


Genetic and Environmental Associations Between Child Personality and Parenting

Social Psychological and
Personality Science
2019, Vol. 10(6) 711–721
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DOI: 10.1177/1948550618784890
journals.sagepub.com/home/spp



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Abstract

Parenting is often conceptualized in terms of its effects on offspring. However, children may also play an active role in influencing the parenting they receive. Simple correlations between parenting and child outcomes may be due to parent-to-child causation, child-to-parent causation, or some combination of the two. We use a multirater, genetically informative, large sample ($n = 1,411$ twin sets) to gain traction on this issue as it relates to parental warmth and stress in the context of child Big Five personality. Considerable variance in parental warmth (27%) and stress (45%) was attributable to child genetic influences on parenting. Incorporating child Big Five personality into the model roughly explained half of this variance. This result is consistent with the hypothesis that parents mold their parenting in response to their child's personality. Residual heritability of parenting is likely due to child characteristics beyond the Big Five.

Keywords

parenting, Big Five, behavior genetics, personality, personality development

Parenting, which refers to the set of behaviors, emotions, cognitions, values, attributions, and attitudes directed by parents toward their children (Berg-Nielsen, Vikan, & Dahl, 2002), has been traditionally conceptualized in terms of its effects on children. However, simple parent-offspring correlations are consistent with both parent socialization on child outcomes or child evocative effects on parent behavior (Bell, 1968). Put differently, parental behavior may play a role in child development, but child characteristics may also influence the type of parenting provided (Anderson, Lytton, & Romney, 1986; Karraker & Coleman, 2005; Stern & Hildebrandt, 1986). Methods for assessing bidirectional relations are necessary to distinguish parent-to-child and child-to-parent pathways (Belsky, 1984).

Genetically informative designs give insight into the mechanisms underlying associations between parenting and child characteristics (Avinun & Knafo, 2014; Klahr & Burt, 2014). Using these designs, variance in parenting can be decomposed into components resulting from child effects (e.g., parents responding to genetically influenced characteristics of their children), shared environmental effects (e.g., characteristics of the parent that lead to similar parenting across family members), and nonshared environmental effects (e.g., unique relationships between parents and children that lead to different parenting across family members, including measurement error). Multivariate genetically informed designs also allow for the exploration of *which* child characteristics parents respond to.

In this study, we use a behavior genetic design to evaluate bidirectional effects of children's behavior on parenting, in particular children's Big Five personality. We focus on two parenting dimensions, warmth and stress, which are examples of positive and negative parenting dimensions, respectively. Parental warmth is defined as parental behaviors characterized by affection, responsiveness, and support (Patterson, Cheung, Mann, Tucker-Drob, & Harden, 2017), whereas parental stress refers to parental feelings characterized by trouble, pressure, and tension (McBride, Schoppe, & Rane, 2002).

Using Behavior Genetic Designs to Disentangle Child Effects on Parenting

Behavior genetic designs make inferences about genetic and environmental influences on a phenotype based on the similarities between siblings. To the extent that identical twins, who

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share 100% of their genetic material, are more similar on the outcome of interest than fraternal twins, who share 50% of their segregating genetic material on average, additive genetic influences (A) on that outcome are implied. If identical twins are more than twice as similar as fraternal twins on the outcome, nonadditive genetic influences (e.g., dominance, D, or Epistasis, I) on that outcome are implied. In the case of dominance, identical twins are expected to be 100% congruent, but fraternal twins are only expected to be 25% congruent for dominant genetic effects.¹ To the extent that siblings, regardless of zygosity, are similar on the outcome after accounting for genetic influences, shared environmental influences (C) are implied. Finally, to the extent that siblings are dissimilar on the outcome, nonshared environmental (E) influences, which include measurement error, are implied.

Child-based twin designs allow for inferences about influences on parenting based on the genetic relatedness between child twins. If parents respond to genetically influenced characteristics of their children, then identical twins should receive more similar parenting compared to fraternal twins, a form of gene–environment correlation² (Plomin, Reiss, Hetherington, & Howe, 1994). Parents of fraternal twins might treat their children more differently compared to identical twins because (genetically) less similar children require more individualized strategies or fraternal twins differentially shape the type of parenting offered. To the extent that parenting displays significant heritability, bidirectional models of parenting are implied. At a first glance, it might be counterintuitive to think of parenting as heritable on the part of the child because parenting represents an environment for the child. However, the parenting environment can be evoked or selected by the child's genetically influenced traits. Thus, parenting becomes matched with child's genotype, also known as gene–environment correlation (Plomin, DeFries, & Loehlin, 1977; Scarr & McCartney, 1983).

In addition to examining genetic influences on parenting, child-based twin designs also enable the disentangling of shared and nonshared environmental influences on parenting. Shared environment reflects environmental factors that cause twins to receive the same parenting. To the extent that *parent* genetic variation impacts parenting, child-based designs reflect this as shared environmental variance given that these effects create between-family differences in parenting. Shared environmental influences may also include factors such as parental personality traits, personal values related to parenting, parental socioeconomic status, and anything else that would lead to similar parenting within a household. The nonshared environment reflects environmental factors that cause twins to receive different parenting, creating within-family differences in parenting, even in identical twins. Factors that would increase estimates of a nonshared environment may include illness of one twin but not the other, unique (nongenetically influenced variation in) child characteristics, anything else that would lead to different parenting within a household, and measurement error.

Child-based twin designs have been widely used by researchers interested in parenting. Avinun and Knafo (2014)

conducted a meta-analysis of child genetic and environmental influences on parenting in child-based twin designs. They found that 23% of the variance in parenting behavior was attributable to child genetic effects, 43% to shared environmental effects, and 34% to nonshared environmental effects. Another meta-analysis of genetically informative studies of parenting estimated that 26% of the variance in parental warmth was attributable to child genetic influences, 39% to shared environmental influences, and the remaining 35% of the variance attributable to the nonshared environment (Klahr & Burt, 2014). Parental negativity was slightly more strongly influenced by child genetic influences (40%) compared to the shared environment (27%), with the remaining 33% of the variance attributable to the nonshared environment.

These moderate child genetic influences on parenting behavior are consistent with children influencing the parenting they receive. This influence may entail a transactional feedback process in which child behaviors evoke parenting behaviors which in turn influence child behavior, and so forth (Sameroff, 2009). Shared and nonshared environmental variance in parenting is somewhat more ambiguous in terms of the direction of influence. Most likely, these sources of variance reflect characteristics of the parent or the family on the child's behavior (i.e., parental education may affect parenting). However, it is also possible that some environmental source of variance influenced child development, and it is this aspect of the child's environment influencing the parent indirectly (i.e., due to an environmental stressor, a child becomes more difficult, increasing parental stress).

Child Characteristics That Influence Parenting

As nearly all child characteristics that vary in the population are genetically influenced (Turkheimer, 2000), many child psychological dimensions may explain child genetic influences on parenting. Researchers have traditionally examined associations between child temperament, parenting, and child outcomes through correlational designs. In general, parental warmth tends to be associated with positive outcomes, such as soothability, inhibitory control, emotional regulation, and social responsiveness (Coplan, Reichel, & Rowan, 2009; Smith, 2010; Verhoeven, Junger, Van Aken, Deković, & Van Aken, 2007). On the other hand, stressful parental behavior, such as hostility, is associated with lack of effortful control, negative affect, and irritability (Morris et al., 2002).

Similarly, genetically informative designs have found gene–environment correlations between parenting and child characteristics. For example, part of the child genetic variance in parental negativity has been associated with child personality dimensions, such as depression, anxiety, and externalizing behavior (Button, Lau, Maughan, & Eley, 2008; Jaffee et al., 2004; McAdams, Gregory, & Eley, 2013; Narusyte, Andeshed, Neiderhiser, & Lichtenstein, 2007). Turning toward more positive factors, genetic variance in parental positivity was partially accounted for by a child's prosocial behavior

(Knafo & Plomin, 2006). In the academic realm, parental educational expectations are formed in part based on their children's genetically influenced personality characteristics, in addition to children's academic performance (Briley, Harden, & Tucker-Drob, 2014). In general, common variance shared between parenting and child characteristics across these studies tended to reflect genetic pathways, although environmental associations were also found.

Present Study

In this study, we use a genetically informative design to examine the influence of child Big Five personality on parental warmth and stress. To the best of our knowledge, this is the first study that incorporates a child's Big Five personality traits to evaluate the influence of a child's genetically influenced traits on parenting. To the extent that child personality accounts for genetic variance in parenting, this result would support the notion that child personality molds parenting behavior. Using data from a large child and adolescent twin sample, we estimate the extent to which child genetic and environmental influences contribute to (1) variance in warmth and stress and (2) covariance between parenting and child personality. To avoid issues of method bias inflating associations, parenting and child personality were evaluated by independent raters, such that parents reported on their parenting, while children reported on their personality.

Method

Participants

Data were obtained from the Texas Twin Project (Harden, Tucker-Drob, & Tackett, 2013), an ongoing study of child development of twins and multiples enrolled in public schools in multiple cities in Texas. Data for this project were available from 2,951 participants from 1,313 families. The participants comprised 1,411 pairs (including all possible triplet pairs), out of which 497 (35.22%) were identical pairs, 480 (34.02%) were same-sex fraternal pairs, and 434 (30.76%) were opposite-sex fraternal pairs.³ The mean age of the participants was 13.22 ($SD = 3.18$), and 50% were male. In terms of ethnicity, our sample included 53% non-Hispanic White, 22% Hispanic, 10% African American, and 6% Asian participants, with the remaining 9% of individuals selecting some other race/ethnicity. In addition to the focal child participants, one parent from each family completed a survey. Due to differences in protocols across subprojects (e.g., child reports were not obtained from very young children, and some parents failed to complete the parent survey), the data set included complete information for 2,425 observations, only child personality for 253 observations, and only parenting for 273 observations.

Sample size was not determined in reference to this project. The Texas Twin Project has collected data relevant to this project for more than 7 years. Using the lowest meta-analytic estimates of child genetic influences on parenting (Avinun & Knafo, 2014), the current sample size has over 99% power to

detect genetic and environmental influences on parenting. Assuming only 2% of the variance in parenting was shared with personality split evenly between genetic and environmental sources, power to detect genetic (96%) and nonshared environmental (97%) covariance was high. No observations were excluded. All measures relevant to the study hypotheses are included in this report.

Measures

Parenting. Parents completed questions related to parental warmth and stress. Four items assessed warmth (e.g., Even when I am in a bad mood, I show TWIN1 a lot of love) and 4 items assessed stress (e.g., TWIN1 does things that really bother me). Parents rated their parenting behaviors toward each twin separately using a 4-point scale (1 = *completely true*, 4 = *not at all true*). The reliability of the warmth and stress subscales was Cronbach's $\alpha = .79$ and $.66$, respectively. Although the reliability of stress was somewhat low, the mean interitem correlation was $.37$, which is relatively large. To give a sense, if the number of items had been doubled, the expected internal consistency would have been $.94$ using the Spearman-Brown prophecy formula. Nevertheless, low reliability may attenuate associations.

Child personality. Each twin completed the child version of the Big Five Inventory (John, Naumann, & Soto, 2008). Each item was rated using a 5-point scale (1 = *strongly disagree*, 5 = *strongly agree*). The Cronbach α reliabilities were $.80$ for extroversion (8 items), $.74$ for agreeableness (9 items), $.76$ for conscientiousness (9 items), $.74$ for neuroticism (8 items), and $.73$ for openness to experience (10 items). To control for acquiescent response style, that is, the tendency to consistently agree or disagree with the items regardless of their content, within-person centering of scores was performed by subtracting the mean acquiescence score derived from pairs of items with opposite implications for personality (for more information about acquiescence score calculations, see Soto & John, 2009).

Zygosity. Information concerning co-twins' physical similarity was used to classify zygosity (i.e., whether the twin pair was identical or fraternal). For all participants, parents completed a physical similarity questionnaire in which they rated the twins' similarity on 10 items such as hair color, eye color, and the frequency with which people confuse the twins (Rietveld et al., 2000). When available, we also included twin self-report (26.33% of total observations) and research assistant report (58.65% of total observations) of physical similarity. This information was only available for a subset of twins who completed in-laboratory assessments. We used latent class analysis using all available data to classify same-sex twins as identical or fraternal. Past research has shown latent class analysis based on physical similarity ratings to be at least 99% accurate when compared with genotyping (Heath et al., 2003).

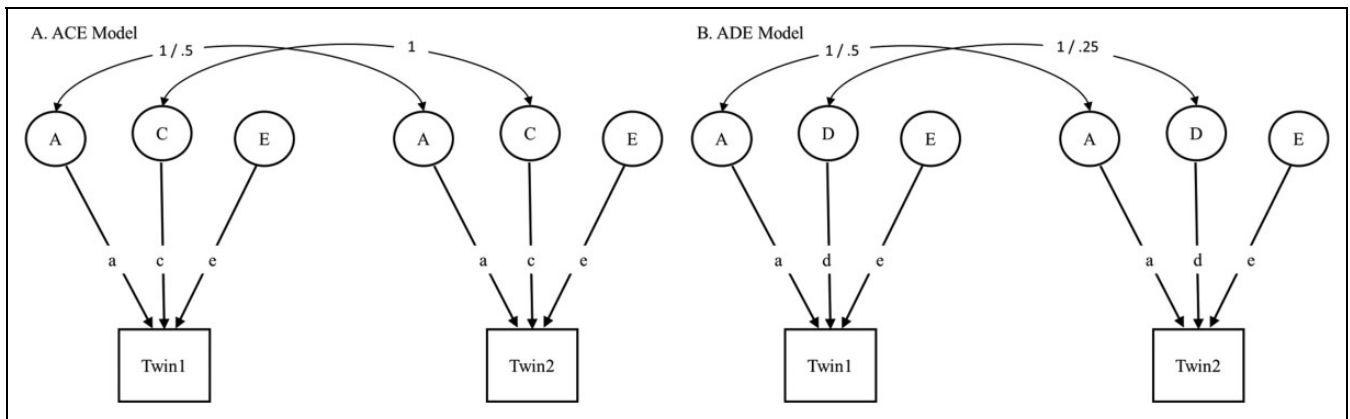


Figure 1. Examples of ACE model and ADE model (right). The ACE model decomposes variance in an observed variable into additive genetic (A), shared environmental (C), and nonshared environmental (E) components. This decomposition is accomplished by specifying a multiple group model in which the correlation between the A factor for Twin1 and the A factor for Twin2 is fixed to 1 for identical twins and 0.5 for fraternal twins. The shared environmental factor is correlated at 1 and the nonshared environment correlated at 0 across twins regardless of zygosity. When identical twins are correlated more than twice as strong as fraternal twins, this pattern implies nonadditive genetic influences (D). In this case, C cannot be estimated, and the D Factors are correlated at 1 for identical twins and .25 for fraternal twins.

Analytic Plan

Our analyses followed four steps: descriptive analyses, univariate variance decomposition, bivariate associations, and a full multivariate model. First, we examined basic descriptive statistics and twin correlations. Next, we fit biometric models to our data to estimate the proportion of variance in our phenotypes that is due to the A, C, D, and E components. We fit both ADE and ACE models that consist of three latent variables (see Figure 1). Although each variance component may play a role (Boomsma et al., 2018), the classical twin design can only identify three simultaneously. The letters a^2 , c^2 , d^2 , and e^2 refer to the squared path coefficients, representing the proportion of variance explained by each factor.

To identify associations between parenting and child personality, we fit bivariate Cholesky decompositions to explore the extent to which genetic and environmental variance in parenting is accounted for by genetic and environmental influences on child personality. Figure 2 presents an example of this model. The “11” and “22” subscripts refer to influences on personality and parenting, respectively. The pathways unique to parenting represent residual variance not shared with personality. The “21” subscript refers to the cross-path representing shared genetic and environmental influences between personality and parenting. These parameters are the behavior genetic analog to regression analysis. Instead of a single β coefficient, three coefficients are estimated, one reflecting each variance component. The A/D cross-path indicates genetic covariance between personality and parenting. The E cross-path indicates nonshared environmental covariance between personality and parenting. Due to convergence problems, we could not estimate the A and D cross-paths separately, presumably because the model has relatively little power to separate these two genetic components and because of very small estimates of either A or D on personality. Therefore, we fixed both genetic cross-paths to be equal and interpret these parameters as

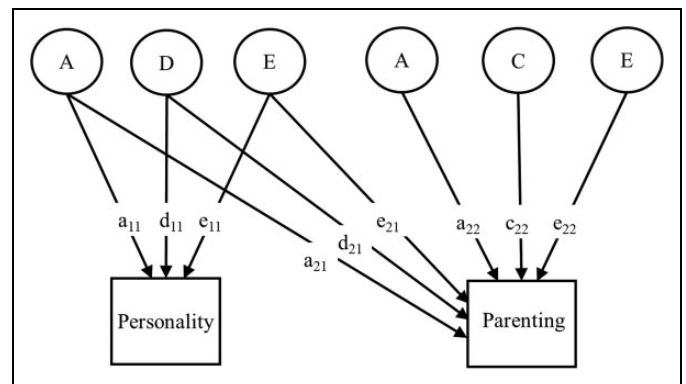


Figure 2. Example of a Cholesky model. Parenting is regressed on the genetic and environmental factors of the personality variable. This model is analogous to a regression model, except that the single regression coefficient is decomposed into genetic and environmental components. The cross-pathways indicate the extent to which genetic and environmental influences on personality are shared with parenting.

representing broadly defined genetic influences. We tested the robustness of the results across multiple specifications.

Finally, shared genetic and environmental influences between personality and parenting could be due to overlapping influence with other dimensions of personality. To account for overlapping personality variance, we fit multivariate Cholesky models in which all Big Five traits are entered in one model (Figure 3). In these models, cross-path estimates are interpreted similar to multiple regression coefficients, except that the ordering of the phenotypes is important, as variables entered earlier in the model (i.e., toward the left-hand side) account for variance in variables entered later (i.e., toward the right-hand side).

All analyses were conducted in Mplus Version 7.4 software. In each behavior genetic model, we residualize for age, sex, age², and Age \times Sex (McGue & Bouchard, 1984). As some

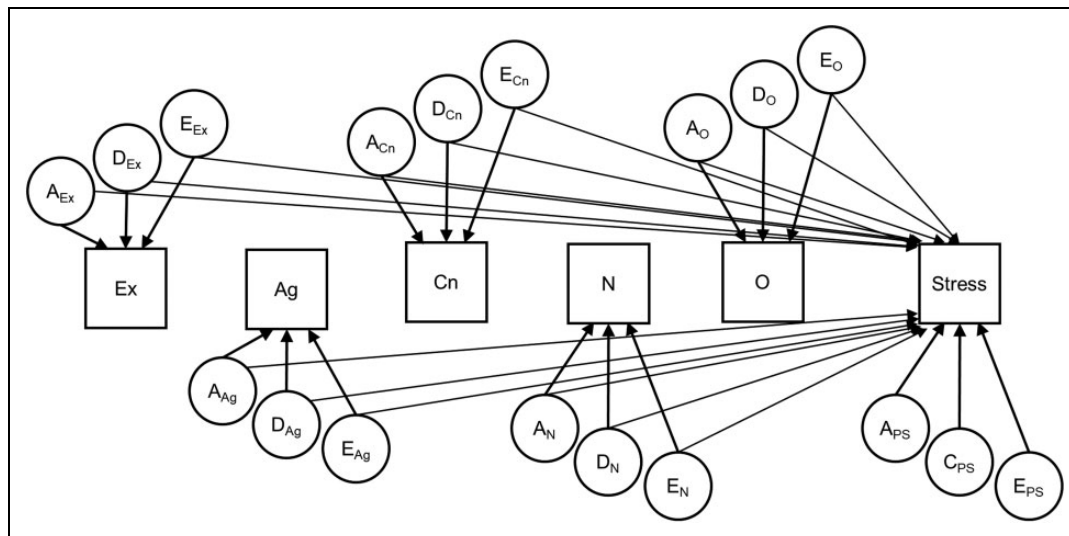


Figure 3. Example of a multivariate Cholesky model decomposing genetic and environmental associations among all phenotypes. The cross-path estimates are interpreted similar to multiple regression coefficients. The additive and nonadditive genetic cross-paths are fixed to be equal. The paths between personality traits are omitted for simplicity. Ex = extroversion; Ag = agreeableness; Cn = conscientiousness; N = neuroticism; O = openness to experience; A = additive genetic effects; D = dominant genetic effects; E = nonshared environmental effects; and C = shared environmental effects.

Table 1. Zero-Order Phenotypic Correlations and Demographic Effects.

Variable	Zero-Order Phenotypic Correlations						Demographic Effects			
	1	2	3	4	5	6	Age	Age ²	Male	Age × Male
1. PW							-.20***	.002	-.05	-.06
2. PS	-.24***						.01	.02	-.04	.04
3. Child E	.05*	.006					-.13***	-.07**	.01	.02
4. Child A	.13***	-.16***	.15***				-.12***	.02	-.12***	.02
5. Child C	.14***	-.15***	.07**	.38***			-.18***	.08**	-.13***	-.05
6. Child N	-.08**	.16***	-.20***	-.34***	-.26***		.03	.04	-.43***	-.22***
7. Child O	.05*	-.03	.18***	.21***	.15***	-.05*	-.20***	-.05*	-.08*	.04

Note. All *p* values are from two-tailed tests. Age, parenting, and personality variables were standardized prior to analysis. Demographic effects report unstandardized regression coefficients. PW = parental warmth; PS = parental stress; E = extroversion; A = agreeableness; C = conscientiousness; N = neuroticism; and O = openness to experience.

p* < .05. *p* < .01. ****p* < .001.

families contributed multiple pairs (e.g., triplets provide three possible pairs), we correct for nonindependence by using the “complex survey” option with the family as the clustering variable. We also correct for individuals in triplet pairs being represented in two pairs by downweighting each triplet pair’s contribution by half. To evaluate model fit, we relied on standard cutoffs of root mean square error of approximation (RMSEA) less than .06 and confirmatory fit index (CFI) above .95 as indicators of good fit (Hu & Bentler, 1999).

Results

Descriptive Statistics

Table 1 reports zero-order phenotypic correlations. We found that parental warmth significantly correlated with all child personality variables. The correlations were small, ranging

between absolute values of .05 and .14. Except for neuroticism, the correlations between warmth and personality were positive. The largest correlations were those with conscientiousness (*r* = .14) and agreeableness (*r* = .13). Parental stress significantly and negatively correlated with agreeableness (*r* = -.16) and conscientiousness (*r* = -.15) but positively correlated with neuroticism (*r* = .16). Turning toward demographic covariates, parental warmth was negatively associated with child age (*r* = -.20). Similarly, all personality traits, except for neuroticism, negatively correlated with age. This result is consistent with past research in this age range (Göllner et al., 2017).

Twin Correlations and Cross-Twin Cross-Trait Correlations

Table 2 reports twin correlations and cross-twin cross-trait correlations. Correlations between identical twins were greater

Table 2. Twin Correlations and Cross-Twin Cross-Trait Correlations.

Variable	Twin Correlations		Cross-Twin Cross-Trait Correlations			
	Identical Twins	Fraternal Twins	Identical Twins (Warmth)	Fraternal Twins (Warmth)	Identical Twins (Stress)	Fraternal Twins (Stress)
E	.47	-.02	.06	.06	.01	-.05
A	.39	.10	.10	.05	-.10	.02
C	.38	.10	.11	.09	-.05	-.02
N	.40	.02	-.04	-.05	.04	.02
O	.41	.12	.07	.05	-.02	.02
Parental warmth	.86	.73				
Parental stress	.59	.36				

Note. Models are residualized for age, sex, age², and Age × Sex. E = extroversion, A = agreeableness, C = conscientiousness, N = neuroticism, and O = openness to experience.

Table 3. Variance Decomposition Estimates for Parenting and Personality Variables.

Variable	a^2	c^2	d^2	e^2
E	0 (.00, .00)	—	.38 (.29, .47)	.62 (.53, .71)
A	0 (.00, .00)	—	.32 (.24, .40)	.68 (.60, .76)
C	0 (.00, .00)	—	.33 (.24, .43)	.67 (.57, .76)
N	0 (.00, .00)	—	.28 (.19, .36)	.72 (.64, .81)
O	.03 (-.28, .33)	—	.32 (-.02, .66)	.66 (.57, .74)
Parental warmth	.27 (.12, .41)	.56 (.44, .68)	—	.17 (.13, .22)
Parental stress	.45 (.17, .73)	.14 (-.06, .33)	—	.41 (.30, .52)

Note. Models are residualized for age, sex, age², and Age × Sex. All reported parameter estimates were standardized. E = extroversion, A = agreeableness, C = conscientiousness, N = neuroticism, and O = openness to experience.

than correlations between fraternal twins for personality and parenting variables, suggesting genetic influences. For personality measures, identical twins were more than twice as similar as fraternal twins, indicating nonadditive genetic effects in addition to additive genetic effects. The ADE model is used as D and C cannot both be estimated simultaneously with our data. Furthermore, parenting was highly correlated among both identical and fraternal twins, indicating shared environmental effects. The cross-twin cross-trait correlations were generally larger for identical twins than for fraternal twins, indicative of genetic covariance.

Univariate Genetic Analyses

We report the results of the behavior genetic decompositions in Table 3. For all but one phenotype, model fit statistics were good: The highest RMSEA was .03 and the lowest CFI was .90. In contrast, the univariate model for neuroticism exhibited relatively poor fit to the data (RMSEA = .06, CFI = .76). Nonshared environmental influences accounted for the greatest percentage of variance (62–72%) in personality traits. Dominant genetic effects were also significant, accounting for between 28% and 38% of the variance. Additive genetic effects were small and nonsignificant for personality traits (0–3%).

Regarding parenting variables, child additive genetic effects (45%) explained a substantial portion of variance in stress. A similar portion of the variance was attributed to nonshared

environmental effects (41%), leaving small shared environmental effects (14%). Shared environmental effects (56%) accounted for the largest portion of variance in warmth, with a moderate portion explained by child additive genetic effects (27%) and a smaller portion by nonshared environmental effects (17%).

Bivariate Genetic Analyses

In 10 separate models, each of two parenting variables (warmth and stress) was regressed on the latent additive genetic, dominant genetic, and nonshared environmental factors that contribute variance to the five personality traits. For all but one phenotype, model fit statistics were good: The highest RMSEA was .02 and the lowest CFI was .92. In contrast, models including neuroticism exhibited adequate fit to the data (RMSEA = .04, CFI = .92 and .96). We report the path coefficients in Table 4. Recall that a significant a_{21} parameter indicates shared genetic influences between parenting and personality, a significant e_{21} parameter indicates common within-family differences between parenting and personality, and we fixed the a_{21} and d_{21} pathways to be equal due to convergence difficulties.

As shown in Table 4, we found significant and positive a_{21} cross-pathways between child agreeableness and conscientiousness with parental warmth. We also found a significant and negative a_{21} cross-pathway between child agreeableness

Table 4. Results of Bivariate Genetic Analyses.

Variable	a_{11}	a_{21}	a_{22}	d_{11}	d_{21}	c_{22}	e_{11}	e_{21}	e_{22}
Panel 1: Parental warmth									
E	.04 (.04)	.05 (.04)	.50 (.08)***	.61 (.04)***	.05 (.04)	.74 (.05)***	.78 (.03)***	-.02 (.02)	.41 (.03)***
A	.14 (.11)	.13 (.04)**	.48 (.07)***	.54 (.05)***	.13 (.04)**	.74 (.04)***	.82 (.03)**	.04 (.02)	.41 (.03)**
C	.10 (.06)	.11 (.04)**	.49 (.07)***	.55 (.05)***	.11 (.04)**	.73 (.04)***	.81 (.03)***	.03 (.02)	.41 (.03)***
N	.02 (.04)	-.05 (.05)	.51 (.07)***	.52 (.04)***	-.05 (.05)	.74 (.04)***	.84 (.03)***	-.007 (.02)	.41 (.03)***
O	.23 (.25)	.07 (.03)	.50 (.08)***	.53 (.12)***	.07 (.03)	.74 (.05)***	.80 (.03)***	-.03 (.02)	.41 (.03)***
Panel 2: Parental stress									
E	.009 (.03)	-.02 (.05)	.66 (.11)***	.61 (.04)***	-.02 (.05)	.37 (.13)**	.78 (.03)***	.03 (.03)	.64 (.05)***
A	0 (0)***	-.20 (.06)**	.57 (.12)***	.56 (.04)***	-.20 (.06)**	.42 (.11)***	.81 (.03)***	-.05 (.03)	.64 (.05)***
C	.02 (.04)	-.10 (.05)	.66 (.10)***	.57 (.04)***	-.10 (.05)	.37 (.13)**	.80 (.03)***	-.09 (.03)**	.63 (.05)***
N	.006 (.02)	.03 (.06)	.66 (.10)***	.52 (.04)***	.03 (.06)	.37 (.13)**	.83 (.03)***	.14 (.03)***	.62 (.04)***
O	0 (0)***	-.06 (.06)	.66 (.11)***	.58 (.04)***	-.06 (.06)	.37 (.13)**	.79 (.03)***	.001 (.03)	.64 (.05)***

Note. All p values are from two-tailed tests. Models are residualized for age, sex, age², and Age \times Sex. All reported parameter estimates were standardized. The additive genetic and nonadditive genetic cross-paths were constrained to be equal. E = extroversion, A = agreeableness, C = conscientiousness, N = neuroticism, and O = openness to experience.

** $p < .01$. *** $p < .001$.

and parental stress. In all models, residual genetic effects on parenting remained statistically significant and large in size (residual a^2 between 23% and 44%), indicating that there remain child-specific genetic influences on parenting not accounted for by genetic influences of child personality. There were no significant nonshared environmental cross-pathways between child personality and parental warmth. However, there was a significant and negative pathway between child conscientiousness and parental stress and a significant and positive pathway between child neuroticism and parental stress.

To test the robustness of these results, we fitted alternative models where A and D cross-paths were estimated one at a time (Supplemental Tables S1–S4). The model fit statistics were very similar across the three models. In the A-only models, cross-paths were typically large with little to no residual genetic variance in parenting (an intuitively unlikely outcome given the small phenotypic associations). These models demonstrated that models which constrained A and D pathways were both the best fitting and most conservative of the models.

Multivariate Genetic Analyses

We next fitted two models with warmth and stress as the final variables in an extended Cholesky model (see Figure 3). RMSEA values for both models were less than .06. Table 5 presents the genetic effects matrix, dominant genetic or shared environmental matrix, and nonshared environmental effects matrix resulting from the multivariate genetic analysis. The genetic effects matrix represents additive and dominant genetic effects, as the cross-pathways of these effects were fixed to be equal. In each matrix, results for warmth are presented above the diagonal and those for stress are below the diagonal.

As shown in the genetic effects panel, there was one significant and positive pathway between child agreeableness and parental warmth and a significant and negative pathway between child agreeableness and parental stress. These results imply that, to some extent, the bivariate associations reflect

genetic variance shared across personality dimensions, rather than independent associations. Residual child genetic influences on parenting remained even when controlling for all Big Five child personality traits (17% warmth, 21% stress). Child personality accounted for 38% and 53% of the total child genetic influences on warmth and stress, respectively. Conscientiousness, agreeableness, and neuroticism had significant nonshared environmental associations with stress when entered simultaneously, indicating that these were independent associations. Child personality accounted for only 1% of the total nonshared environmental variance in warmth and around 4% for stress, with substantial residual nonshared environmental variance in warmth (17%) and stress (38%). The remaining residual variance in parental warmth (55%) and stress (21%) was due to the shared environment.

Discussion

Parenting is a bidirectional process in which parents and children alike exert influence on each other's behavior. To distinguish between these two processes, we used a genetically informative design to disentangle child genetic and environmental effects on parental warmth and stress. The current effect sizes are in line with previous reports of child genetic influences on parenting (Klahr & Burt, 2014). We also incorporated measures of child Big Five personality traits to examine possible genetic influences on parenting. Agreeableness, conscientiousness, and neuroticism were the dimensions most strongly linked to parenting in our phenotypic analyses.

Heritability of Parenting

We found that 27% and 45% of variance in warmth and stress, respectively, was attributable to child genetic influences. Specifically, we found significant and positive associations between child genetic influences on warmth and child agreeableness and conscientiousness. We also found a significant

Table 5. Results of Multivariate Genetic Analyses.

Variable	E	A	C	N	O	Parenting Variable
Panel 1: Additive genetic effects matrix						
E	0 (.11) .06 (.06)	.17 (.05)**	.14 (.04)***	-.09 (.04)*	-.001 (.04)	.06 (.03)
A	.15 (.04)***	.008 (.13) .04 (.10)	.30 (.04)***	-.16 (.06)**	.09 (.05)	.14 (.05)**
C	.14 (.04)***	.29 (.04)***	.001 (.001) 0 (0)	.02 (.10)	-.14 (.13)	-.12 (.11)
N	-.09 (.04)*	-.16 (.05)**	0 (.08)	.002 (.001) 0 (0)***	-.02 (.11)	.07 (.10)
O	.002 (.04)	.08 (.05)	-.09 (.11)	-.04 (.09)	.03 (.19) .21 (.18)	-.01 (.12)
Parenting variable	-.01 (.05)	-.18 (.06)**	.19 (.12)	-.09 (.11)	.03 (.14)	.41 (.25) .46 (.32)
Panel 2: Dominant genetic/shared environmental effects matrix						
d_{11}	.61 (.04)*** .61 (.04)***	.50 (.07)*** .52 (.06)***	.28 (.10)** .31 (.07)***	.45 (.07)*** .46 (.06)***	.53 (.18)** .51 (.17)**	— —
c_{22}	— —	— —	— —	— —	— —	.74 (.04)*** .46 (.11)***
Panel 3: Nonshared environmental effects matrix						
E	.77 (.03)*** .77 (.03)***	.21 (.04)***	.15 (.03)***	.04 (.03)	.25 (.03)***	-.02 (.02)
A	.21 (.04)***	.79 (.02)*** .79 (.02)***	.28 (.03)***	-.05 (.04)	.09 (.03)**	.04 (.02)
C	.15 (.03)***	.28 (.03)***	.75 (.02)*** .75 (.02)***	.07 (.04)*	.12 (.03)***	.03 (.02)
N	.04 (.03)	-.04 (.04)	.07 (.04)*	.83 (.03)*** .83 (.03)***	.07 (.03)*	-.008 (.02)
O	.25 (.03)***	.09 (.03)**	.11 (.03)***	.07 (.03)*	.74 (.02)*** .74 (.02)***	-.03 (.02)
Parenting variable	.03 (.03)	-.07 (.03)*	-.09 (.03)**	.15 (.03)***	-.004 (.03)	.41 (.03)*** .62 (.04)***

Note. All p values are from two-tailed tests. Models are residualized for age, sex, age², and Age \times Sex. All reported parameter estimates were standardized. Results for parental warmth displayed on the upper diagonal. Results for parental stress displayed on the lower diagonal. E = extroversion, A = agreeableness, C = conscientiousness, N = neuroticism, and O = openness to experience.

* $p < .05$. ** $p < .01$. *** $p < .001$.

and negative association between child genetic contributions to stress and child agreeableness. These associations indicate that children either evoke parenting behavior or actively shape the parenting they receive based on these genetically influenced personality traits. Neither extroversion nor openness to experience had significant associations with warmth or stress. Estimates of the genetic influences on parenting were reduced when all the personality dimensions were included in one model, but substantial amounts of child genetic variance in parenting remained that were not shared with child personality. This remaining variance could be explained by child personality dimensions other than the Big Five, such as depression (Pike, McGuire, Hetherington, Reiss, & Plomin, 1996), anxiety (McAdams et al., 2013), and externalizing behaviors (Button et al., 2008), or other sorts of genetically influenced characteristics.

Nonshared Environmental Influences

In addition to finding significant child genetic effects on parenting, we found significant nonshared environmental

associations between stress and child conscientiousness and neuroticism. These nonshared environmental effects reflect within-pair differences and are commonly conceptualized as quasi-causal because genetic and shared environmental confounding is eliminated (Turkheimer & Harden, 2014). Although we know that the direction of child genetic effects flows from child-to-parent in child-based twin designs, the direction is not clear with nonshared environmental effects. For example, the negative within-pair association between child conscientiousness and stress could mean that parents' experience of greater stress leads to reductions in the affected twin's conscientiousness. Alternatively, it could be that twins who are higher in conscientiousness than their co-twins cause their parents less stress. Both interpretations are consistent with our results, and both directions of effect may operate simultaneously. In general, however, we found few nonshared environmental associations compared to genetic associations. This discrepancy may be due to idiosyncratic effects, such as measurement error, that obscure environmental associations, or it may be that environmental sources of personality variance are

too unstable to make a lasting impact on parenting in this age range.

It is worth noting that our estimates of genetic and environmental influences on parenting are consistent with previous meta-analytic estimates (e.g., Avinun & Knafo, 2014; Klahr & Burt, 2014). Also similar to past work, we found that socially oriented personality dimensions, such as agreeableness and conscientiousness, were positively associated with warmth (e.g., de Haan, Deković, van den Akker, Stoltz, & Prinzie, 2013; Smith, 2010) and that neuroticism was associated with stress (e.g., Morris et al., 2002; van den Akker, Deković, & Prinzie, 2010). Unlike this past work, we were able to document that some portion of this association occurs due to gene–environment correlation, which may imply dynamic, transactional models.

Implications

The findings of our study have theoretical and practical implications. On the theoretical side, our results lend support for research on child effects on parenting. Given the current evidence, it is untenable to conceptualize parents purely as socializers. Instead, it is more accurate to conceptualize parenting as a transactional process in which both parents and children exert simultaneous and continuous influence on each other (Karraker & Coleman, 2005). On the practical side, the results suggest that parenting interventions may be more efficacious if both parents and children are treated, such that the intervention is tailored to the unique qualities of both parties (e.g., Webster-Stratton, Reid, & Hammond, 2004).

Strengths and Limitations

Our study has several important strengths, such as using a highly powered, genetically informative, multirater sample. This study is the first to incorporate child Big Five personality to examine genetic and environmental influences on parenting. Despite these strengths, the current study faced a few challenges.

First, there was a mismatch between the biometric model applied to parenting (ACE) relative to personality (ADE). Previous large-scale twin studies consistently demonstrate nonadditive genetic influences on personality as indicated by twin correlations (Polderman et al., 2015; Rimfeld, Kovas, Dale, & Plomin, 2016; van den Berg et al., 2014). Estimates of the nonadditive genetic influences vary across the studies, rendering the expected proportion of additive and nonadditive variance unclear. Although our variance decomposition accurately reflected the underlying data, as evidenced by past research (e.g., Keller, Coventry, Heath, & Martin, 2005), it posed difficulties in estimating covariance across phenotypes. Our solution was to constrain additive and nonadditive genetic pathways to be equal, but future work can more accurately delineate these pathways. In a series of sensitivity analyses, we demonstrate that this solution both fits the data well and

is conservative. Future work that incorporates extended pedigrees (e.g., Boomsma et al., 2018) could more accurately model these associations.

Second, cross-sectional data provided a limited snapshot of the association between parenting and child personality. To examine changes in child effects on parenting, longitudinal designs that assess child personality and parenting throughout development will be useful, especially because parenting can take different meanings across different developmental stages.

Third, the larger estimates of the nonshared environment for parental stress compared to warmth are likely driven by the relatively low reliability of the stress measure, and this measurement error may also have attenuated nonshared environmental associations. Future work should measure stress better.

Fourth, we used ratings of physical similarity to diagnose twin zygosity, which may have led to an incorrect classification. Also, we did not consider other possible forms of sibling relationships (e.g., Wenk, Houtz, Brookes, & Chiafari, 1992). It should be noted though that ratings of physical similarity are over 99% accurate when compared with genotypic data (Heath et al., 2003).

Conclusion

The results of our study support the view that parenting is a dyadic and dynamic process, whereby both parents and children influence each other. We found that some of the child Big Five personality traits, which are genetically influenced characteristics, are associated with variance in parental warmth and stress. In other words, warmth and stress are partially shaped by child personality. We also found nonshared environmental influences common between child personality and parenting. However, substantial portions of genetic and environmental variance in parenting could not be accounted for by child personality. Therefore, future research may benefit from examining other heritable child characteristics that evoke variation in parenting.


Declaration of Conflicting Interests


The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: Data collection for the Texas Twin Project has been supported by NIH grants R01HD083613, R21HD081437, R21AA023322, and R21AA020588.

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Supplemental Material

The supplemental material is available in the online version of the article.

Notes

1. Estimates of genetic similarity for fraternal twins assume no assortative mating. If violated, this assumption would lead to underestimates of genetic influences.
2. It is easy to confuse this form of gene–environment correlation with the equal environments assumption, which states that identical twins are not treated systematically differently simply by being identical twins in a way that influences development of the phenotype(s) under investigation. When children evoke parental behavior on the basis of their genetically influenced characteristics, the assumption is not necessarily violated. Further, empirical tests support the equal environments assumption (Conley, Rauscher, Dawes, Magnusson, & Siegal, 2013).
3. As a robustness check, we estimated all of our models with opposite-sex twins omitted (see Supplemental Tables S6–S9). None of our conclusions differ.

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Handling Editor: Gregory Webster