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Common Genetic and Non-shared Environmental Factors Contribute to the Association between Socioemotional Dispositions and the Externalizing Factor in Children

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Abstract

Background—Childhood behavioral disorders including conduct disorder (CD), oppositional defiant disorder (ODD), and attention-deficit/hyperactivity disorder (ADHD) often co-occur. Prior twin research shows that common sets of genetic and environmental factors are associated with these various disorders and they form a latent factor called Externalizing. The developmental propensity model posits that CD develops in part from socioemotional dispositions of Prosociality, Negative Emotionality, and Daring, and recent research has supported the expected genetic and environmental associations between these dispositions and CD. This study examined the developmental propensity model in relation to the broader Externalizing factor that represents the covariance among behavior disorders in children.

Methods—Parents of 686 6- to 12-year-old twin pairs rated them on symptoms of CD, ADHD, and ODD using the Disruptive Behavior Disorder scale and on Prosociality, Negative Emotionality, and Daring using the Child and Adolescent Dispositions Scale. A latent factor multivariate Cholesky model was used with each disposition latent factor comprised of respective questionnaire items and the Externalizing factor comprised of symptom dimensions of CD, ADHD inattention, ADHD hyperactivity/impulsivity, and ODD.

Results—Results supported the hypothesis that the socioemotional dispositions and the Externalizing factor have genetic factors in common, but there was not a single genetic factor associated with all of the constructs. As expected, non-shared environment factors were shared by the dispositions and Externalizing factor but, again, no single non-shared environmental factor was common to all constructs. A shared environmental factor was associated with both Negative Emotionality and Externalizing.

Conclusions—The developmental propensity model was supported and appears to extend to the broader externalizing spectrum of childhood disorders. Socioemotional dispositions of prosociality, negative emotionality, and (to a lesser extent) daring may contribute to the covariation among behavioral disorders and perhaps to their comorbid expression through common sets of primarily genetic but also environmental factors.

Keywords

externalizing; genetic; temperament; dispositions

Attention-deficit/hyperactivity disorder (ADHD), oppositional defiant disorder (ODD), and conduct disorder (CD) are common and costly childhood disorders (Faraone, Sergeant,

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Gillberg, & Biederman, 2003; Maughan, Rowe, Messer, Goodman, & Meltzer, 2004) accounting for over half of childhood mental health services referrals (Waschbusch, 2002). Rates of comorbidity of ADHD, ODD, and CD are substantial, ranging from 29 to 71% (Simonoff et al., 1997; Waschbusch, 2002). Further, this comorbidity is associated with increased functional impairment, a greater chance of psychiatric inpatient admissions, and increased risks for later psychiatric problems (Dalsgaard, Mortensen, Frydenberg, & Thomsen, 2002; Waschbusch, 2002). Recent factor analyses of childhood behavior disorders find a higher-order Externalizing factor consisting of lower-order inattention, hyperactive/impulsive, ODD, and CD factors (Bezdjian et al., 2011; Lahey, Rathouz, et al., 2008), suggesting that these disorders are part of a latent Externalizing factor. The covariation of externalizing disorders is important in terms of both its magnitude and its impact and efforts have been made over the past decade to understand the factors that underlie this covariation, including genetic and environmental factors.

Genetically informative studies (e.g., twin studies) can be used to estimate the extent to which individual differences in a behavior are associated with differences in genetic factors (that serve to make biological relatives alike), shared environmental factors (that serve to make individuals who live together more alike), and non-shared environmental factors (that serve to make individuals different from each other). Multiple research groups have used data from twins to disentangle the unique and common genetic and environmental contributions to the comorbidity or covariation among ADHD, ODD, and CD. For instance, Eaves et al. (2000) reported that across multiple informants on a sample of 8- to 16-year-old twins only shared genes significantly contributed to the association between ODD and CD and that genes and non-shared environment accounted for the correlations among inattention, hyperactivity, and impulsivity. Other studies using different measures, methods, and raters consistently support the idea that substantial genetic and small non-shared environmental influences contribute to the overlap among ADHD, ODD, and CD (Dick, Viken, Kaprio, Pulkkinen, & Rose, 2005; Nadder, Rutter, Silberg, Maes, & Eaves, 2002; Rietveld, Hudziak, Bartels, van Beijsterveldt, & Boomsma, 2003; Tuvblad, Zheng, Raine, & Baker, 2009). Notably, one research group has also found significant shared environmental influences on the covariation among these disorders in 11-year-old twins (Burt, Krueger, McGue, & Iacono, 2001, 2003). Whereas these studies clearly show that ADHD, ODD, and CD are influenced by some of the same genetic factors, the reasons for etiological connections are not well understood.

Certain theories or models explaining the comorbidity among childhood externalizing disorders stem from the observation that they are reliably related to certain temperament or personality traits that may serve to increase the likelihood of expressing the disorders. An extensive literature provides evidence of the covariation between externalizing behaviors and personality traits involving undercontrol and risk-taking (e.g., Iacono, Malone, & McGue, 2008; Khan, Jacobson, Gardner, Prescott, & Kendler, 2005; see Muris & Ollendick, 2005 for a review). Further, studies show that the externalizing dimension can be extended to include certain personality traits with common genetic and non-shared environmental influences such as novelty seeking (Young, Stallings, Corley, Krauter, & Hewitt, 2000) and lack of constraint (Krueger et al., 2002; Krueger, Markon, Patrick, Benning, & Kramer, 2007; Krueger & Tackett, 2003). Although personality traits involving undercontrol or risk-taking have shown common sources of genes and environment with externalizing behaviors (e.g., Krueger et al., 2002; Young et al.), there are other trait dimensions related to externalizing disorders in children.

Lahey and colleagues have posited a developmental propensity model in which the same socioemotional and cognitive dispositions are thought to underlie the various childhood externalizing disorders (Lahey & Waldman, 2003; Waldman, 2005; Waldman, Singh, &

Lahey, 2006). Dispositions are proposed to have an indirect role in the manifestation of specific externalizing phenotypes like CD through interaction with the environment. Lahey, Applegate, et al. (2008) created the Child and Adolescent Dispositions Scale (CADS) to test the developmental propensity model (Lahey & Waldman, 2003). The CADS measures three dispositions (Prosociality, Negative Emotionality, and Daring) that were identified based on evidence that they were concurrently and predictively related to conduct problems in children (e.g., Dadds, Fraser, Frost, & Hawes, 2005; Lahey, Rathouz et al., 2008; Leve, Kim, & Pears, 2005; Singh & Waldman, 2010). Lahey and Waldman (2003) define the Prosociality disposition as respect for rules, helping and sharing, guilt over transgressions, and sympathetic concern for others. Negative Emotionality reflects mood lability and stress reactivity. Daring refers to excitement seeking and risk taking. These dispositions are proposed, in part, to underlie the development of CD via common genetic factors coupled with requisite environmental conditions (Lahey and Waldman, 2003). Thus, the developmental propensity model would predict genetic influences on each of the socioemotional dispositions as well as common genetic factors associated with the dispositions and CD and, by extension, externalizing disorders more broadly.

In the only published study of its kind, Waldman et al. (2011) tested the developmental propensity model in terms of common genetic influence with an externalizing disorder, CD. Genetic influences unique to Prosociality and Negative Emotionality contributed to 20 and 16% of the variance on CD. Genetic influences unique to Daring accounted for only a small but significant amount of the variance on CD (3%). The overlap between the three socioemotional dispositions and CD was primarily genetic with small effects for non-shared environment. This provided initial evidence that the covariance of socioemotional dispositions with externalizing behavior disorders and perhaps their covariation is likely to be attributable primarily to genetic and non-shared environmental influences.

The Current Study

Although Waldman et al. (2011) demonstrated support for the developmental propensity model with regard to CD the study was limited in that it did not provide a test of the model in regard to the broader externalizing spectrum. The present study addresses this gap and tests whether common genetic, shared environmental, and non-shared environmental factors are associated with Prosociality, Negative Emotionality, and Daring, and a latent Externalizing factor representing the common variance among childhood behavioral disorders. It is possible that the socioemotional dispositions will not show genetic and environmental overlap with Externalizing, indicating that perhaps particular dispositions share common genetic and environmental variance only with specific behavioral disorders (e.g., CD). However, it is also possible that the developmental propensity model can be used to understand the common variance or covariance among behavioral disorders in children. Consistent with this idea and based on findings from Waldman et al. for CD, Prosociality, Negative Emotionality, and Daring were expected to have genetic variance in common with the latent Externalizing factor. Also in line with Waldman et al., Prosociality and Negative Emotionality (but not Daring) were expected to have non-shared environmental variance in common with Externalizing.

Method

Participants

Twins in this study were initially ascertained for the Florida Twin Project on Reading study (e.g., Taylor & Schatschneider, 2010) using Florida's state-wide Progress Monitoring and Reporting Network (PMRN) data base to identify children in kindergarten through fifth grade who matched on last name, birth date, and school. Parents of potential twins were

provided with information about the study and given a reply form where they gave permission to include the twins in the Florida State Twin Registry. The form also included five questions assessing zygosity that has been used in other twin studies and shows a high accuracy rate (Lykken, Bouchard, McGue, & Tellegen, 1990).

Participants for this study were members of 686 same-sex twin pairs age 7–13 years ($M = 10.08$; $SD = 1.71$) in the Florida State Twin Registry (Taylor, James, Reeves, & Bobadilla, 2006). Twins age 9 and older were asked to complete a packet of questionnaires on behavior and emotions as well as a peer behavior measure. Parents received a \$30 gift card to a retailer of their choice and each twin received a \$10 gift card for completing and returning their respective packets along with signed consent/assent forms. Of the 1,624 families of same-sex twins targeted for recruitment into the study of behavior and environment, packets addressed to 150 (9%) families were returned by the post office as undeliverable. Of the 1,474 packets that were delivered 718 families (49%) replied and 97% (693) of those who replied agreed to participate and returned a completed packet (352 families with female twins; 341 families with male twins). Sampling bias was evaluated by comparing participants and non-participants on 2000 Census data using zip code for the twins' residence. No significant differences ($p > .13$) were found for housing value or number of households. Zip codes in which non-participants lived had significantly lower median family income ($t = 2.18$, $p = .03$; $d = .12$) and more households receiving public assistance ($t = 4.44$, $p < .001$; $d = .24$) than zip codes where participants lived though the effects were small.

Analyses for the current study were conducted on data from 347 MZ pairs (180 female) and 339 DZ pairs (167 female); the remaining seven pairs were excluded due to indeterminable zygosity or missing data on all study measures. In order to maximize the sample size, only parent rated data were used in this study. According to parent report, the racial composition of the present sample was 71% White, 12% African American, 9% mixed race, 2% Asian, 5% Other, and 1% failed to provide information on race. The ethnic composition of the present sample was 24% Hispanic and 71% non-Hispanic (5% failed to provide information on ethnicity). Parents reported on their family income using a scale that ranged from 1 "less than \$10,000" to 6 "\$90,000 or more." The mean was 3.89 ($SD = 1.63$), which corresponds roughly to "\$50,000 – 69,000" on the rating scale. Seven percent of respondents reported a household income of less than \$10,000 and 14% reported a household income of \$10,000 – 29,000.

Measures

Externalizing disorder symptoms—Parents completed the 45-item Disruptive Behavior Disorder (DBD) scale (Pelham, Gnagy, Greenslade, & Milich, 1992) that assesses DSM-IV symptoms of ADHD, CD, and ODD. Items were rated on a 4-point scale (Not at all; Just a little; Pretty much; Very much) and scored 0–3 points, respectively. Scales reflecting dimensional conceptualizations of the disorders were calculated by averaging the ratings across symptoms. The ODD dimension had 8 items (alpha reliability was .88). The ADHD inattention dimension had 9 items (alpha was .90). The ADHD hyperactivity/impulsivity dimension had 9 items (alpha was .85). The CD dimension contained 15 items (alpha was .71).

Dispositions—Parents completed the Child and Adolescent Dispositions Scale (CADS; Lahey, Applegate, et al., 2008) that includes 57 questions rated on a 4-point scale (1 = Not at all to 4 = Very much/very often). Prosociality had 12 items that tapped concern for others, empathy, and respect for rules. To aid in model-fitting, this scale was reverse scored for analyses (referred to as rProsociality). Negative emotionality had nine items reflecting mood

lability, boredom proneness, and stress reactivity. Daring had five items reflecting risk-taking and excitement seeking. Scale scores were not used to test the study hypothesis. Rather, items for each scale were used to create latent factors representing rProsociality (reverse scored Prosociality), Negative Emotionality, and Daring constructs in the multivariate biometrical model. However, the observed scale data were used to provide descriptive information about the measures in the sample. Alpha reliability for observed rProsociality, Negative Emotionality, and Daring was .82, .78, and .77, respectively, in this sample.

Data Analysis

Twin intraclass correlations were calculated by zygosity to provide initial information about the additive genetic (A), shared environmental (C), and non-shared environmental (E) variance associated with individual differences in each of the externalizing disorder dimensions and dispositions at the observed variable level. Given that MZ twins share 100% of their segregating genes and DZ twins share, on average, 50% of their segregating genes and the members within each twin pair share an environment, it is possible to draw inferences about the relative contributions of A, C, and E by comparing magnitudes of the twin correlations. Specifically, when the MZ correlation is greater than the DZ correlation, there is evidence of genetic influence. If the MZ correlation is less than twice the magnitude of the DZ correlation, then this is evidence for shared environment. An MZ correlation less than 1 is evidence of non-shared environment, which reflects unique environmental experiences that make biological relatives different from each other but also measurement error. Cross-twin cross-trait correlations were also calculated by zygosity to provide an initial indication of the extent to which those same sources of variance were associated with the covariation among the externalizing disorder dimensions and dispositions at the observed variable level. Inferences drawn from comparisons of cross-twin cross-trait correlations are the same as those described for intraclass correlations but apply to influences on the covariance of two variables.

The model used to test the study hypothesis (shown in Figure 1) was a Cholesky decomposition model. Latent factors were used to test construct validity and provide error-free factors (see Gayan & Olson, 2003). In this model, each disposition was treated as a factor with its individual items as indicators. A latent Externalizing factor was modeled with CD, ADHD inattention, ADHD hyperactivity/impulsivity, and ODD dimensions as phenotypic indicators. The extent to which the same sources of variance contributed to one or more latent factors was evidenced by the significance of the paths from A_1 , C_1 , and E_1 to latent variables in the model. The dispositions latent factors were entered first based on the developmental dispositions model that suggests that underlying dispositions may precede disorders. The model was fit to raw data using Full Information Maximum Likelihood (FIML) estimation in Mx (Neale, Boker, Xie, & Maes, 2003). Model fit statistics included Akaike's information criterion (AIC; Akaike, 1987) and the Bayesian information criterion (BIC; Raftery, 1995). Rather than fitting multiple nested models to test the significance of paths, a full model was fit and the 95% CI was calculated for each path estimate to show significance (i.e., when the CI did not include zero).

Results

Prior to analyses, the distributions of all variables were examined for normality. The distributions of psychiatric symptom dimensions were positively skewed. Given that the sample was mixed in terms of gender and age of twins, data were age- and gender-corrected using a regression procedure recommended by McGue and Bouchard (1984). Once the data were corrected for age and gender, the distribution of each externalizing disorder variable

was transformed and normalized using Blom's formula consistent with the approach taken by Krueger et al. (2002).

Descriptive and Twin Analyses

Diagnoses can be estimated from the DBD symptom ratings and this information is provided for descriptive purposes. These diagnoses could not be verified through clinical interview and should be viewed with due caution. According to the DBD rating, the following percentage of twins within the sample met criteria for each externalizing disorder: 4.8% ADHD, Attentive Type; 2.7% ADHD, Impulsive/hyperactive Type; 1.4% ADHD, Combined Type; 4.1% ODD; 1.2% CD. Given the focus of the present analysis on the Externalizing factor, which represents the shared variance among childhood behavior disorders, the rates of co-morbid diagnoses provides a relevant description of the sample (although these rates are also based solely on the DBD scale and must be viewed cautiously). Of the twins with an ADHD, Attentive Type diagnosis according to the DBD, 28.8% also had ADHD, Impulsive/hyperactive Type, 21.2% had ODD, and 6.1% had CD. Of the twins with an ADHD, Impulsive/hyperactive Type diagnosis according to the DBD, 43.2% also had ODD, and 16.2% had CD. Finally, of twins with an ODD diagnosis according to the DBD, 16.1% also had a CD diagnosis.

Means and standard deviations and interclass correlations among observed dispositions and externalizing disorder dimensions are given in Table 1 to provide a description of the data used in this study. Data were missing for a very small number of individuals on some variables due to individual items left unrated by the parent that precluded a scale score calculation even with the 10% missing data allowance used when creating scales. Associations among the disposition scales were non-significant in most instances and Daring was only associated with ADHD hyperactivity/impulsivity. The externalizing dimensions were all significantly correlated with each other and with rProsociality and Negative Emotionality. Twin correlations on observed variables are presented in Table 2 to provide some description of the data. (The authors will provide item-level descriptive data for dispositions upon request.) The MZ correlations were larger than the DZ correlations although not always by twice the magnitude, indicating that shared environmental variance was associated with various disorder and disposition dimensions. Table 2 also shows the cross-twin cross-trait correlations among observed variables and, as can be seen in Table 2, the magnitude of the MZ cross-twin cross-trait correlations exceeded that of the DZ twins suggesting additive genetic influence on the covariation of externalizing disorders and dispositions. There was also evidence of possible shared environmental influence given that the MZ cross-twin cross-trait correlations were not twice the magnitude of the DZ correlations.

Biometrical analysis

The latent factor Cholesky model is presented in Figure 1 (paths with 95% CIs that do not include zero are significant). The model fit statistics were as follows: $-2LL = 87,350.85$; $df = 40868$; $AIC = 5,614.85$; $BIC = -89,776.53$. Given the number of items on each dispositional factor, the individual item loadings are not presented but are available from the authors upon request. Loadings of items ranged from .42–.77 for the rProsociality factor, .28–.70 for Negative Emotionality, and .50–.78 for Daring. Loadings of symptom dimension scales on the Externalizing factor were .69 for CD, .77 for ADHD inattention, .78 for ADHD hyperactivity/impulsivity, and .88 for ODD.

The hypothesis that rProsociality, Negative Emotionality, and Daring would have genetic and non-shared environmental variance in common with the latent Externalizing factor was largely supported. However, there was no single genetic factor common to all of the

dispositions and Externalizing. The first genetic factor (A_1) was associated with rProsociality (.81), Negative Emotionality (.27), and Externalizing (.40), but not Daring (.00). Rather, Daring showed common genetic variance with Externalizing through a factor associated with Negative Emotionality (A_2) and through a factor common only to Daring and Externalizing (A_3). Also consistent with expectation, rProsociality and Negative Emotionality had non-shared environmental variance in common with the Externalizing factor, but through different factors (E_1 and E_2 , respectively). Contrary to expectations, Daring had non-shared environmental variance in common with Externalizing (through the E_1 factor). Results also showed significant shared environmental variance common to Negative Emotionality (.20) and Externalizing (.72) via the C_2 factor. The rProsociality disposition factor was associated with substantial shared environmental variance of its own (.57).

Discussion

The developmental propensity model posits that childhood behavioral disorders co-occur because they reflect the same underlying socioemotional and cognitive dispositions (Lahey & Waldman, 2003; Waldman, 2005; Waldman et al., 2006). These dispositions (Prosociality, Negative Emotionality, and Daring) interact with the environment to manifest in specific disorders like CD. Waldman et al. (2011) provided evidence for the developmental propensity model in relation to CD by showing common genetic and non-shared environmental factors associated with CD and the dispositions. The present study extended their work in an important way by testing whether genetic and environmental factors were shared among the socioemotional dispositions the Externalizing factor comprised of CD, ADHD, and ODD. Results were largely in line with findings from Waldman et al. and suggest that the developmental propensity model may indeed help explain the covariation of behavioral problems in children and perhaps their comorbid expression.

Consistent with the hypothesis, Externalizing had genetic factors in common with rProsociality, Negative Emotionality, and Daring. Waldman et al. (2011) found unique additive genetic influences associated with CD, whereas, no unique genetic variance remained for the latent Externalizing factor in the present study. Moreover, Daring and rProsociality shared no genetic variance, whereas, Negative Emotionality had common genetic variance with rProsociality, Daring, and Externalizing. Waldman et al. noted that their results were consistent with a number of developmental models of CD, including those that posit heterogeneity in factors leading to CD. The present results are consistent with that idea and suggest that risk for an externalizing propensity (latent dimension that can result in a behavioral disorder like CD) stems from at least three sets of genetic factors that are associated with individual differences in socioemotional dispositions related to prosociality (lack of), negative emotionality, and daringness. How much of each genetic factor or whether all three sets of genetic factors are necessary to produce a psychological disorder within the externalizing spectrum cannot be determined from this data. Rather, the present data highlight the need for continued examination of the developmental propensity model in relation to the broader externalizing dimension and the comorbid expression of disruptive behavior disorders in children.

Also consistent with the hypothesis and with the Waldman et al. results, there was non-shared environmental variance associated with the Externalizing factor, Prosociality, and Negative Emotionality. However, the present study showed that Daring and Externalizing also have non-shared environmental variance in common. Although the variance associated with Externalizing was small, there appear to be a set of non-shared environmental factors (E_1) contributing to that latent factor and to Daring and rProsociality. There were no

measured environmental variables included in this study, but reasonable candidates for common non-shared environmental influences on rProsociality, Daring, and Externalizing include antisocial and/or risk-taking peers (Lahey, Applegate, et al., 2008).

The lack of unique genetic influences for the externalizing dimension presents a point of departure from the results of Waldman et al. (2011). The simplest explanation for the difference is that Waldman et al. examined variance in a single disorder, CD, whereas the present study examined common variance among multiple behavioral disorders. To test this possibility, the model in Figure 1 was fit to a latent CD factor (with items from the DBD as indicators) and produced results similar to Waldman et al. with unique genetic influence on CD (.46 in the present sample compared to .58 in the Waldman et al. study). Thus, although the present results largely replicate the findings of Waldman et al. and extend them to the externalizing spectrum of disorders in children, there remains a need for additional studies of the developmental propensity model dispositions as they relate to individual behavioral disorders in the externalizing spectrum.

Results from the present study suggest that two sets of non-shared environmental factors completely account for the non-shared environmental variance in socioemotional dispositions as well as the common variance across behavioral disorders in children. Daring shares genetic but not “direct” environmental variance with Externalizing. That is, environmental variance in Daring is common to Externalizing but it is also shared with another disposition (rProsociality). It may be that Daring contributes to the development of externalizing behavior problems through an interaction with other dispositions and this possibility warrants further study. Notably, Daring showed a significant phenotypic correlation only with ADHD hyperactivity/impulsivity. In a follow-up analysis, the latent factor model depicted in Figure 1 was fit without the ADHD hyperactivity/impulsivity indicator on the Externalizing factor and the path from A_3 to the Externalizing factor was reduced but still significant (.06; CI: .01–.11). Moreover, the estimates of the A_2 paths that provided for a common set of genes between Daring, Negative Emotionality, and Externalizing were nearly identical to the original results presented in Figure 1. Thus, Daring appears to have a significant role to play, but this element of the developmental propensity model may need further study to determine the nature of its contribution to the development of childhood behavioral disorders.

Significant shared environmental influences were found for rProsociality and this was consistent with results from Waldman et al. (2011). However, a set of shared environmental effects were also found for Negative Emotionality and the Externalizing factor. At least one other research group has found shared environmental effects on the covariation among externalizing disorders (Burt et al., 2001, 2003). Furthermore, a recent meta-analysis by Burt (2009) showed that shared environmental influences are important for broad externalizing problems at the univariate level. Some potential explanations for differences in shared environment estimates across studies could include differences in assessment method or informants. Studies using questionnaires rather than diagnostic interviews, and parent report rather than child report, tend to find higher estimates of shared environment (Burt, 2009). Some research also suggests that shared environmental influences are more pronounced in high-risk or disadvantaged environments (Cleveland, 2003; Tuvblad, Grann & Lichtenstein, 2005). Given that the present study used parent-rated questionnaires from an economically diverse sample, the finding of significant shared environmental influences is perhaps not surprising. Nonetheless, the inconsistency in estimates of shared environmental influences across the literature warrants further attention.

The results of the present study do not directly address the issue of gene $\times$ environment interaction posited in the developmental propensity model (Lahey & Waldman, 2003), but

these results are consistent with such a proposal. Evidence from twin and adoption studies support the premise of environmental moderators on the genetic influence on conduct problems (Button, Scourfield, Martin, Purcell, & McGuffin, 2005; Cadoret, Yates, Troughton, Woodworth, & Stewart, 1995; Feinberg, Button, Neiderhiser, Reiss, & Hetherington, 2007), ADHD (e.g., Nikolas, Klump, & Burt, 2012; Pennington et al., 2009), and the broader Externalizing factor (Legrand, Keyes, McGue, Iacono, & Krueger, 2008). The present findings suggest that socioemotional dispositions have genetic factors in common with externalizing disorders. When viewed in light of the extant literature on gene $\times$ environment interaction, it may be the case that the common genetic effects for socioemotional dispositions and externalizing disorders are moderated by some of the same environmental factors (e.g., neglect). This possibility can be tested through studies of environmental moderators of genetic influence on Negative Emotionality, Daring, and Prosociality to identify commonalities with moderators found for externalizing disorder and perhaps through direct tests of moderation of the common genetic effects on dispositions and externalizing disorders through gene $\times$ environment biometric models that can be expanded to include multiple phenotypes.

Some limitations should be considered when interpreting the present results. First, all data were based on parent report. Had multiple informants been available this may have resulted in somewhat different estimates of genetic and environmental influences. However, using multiple informants also has drawbacks as agreement among raters tends to be quite low (Achenbach, McConaughy, & Howell, 1987). Therefore, a study focusing on the variance associated with overlap among raters will necessarily result in explaining only a fraction of the variance in the overall construct (Burt, McGue, Krueger, & Iacono, 2005). Second, the present study relied on questionnaires rather than diagnostic interviews to assess symptoms. Nonetheless, the factor structure of the externalizing disorders found in the current study was similar to the structure established in other studies using interviews (Lahey, Rathouz, et al., 2008; Tuvblad et al., 2009), providing confidence in the present results. Finally, the sample in the current study was racially/ethnically/economically diverse, covered the range of childhood ages, and had an equal distribution of genders. Although the diversity in the sample enhances the generalizability of the present findings, the sample was not large enough to adequately test the potential influences of age, gender, and socioeconomic status that may be important for understanding the etiology of externalizing disorders.

Conclusions

The present study fills a gap in the literature and suggests that the socioemotional dispositions may contribute not only to the development of CD but to the co-occurrence of behavioral disorders in children. In addition, future studies should build on the work of Burt et al. (2003) in identifying what measurable variables comprise the shared environmental effects on the latent Externalizing factor in children. Parent-child conflict within the family appears to be one such variable (Burt et al.), and future work could build on the present results by examining whether it relates to socioemotional dispositions. Lahey, Applegate, et al. (2008) suggest that affiliation with antisocial peers is one of the main forces of environment that will push a child with low prosociality toward the development of CD. This represents another environmental influence that should be investigated within regard to the pathway from dispositions to disorders. Finally, additional work is needed to bridge the present results with those of Waldman et al. by examining the other individual disorders that comprise the externalizing spectrum (ADHD and ODD) in children.

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Key Points

- Conduct disorder, attention-deficit/hyperactivity disorder, and oppositional defiant disorder form a latent Externalizing factor that has genetic and environmental underpinnings.
- The developmental propensity model was supported with regard to the Externalizing factor such that socioemotional dispositions of Prosociality, Negative Emotionality, and Daring shared common genetic and environmental factors with Externalizing.
- The findings highlight the need for clinicians to consider temperament/personality traits in children as factors associated with the development of the broad spectrum of externalizing behavior disorders.

Figure 1.

Cholesky decomposition model representing each disposition and the externalizing dimension as separate latent factors. Standardized path coefficients (and 95% confidence intervals) are provided. A = additive genetic influence; C = shared environmental influence; E = non-shared environmental influence. The rProsociality (Prosociality reverse scored), NEM (Negative Emotionality), and Daring latent factors comprised their respective scale items. The EXT (Externalizing) latent factor comprised conduct disorder, attention-deficit hyperactivity disorder inattention, attention-deficit hyperactivity disorder hyperactivity/impulsivity, and oppositional defiant disorder symptom dimension scores.

Table 1
Interclass Correlations, Means, and Standard Deviations for Observed Scales by Zygosity

	rProsociality	Negative Emotionality	Daring	ODD	ADHD Inattention	ADHD Hyperactivity/Impulsivity	CD	M (SD)
rProsociality		.17	-.10	.40	.34	.27	.35	1.75 (0.44)
Negative Emotionality	.12		.01	.59	.39	.47	.32	2.10 (0.50)
Daring	-.07	.05		.05	.05	.20	.08	2.62 (0.68)
ODD	.27	.63	.14		.60	.64	.64	0.41 (0.42)
ADHD Inattention	.25	.51	.05	.65		.70	.47	0.54 (0.57)
ADHD Hyperactivity/Impulsivity	.23	.55	.21	.65	.67		.45	0.52 (0.51)
CD	.22	.42	.16	.63	.48	.45		0.05 (0.11)
M (SD)	1.68 (0.42)	2.01 (0.49)	2.58 (0.62)	0.34 (0.41)	0.48 (0.48)	0.48 (0.45)	0.04 (0.11)	

Note: Data for monozygotic twins (N = 340–347 pairs) are below the diagonal; data for dizygotic twins (N = 332–339 pairs) are above the diagonal. ODD = oppositional defiant disorder; ADHD = attention-deficit/hyperactivity disorder; CD = conduct disorder; rProsociality = reversed Prosociality. All correlations except those in italics are significant at $p < .001$.

Table 2

Twin Intraclass and Cross-twin Cross-trait Correlations for Observed Scales

Twin 2	Twin 1	rProsociality	Negative Emotionality	Daring	ODD	ADHD Inattention	ADHD Hyperactivity/Impulsivity	CD
rProsociality		.86/.59	.18	-.13	.23	.18	.14	.26
Negative Emotionality		.15	.78/.46	-.04	.28	.36	.34	.25
Daring		-.10	.14	.77/.19	-.03	-.11	-.11	-.02
ODD		.28	.58	.12	.85/.55	.50	.43	.47
ADHD Inattention		.24	.53	.02	.66	.83/.59	.52	.45
ADHD Hyperactivity/Impulsivity		.22	.54	.20	.63	.61	.89/.59	.31
CD		.19	.38	.17	.59	.42	.43	.92/.66

Note: Correlations for monozygotic twins (N = 340–347 pairs) are below the diagonal; correlations for dizygotic twins (N = 332–339 pairs) are above the diagonal. Intraclass correlations are on the diagonal. Cross-twin cross-trait correlations are off diagonal. ODD = oppositional defiant disorder; ADHD = attention-deficit/hyperactivity disorder; CD = conduct disorder; rProsociality = reversed Prosociality. All correlations except those in italics are significant at $p < .001$.