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Difficult temperament and negative parenting in early childhood: a genetically informed cross-lagged analysis

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Abstract

A genetically informed longitudinal cross-lagged model was applied to twin data to explore etiological links between difficult temperament and negative parenting in early childhood. The sample comprised 313 monozygotic (MZ) and dizygotic (DZ) twin pairs. Difficult temperament and negative parenting were assessed at ages 2 and 3 using parent ratings. Both constructs were interrelated within and across age (r_s .34–.47) and showed substantial stability (r_s .65–.68). Difficult temperament and negative parenting were influenced by genetic and environmental factors at ages 2 and 3. The genetic and nonshared environmental correlations (r_s .21–.76) at both ages suggest overlap at the level of etiology between the phenotypes. Significant bidirectional associations between difficult temperament and negative parenting were found. The cross-lagged association from difficult temperament at age 2 to negative parenting at age 3 and from negative parenting at age 2 and difficult temperament at age 3 were due to genetic, shared environmental, and nonshared environmental factors. Substantial novel genetic and nonshared environmental influences emerged at age 3 and suggest change in the etiology of these constructs over time.

Introduction

Difficult temperament describes children who are characterized by negative mood, withdrawal, low adaptability, high intensity, and low regularity (Thomas, Chess, Birch, Hertzog & Korn, 1963). Temperamental difficulty has been associated with a variety of developmental outcomes, including personality, socialization, and behavior problems (Karreman, de Haas, van Tuijl, van Aken & Dekovi, 2010; Sanson, Hemphill, Yagmurlu & McClowry, 2011). Prior work on the continuity of difficult temperament has revealed that it remains stable from infancy through adolescence (Carey & McDevitt, 1978; Korn, 1984; Lee & Bates, 1985). Given its developmental significance and stability, it is important to understand the factors that influence difficult temperament and its continuity across age.

Difficult temperament and negative parenting

One factor that impacts difficult temperament is parenting. The association between child difficult temperament and negative parenting has been well documented in the literature. Research on the longitudinal association from difficult temperament to negative parenting (*child-driven effects*) has demonstrated that difficult temperament puts children at risk for

eliciting parenting that is negative, angry or coercing, and controlling (Belsky, 1984). Children who have more difficult temperaments (i.e. irritable, fearful, angry) evoke more negative parenting (Eisenberg, Fabes, Shepard, Guthrie, Murphy *et al.*, 1999; Lengua & Kovacs, 2005), whereas children who are easily soothed and slow to anger experience increased positive emotionality and warmth from the parent (Putnam, Sanson & Rothbart, 1995). The reverse is also true; negative parenting can influence child fearfulness, irritability, and anger (Eisenberg *et al.*, 1999; Lengua & Kovacs, 2005) at subsequent ages (*parent-driven effects*). Negative parenting may therefore exacerbate difficult temperament in children.

Taken together, these longitudinal studies suggest that there may be a bidirectional relation between difficult temperament and negative parenting. That is, there may be a reciprocal dyadic relation between a child and caregiver that is mutually interactive, with both participants redirecting, stimulating, and augmenting one another's behavior (Bell, 1968). A problem with existing research, however, is that simply looking at the contemporaneous and cross-lagged correlations between difficult temperament and negative parenting may not reveal directions of effects. That is, it is possible for cross-lagged correlations to be similar in magnitude even though there are different directions of effects (Greven, Asherson, Rijdsdijk & Plomin, 2011). Cross-lagged models that include both contemporaneous and cross-lagged associations are needed. That is, models that simultaneously analyze the cross-lagged effects independent of the pre-existing association between the constructs at the first time point and the stability of each construct across age are needed to provide a better test of a reciprocal effects model of difficult temperament and negative parenting (Greven *et al.*, 2011).

Etiology of the association between difficult temperament and negative parenting—Difficult temperament and negative parenting are phenotypically associated, which raises the question of why these constructs are linked. One possibility is that they may be genetically related. Although there is an abundance of research showing that most temperament dimensions are genetically influenced (see Saudino & Wang, 2012), the etiology of individual differences in difficult temperament is relatively unexplored. Many of the behaviors that comprise difficult temperament (e.g. emotionality, activity level, soothability) have genetic bases (Saudino, 2005). Only three studies have investigated the etiology of difficult temperament, two in early infancy (Boivin, Pélusse, Dionne, Saysset, Zoccolillo *et al.*, 2005; Silberg, San Miguel, Murrelle, Prom, Bates *et al.*, 2005) and one in middle childhood (Lemery & Goldsmith, 2001). All suggest that variation in difficult temperament is due, in part, to genetic influences. Approximately 75% of the variance in difficult temperament is due to genetic effects with the remainder attributable to nonshared environmental influences (Lemery & Goldsmith, 2001; Silberg *et al.*, 2005). What is missing, however, are studies exploring genetic and environmental influences on individual differences in difficult temperament in toddlerhood – a time that may be particularly important, as it has been shown that difficult temperament in early childhood is predictive of later behavior problems (Bates, Bayles, Bennett, Ridge & Brown, 1991). In addition, there have been no longitudinal behavioral genetic studies of difficult temperament which are needed to inform about the etiology of stability and change in difficult temperament. Genes

are dynamic in nature, changing in the quantity and quality of their effects as the organism changes developmentally (Plomin & Nesselroade, 1990). Moreover, different genes can be involved at different stages of development. Thus, genetic factors can be a source of change as well as continuity in behavioral development.

In contrast to difficult temperament, the genetic and environmental influences on negative parenting behaviors have been well studied. Significant genetic contributions to negative parental affect, maternal and paternal punitive discipline, and negativity have been found (e.g. Plomin, Reiss, Hetherington & Howe, 1994). When treated as a phenotype of the child, the degree of similarity in parenting that siblings receive covaries with their degree of genetic relatedness. For example, in a simple twin study, identical twins receive more similar parenting than fraternal twins, suggesting genetic influences. These effects are child-based genetic effects, and reflect the child factors in the elicitation of parent behaviors (Plomin, DeFries & Loehlin, 1977; Scarr & McCartney, 1983).

Given the well-documented association between difficult temperament and negative parenting, and that both are genetically influenced, it is possible that these constructs are linked because of shared genetic effects. To our knowledge, only one study has investigated the genetic and environmental covariance between difficult temperament and negative parenting. Difficult temperament in 5-month-old twins was positively associated with one aspect of negative parenting, maternal hostile-reactive behavior (Boivin *et al.*, 2005). Multivariate genetic analyses revealed a moderately-high genetic correlation ($r_g = .55$) between the two, suggesting that there is overlap in the genetic factors that influence both phenotypes. A likely mechanism that underlies the association between difficult temperament and negative parenting is that the child's genetically influenced difficult temperament evokes negative parenting behaviors. That is, there is an evocative gene–environment correlation (r_{GE}). Thus, the genetic influence on negative parenting in part reflects parents' reactions to their children's genetically influenced difficult temperament. Nothing is known, however, about the genetic and environmental links between difficult temperament and negative parenting beyond early infancy. Parenting a toddler is very different from parenting an infant, and therefore the factors that link the two may change across development. Moreover, behavioral genetic studies of the longitudinal association between the two have not been undertaken. The present study examines the genetic and environmental links between difficult temperament and negative parenting at ages 2 and 3. A biometric cross-lagged model (Burt, McGue, Krueger & Iacono, 2005) was used to inform about sources of genetic and environmental covariation between the two constructs within and across age and can provide information about the directions of effects at the etiological level.

Although the directions of effects between difficult temperament and negative parenting has not been examined, recent work has revealed bidirectional associations between a related construct, child behavior problems, and parenting. Biometric cross-lagged models have been fit to parent–child conflict and externalizing problems (Burt, McGue, Krueger & Iacono, 2005), parental negativity and antisocial behavior (Larsson, Viding, Rijdsdijk & Plomin, 2008), and parental negativity and behavior problems (Alemany, Rijdsdijk, Haworth, Fañanás & Plomin, 2013). All analyses revealed reciprocal relations among the respective constructs.

That is, both parent-driven and child-driven effects underlie these associations. Given that difficult temperament has been shown to predict later behavior problems (Bates *et al.*, 1991), exploration of the link between difficult temperament and negative parenting may be more informative regarding early risk factors for maladaptive behaviors. Based on the existing literature demonstrating concurrent and longitudinal associations between difficult temperament and negative parenting, and the bidirectionality evidenced in prior work on related constructs, it was predicted that the constructs in the present study would also demonstrate reciprocal effects and that the overlap within and across age would be due largely to genetic factors.

Methods

Participants

The Boston University Twin Project (BUTP) sample was recruited from the Massachusetts Registry of Vital Records. Twins with birth weights less than 1750 grams or with gestational ages less than 34 weeks were not included in the study. The sample comprised 313 same-sex twin pairs (145 MZ and 168 DZ) at age 2, of which 300 twin pairs (137 MZ and 163 DZ) were assessed at age 3. There were approximately equal numbers of males and females. Ethnicity of the sample was generally representative of the state of Massachusetts (85.4% Caucasian, 3.2% Black, 2% Asian, 7.3% Mixed, 2.2% Other). Socioeconomic status according to the Holling-shead (1975) Four Factor Index ranged from low to upper middle class (range = 20.5–66; $M = 50.9$, $SD = 14.1$). Zygosity was determined using DNA analyses obtained through cheek swab samples. In cases where DNA was not available ($n = 3$) zygosity was determined using parent responses on physical similarity questionnaires, which have been shown to be more than 95% accurate when compared to DNA markers (Price, Freeman, Craig, Ebersole & Plomin, 2000).

Measures

Difficult temperament—Child temperament was assessed with the Toddler Behavior Assessment Questionnaire- Revised (TBAQ-R; Goldsmith, 1996). Parents reported on their children's behaviors in specific situations (i.e. 'When your child needed to sit still, as in a waiting room or restaurant, how often did s/he play quietly?') observed in the past month on a scale of 1 (*never*) to 7 (*always*). Secondary factor analysis of the TBAQ-R subscales yielded a difficult temperament factor consisting of activity level, anger, sadness, soothability (reversed), and inhibitory control (reversed) subscales (Saudino & Ganiban, 2013). A difficult temperament composite was created using the average of the standardized z -scores for each of these subscales. The reliability for difficult temperament as indicated by Cronbach's alpha was .76 at age 2 and .80 at age 3.

Negative parenting—Parents rated their positive and negative feelings toward their children on the Parent Feelings Questionnaire (PFQ; Deater-Deckard, 1996), a list of 24 statements (i.e. 'I enjoy hugging or cuddling this child', 'Sometimes this child really tests my patience') on a 5-point scale ranging from 1 (*definitely untrue for me*) to 5 (*definitely true for me*). The PFQ also includes a 10-point scale ranging from 1 (*never*) to 10 (*always*) for parents to indicate how frequently, on average, they experience each emotion (happy,

sad, angry, excited, hostile, joyful, frustrated, proud, furious, amused) with each twin. Parent negative feelings and emotions were composited according to Deater-Deckard (2000).

A measure of harsh discipline was obtained via a widely used semi-structured interview (Deater-Deckard, 2000; Deater-Deckard, Dodge, Bates & Pettit, 1996) which was modified to a parent report format (Knafo & Plomin, 2006) for use with twins in the Twins Early Development Study (TEDS). Parents were asked to rate on a 5-point scale ranging from 1 (*I rarely or never do this*) to 5 (*I usually do this*) how frequently they use each of 14 discipline methods (i.e. 'Spank or slap', 'I am usually affectionate with this child') with their first-born twin. Parents were then asked to provide a differential rating of discipline for the second born twin by indicating on a scale from 2 (*a lot more*) to -2 (*a lot less*) the extent to which they used the same technique with the second-born twin relative to twin 1. Following the TEDS procedure, a twin 2 discipline score was then created by summing the twin 1 score with the differential score. To form the discipline variable, each item was standardized and scales were formed based on factor analysis. Factor analysis indicated that yelling, arguing, spanking, and asking someone else to deal with the child loaded on harsh discipline at both ages. At age 2, harsh discipline also included ignoring the child. Despite the slight difference in items, the two harsh discipline measures were substantially correlated across age (.49, $p < .05$). An overall measure of negative parenting at each age was formed by averaging standardized scores for parent negative feelings, negative emotions and harsh discipline. In the present study, Cronbach's alpha for negative parenting was .74 at age 2 and .79 at age 3.

Statistical approach

Data transformations—The negative parenting variable was positively skewed and was rank transformed to correct for skewedness at both ages. Because twin covariances can be inflated by variance due to sex, all scores were residualized for sex effects (see McGue & Bouchard, 1984). These residualized scores were used in all behavioral genetic analyses in the present study.

Twin design—The twin method involves comparing MZ twins, who share 100% of their genes with DZ twins who share, on average, 50% of their segregating genes. Additive genetic influence (A) is suggested when twin similarity on a trait varies with genetic relatedness. When correlational analyses are used to index co-twin similarity, MZ correlations that exceed DZ correlations indicate genetic influences on the phenotype under study. Shared environments (C), family-wide experiences that act to make twins more similar, are assumed to be equal for both MZ and DZ twins raised in the same family. DZ twin correlations that are more than half of MZ twin correlations suggest shared environmental influences. Nonshared environmental influences (E) are experiences that are unique to the individual and make individuals within a family different. MZ twin correlations that are less than 1 indicate the influences of nonshared environments on the phenotype. Based on twin methodology, structural equation models can be used to estimate the contributions of A, C, and E to difficult temperament and negative parenting and to the covariation between the constructs.

Cross-lagged analysis—A genetically informed cross-lagged model (Figure 1) was used to provide information about the genetic and environmental sources of variance at each age and the covariation between traits within and across ages, as well as the stability of each trait. This model constrains all cross-age associations to function as phenotypic partial regression coefficients (i.e. b_{11} , b_{22} , b_{12} , b_{21}). The paths leading from the phenotype at age 2 to the same phenotype at age 3 (b_{11} and b_{22}) index the stability of the phenotype while controlling for any prior association with the second phenotype. The cross-lagged paths (b_{12} and b_{21}) reflect the effects of each trait at Time 1 on the other trait at Time 2 and allow us to partial out the independent impact of traits across age above and beyond their pre-existing relation. For example, path b_{12} indicates whether difficult temperament at age 2 impacts negative parenting at age 3 above and beyond their association at age 2. Variances of difficult temperament and negative parenting at age 2 were decomposed into their genetic, shared environmental, and nonshared environmental path estimates. The path estimates a_1 , c_1 , e_1 and a_2 , c_2 , e_2 indicate the relative influences of the latent variables A_1 , C_1 , and E_1 and A_2 , C_2 , and E_2 on their respective phenotype at age 2 and the square of these path values represent genetic and environmental variances. The genetic correlation at age 2 (r_{g1}) indicates the extent to which the genetic effects on difficult temperament correlate with the genetic effects on negative parenting independent of the heritability of each. The genetic factors that influence two measures can covary perfectly although the genetic effects on each measure contribute only marginally to the phenotypic variance. Therefore, r_{g1} can be 1.0 when the heritability of each measure is modest. Conversely, two measures may be highly heritable, but if there is no genetic overlap, the genetic correlation would be zero. A similar logic applies to the shared environmental correlation (r_{c1}) and nonshared environmental correlation (r_{e1}). The effects at age 3 are residual effects that are independent of age 2. Thus, a_3 , c_3 , e_3 and a_4 , c_4 , e_4 estimate the relative influences of the latent variables A_3 , C_3 , and E_3 and A_4 , C_4 , and E_4 on the phenotypes at age 3 that are independent of the age 2 effects, and thus reflect change. The genetic and environmental correlations at age 3 (r_{g2} , r_{c2} , r_{e2}) index genetic and environmental overlap of these novel effects across the phenotypes.

To understand the extent to which difficult temperament and negative parenting influence each other over time, the genetic and environmental variances in difficult temperament and negative parenting at age 3 can be further portioned into four different effects. That is, the total genetic variance in difficult temperament at age 3 can be decomposed into: (1) *stability effects*: genetic influences specific to difficult temperament at age 2 that are transmitted to age 3 (calculation; $b_{11}^2 \times a_1^2$); (2) *cross-lagged effects*: genetic influences specific to negative parenting at age 2 transmitted to difficult temperament at age 3 (calculation; $b_{21}^2 \times a_2^2$); (3) *common effects from age 2*: the genetic effects common to difficult temperament and negative parenting at age 2 (calculation; $2 \times [b_{11} \times a_1 \times r_{g1} \times a_2 \times b_{21}]$); and (4) *residual effects*: unique genetic effects on difficult temperament at age 3 (calculation; a_3^2) (Larsson et al., 2008). The age 3 variance for negative parenting is similarly decomposed.

Raw maximum likelihood estimation was used to account for missing data in Mx structural equation modeling software (Neale, Boker, Xie & Maes, 2006). Goodness of model fit was assessed using likelihood-ratio chi-square (χ^2) tests, calculated as the difference between the $-2 \log$ likelihood ($-2LL$) of the full model and that of a saturated model (i.e. a model in

which the variance–covariance structure is not estimated and all variances and covariances for MZ and DZ twins are estimated). The difference in $-2LL$ is asymptotically distributed as χ^2 with degrees of freedom (df) which reflects the difference in the amount of estimated parameters between the full model and a saturated model. A reduced model, in which all nonsignificant parameters were dropped, was compared to the full model in which all parameters were estimated. The relative fit of the reduced model was determined by the chi-square difference (χ^2) between the full model and the reduced model and corresponding change in degrees of freedom (df). A nonsignificant change in chi-square between the full and reduced model indicates that the nonsignificant parameters can be dropped from the model without a significant decrement in overall model fit. Akaike's Information Criterion (AIC ; $AIC = \chi^2 - 2 * df$) values were also computed, with lower AIC values indicating better fit of the model to the observed data.

Results

Descriptive statistics

Table 1 lists the means and standard deviations (SD) for difficult temperament and negative parenting at age 2 and age 3 by sex. Mean differences were assessed using linear mixed effects models fitted using the SAS PROC MIXED procedure to account for the nested structure of the data. Family was the group effect and individual twins represented repeated observations. For difficult temperament, the main effect for time and the interaction between time and gender were nonsignificant. There was a significant main effect of gender, with boys having more difficult temperaments than girls ($p < .001$). For negative parenting, the main effects of gender and time were nonsignificant ($p > .05$), but the interaction between time and gender was significant ($p < .05$). Post-hoc analyses using Tukey pairwise comparisons indicated that the interaction between time and gender for boys approached significance ($p = .07$), with the mean level of negative parenting for boys decreasing from age 2 to age 3.

Phenotypic correlations

There were moderate age-specific relations among difficult temperament and negative parenting at age 2 ($r = .41, p < .001$) and at age 3 ($r = .47, p < .001$). There was high stability in difficult temperament ($r = .65, p < .001$) and negative parenting ($r = .68, p < .001$) across age. The cross-age cross-construct correlation between difficult temperament at age 2 and negative parenting at age 3 was moderate ($r = .34, p < .001$) and a similar correlation was obtained for negative parenting at age 2 and difficult temperament at age 3 ($r = .37, p < .001$).

Intraclass and cross correlations

Table 2 contains the intraclass correlations and cross correlations for difficult temperament and negative parenting at ages 2 and 3 by zygosity. For both measures at both ages, the intraclass correlations for MZ twins exceed those of DZ twins, suggesting that genetic influences contribute to individual differences in these traits. In all instances, the DZ intraclass correlations are greater than half of the MZ correlations, which suggests that shared environmental influences also impact these traits. With one exception, the cross-age

cross-construct correlation between difficult temperament at age 2 and negative parenting at age 3, the cross correlations show a similar pattern of results. The genetic and environmental influences on these phenotypes can be tested by more powerful multivariate genetic model-fitting analyses.

Model-fitting analyses

Table 3 presents the fit statistics for the full cross-lagged model. The residual shared environmental effects on both difficult temperament and negative parenting at age 3 and the shared environmental correlation between the two phenotypes at both ages were nonsignificant in the full model and dropping these paths did not result in significantly worse model fit. All other paths were significant and thus were retained in the best-fitting model (Figure 2).

Genetic and environmental influences on difficult temperament and negative parenting in early childhood

The genetic and environmental contributions to difficult temperament and negative parenting at age 2 are the squared path values of the latent variables A_1 , C_1 , E_1 and A_2 , C_2 , E_2 in Figure 2. These values represent the percentage of variance due to genetic, shared environmental, and nonshared environmental effects, respectively. For difficult temperament, genetic factors explained 54% of the variance, and shared environmental and nonshared environmental influences contributed 33% and 13% of the variance, respectively. For negative parenting, genetic factors explained 43% of the variance, shared environmental influences explained 45% of the variance, and nonshared environmental factors accounted for 12% of the variance.

The paths on the right side of the model at age 3 represent novel genetic and environmental effects that are independent of the effects at age 2. As indicated earlier, in this model the genetic and environmental influences at age 3 are decomposed into effects transmitted from age 2 and novel effects at age 3 (Table 4). In terms of overall effects, genetic factors accounted for 61.4% of the variance in difficult temperament at age 3 and nonshared environmental influences accounted for 27.7% of the variance. Although no novel shared environmental effects were observed at age 3, shared environmental effects from age 2 are transmitted to age 3 via the cross-lagged path from negative parenting at age 2 and the stability from difficult temperament at age 2 (Table 4). Shared environmental factors accounted for 10.8% of the variance in difficult temperament at age 3. The variance in negative parenting at age 3 was primarily accounted for by genetics (62.3%) and, to a lesser extent, by nonshared environmental influences (21.4%). Once again, shared environmental influences from age 2 are transmitted to age 3 via the cross-lagged path from difficult temperament at age 2 and the stability path from negative parenting at age 2. These effects account for 16.3% of the variance in negative parenting at age 3. The squared path values representing novel variance at age 3 sum to 61% (i.e. 38% + 23%) for difficult temperament and 57% (i.e. 41% + 16%) for negative parenting. This indicates that approximately 40% (total variance [100%] minus age 3 variance) of the variance in these variables was explained by difficult temperament and negative parenting at age 2.

Concurrent overlap between difficult temperament and negative parenting at each age

At age 2, the genetic correlation ($r_{g1} = .76$) suggests that many of the same genetic effects are common among difficult temperament and negative parenting at age 2. The nonshared environmental correlation at age 2 ($r_{e1} = .21$) indicates that although these two phenotypes have some nonshared environmental influences in common, many of the effects are unique to each phenotype. At age 3, the genetic and nonshared environmental correlations between the residual variances of difficult temperament and negative parenting were .34 and .30, respectively. These moderate correlations suggest that there are both common and unique genetic and nonshared environmental influences on difficult temperament and negative parenting at age 3 that are independent of the common effects at age 2. The overall genetic correlation at age 3 (not just for novel effects) was .55.

Difficult temperament and negative parenting across age (stability and cross-lagged effects)

All stability and cross-lagged paths (i.e. b_{11} , b_{22} , b_{12} , b_{21}) were significant in the full model and could not be dropped without a significant decrement in fit ($\chi^2 = 565.619$, $df = 4$, $p < .001$). This indicates that there is stability in both phenotypes and a bidirectional association between difficult temperament and negative parenting at ages 2 and 3. Estimates of variance due to cross-lagged and stability effects can be obtained by squaring the partial regression coefficients for the respective paths. Stability effects from age 2 explained 30.3% of the variance in difficult temperament at age 3 and 34.8% of the variance negative parenting at age 3. The cross-lagged effects were modest. Difficult temperament at age 2 independently explained 1.7% of the variance in negative parenting at age 3. Negative parenting at age 2 explained 2.3% of the variance in difficult temperament at age 3.

Genetic and environmental influences over time

The genetic and environmental covariance between difficult temperament and negative parenting across age act indirectly through the cross-lagged regression coefficients (b_{12} , b_{21}) in Figure 1. Therefore, examining the genetic and environmental contributions from age 2 to the cross-lagged and stability paths allows us to examine how difficult temperament and negative parenting at age 2 impact the genetic and environmental contributions to these phenotypes at age 3. Table 4 decomposes the genetic, shared environmental, and nonshared environmental effects on difficult temperament and negative parenting at age 3 into components that are transmitted from age 2 and residual effects that are specific to age 3. The total variance at age 3 is the sum of the component variances. The genetic variance in difficult temperament at age 3 was primarily accounted for by novel genetic effects (i.e. the novel genetic effects at age 3 divided by the total genetic variance in difficult temperament at age 3 [$.381/.614 \times 100 = 62.1\%$]). Approximately a quarter of the genetic variance in difficult temperament at age 3 was due to cross-age stability (i.e. $.163/.614 \times 100 = 26.5\%$), that is, the genetic effects on difficult temperament at age 2 that are transmitted across age. Genetic influences that are common to both phenotypes at age 2 account for 9.8% (i.e. $.060/.614 \times 100$) of the genetic variance in difficult temperament at age 3, suggesting that shared genetic influences between difficult temperament and negative parenting at age 2 also influence difficult temperament at age 3. Shared environmental influences on difficult

temperament at age 3 are modest (10.8% of the variance) and entirely transmitted from age 2. The majority of shared environmental influences on difficult temperament at age 3 were due to stability effects (i.e. $.098/.108 \times 100 = 90.7\%$), indicating that shared environmental effects from age 2 persist at age 3 and largely contribute to the modest shared environmental variance in difficult temperament at age 3. The remaining shared environmental variance in difficult temperament at age 3 (i.e. $.010/.108 \times 100 = 9.3\%$) was attributable to shared environmental influences on negative parenting at age 2 (i.e. cross-lagged effects). Nonshared environmental influences at age 3 are primarily due to novel effects ($.232/.277 \times 100 = 83.8\%$), and to a lesser extent due to cross-age stability effects that are transmitted from age 2 ($.038/.277 \times 100 = 13.7\%$).

The genetic influences on negative parenting at age 3 (see Table 4) are similarly accounted for by novel genetic effects at age 3 ($.405/.623 \times 100 = 65\%$) and cross-age genetic stability ($.152/.623 \times 100 = 24.4\%$), indicating that although new genetic influences emerge at age 3, approximately a quarter of the genetic effects on negative parenting at age 3 are transmitted from negative parenting at age 2. As was the case for difficult temperament, shared environmental influences on negative parenting at age 3 were modest (16.3%) and transmitted from age 2. Shared environmental influences from negative parenting at age 2 explained 96.9% (i.e. $.158/.163 \times 100$) of the shared environmental effects on negative parenting at age 3 (i.e. stability effects). Nonshared environmental effects on negative parenting at age 3 were primarily a function of new age 3 effects (i.e. $.164/.214 \times 100 = 76.6\%$), although a portion of the nonshared environmental variance in negative parenting at age 3 was transmitted from age 2 (i.e. $.044/.214 \times 100 = 20.6\%$).

Discussion

The present study is the first to explore both the contemporaneous and longitudinal association between difficult temperament and negative parenting from a behavioral genetic perspective. The application of the biometric cross-lagged model to our data provides novel findings regarding genetic and environmental influences on difficult temperament and negative parenting in toddlerhood; genetic and environmental sources of covariance between the two domains; and genetic and environmental contributions to stability and change and to bidirectional effects across age. We discuss these findings below.

Genetic and environmental influences on difficult temperament and negative parenting in early childhood

Consistent with prior research (Boivin *et al.*, 2005; Lemery & Goldsmith, 2001; Silberg *et al.*, 2005), the present study finds that difficult temperament is influenced by genetic and nonshared environmental factors in early childhood. However, in contrast to earlier findings, difficult temperament was also influenced by shared environmental factors at both ages. The previous failures to find significant shared environmental effects are likely due to contrast effects (Saudino, 2003). Parent ratings of temperament are prone to rater biases that exaggerate differences between co-twins. These biases result in 'too-low' DZ correlations; that is, DZ correlations that are much less than half of the MZ correlations (often near zero). Contrast effects can mask shared environmental influences. Indeed, the prior studies of

difficult temperament show a pattern of DZ correlations that are lower than would be expected by the genetic hypothesis, and a model that accounts for contrast effects best explains difficult temperament in the first year of life (Silberg *et al.*, 2005). For most temperament dimensions, accounting for contrast effects reveals shared environmental effects on parent-rated temperament (Saudino, McGuire, Reiss, Hetherington & Plomin, 1995). The TBAQ used in the present study is not prone to contrast effects (Saudino, 2012), and the pattern of low DZ correlations did not emerge in our sample. Thus, we suggest that our findings of shared environmental influences on difficult temperament are real and provide novel evidence of family-wide influences on this important behavioral style. Characteristics of the parent or the co-parenting relationship have been suggested as factors that may contribute to the shared environmental influences on child behavior (e.g. Belsky & Jaffee, 2006). Further, parent personalities may structure the environment in a particular way that contributes to difficult temperaments in their children. For example, parent personality can impact the sensitivity to signals from the child and responsiveness to their needs (Dix, 1992). Family conflict and co-parenting quality may also influence child difficult temperament. Children are sensitive to disagreements and conflict in the family and those with difficult temperaments may be more vulnerable to negative life events such as family conflict and dysfunctional parenting (Belsky & Jaffee, 2006).

Prior work on genetic influences on parenting behaviors finds that there are child-based genetic contributions to negative parental affect, maternal and paternal punitive discipline, and negativity (e.g. Plomin *et al.*, 1994). The present study also revealed child-based genetic influences on a broader measure of negative parenting in early childhood, but shared environmental influences are also implicated. Some of the shared environmental factors that may influence negative parenting are characteristics of the parent, such as self-efficacy, stress-management (Webster-Stratton, 1990) and personality. In addition, family circumstances such as socioeconomic status may impact parenting quality (Webster-Stratton, 1990).

Concurrent overlap between difficult temperament and negative parenting at each age

The present study provides novel evidence for genetic overlap between difficult temperament and negative parenting in early childhood. That is, to some extent, the same genetic factors that influence difficult temperament also underlie negative parenting. Prior work has similarly uncovered genetic overlap between difficult temperament and hostile-reactive parent behavior in infancy (Boivin *et al.*, 2005). This is the first study to assess the association in early childhood, and our results extend this finding by revealing genetic overlap between difficult temperament and a more encompassing measure of negative parenting. In addition, these findings suggest that although parenting a toddler is very different from parenting an infant, genetic factors continue to underlie the association between difficult temperament and negative parenting across development. Common genetic influences on difficult temperament and negative parenting suggest that basic temperamental dispositions of children may evoke negative parenting behaviors (i.e. evocative *rGE*). However, as indicated in the next section, the parent's behavior also influences the temperament of their children.

Prior research has found overlapping shared environmental effects between child behavior problems and parenting (Burt *et al.*, 2005; Larsson *et al.*, 2008). This was not the case for difficult temperament and negative parenting in the present study. That is, although both constructs were influenced by shared environments, the shared environmental influences that impact difficult temperament differ from those that influence negative parenting. The different pattern of results for difficult temperament and behavior problems across studies supports the notion that difficult temperament and behavior problems are not isomorphic.

Difficult temperament and negative parenting across age (stability and cross-lagged effects)

In addition to concurrent overlap between difficult temperament and negative parenting at each age, both phenotypes showed substantial stability. The cross-lagged path from difficult temperament at age 2 to negative parenting at age 3 suggests that early difficult temperament has lasting evocative effects on later parenting. The cross-lagged path from negative parenting at age 2 to difficult temperament at age 3 reveals that negative parenting also elicits later difficult temperament. These findings further support the notion that poor parenting behaviors can initiate coercive family processes that escalate a negative pattern of child behaviors (Keenan & Shaw, 1995). The small, but significant, bidirectional associations between difficult temperament and negative parenting suggest that both child-driven and parent-driven effects, in part, underlie this association, but the effects are modest. A pattern of small cross-lagged effects is typical, as these conservative effects are independent of the pre-existing association at Time 1 and stability effects (Greven *et al.*, 2011). As indicated by the overlapping confidence intervals, these paths were of similar magnitude and do not indicate differential influence, but support the notion of bidirectionality.

Genetic and environmental influences over time

At age 3, a portion of the variance in both constructs is due to persisting effects from age 2. This suggests that genetic factors and environmental factors, such as characteristics of the parent and the family context (shared environmental influences) and peer groups (nonshared environmental factors), that influence difficult temperament and negative parenting at age 2 continue to influence difficult temperament and negative parenting at age 3. Despite this, for both constructs, much of the genetic and nonshared environmental variance at age 3 is novel and independent of the effects that are transmitted from age 2. Although no novel shared environmental influences emerge at age 3, the same shared environmental effects on difficult temperament and negative parenting at age 2 persist longitudinally to age 3. This raises an interesting question about possible sources of *stable* shared environmental influences on early difficult temperament and negative parenting (i.e. family-wide influences that are experienced early in toddlerhood and have persistent effects). As indicated above, there are some likely candidates for sources of shared environmental effects on difficult temperament; at question is how long these early family-wide shared environments continue to influence difficult temperament and negative parenting. Longitudinal behavioral genetic studies across larger time periods are needed to address this. Nonetheless, the present findings highlight the importance of the early family environment on child temperament – at least in toddlerhood.

Implications

The importance of developmental change in difficult temperament and negative parenting at the etiological level has been noted, and this raises the question of what factors are bringing out the novel effects at age 3. Since genes come on and off as development proceeds, it is reasonable that new genetic effects emerge at age 3 and are substantial. This has implications for molecular genetic research; as genetic influences change across time, age should be considered in these analyses. Further, at age 3 children are entering into many new environments, such as preschool, and are experiencing novel social situations as they begin to interact more with their peers in these settings. It is possible that these new environments are accounting for the novel nonshared environmental influences emerging at age 3. Thus, it is important to consider age in research explaining environmental influences on difficult temperament.

In addition, there are important implications for interventions on the reciprocal nature of the dyadic interaction. Because there is a bidirectional association between difficult temperament and negative parenting, interventions that encourage both child-directed and parent-directed intervention are likely to be most effective. Although bidirectional effects were modest, it is possible that they may have a snowballing or cascading effect across development (e.g. Martel, Pierce, Nigg, Jester, Adams *et al.*, 2009). Further, encouraging parental attention and respect for the individuality of their children's temperaments may help to increase the efficacy of parent-child interaction therapies. These findings argue for family-wide interventions that are early (i.e. before age 3). Future research should investigate what parenting techniques are most effective for dealing with difficult temperaments and parent-child interventions should be specific to the temperament of the child.

Limitations

Because parents provided information about both parenting and their children's temperament, it is possible that the results somehow reflect shared method variance. This does not, however, appear to be the case, as a benefit of the cross-lagged model is that the shared method variance is part of the synchronic correlation at Time 1 and is statistically controlled (Greven *et al.*, 2011; Rubin, Nelson, Hastings & Asendorpf, 1999). Additionally, because the same parent provided information about both twins' temperaments, it is possible that the shared environmental effects on difficult temperament to some extent reflect shared rater variance. However, in prior studies of difficult temperament in which the same parent rates both twins, shared environmental influences do not emerge (Boivin *et al.*, 2005; Lemery & Goldsmith, 2001; Silberg *et al.*, 2005). Therefore, simply being rated by the same parent does not always yield findings of shared environmental effects on difficult temperament. Of course, it is possible that the TBAQ may be more prone to shared rater variance than other parent rating measures, but this seems unlikely given that the TBAQ has been found to be less prone to rater biases and, further, shared environmental influences do not emerge for all temperament dimensions assessed with the TBAQ (Saudino, 2012). Nonetheless, future research should employ a multi-method approach, such as utilizing multiple raters (i.e. mothers, fathers, teachers) or observational assessments of temperament.

It should also be noted that our model cannot distinguish between passive, evocative, and active gene–environment correlations. While we suggest that the genetic covariance between difficult temperament and negative parenting in toddlers is most plausibly due to evocative effects, we acknowledge that this is not a certainty. Lastly, given our moderate sample size, power to detect significant effects is always a concern; however, in our sample, power analyses revealed over 80% power to detect the presence of genetic and shared environmental influences with heritabilities in the range of .5 and shared environmental effects in the range of .25. Power to detect small cross-lagged effects ($f^2 = .02$; Cohen, 1988) was also greater than 80% with our sample size. Nonetheless, our sample size did not afford sufficient power to explore sex differences in the magnitude of genetic and environmental effects and remains a question for future research.

Conclusions

Individual differences in difficult temperament in toddlerhood are genetically influenced, but the environment is also important. Shared environmental influences are present and persist across ages 2 to 3. Continuity and change in difficult temperament across early childhood is due to both genetic and environmental factors. Difficult temperament and negative parenting in early childhood are linked through common genetic and environmental effects and mutually influence each other over time. The findings of genetic correlations within and across ages suggest that reciprocal and evocative processes, in part, underlie the association between difficult temperament and negative parenting. Evidence of both child-driven and parent-driven effects support the notion that children with difficult temperaments evoke negative parenting, but negative parenting also elicits difficult temperament. These findings further support Bell's (1986) conceptualization of the dyadic relationship as mutually interactive, with both participants playing an active role in the other's behavior.

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Research highlights

- In addition to revealing genetic and nonshared environmental influences on individual differences in difficult temperament in toddlerhood, the present study provides novel evidence for shared environmental effects.
- Continuity in difficult temperament is largely due to genetic factors, and both genetic and nonshared environmental influences contribute to change.
- The within-age genetic associations between difficult temperament and negative parenting indicate that, to some extent, parenting reflects child temperament.
- In addition to contemporaneous associations at each age, there is evidence of a bidirectional association between difficult temperament and negative parenting that is due to both genetic and environmental effects.

Figure 1. A path diagram of the cross-lagged model shown for one twin

Latent factors appear in circles (i.e. A for genetic factors, C for shared environments, E for nonshared environments). Difficult temperament (DIFF) and negative parenting (NEG) are observed (measured) variables and appear in rectangles. Latent factors at age 3 represent residual variances. Standardized path estimates for the latent factors are indicated by subscripts (e.g. a_1 , c_1 , e_1). Cross-age stability is represented by b_{11} and b_{22} , while b_{12} and b_{21} indicate cross-lagged effects. Double-headed arrows linking two latent factors represent genetic, shared environmental, or nonshared environmental correlations (i.e. r_{g1} , r_{c1} , r_{e1} , r_{g2} , r_{c2} , r_{e2}).

Figure 2. The best-fitting cross-lagged model

Latent factors appear in circles (i.e. A for genetic factors, C for shared environments, E for nonshared environments). Difficult temperament (DIFF) and negative parenting (NEG) are observed (measured) variables and appear in rectangles. 95% confidence intervals appear in parentheses.

Table 1

Means (standard deviations) of measures of difficult temperament and negative parenting at age 2 and age 3 by gender

Measures	Males	Females	Gender <i>F</i> (<i>df</i>)	Time <i>F</i> (<i>df</i>)	Time × Gender <i>F</i> (<i>df</i>)
Difficult temperament					
Age 2	0.13 (0.75)	-0.15 (0.67)			
Age 3	0.09 (0.75)	-0.09 (0.74)	14.11 (312) ***	1.64 (296)	3.03 (297)
Negative parenting					
Age 2	0.04 (0.73)	-0.04 (0.72)			
Age 3	-0.03 (0.81)	0.02 (0.88)	0.94 (313)	3.06 (304)	5.23 (302) *

* $p < .05$;

*** $p < .001$.

Table 2

Twin intraclass and cross correlations

	Age 2			Age 3		
	<u>Difficult temperament</u>		<u>Negative parenting</u>	<u>Difficult temperament</u>		<u>Negative parenting</u>
	MZ	DZ	MZ	DZ	MZ	DZ
Age 2						
Difficult temperament	.87	.63	–	–	–	–
Negative parenting	.37	.25	.87	.70	–	–
Age 3						
Difficult temperament	.60	.50	.33	.26	.78	.58
Negative parenting	.25	.26	.64	.56	.37	.31
					.81	.65

Note: MZ = monozygotic twins, DZ = dizygotic twins. Intraclass correlations are bolded. All correlations are significant at $p < .01$.

Table 3

Model fitting results for difficult temperament and negative parenting at age 2 and age 3

Model	Fit of model compared to saturated model ^a				Difference in fit of models ^b		
	-2LL	df	χ^2	df	p	AIC	χ^2 df p
Saturated	4312.059	2342					
Full	4433.092	2392	121.033	50	<.001	21.033	
Reduced	4436.532	2396	124.473	54	<.001	16.473	3.441 4 .51

Note: -2LL = log likelihood statistic; df = degrees of freedom; χ^2 = chi-square fit statistic; AIC = Akaike's information criterion.

^a Overall fit of the model determined by the difference in -2LL of the model and that of a saturated model.

^b Relative fit of the model determined by the χ^2 difference () χ^2 between full model and reduced model, in which all nonsignificant paths were dropped.

Table 4

Proportion of the total genetic, shared environmental, and nonshared environmental variation in difficult temperament and negative parenting at age 3

Difficult temperament at age 3	Total^I variance	A	C	E
Total ACE variance due to:	1.000	.614	.108	.277
Difficult temperament at age 2 (cross-age stability effects)	.299	.163 (26.5%)	.098 (90.7%)	.038 (13.7%)
Negative parenting at age 2 (cross-lagged effects)	.023	.010 (1.6%)	.010 (9.3%)	.003 (1.1%)
Common effects at age 2	.064	.060 (9.8%)	–	.004 (1.4%)
Specific effects at age 3	.613	.381 (62.1%)	–	.232 (83.8%)
Negative Parenting at age 3	Total Variance	A	C	E
Total ACE variance due to:	1.000	.623	.163	.214
Negative parenting at age 2 (cross-age stability effects)	.354	.152 (24.4%)	.158 (96.9%)	.044 (20.6%)
Difficult temperament at age 2 (cross-lagged effects)	.016	.009 (1.4%)	.005 (3.1%)	.002 (0.9%)
Common effects at age 2	.061	.057 (9.1%)	–	.004 (1.9%)
Specific effects at age 3	.569	.405 (65%)	–	.164 (76.6%)

Note: A = Genetic influences; C = Shared environmental influences; E = Nonshared environmental influences. Percentages of genetic, shared environmental, and nonshared environmental influences, respectively, due to four sources are provided in parentheses.

^ITotal A, C, and E variance do not add to 1.000 due to rounding.