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The Quality of the Inter-parental Relationship Does Not Moderate the Etiology of Child Conduct Problems

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Abstract

Background—Although there is a clear phenotypic relationship between the quality of the inter-parental or marital relationship and child conduct problems (CP), the etiology of this association is as yet unclear. One possibility is that this association takes the form of a genotype-environment interaction (GxE), whereby the quality of the inter-parental relationship acts to moderate the etiology of child CP. The current study sought to evaluate this possibility.

Methods—We examined multiple measures and informant-reports of the quality of the inter-parental relationship in a sample of more than 700 child twin families from the Michigan State University Twin Registry (MSUTR). Analyses consisted of a series of latent GxE models.

Results—The ‘no moderation’ model provided the best fit to the data in nearly all cases, findings that collectively provide strong evidence against the possibility that the etiology of CP is moderated by the quality of the interparental relationship.

Conclusions—Such findings suggest that, contrary to implicit (and sometimes explicit) assumptions in the field, it is not the case that every environmental risk (or protective) factor exacerbates (or suppresses) genetic influences on CP. Future research should seek to delineate the specific environmental experiences that do serve as etiologic moderators of CP, and to clarify how this gene-environment interplay might change over the course of development.

Keywords

antisocial behavior; conduct problems; marital relationship; GxE

The association between the quality of the inter-parental or marital relationship and child emotional and behavioral adjustment is a robust one. High levels of inter-parental conflict and low levels of marital satisfaction have both been consistently associated with increased behavior problems in children (Cummings and Davies, 2002, Cummings and Davis, 1994, Rhoades *et al.*, 2011). Available work has indicated that this association is likely bidirectional in nature (Davies *et al.*, 2002, Grych *et al.*, 2003, Harden *et al.*, 2007, Harold and Conger, 1997, Schulz *et al.*, 2006). On the one hand, longitudinal and intervention studies have suggested that this association is at least partially causal in origin (Davies *et al.*,

2002, Grych *et al.*, 2003, Harold and Conger, 1997, Schulz *et al.*, 2006), such that child behavior problems tend to improve following either 1) improvements in the inter-parental relationship in response to intervention or 2) the dissolution of high-conflict marriages (Amato and Booth, 1996, Booth and Amato, 2001, Morrison and Coiro, 1999, Schulz *et al.*, 2006). On the other hand, genetically-informed studies (Harden *et al.*, 2007) have indicated that the association partially reflects genetic influences on child antisocial behavior, results that are more in keeping with a child-driven effect.

Importantly, however, available work has yet to consider the possible role of the gene-environment interaction (GxE). GxE is typically defined as differential responsiveness to environmental risk as a function of genotype (Plomin *et al.*, 1977), and in this case, would manifest as differential responsiveness to inter-parental conflict as a function of one's predisposition towards antisocial behavior. Although no studies to our knowledge have examined this possibility in regards to inter-parental conflict and youth conduct problems (for a study of child anger, however, please see Rhoades *et al.*, 2011), studies of other environmental moderators have unambiguously supported a role for GxE in antisocial/externalizing behaviors (Burt and Klump, 2013a, 2014a, b, Feinberg *et al.*, 2007, Hicks *et al.*, 2009, Kim-Cohen *et al.*, 2006). As one example, Feinberg and colleagues (2007) examined whether parental negativity and warmth moderated genetic and environmental influences on adolescent behavior problems, and found that genetic influences were potentiated in the face of either negative parenting or low warmth. Consistent with these sorts of results, GxE are now widely thought to constitute a fundamental mechanism through which genes and environments influence human behavior and mental health (Rutter *et al.*, 2006).

The goal of the current study was thus to examine whether and how positive and negative aspects of the inter-parental relationship moderated the etiology of child antisocial behavior. To ensure the robustness of our results, we examined multiple measures and informant-reports of the inter-parental relationship, including mother/wife- and father/husband-reports, observer-ratings of videotaped inter-parental interactions, and the perceptions of the twin children, and did so in a large sample of child twin families. Given the comprehensive nature of these analyses, results will provide clear evidence for or against GxE in the association between the inter-parental relationship and child antisocial behavior.

Methods

PARTICIPANTS

Participants were drawn from the Twin Study of Behavioral and Emotional Development in Children (TBED-C), a study within the population-based Michigan State University Twin Registry (MSUTR) (Burt and Klump, 2013b, Klump and Burt, 2006). Given our specific focus on the quality of the inter-parental relationship (rather than on the effects of divorce or separation), we restricted our primary analyses to families in which the twins' primary caregivers were currently married/cohabitating (N=720 families or 1,440 twins and their parent/s). The TBED-C includes both a population-based sample (n=500 families of which 440 were 'intact' or had currently married/cohabitating parents) and an independent on-going sample for which inclusion criteria also specified that participating twin families lived

in moderately- to severely-disadvantaged neighborhoods (current N=380 families of which 280 were 'intact').

To be eligible for participation in the TBED-C, neither twin could have a cognitive or physical condition (as assessed via parental screen; e.g., a significant developmental delay) that would preclude completion of the assessment. Children provided informed assent, while parents provided informed consent for themselves and their children. The twins ranged in age from 6 to 10 years (mean = 8.11, SD = 1.41; although a few twins had turned 11 by the time they participated) and were 48% female. Although all families in this sample were 'intact', a portion of the fathers/step-fathers did not participate at all (n=80 families) or completed only a portion of the study (n=61 families). In these cases, no spousal interaction video was obtained.

The Department of Vital Records in the Michigan Department of Community Health identified twins in our age-range either directly from birth records or via the Michigan Twins Project, a large-scale population-based registry of twins in lower Michigan that were themselves recruited via birth records. The Michigan Bureau of Integration, Information, and Planning Services database was used to locate family addresses within 120 miles of East Lansing, MI through parent drivers' license information. Pre-made recruitment packets were then mailed to parents on our behalf by the Michigan Department of Community Health. A reply postcard was included for parents to indicate their interest in participating. Interested families were contacted directly by project staff. Parents who did not respond to the first mailing were sent additional mailings approximately one month apart until either a reply was received or up to four letters had been mailed.

This recruitment strategy yielded overall response rates of 62% for the population-based sample and 57% for the at-risk sample, which are similar to or better than those of other twin registries that use anonymous recruitment mailings (Baker *et al.*, 2002, Hay *et al.*, 2002). Families participating in the population-based sample endorsed ethnic group memberships at rates comparable to area inhabitants (e.g., Caucasian: 86.4% and 85.5%, African-American: 5.4% and 6.3% for the participating families and the local census, respectively). The at-risk sample was significantly more racially diverse (15% African American, 75% Caucasian) than the population-based sample, although this difference was effectively washed away here by our focus on intact families only (5.4% African American, 85.7% Caucasian). Moreover, both samples appear to be representative of the families recruited for that particular study (as assessed via a brief questionnaire screen administered to 85% of non-participating families). Participating twins were not experiencing higher levels of conduct problems, emotional symptoms, or hyperactivity than were non-participating twins (Cohen's *d* effect sizes ranged from $-.08$ to $.01$ in the population-based sample and $.01$ to $.09$ in the at-risk sample; all ns). Participating families also did not differ from non-participating families in paternal felony convictions ($d = -.01$ and $.13$ for the population-based and the at-risk samples, respectively), rate of single parent homes ($d = .10$ and $-.01$ for the population-based and the at-risk samples, respectively), paternal years of education (both $d = .12$), or maternal and paternal alcohol problems (d ranged from $.03$ to $.05$ in both samples). However, participating mothers in both samples reported slightly more years of education ($d = .17$ and $.26$, both $p < .05$) than non-participating mothers. Maternal

felony convictions also differed across participating and non-participating families, but only in the population-based sample ($d = -.20$; $p < .05$; at-risk sample $d = .02$, ns).

Zygosity was established using physical similarity questionnaires administered to the twins' primary caregiver (Peeters *et al.*, 1998). On average, the physical similarity questionnaires used by the MSUTR have accuracy rates of 95% or better. The current study included 315 MZ twin pairs and 405 DZ twin pairs.

MEASURES

Child Antisocial Behavior—Mothers and fathers completed the Child Behavior Checklist (CBCL; Achenbach and Rescorla, 2001) separately for each twin, while the twins individually completed the Semistructured Clinical Interview for Children and Adolescents (SCICA; McConaughy and Achenbach, 2001). The DSM-oriented Conduct Problems (CP) scale comprises 17 CBCL items and 19 SCICA items viewed as “very consistent” with the DSM-IV diagnostic category of Conduct Disorder (e.g., stealing, fighting, setting fires, cruelty to animals, etc.). Internal consistency reliabilities for the CBCL CP scales were adequate ($\alpha = .80$ and $.76$ for mother and father informant-reports, respectively). Roughly 10% of the SCICA interviews were videotaped to obtain inter-rater reliability. The intraclass correlation for CP across all raters was $.88$.

Maternal, paternal, and child informant-reports of CP were available for 99.8%, 95.3%, and 99.9% of twins, respectively. The various informant-reports were correlated $.29$ to $.49$ (all $p < .01$), consistent with the moderate cross-informant correlations seen in other studies (Achenbach *et al.*, 1987). CP data were averaged across informants to create a CP composite. At least two informant reports were available for all twins. The use of this combined informant approach is thought to allow for a more complete assessment of twin symptomatology than would the use of any one informant alone (Achenbach *et al.*, 1987). CP data were log-transformed prior to analysis to adjust for positive skew (skews before and after transformation were 2.37 and 0.53 , respectively).

Quality of the inter-parental relationship—The Dyadic Adjustment Scale (DAS; Spanier, 1976) was used to assess mother/wife and father/husband ratings of their relationship. Each member of the couple was asked to complete the questionnaire. The DAS measures four dimensions of marital adjustment: satisfaction, consensus, cohesion, and affective expression, as well as an overall measure of marital adjustment (the sum of the four dimensions). All five scales were examined here, separately for husbands and wives. The DAS demonstrated good internal consistency reliabilities across both informants for the individual scales ($\alpha = .70-.86$) and the overall scale ($\alpha = .94-.95$).

We also examined observer-ratings of a 10-minute videotaped interaction between spouses. Each parental dyad was asked to discuss and attempt to resolve recent conflicts in their relationship. Trained raters then coded the videos using the Brief Romantic Relationship Interaction Coding Scheme (BRICCS; Humbad *et al.*, 2011). The BRICCS was designed to assess various aspects of romantic relationships, including specific components of the dyadic interaction. The latter included positive reciprocity (i.e., overall positivity and warmth in the couple; smiling, laughing, and joking with each other), demand-withdraw

pattern (i.e., a pattern in which one partner “nags” the other partner who then withdraws from the interaction), negative reciprocity (i.e., hostility, harsh tone, frowning, and/or criticism towards each other), and overall satisfaction (i.e., observer perceptions of the extent to which the couple is satisfied and happy with their marriage). The inter-rater reliabilities ranged from 0.87–0.97 for the four scales.

We also examined twin perceptions of conflict in the inter-parental relationship, as assessed with the Children’s Perception of Inter-parental Conflict scale (CPIC; Grych *et al.*, 1992, Nigg *et al.*, 2009). For the current study, we focused specifically on the Conflict Properties scale ($n=11$ items, $\alpha = .77$), which assesses the frequency and intensity of inter-parental conflict as observed by the child (e.g., “My parents get really mad when they argue”). The other three scales on the CPIC (namely, Threat, Self-Blame, and Triangulation/Stability) were not examined because they assess the child’s emotional and/or cognitive appraisals of inter-parental conflict (e.g., “I am to blame when my parents argue”) rather than their observations (Nikolas *et al.*, 2010, Nikolas *et al.*, 2013).

Analyses

Twin studies leverage the difference in the proportion of genes shared between monozygotic or MZ twins (who share 100% of their genes) and dizygotic or DZ twins (who share an average of 50% of their segregating genes) to estimate the relative contributions of additive genetic (A), shared environmental (i.e., factors that make twins similar to each other regardless of the degree of their genetic relationship; C), and non-shared environmental effects (i.e., factors that make twins different from each other, including measurement error; E) to the variance within observed behaviors or characteristics (phenotypes). More information on twin studies is provided elsewhere (Neale and Cardon, 1992).

We evaluated whether the quality of the inter-parental relationship might moderate the etiology of CP using the original ‘univariate GxE’ model (Purcell, 2002) or the ‘extended univariate GxE’ model (van der Sluis *et al.*, 2012), as appropriate. The Purcell model is more powerful statistically, but is prone to false positives when twins are not perfectly correlated on the moderator variable (van der Sluis *et al.*, 2012). We thus made use of the Purcell model when examining moderation by the family-level measures of the inter-parental relationship (i.e., those that did not vary across twins; mother and father reports of the DAS and observer-ratings of the inter-parental relationship), and employed the van der Sluis *et al.* model when examining moderation by individual twin perceptions of the inter-parental relationship. To circumvent possible gene-environment correlational confounds (in which genetic effects overlap across the moderator and the outcome), the moderator values are entered in a means model of CP separately across twins and zygosity. Moderation is then modeled on the residual CP variance (i.e., that which does not overlap with the moderators). The first and least restrictive of these models allows for linear and non-linear moderation. We then fitted a series of more restrictive moderator models, constraining the linear and non-linear moderators to be zero and evaluating the reduction in model fit.

Each moderator was floored at zero and then divided by its highest value prior to analysis, so that it ranged from 0 to 1. The only exception to this treatment of the moderator was for demand-withdraw, as this variable was assessed dichotomously (no=0, yes=1). As it is

generally recommended that unstandardized or absolute ACE estimates be presented (Purcell, 2002), we standardized our log-transformed CP score to have a mean of zero and a standard deviation of one to facilitate interpretation of the unstandardized values.

Mx, a structural-equation modeling program (Neale *et al.*, 2003), was used to fit models to the transformed raw data using Full-Information Maximum-Likelihood techniques. When fitting models to raw data, variances, covariances, and means are first freely estimated. Model fit for the biometric GxE models was then evaluated using four information theoretic indices that balance overall fit (via minus twice the log-likelihood) with model parsimony: the Akaike's Information Criterion (AIC; Akaike, 1987), the Bayesian Information Criteria (BIC; Raftery, 1995), the sample-size adjusted Bayesian Information Criterion (SABIC; Sclove, 1987), and the Deviance Information Criterion (DIC; Spiegelhalter *et al.*, 2002). The lowest or most negative AIC, BIC, SABIC, and DIC among a series of nested models is considered best. Because fit indices do not always agree (they place different values on parsimony, among other things), we reasoned that the best fitting model should yield lower or more negative values for at least 3 of the 4 fit indices (Burt and Klump, 2013a, 2014a, Hicks *et al.*, 2009).

Results

Descriptive statistics for the various measures of the inter-parental relationship are presented in Table 1. As seen there, the quality of the interparental relationship varied quite a bit across the sample, indicating that range restriction in the moderator is unlikely to influence our results. This is especially the case for child-reports, observer-ratings, and to a lesser extent, mother/wife-reports of the marital relationship, in that the full range of possible values was present for most of these variables. Father/husband-reports of the marital relationship showed slightly less variability.

The prevalence of child CP in these data was consistent with population averages: 13.8% of the twins evidenced marginally-to-clinically significant levels of CP by either mother or father report (using the clinical cut-points described in the CBCL manual). Such results indicate that range restriction in the outcome is also unlikely to influence our results. As expected, mean levels of child CP varied across sex (Cohen's $d = .47$, $p < .001$), such that boys demonstrated higher rates of CP than did girls. CP also demonstrated a small negative association with age ($r = -.13$, $p < .001$). Sex and age were thus regressed out of the log-transformed CP data prior to the GxE analyses (McGue and Bouchard, 1984).

Phenotypic correlations between child CP and the inter-parental relationship are presented in Table 2. All associations were in the expected direction (e.g., marital conflict was positively associated with CP, whereas marital satisfaction was negatively correlated with CP), but were typically only modest in magnitude. Associations across the various informants/measures of the inter-parental relationship are also presented in Table 2. The strongest cross-informant associations were seen between mother- and father-reports of their relationship (both of which were obtained using the DAS), with correlations in the .4–.6 range. Associations with twin-reports and observer-ratings were small-to-moderate in magnitude (typically in the .2–.4 range), results that are very much in keeping with the cross informant/

measure associations seen in other studies (Achenbach *et al.*, 1987). Indeed, the overall pattern of correlations indicates that all informants appeared to be providing “valid” reports of the quality of the inter-parental relationship.

Univariate Analyses

Prior to model fitting analyses, we examined the etiology of CP independently of the interparental relationship. MZ and DZ intraclass correlations were .59 and .39, respectively, indicating the presence of genetic, shared, and non-shared environmental influences. Model fitting results further indicated that genetic (44%) and non-shared environmental (40%) influences made significant contributions to CP (both $p < .05$). Shared environmental influences accounted for 16% of the variance, but did not reach statistical significance.

GxE Analyses

We next fitted the GxE models to the data. Fit indices for moderation by mother/wife- and father/husband-reports of their marital relationship are presented in Table 3, while those for moderation by observer-ratings and child-reports are presented in Tables 4 and 5, respectively. Parameter estimates for all models are presented in Table 6. As seen there, there was no evidence that the etiology of CP was moderated by mother/wife reports of the quality of the inter-parental relationship. For all five measures of relationship quality, fit indices pointed squarely towards the no moderation model as the best-fitting model. Moreover, none of the moderator estimates were significantly greater than zero. Examination of observer-ratings of inter-parental interactions (Table 4) and twin-reports of observed inter-parental conflict (Table 5) were fully consistent with those of mother/wife-reports. The no moderation model was selected as the best-fitting model in all five analyses. None of the moderator estimates in these models were significantly greater than zero (Table 6), with the exception of the non-linear genetic parameter for observer-rated marital conflict. As noted, however, the no moderation model provided the better fit to these data overall, according to three of the four fit indices.

Results were slightly more ambiguous for father/husband-reports of marital quality (see Table 3). There was little-to-no evidence of etiologic moderation by father/husband-reports of consensus, affection, cohesion, or overall quality. For father/husband-reports of satisfaction, however, only two of the fit indices pointed towards the no moderation model. The other two indicated the presence of possible linear moderation. Examination of the linear moderator estimates, however, indicated that none of the moderators were individually significant (see Table 6), arguing against this possibility. Indeed, only the non-shared environmental moderator even approached significance ($p = .12$).

Confirmatory analyses—As indicated previously, the above analyses were restricted to children living in families with married/cohabitating parents, so as to directly examine the moderating role of inter-parental relationship quality (rather than the important but nevertheless separable experience of marriage dissolution). Critically, however, it is not uncommon for divorced/non-cohabitating parents to continue to interact, particularly around the parenting of their children. To evaluate whether the exclusion of such families influenced our results, we repeated our GxE analyses after including 72 families with

divorced, separated, or ambiguously-partnered parents (total N=792 families). These confirmatory analyses were restricted to mother, father, and twin-reports of relationship quality (observer-rating analyses were not repeated, as parents were not asked to complete this task if they were divorced). Of note, the observed ranges of all moderators in this augmented sample were identical to those reported in Table 1, offering additional evidence that range restriction in the moderator is not influencing our findings. Our GxE conclusions were similarly unchanged. Fit indices uniformly pointed towards the no moderation model for mother- and twin-reports of the inter-parental relationship (results available upon request). For father-reports, 3 of the 5 tests pointed to the no moderation model (for father-reported satisfaction and overall quality, the fit was ambiguous, with two fit indices pointing towards the no moderation model and two pointing towards the linear moderation model). Such results clearly suggest that the exclusion of these families does not account for our null results.

Discussion

The goal of the current study was to evaluate whether and how the quality of the inter-parental relationship might moderate the etiology of child CP. Results revealed little-to-no evidence of etiologic moderation, results that persisted across multiple informant-reports of the inter-parental relationship (i.e., mother/wife-report, father/husband-report, observer-ratings of videotaped spousal interactions, and child perceptions of the frequency and severity of his or her parents' conflict), as well as across cohabitating and non-cohabitating parents. Such findings collectively argue against inter-parental relationship quality as an etiologic moderator of child CP.

The strength of the above conclusion is augmented by our examination of a large and ethnically diverse sample of twins. This sample was adequately powered to detect both linear and non-linear GxE (see simulation studies in Purcell, 2002). Moreover, because our sample included twins 'at-risk' for child CP (based on their residence in a disadvantaged neighborhood), our null results cannot be attributed to the relatively low base rate of child CP in population-based samples. Our extensive phenotyping of both CP and inter-parental conflict further bolsters our confidence in our results, particularly since the multi-informant operationalization of child CP used here has yielded clear evidence of moderation by the parent-child relationship (Burt *et al.*, 2013, Burt and Klump, 2014a). These strengths are somewhat offset, however, by the cross-sectional nature of our data. Namely, the current results are specific to middle childhood, and should not be applied to other developmental periods (i.e., adolescence). This is particularly the case given the known roles of development in the etiology (Bergen *et al.*, 2007, Lyons *et al.*, 1995, Miles and Carey, 1997, van Beijsterveldt *et al.*, 2003) and phenotypic expression (Burt, 2012, Tremblay, 2010) of youth CP, as well as the possible role of development in GxE processes (Burt, 2011). Similarly, our results are specific to child CP, and do not extend to other forms of childhood psychopathology. Our results are also specific to moderation by the inter-parental relationship, and do not extend to separation or divorce per se. Future work should explore etiologic moderation by parental divorce/separation.

One final limitation concerns the few analyses for which fit indices/parameter estimates did not uniformly agree on the best-fitting model. Namely, the ‘no moderation’ model provided the best fit to the data according to all four fit indices for 10 of the 15 potential moderator variables. For four additional moderator variables, three of the four fit indices pointed towards the ‘no moderation’ model. In one of these models (that for observer-ratings of marital conflict), the non-linear genetic moderator estimate was significantly greater than zero. Although this may represent legitimate moderation, it is worth noting that this finding was not replicated when evaluating twin-reports of conflict properties. Moreover, we estimated 129 moderator values across the 15 moderators. We would thus expect roughly 6 of these to emerge as significant at $p < .05$, simply by chance.

Building on the above, three of the four fit indices pointed towards the ‘no moderation’ model for mother-reported satisfaction. Although this level of agreement (i.e., three of four fit indices) is interpreted as supportive of the ‘no moderation’ model (see Hicks et al., 2009), and none of the linear moderators for mother-reported satisfaction were significantly greater than zero, these results are interesting given the uncertain model fit for father-reported marital satisfaction. As seen in Table 6, however, the non-shared environmental moderator for mother-reported satisfaction was positively-signed instead of negatively-signed as it was for father-reported satisfaction, a critical difference (particularly since the E paths for both father-reported and mother-reported satisfaction were positively signed. In other words, our results indicate that while non-shared environmental influences on CP decrease (non-significantly) with father-reported satisfaction, they increase (non-significantly) with mother-reported satisfaction. Although not necessarily meaningless, it is not clear what to make of such contradictory findings, particularly given the fact that they were not replicated using observer-ratings of satisfaction, for which all four fit indices pointed towards no moderation. We would thus argue that the weight of the evidence still points squarely away from a role for GxE in the association between the inter-parental relationship and child CP.

Despite these limitations, the current study does have important implications for future research. Our results clearly suggest that the etiology of child CP is not significantly moderated by the quality of the inter-parental relationship. Across multiple measures of the inter-parental relationship, as completed by four different informants, the ‘no moderation’ model provided the best fit to the data. These null findings are striking, for two reasons. First, although marital quality may not moderate the etiology of child CP, child CP is nevertheless associated with the quality of the inter-parental relationship. Although it would be beyond the scope of the current study to clarify the origins of this association, future work should seek to do just this. For instance, marital quality may influence child CP via an environmental main effect, in which the quality of the inter-parental relationship causally shapes child behavior. Alternately, their association may be a function of a passive gene-environmental correlation in which those with a genetic predisposition towards CP are more likely to have lower quality romantic relationships and to pass on genetic of risk for CP to their children. Finally, they may be associated via overlapping genetic influences. Genetic overlap would likely reflect an evocative gene-environment correlational process, whereby the difficulties associated with parenting a child that has high levels of CP take a toll on the inter-parental relationship. Future work should distinguish between these very different possibilities.

Second, and perhaps more importantly, conflict, warmth, and control in the parent-child relationship have all been shown to moderate the etiology of child CP (Burt *et al.*, 2013, Burt and Klump, 2014a). The notable absence of this same etiologic moderation by the inter-parental relationship accordingly argues against the notion that every environmental pathogen exacerbates genetic influences on psychopathology (the diathesis-stress model of GxE), or that every protective environment suppresses genetic influences. Instead, the presence and form of etiologic moderation (diathesis-stress versus other types of GxE; Pennington *et al.*, 2009) seems likely to vary according to the phenotype and environmental experience(s) under study (Burt, 2011), and perhaps to developmental stage as well (Burt *et al.*, 2013). Although this point may seem obvious, a broad reading of the literature reveals that diathesis stress GxE are often implicitly, and sometimes even explicitly, assumed to broadly contribute to risk factor-psychopathology associations (see, for example, Hicks *et al.*, 2009). Future research should thus seek to not only delineate the specific environmental experiences that serve as etiologic moderators of CP, but also to clarify how this gene-environment interplay might change over the course of development.

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Table 1

Descriptive statistics for the various measures of the inter-parental relationship

	Mean	SD	Observed range	Possible range
Observer-ratings, Positive reciprocity	3.48	1.27	1 – 6	1 – 6
Observer-ratings, Marital conflict	1.53	0.88	1 – 6	1 – 6
Observer-ratings, Demand-withdraw	1.11	0.31	1 – 2	1 – 2
Observer-ratings, Overall Satisfaction	3.73	0.98	1 – 5	1 – 5
Twin-report, Conflict Properties	19.48	4.68	11 – 33	11 – 33
Mother-report, DAS Overall	155.48	18.11	51 – 193	34 – 193
Mother-report, DAS Consensus	49.05	5.41	20 – 60	10 – 60
Mother-report, DAS Satisfaction	23.56	2.74	10 – 30	5 – 30
Mother-report, DAS Affection	21.88	3.30	6 – 27	6 – 27
Mother-report, DAS Cohesion	17.27	3.56	5 – 24	4 – 24
Father-report, DAS Overall	155.82	16.66	87 – 193	34 – 193
Father-report, DAS Consensus	49.02	5.27	20 – 60	10 – 60
Father-report, DAS Satisfaction	23.95	2.78	12 – 30	5 – 30
Father-report, DAS Affection	22.00	3.14	8 – 27	6 – 27
Father-report, DAS Cohesion	17.02	3.31	8 – 24	4 – 24

Note. With the exception of twin reports of conflict properties, observer-rated marital conflict and observer-rated demand-withdraw, high scores index higher levels of relationship quality.

Table 2

Correlations.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.
1. Twin CP	--															
2. Mother-report, DAS Overall	-.11*	--														
3. Mother-report, DAS Consensus	-.12*	.88*	--													
4. Mother-report, DAS Satisfaction	-.18*	.79*	.67*	--												
5. Mother-report, DAS Affection	-.05*	.82*	.60*	.56*	--											
6. Mother-report, DAS Cohesion	-.05*	.82*	.60*	.56*	.66*	--										
7. Father-report, DAS Overall	-.15*	.60*	.51*	.52*	.50*	.44*	--									
8. Father-report, DAS Consensus	-.13*	.46*	.47*	.39*	.33*	.30*	.86*	--								
9. Father-report, DAS Satisfaction	-.22*	.45*	.38*	.48*	.33*	.31*	.78*	.66*	--							
10. Father-report, DAS Affection	-.07*	.50*	.37*	.36*	.59*	.38*	.78*	.55*	.47*	--						
11. Father-report, DAS Cohesion	-.06*	.47*	.35*	.39*	.40*	.42*	.79*	.55*	.49*	.62*	--					
12. Observer-ratings, Positive reciprocity	-.11*	.34*	.25*	.32*	.28*	.27*	.29*	.17*	.28*	.21*	.28*	--				
13. Observer-ratings, Marital conflict	.08*	-.39*	-.36*	-.37*	-.33*	-.23*	-.38*	-.30*	-.39*	-.28*	-.24*	-.40*	--			
14. Observer-ratings, Demand-withdraw	.09*	-.24*	-.22*	-.22*	-.19*	-.13*	-.23*	-.16*	-.21*	-.15*	-.19*	-.31*	.31*	--		
15. Observer-ratings, Overall Satisfaction	-.13*	.43*	.35*	.39*	.37*	.29*	.39*	.25*	.33*	.29*	.34*	.74*	-.56*	-.43*	--	
16. Twin-report, Conflict Properties	.17*	-.25*	-.21*	-.27*	-.18*	-.18*	-.24*	-.20*	-.24*	-.18*	-.11*	-.14*	.24*	.11*	-.22*	--

Note. Zero-order associations among the variables are presented. CP and DAS represent child conduct problems and the Dyadic Adjustment Scale, respectively. Associations between CP and the measures/informants of the inter-parental relationship are presented in bold italics. Associations across the various measures/informants of the inter-parental relationship are highlighted in gray.

* indicates that correlation is significantly greater than zero at $p = .05$.

Table 3

Fit indices for etiologic moderation by mother- and father reports of the quality of their relationship, as assessed via the Dyadic Adjustment Scale

Model	-2lnL	df	AIC	BIC	SABIC	DIC
<u>Mother-report, overall marital/relationship quality</u>						
Linear and non-linear ACE moderation	3712.34	1377	958.34	-2648.32	-462.21	-1382.94
Linear ACE moderation	3713.12	1380	953.12	-2657.75	-466.87	-1389.61
No moderation	3716.93	1383	950.93	-2665.65	-470.02	-1394.76
<u>Mother-report, consensus scale</u>						
Linear and non-linear ACE moderation	3727.47	1383	961.47	-2663.37	-467.73	-1392.48
Linear ACE moderation	3728.03	1386	956.03	-2672.91	-472.50	-1399.26
No moderation	3731.60	1389	953.60	-2680.94	-475.78	-1404.54
<u>Mother-report, satisfaction scale</u>						
Linear and non-linear ACE moderation	3678.28	1373	932.28	-2650.28	-470.53	-1388.58
Linear ACE moderation	3679.72	1376	927.72	-2659.38	-474.86	-1394.92
No moderation	3686.45	1379	928.45	-2665.82	-476.54	-1398.61
<u>Mother-report, affection scale</u>						
Linear and non-linear ACE moderation	3719.86	1377	965.86	-2644.56	-458.45	-1379.19
Linear ACE moderation	3723.61	1380	963.61	-2652.50	-461.63	-1384.37
No moderation	3725.57	1383	959.57	-2661.34	-465.70	-1390.44
<u>Mother-report, cohesion scale</u>						
Linear and non-linear ACE moderation	3726.40	1379	968.40	-2648.83	-459.54	-1381.61
Linear ACE moderation	3728.87	1382	964.87	-2657.41	-463.36	-1387.43
No moderation	3729.48	1385	959.48	-2666.92	-468.11	-1394.19
<u>Father-report, overall marital/relationship quality</u>						
Linear and non-linear ACE moderation	3228.82	1219	790.82	-2299.57	-364.53	-1179.39
Linear ACE moderation	3238.43	1222	794.43	-2304.40	-364.59	-1181.45
No moderation	3246.18	1225	796.18	-2310.15	-365.58	-1184.45
<u>Father-report, consensus scale</u>						

Model	-2lnL	df	AIC	BIC	SABIC	DIC
Linear and non-linear ACE moderation	3247.34	1223	801.34	-2305.14	-363.74	-1181.27
Linear ACE moderation	3256.84	1226	804.84	-2310.03	-363.86	-1183.41
No moderation	3261.78	1229	803.78	-2317.19	-366.27	-1187.82
<u>Father-report, satisfaction scale</u>						
Linear and non-linear ACE moderation	3207.44	1217	773.44	-2302.85	-370.98	-1184.50
Linear ACE moderation	3208.34	1220	768.34	-2312.03	-375.40	-1190.92
No moderation	3219.91	1223	773.91	-2315.87	-374.48	-1192.01
<u>Father-report, affection scale</u>						
Linear and non-linear ACE moderation	3215.04	1203	809.04	-2247.21	-337.59	-1141.73
Linear ACE moderation	3224.64	1206	812.64	-2252.02	-337.64	-1143.78
No moderation	3226.64	1209	808.64	-2260.64	-341.49	-1149.64
<u>Father-report, cohesion scale</u>						
Linear and non-linear ACE moderation	3269.82	1221	827.82	-2286.48	-348.26	-1164.46
Linear ACE moderation	3272.91	1224	824.91	-2294.57	-351.59	-1169.79
No moderation	3274.03	1227	820.03	-2303.65	-355.90	-1176.11

Note. The best fitting model for a given set of analyses is highlighted in bold font, and is indicated by the lowest AIC (Akaike's Information Criterion), BIC (Bayesian Information Criterion), SABIC (sample size adjusted Bayesian Information Criterion), and DIC (Deviance Information Criterion) values for at least 3 of the 4 fit indices.

Table 4

Fit indices for etiologic moderation by observer-ratings of spousal interactions

Model	-2lnL	df	AIC	BIC	SABIC	DIC
<u>Positive reciprocity between spouses</u>						
Linear and non-linear ACE moderation	3172.88	1185	802.88	-2201.76	-320.75	-1112.82
Linear ACE moderation	3174.70	1188	798.70	-2210.44	-324.66	-1118.74
No moderation	3177.38	1191	795.38	-2218.69	-328.15	-1124.24
<u>Marital conflict</u>						
Linear and non-linear ACE moderation	3173.11	1185	803.11	-2201.65	-320.63	-1112.70
Linear ACE moderation	3182.84	1188	806.84	-2206.38	-320.59	-1114.68
No moderation	3187.30	1191	805.30	-2213.74	-323.19	-1119.28
<u>Demand-withdraw pattern</u>						
Linear and non-linear ACE moderation	---	---	---	---	---	---
Linear ACE moderation	3183.85	1188	807.85	-2205.87	-320.09	-1114.17
No moderation	3185.20	1191	803.20	-2214.78	-324.24	-1120.33
<u>Overall marital satisfaction</u>						
Linear and non-linear ACE moderation	3172.41	1185	802.41	-2202.00	-320.98	-1113.06
Linear ACE moderation	3176.39	1188	800.39	-2209.60	-323.82	-1117.90
No moderation	3177.13	1191	795.13	-2218.82	-328.28	-1124.36

Note. The best fitting model for a given set of analyses is highlighted in bold font, and is indicated by the lowest AIC (Akaike's Information Criterion), BIC (Bayesian Information Criterion), SABIC (sample size adjusted Bayesian Information Criterion), and DIC (Deviance Information Criterion) values for at least 3 of the 4 fit indices.

Table 5

Fit indices for etiologic moderation by twin-reports of interparental conflict

Model	-2lnL	df	AIC	BIC	SABIC	DIC
<u>Child-report, conflict properties</u>						
Linear and non-linear ACE moderation	3562.93	1343	876.93	-2597.13	-465.04	-1363.00
Linear ACE moderation	3564.89	1346	872.89	-2605.93	-469.08	-1369.04
No moderation	3570.73	1349	872.73	-2612.79	-471.18	-1373.15

Note. The best fitting model for a given set of analyses is highlighted in bold font, and is indicated by the lowest AIC (Akaike's Information Criterion), BIC (Bayesian Information Criterion), SABIC (sample size adjusted Bayesian Information Criterion), and DIC (Deviance Information Criterion) values for at least 3 of the 4 fit indices.

Table 6

Unstandardized path and moderator parameter estimates for all models

PATHS			LINEAR MODERATORS			NON-LINEAR MODERATORS			
a	c	e	A ₁	C ₁	E ₁	A ₂	C ₂	E ₂	
Mother-report, overall marital/relationship quality									
a)	1.50 (-0.33, 2.69)	-0.13 (-1.96, 1.62)	0.23 (-0.52, 1.35)	-2.04 (-5.00, 3.47)	1.70 (-3.39, 5.00)	1.13 (-2.11, 3.45)	1.15 (-3.31, 3.77)	-1.26 (-4.57, 2.46)	-0.78 (-2.52, 1.56)
b)	1.09* (0.27, 1.67)	0.29 (-0.77, 1.19)	0.57* (0.29, 0.91)	-0.61 (-1.48, 0.46)	0.17 (-1.11, 1.39)	0.07 (-0.38, 0.46)	---	---	---
c)	0.66* (0.49, 0.80)	0.40 (-0.57, 0.57)	0.62* (0.58, 0.68)	---	---	---	---	---	---
Mother-report, consensus scale									
a)	1.26 (-0.51, 2.56)	-0.12 (-1.75, 1.32)	0.49 (-0.15, 1.43)	-1.53 (-5.00, 2.73)	1.74 (-2.58, 5.00)	0.46 (-2.21, 2.41)	0.90 (-4.13, 3.73)	-1.32 (-4.58, 2.00)	-0.37 (-1.82, 1.57)
b)	1.00* (0.23, 1.59)	0.28 (-0.64, 1.10)	0.65* (0.38, 0.96)	-0.49 (-1.38, 0.50)	0.19 (-0.98, 1.24)	-0.03 (-0.44, 0.34)	---	---	---
c)	0.66* (0.49, 0.80)	0.40 (-0.57, 0.57)	0.62* (0.58, 0.68)	---	---	---	---	---	---
Mother-report, satisfaction scale									
a)	1.53* (0.56, 2.48)	0.48 (-1.97, 2.14)	0.11 (-0.51, 0.93)	-2.07 (-5.00, 5.00)	-0.54 (-5.00, 5.00)	1.46 (-1.07, 4.07)	1.08 (-4.28, 3.97)	0.58 (-5.00, 5.00)	-0.99 (-3.32, 0.95)
b)	1.28* (0.48, 1.74)	-0.02 (-1.49, 1.49)	0.47* (0.24, 0.76)	-0.94 (-1.72, 0.24)	0.57 (-2.20, 2.20)	0.23 (-0.18, 0.58)	---	---	---
c)	0.66* (0.48, 0.80)	0.38 (-0.56, 0.56)	0.62* (0.58, 0.68)	---	---	---	---	---	---
Mother-report, affection scale									
a)	1.41 (-0.86, 2.33)	-1.32 (-1.79, 0.60)	0.00 (-0.52, 1.11)	-2.02 (-5.00, 5.00)	4.98 (-0.48, 5.00)	1.65 (-1.71, 3.37)	1.24 (-4.48, 3.64)	-3.39 (-4.09, 0.44)	-1.04 (-2.37, 1.40)
b)	0.96* (0.41, 1.39)	0.26 (-0.52, 0.89)	0.47* (0.26, 0.74)	-0.41 (-1.05, 0.28)	0.20 (-0.66, 1.08)	0.20 (-0.14, 0.49)	---	---	---
c)	0.66* (0.48, 0.80)	0.41 (-0.58, 0.58)	0.62* (0.58, 0.68)	---	---	---	---	---	---
Mother-report, cohesion scale									
a)	1.09 (-1.92, 1.85)	0.10 (-1.39, 1.49)	0.71* (0.29, 1.25)	-1.56 (-4.36, 5.00)	1.08 (-3.48, 5.00)	-0.26 (-1.97, 1.15)	1.25 (-1.07, 3.54)	-0.84 (-4.51, 2.73)	0.19 (-0.94, 1.53)

	PATHS			LINEAR MODERATORS			NON-LINEAR MODERATORS		
b)	0.86 (-0.29, 1.21)	0.09 (-1.13, 1.13)	0.62* (0.45, 0.88)	-0.31 (-0.98, 1.21)	0.47 (-1.69, 1.69)	0.01 (-0.36, 0.28)	---	---	---
c)	0.66* (0.48, 0.80)	0.41 (-0.58, 0.58)	0.62* (0.58, 0.68)	---	---	---	---	---	---
<u>Father-report, overall marital/relationship quality</u>									
a)	-0.61 (-1.16, 1.15)	-0.88 (-1.85, 1.65)	0.74* (0.38, 1.30)	5.59 (-1.52, 10.0)	3.41 (-5.00, 5.00)	-0.36 (-2.10, 0.84)	-5.55 (-10.0, 1.04)	-2.15 (-4.73, 5.00)	0.27 (-0.72, 1.61)
b)	0.99* (0.51, 1.39)	0.41 (-0.98, 0.98)	0.66* (0.47, 0.88)	-0.54 (-1.16, 0.10)	-0.07 (0.93, 0.78)	-0.06 (-0.37, 0.22)	---	---	---
c)	0.65* (0.47, 0.79)	0.36 (-0.55, 0.55)	0.62* (0.57, 0.67)	---	---	---	---	---	---
<u>Father-report, consensus scale</u>									
a)	-0.24 (-3.34, 1.48)	-2.47 (-3.36, 3.36)	0.61* (0.21, 1.52)	2.67 (-2.46, 5.00)	8.68 (-10.0, 10.0)	0.18 (-2.29, 1.46)	-1.94 (-5.00, 1.65)	-6.45 (-8.08, 8.08)	-0.22 (-1.23, 1.47)
b)	1.02* (0.41, 1.53)	0.38 (-1.10, 1.10)	0.66* (0.41, 0.96)	-0.51 (-1.23, 0.25)	-0.01 (-1.03, 0.95)	-0.06 (-0.44, 0.28)	---	---	---
c)	0.66* (0.48, 0.80)	0.36 (-0.55, 0.55)	0.62* (0.57, 0.67)	---	---	---	---	---	---
<u>Father-report, satisfaction scale</u>									
a)	1.00 (-1.93, 2.08)	-1.33 (-2.45, 2.45)	0.74* (0.38, 1.51)	-0.58 (-4.22, 5.00)	4.23 (-5.00, 5.00)	-0.10 (-2.22, 1.01)	0.12 (-4.59, 2.94)	-2.65 (-4.92, 4.92)	-0.12 (-0.99, 1.19)
b)	0.84* (0.06, 1.39)	0.42 (-1.27, 1.27)	0.80* (0.57, 1.05)	-0.28 (-1.15, 0.72)	-0.14 (-1.70, 1.70)	-0.28 (-0.62, 0.07)	---	---	---
c)	0.66* (0.48, 0.79)	0.32 (-0.52, 0.52)	0.62* (0.57, 0.67)	---	---	---	---	---	---
<u>Father-report, affection scale</u>									
a)	-0.12 (-1.88, 0.79)	-0.35 (-2.15, 1.07)	0.92* (0.47, 1.55)	2.80 (-0.27, 5.00)	2.05 (-5.00, 5.00)	-0.84 (-2.66, 0.55)	-2.28 (-5.00, 0.11)	-1.35 (-5.00, 5.00)	0.56 (-0.49, 1.86)
b)	0.77* (0.27, 1.19)	0.34 (-0.88, 0.88)	0.71* (0.51, 0.93)	-0.16 (-0.73, 0.42)	0.07 (-0.66, 0.80)	-0.12 (-0.40, 0.14)	---	---	---
c)	0.66* (0.47, 0.80)	0.38 (-0.57, 0.57)	0.62* (0.57, 0.68)	---	---	---	---	---	---
<u>Father-report, cohesion scale</u>									
a)	0.74* (0.10, 1.17)	-0.23 (-1.11, 0.74)	0.63* (0.42, 0.92)	-0.28 (-2.13, 1.54)	2.80 (-1.69, 5.00)	-0.16 (-1.16, 0.63)	0.16 (-1.56, 1.77)	-2.71 (-5.00, 1.69)	0.23 (-0.48, 1.09)

	PATHS			LINEAR MODERATORS			NON-LINEAR MODERATORS		
b)	0.77* (0.41, 1.04)	0.33 (-0.74, 0.74)	0.57* (0.45, 0.71)	-0.22 (-0.77, 0.30)	0.12 (-0.64, 0.82)	0.10 (-0.12, 0.30)	---	---	---
c)	0.65* (0.46, 0.80)	0.39 (-0.57, 0.57)	0.62* (0.58, 0.68)				---	---	---
<u>Observer-ratings of positive reciprocity between spouses</u>									
a)	0.52* (0.03, 0.95)	0.55 (-1.00, 1.00)	0.62* (0.47, 0.80)	1.02 (-0.78, 3.32)	-0.34 (-3.42, 3.42)	-0.09 (-0.83, 0.55)	-1.00 (-3.74, 0.61)	-0.58 (-2.76, 2.76)	0.10 (-0.49, 0.77)
b)	0.75* (0.45, 1.00)	0.45 (-0.81, 0.81)	0.60* (0.50, 0.71)	-0.09 (-0.58, 0.31)	-0.24 (-0.97, 0.97)	0.01 (-0.17, 0.18)	---	---	---
c)	0.71* (0.54, 0.83)	0.33 (-0.53, 0.53)	0.60* (0.56, 0.66)	---	---	---	---	---	---
<u>Observer-ratings of marital conflict</u>									
a)	0.63* (0.38, 0.79)	0.34 (-0.58, 0.57)	0.63* (0.57, 0.70)	1.64 (-0.03, 3.00)	-0.22 (-5.00, 5.00)	-0.40 (-1.05, 0.28)	-2.33* (-3.96, -0.23)	0.27 (-5.00, 5.00)	0.18 (-0.69, 1.20)
b)	0.68* (0.50, 0.81)	0.32 (-0.53, 0.53)	0.62* (0.57, 0.68)	0.31 (-0.24, 0.86)	0.19 (-1.10, 1.10)	-0.20 (-0.40, 0.06)	---	---	---
c)	0.71* (0.54, 0.84)	0.35 (-0.54, 0.54)	0.60* (0.55, 0.66)	---	---	---	---	---	---
<u>Observer-ratings of demand-withdraw pattern</u>									
a)	---	---	---	---	---	---	---	---	---
b)	0.70* (0.50, 0.83)	0.36 (-0.56, 0.56)	0.61* (0.56, 0.67)	0.14 (-0.35, 0.43)	-0.14 (-1.18, 1.18)	-0.09 (-0.21, 0.08)	---	---	---
c)	0.71* (0.54, 0.84)	0.34 (-0.54, 0.54)	0.60* (0.55, 0.66)				---	---	---
<u>Observer-ratings of overall marital satisfaction</u>									
a)	0.79* (0.19, 1.25)	-0.06 (-0.78, 0.57)	0.53* (0.33, 0.85)	-0.64 (-2.43, 1.12)	2.37 (-0.22, 4.79)	0.27 (-0.68, 0.96)	0.59 (-0.80, 2.05)	-2.32 (-4.36, 0.11)	-0.21 (-0.79, 0.51)
b)	0.78* (0.38, 1.06)	0.37 (-0.82, 0.82)	0.57* (0.42, 0.74)	-0.11 (-0.57, 0.35)	-0.05 (-0.74, 0.74)	0.05 (-0.17, 0.27)	---	---	---
c)	0.70* (0.54, 0.83)	0.34 (-0.54, 0.54)	0.60* (0.56, 0.66)				---	---	---
<u>Child-report conflict properties</u>									
a)	0.23 (-0.30, 1.01)	0.62 (-0.92, 0.91)	0.64* (0.44, 0.82)	1.91 (-2.61, 4.19)	-0.87 (-4.24, 4.24)	-0.44 (-1.42, 1.43)	-1.92 (-4.62, 2.93)	0.67 (-4.75, 3.61)	0.76 (-1.34, 1.92)

	PATHS		LINEAR MODERATORS				NON-LINEAR MODERATORS			
b)	0.57* (0.23, 0.85)	0.45 (-0.73, 0.73)	0.54* (0.43, 0.66)	0.12 (-0.65, 0.73)	-0.12 (-0.86, 0.84)	0.21 (-0.06, 0.48)	---	---	---	---
c)	0.61* (0.42, 0.76)	0.41 (-0.57, 0.57)	0.62* (0.58, 0.68)	---	---	---	---	---	---	---

Note. A, C, and E (upper and lower case) respectively represent genetic, shared, and non-shared environmental parameters on DSM-oriented Conduct Problems (CP). Models a, b, and c, represent the non-linear, linear, and no moderation models, respectively, from Tables 3, 4, and 5. The 95% confidence intervals were bounded to -5.0 and 5.0, except in those few cases in which the estimate itself was greater than 5.0, to assist with model convergence. Because the non-shared environmental paths and moderators are combined to compute the non-shared environmental variance at each moderator value, the constituent components of that variance estimate need not be significantly greater than zero for the non-shared environmental variance estimate to be greater than zero (as would be expected). Bold font and an asterisk indicate that estimate is significant at $p < .05$.