</i> = 145)	DZ ( <i>N</i> = 77)	MZ ( <i>N</i> = 107)	DZ ( <i>N</i> = 52)
DBI	4.17 (3.74)	5.18 (5.06)	3.10 (3.76)	3.96 (3.57)
log DBI	0.60 (0.33)	0.65 (0.36)	0.48 (0.34)	0.59 (0.31)
Socialization	32.73 (5.45)	31.83 (6.30)	33.40 (6.43)	32.88 (6.46)
Optimism	9.93 (2.18)	9.95 (2.17)	10.47 (1.95)	10.38 (2.13)
Family	7.33 (2.32)	7.18 (2.34)	6.97 (2.80)	6.99 (2.76)
Control	9.10 (2.27)	8.42 (2.63)	9.57 (2.49)	9.18 (2.42)

*Note.* Sample sizes refer to number of twin pairs. DBI = Delinquent Behavior Inventory.

among MZ as compared to DZ twins can be attributed to genetic factors rather than to more similar treatment in the environment. Given that differential similarity of treatment can lead to mean and variance differences between MZ and DZ twins, the means and variances of MZ and DZ twins were compared for each scale within each sex using an independent-samples *t* test and Levene's Test for Equality of Variances. Data for one twin from each pair were randomly selected for use in the analyses in order to adjust for the inflated sample size (which occurs when both twins are used) and to meet the assumption of independent sampling. Very few of the MZ versus DZ differences were significant, and no consistent pattern emerged. Among the girls, there was a significant variance difference,  $F(1, 157) = 4.98, p < .05$ , and a significant mean difference,  $t(123) = -3.54, p < .001$ , only for the log DBI scale, indicating that DZ twins endorsed more delinquent behaviors and showed greater scale variance than MZ twins. There were no significant mean or variance differences among the boys. The random subsample described above also was used to examine mean differences between boys and girls. Again, few significant differences were found. Among MZ twins, boys had significantly higher log DBI scale scores than girls,  $t(250) = 3.51, p < .001$ , whereas girls had significantly higher Control subscale scores than boys,  $t(250) = -2.13, p < .05$  (sex differences on these scales in the DZ sample were in the same direction, although not statistically significant). There were no other significant sex differences.

To ascertain the severity of delinquency in this sample, we examined the endorsement rate of the DBI items and the frequency of DBI scores.

The most commonly endorsed items by both boys and girls were the five least serious behaviors (riding a bike recklessly; driving without a permit; skipping classes; setting off fireworks [which are illegal to possess in Minnesota]; and trespassing). Each of these items was endorsed by 27–68% of this sample. Using this information, we examined the frequencies of DBI scores in four score ranges: 0, 1–5, 6–10, and 11 or higher. Scores of 6–10 likely reflect moderate delinquency, as the individuals in that group are endorsing at least a few serious behaviors. Scores of 11 or higher likely reflect severe delinquency, since the people in that group must be endorsing several of the more serious behaviors. The results for boys were as follows: 10.6% scored 0; 56.7% had scores from 1 to 5; 23.7% had scores from 6 to 10; 9.2% had scores of 11 or higher. The results for girls were as follows: 18.6% scored 0; 60.0% had scores from 1 to 5; 17.6% had scores from 6 to 10; 3.8% had scores of 11 or higher. These results indicate that 28% of our sample contains individuals with moderate or severe delinquency, which is comparable to the rate of self-reported “high delinquency” in other studies of delinquency (e.g., Farrington, 1989).

Pearson product-moment correlations computed among the five scales for boys and girls separately are presented in Table 3. Both the magnitude and the direction of the within-individual correlations among the five scales were similar for boys and girls. Moderate correlations for both sexes were found between Optimism and DBI and between Family and DBI. Not surprisingly, the Control subscale and the DBI evidenced a significantly stronger phenotypic association than did the DBI with either the Optimism or Family subscales within each sex. The correlations among the So scale and its subscales were generally high and positive for both sexes. No significant sex differences were found for any of the phenotypic correlations.

### Univariate Twin Analysis

The twin intraclass correlations for each scale are presented in Table 4. The statistical significance of each intraclass correlation is indicated as well as the significance of the difference between the MZ and DZ correlations within each sex. Among both boys and girls, genetic influence on each scale was suggested by higher MZ than DZ correlations (although the magnitude of the correlation difference was greater for boys than girls). Differences between the MZ and DZ correlation within each

**Table 3**  
Within-Individual Correlations Among Scales for Boys and Girls

<i>Boys (N = 485)<sup>a</sup></i>						
	log DBI	So	Optimism	Family	Control	
log DBI	1.00					
So	-.49	1.00				
Optimism	-.28	.77	1.00			
Family	-.32	.79	.52	1.00		
Control	-.62	.72	.35	.45	1.00	
<i>Girls (N = 382)<sup>a</sup></i>						
	log DBI	So	Optimism	Family	Control	
log DBI	1.00					
So	-.53	1.00				
Optimism	-.33	.77	1.00			
Family	-.35	.79	.49	1.00		
Control	-.65	.74	.45	.43	1.00	

*Note.* So = Socialization scale; DBI = Delinquent Behavior Inventory; all correlations were significant at  $p < .001$ .

<sup>a</sup>Seven people had incomputable scores on one or more scales due to missing values.

sex were tested using the  $z$  statistic. Among boys, the MZ correlation significantly exceeded the DZ correlation for the DBI ( $z = 3.05, p < .01$ ) and the Optimism ( $z = 2.20, p < .05$ ) and Control ( $z = 2.34, p < .05$ ) subscales. Among girls, none of the MZ and DZ correlations differed significantly and all of the DZ correlations were greater than half the MZ values suggesting a significant role for shared environmental influences on each scale.

In order to assess the magnitude of additive genetic, shared environmental, and non-shared environmental influences, full (ACE) univariate models were fit to the data for each scale. The overall fit of each model was assessed with the chi-square ( $\chi^2$ ) goodness-of-fit statistic. Large (statistically significant) chi-square values led to a rejection of the model. Commonly, reduced models (e.g., AE or CE) are fit to the data subsequent to fitting the full ACE model. The fit of the full and reduced models is then compared to determine which model fits the data best (most parsimoniously). This type of extended analysis, however, can obscure the information obtained from the ACE model if the sample size is not adequate to detect the presence of certain etiological factors in the presence of others. That is, extremely large samples of twins are needed

**Table 4**  
Intraclass Correlations Among Boys and Girls for Each Scale

Scale	Boys		Girls	
	$r_{MZ}$	$r_{DZ}$	$r_{MZ}$	$r_{DZ}$
log DBI	.52* <sup>†</sup>	.15	.48*	.37*
Socialization	.51*	.29	.60*	.38*
Optimism	.53* <sup>†</sup>	.27	.47*	.29
Family	.58*	.39*	.63*	.54*
Control	.54* <sup>†</sup>	.26	.54*	.43*

Note. Boys: MZ (monozygotic) pairs = 145, DZ (dizygotic) = 77; Girls: MZ pairs = 107, DZ pairs = 52. DBI = Delinquent Behavior Inventory.

\* $p < .01$ , one-tailed. The correlation is significant.

<sup>†</sup> $p < .05$ , one-tailed. The MZ correlation is significantly larger than the DZ correlation.

to accurately compare the ACE model to a reduced model like AE given that both additive genetic factors and shared environmental factors contribute to phenotypic similarity among family members and are thus more difficult to disentangle. When the sample is not large enough to disentangle these effects, it is possible to choose a reduced model (e.g., AE) as the best-fitting model even when the “true” model is a full model (e.g., ACE). Typically, relatively large sample sizes (as we have here) can provide reasonable estimates of A, C, and E, even though we do not have enough power to evaluate the significance of those estimates (through a comparison to reduced models).

Table 5 presents the univariate model-fitting analyses in which parameters were free to vary across sex. Parameter estimates and model-fitting indices are given for the ACE model fit to the data from each scale. For each model, the standardized proportion of variance is given in parentheses under the variance estimate and the 95% confidence interval for the standardized variance estimate is given in brackets. The ACE model provided a good fit to the data for all but the Optimism scale. As foreshadowed by the twin intraclass correlations, genetic effects appeared to be stronger influences on delinquency and the So scale and its subscales among boys, while shared environmental influences were greater in magnitude among girls. The influence of non-shared environmental factors was of similar magnitude for boys and girls for each scale. Our results support the notion that genetic and environmental factors are differentially associated with subscales of the So scale (Bouchard and McGue, 1990).

**Table 5**  
Univariate Model-Fitting Analysis of Each Scale With Parameters Unconstrained Across Sex

		Males			Females			Goodness-of-Fit Test		Sex Diff.?
	Model	A	C	E	A	C	E	$\chi^2$ (df)	p	
log DBI	ACE	.07 (.55) [.33-.66]	0.0 (.00) [.00-.18]	.05 (.45) [.34-.57]	.01 (.08) [.00-.56]	.04 (.37) [.00-.56]	.06 (.55) [.42-.69]	5.52 (6)	.48	No
Socialization	ACE	18.15 (.54) [.14-.64]	0.0 (.00) [.00-.34]	15.44 (.46) [.36-.59]	19.76 (.47) [.03-.71]	5.53 (.13) [.00-.52]	16.41 (.40) [.29-.52]	7.18 (6)	.31	No
Optimism	ACE	2.34 (.49) [.07-.63]	.17 (.04) [.00-.41]	2.22 (.47) [.37-.59]	2.09 (.52) [.03-.64]	0.0 (.00) [.00-.42]	1.97 (.48) [.36-.64]	14.25 (6)	.03	No
Family	ACE	2.06 (.38) [.01-.67]	1.09 (.20) [.00-.53]	3.29 (.42) [.33-.54]	1.19 (.15) [.00-.61]	3.68 (.47) [.04-.68]	2.94 (.38) [.28-.50]	3.76 (6)	.71	No
Control	ACE	3.37 (.57) [.27-.67]	0.0 (.00) [.00-.25]	2.51 (.43) [.33-.55]	1.12 (.18) [.00-.62]	2.11 (.34) [.00-.60]	2.89 (.48) [.36-.62]	9.84 (6)	.13	No

*Note.* The standardized proportion of variance is shown in parentheses for each model; upper and lower bound of the 95% confidence interval for each standardized variance estimate is given in brackets. The differences in estimates between boys and girls were not statistically significant for any of the scales. A = additive genetic effects; C = shared environmental effects; E = nonshared environmental effects; DBI = Delinquent Behavior Inventory.

Among boys, individual differences in self-reported delinquency (as measured by either the DBI or the Control subscale) were associated with additive genetic and non-shared environmental influences. Among girls, individual differences in delinquency were associated with shared and non-shared environmental influences. Notably, the differences in variance estimates between sexes were not statistically significant and larger samples may be needed to evaluate the existence of real differences in the etiological influences on delinquency among boys and girls.

### Bivariate Analysis

While the within-individual correlation indexes the phenotypic association between two variables, the cross-twin correlation (e.g., DBI of twin 1 with So of twin 2) provides information on the underlying genetic and environmental contributions to the phenotypic correlation. A genetic contribution to the covariance between two traits is evidenced by the MZ cross-twin correlation exceeding the DZ cross-twin correlation. Alternatively, a shared environmental contribution is indicated whenever the MZ cross-twin correlation is less than twice the DZ cross-twin correlation. Finally, a non-shared environmental contribution is evidenced by the within-person correlation exceeding the MZ cross-twin correlation. Among boys, the within-person correlation for the So scale and the DBI was  $-.49$  and the cross-twin correlations for the two scales were  $-.29$  and  $-.12$  for MZ and DZ twins, respectively. Among girls, the within-person correlation was  $-.53$  and the cross-twin correlations were  $-.39$  and  $-.27$  for MZ and DZ twins, respectively. This pattern of correlations suggests a genetic contribution to the covariance of So and DBI scale scores for boys and a shared environmental contribution to the covariance of the scales among girls. Non-shared environmental factors appear to influence the covariance of the So scale and the DBI among both boys and girls.

Figure 1 illustrates the ACE bivariate model used in this analysis and it contains the parameter estimates for each sex. The model was specified such that common genetic and environmental factors contributed both to the So scale and to delinquency, and an additional factor of each type contributed uniquely (residually) to delinquency. The ACE bivariate model was fitted to the data for males and females allowing parameter estimates to vary by sex. The model provided a good fit to the data,  $\chi^2(22) = 18.85$ ,  $p = .66$ . We examined the significance of common etiological

factors by testing models in which a covariance path was omitted (e.g., the additive genetic covariance path,  $a_{21}$ , was set to zero in a model testing pleiotropic effects). Only the shared environmental covariance path could be dropped without causing a significant decrease in the fit of the model, suggesting that different shared environmental factors influence individual differences in So and DBI scale scores.

Table 6 contains the maximum-likelihood estimates of genetic and environmental correlations and the proportion of the correlation between the So scale and the DBI accounted for by genetic and environmental factors. The genetic correlations were high, suggesting a strong association among the genetic factors contributing to variance in the So scale and DBI scale scores among boys and girls. The non-shared environment correlations were modest for both boys and girls, suggesting that the unique environmental factors contributing to individual differences in delinquency are largely separate from those unique environmental factors contributing to individual differences in So scale scores. The high shared environment correlation for boys (.99) is likely an artifact, given that the univariate models for the DBI and the So scale yielded shared environment estimates of zero. The same is not likely true for the high genetic correlation (.99) among girls, as the univariate models suggested some evidence of genetic effects for both the DBI and the So scale. Common genetic factors account for 60–65% of the correlation between the So scale and the DBI, while much of the remainder of the phenotypic

**Table 6**  
Maximum-Likelihood Estimates of Genetic and Environmental Correlation for the Socialization Scale and the Delinquent Behavior Inventory for Boys and Girls

	Correlation Among Factors Contributing to Variance in So and DBI			Proportion of So-DBI Phenotypic Correlation Accounted for by		
	$r_{axy}$	$r_{cxy}$	$r_{exy}$	Genes	Shared Env.	Nonshared Env.
Boys	.60	.99	.38	.64	.00	.36
Girls	.99	.46	.31	.60	.15	.25

*Note.*  $r_{axy}$  = the association of genetic factors contributing to So and DBI scores;  $r_{cxy}$  = the association of shared environmental factors contributing to So and DBI scores;  $r_{exy}$  = the association of unique environmental factors contributing to So and DBI scores.

association is due to non-shared environmental influences for both boys and girls.

## DISCUSSION

This is the first investigation of (a) the etiological influences on empirically derived subscales of the So scale and (b) the etiological influences on the covariance of the So scale and a common behavioral correlate, delinquency. Briefly, the specific aims of this investigation were to (a) derive subscales of the So scale; (b) estimate the A, C, and E variance components of the So scale, the So subscales, and self-reported delinquency; and (c) determine whether the covariance between the So scale and self-reported delinquency owes to common genetic and environmental influences.

Our principal components analysis of the So scale replicated the factor structure identified previously in the literature using earlier versions of the So scale (Butt, 1973; Stein et al., 1966). The 46-item So scale yielded three interpretable factors: The Optimism subscale (reflecting self-concept and trust/distrust); the Family subscale (reflecting features of the home/family life); and the Control subscale (reflecting behavioral control and conduct problems). The phenotypic association between the Control scale and the DBI was greater than the association between the DBI and the full So scale for boys and girls. Moreover, within each sex, a similar pattern was found for the DBI and the Control scale with regard to the relative magnitude of genetic and environmental influences. Given these results, it may be that the Control subscale is a better measure of self-reported delinquency than is the entire So scale (which may be tapping additional aspects of socialization as Gough had intended).

The twin correlations and univariate analysis suggested that different etiological influences are at work with regard to male and female delinquency. From this initial analysis, it appears that individual differences in delinquency among boys are associated with additive genetic and non-shared environmental influences of roughly the same magnitude. Among girls, on the other hand, individual differences in delinquency were associated largely with non-shared environmental influences, modest to moderate levels of shared environmental influences, and little genetic influence. This result is consistent with at least one study examining retrospective reports of delinquency among adult male and female twins pairs (Rushton, 1996). Results from the full (ACE) model reported

from another retrospective study of conduct disorder also indicated shared environmental effects for women, but not men (Slutske et al., 1997). In the latter study, however, the shared environmental influence was not significant and could be dropped from the model fit to the female twin data.

The nature of possible sex differences is beyond the scope of these data to explain. We can, however, speculate on some plausible explanations. The sex differences in parameter estimates we observed may be chance deviations. Indeed, the differences we report, although numerically large, are not statistically significant. Studies with larger samples than ours suggest there are no sex differences in the types of broad etiological factors underlying childhood antisocial behavior (Eley, 1997; Slutske et al., 1997). A second possible explanation for the apparent sex difference is that a similar underlying genetic liability toward delinquency exists for boys and girls, but the family environment plays a more important role in determining whether the phenotype occurs in girls. For example, a “strict” home life may discourage the manifestation of delinquency among girls, while a more permissive home environment may allow delinquency to develop. As such, variance in family environment would be associated with individual differences in delinquency among girls and this effect would overshadow additive genetic effects in models run on anything but extremely large samples.

The nature of the covariance between self-reported delinquency and the So scale was examined using a bivariate structural equation model. The moderate correlation between the So scale and self-reported delinquency among boys and girls owes largely to additive genetic influences. Cross-twin correlations and the estimates of genetic and environmental correlation between the So scale and the DBI suggest that common genetic and shared environmental factors (among girls) influence both measures. Thus, our analysis suggests evidence of pleiotropic genetic and common shared environmental effects on individual differences in So scale scores and delinquency. A weaker association was found among the non-shared environmental influences for the So scale and delinquency, suggesting that each scale is influenced largely by different non-shared environmental factors.

The bivariate results must be reported with the following caveat: the covariance between the So scale and the DBI results, in part, from shared item content. Clearly, some of the items from the Control subscale tap behaviors covered by the DBI (e.g., stealing, getting into trouble at

school, and precocious gambling). Additionally, it is recognized that some Control subscale items, while not directly assessed on the DBI, tap behaviors that may co-occur with delinquency (e.g., drinking alcohol). We do not believe, however, that the bivariate modeling results simply reflect common genetic and environmental variance between overlapping items on the So and DBI scales for two reasons. First, the Control subscale contains all of the antisocial behavior items on the So scale and yet it is not purely a delinquency scale. One quarter of the Control subscale items reflect personality traits related to behavioral control (impulsivity, risk-taking, and traditional moral values). Second, there is substantial So scale content that relates independently to delinquency as indicated by the significant within-person correlations between the Optimism and Family subscales with the DBI presented in Table 3. An examination of the item descriptors for the Optimism and Family subscales given in Table 1 reveals that the So scale does not simply index antisocial behaviors, but instead indexes a variety of factors thought to be associated with delinquency, including family factors (closeness of the family, stability and pleasantness of the home), dispositional factors (happiness, negative self- and worldviews), and non-family environmental factors (e.g., affiliation with “bad” peers). For these reasons, we believe our bivariate analysis is informative because the covariance between the So scale and the DBI reflects more than just a simple overlap in content from the two scales.

This analysis provided the first look at the magnitude of genetic and environmental influences on empirically derived subscales of the So scale. Additionally, it shed light on the nature of the covariance between the So scale and a common behavioral correlate, delinquency. Future directions in research could include similar examinations of traditional personality factors (e.g., constraint or negative affectivity) as they relate to delinquency.

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