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Preschoolers' Genetic, Physiological, and Behavioral Sensitivity Factors Moderate Links Between Parenting Stress and Child Internalizing, Externalizing, and Sleep Problems

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Abstract

This study examined three potential moderators of the relations between maternal parenting stress and preschoolers' adjustment problems: a genetic polymorphism - the short allele of the serotonin transporter (5-HTTLPR, *ss/s/* allele) gene, a physiological indicator - children's baseline respiratory sinus arrhythmia (RSA), and a behavioral indicator - mothers' reports of children's negative emotionality. A total of 108 mothers ($M_{age} = 30.68$ years, $SD_{age} = 6.06$) reported on their parenting stress as well as their preschoolers' ($M_{age} = 3.50$ years, $SD_{age} = .51$, 61% boys) negative emotionality and internalizing, externalizing, and sleep problems. Results indicated that the genetic sensitivity variable functioned according to a differential susceptibility model; however, the results involving physiological and behavioral sensitivity factors were most consistent with a diathesis-stress framework. Implications for prevention and intervention efforts to counter the effects of parenting stress are discussed.

Keywords

respiratory sinus arrhythmia; 5-HTTLPR; negative emotionality; parenting stress; child adjustment

Research suggests that stress due to the demands of parenting (i.e., parenting stress, Deater-Deckard, 1998) is a common phenomenon that is experienced across racial groups and levels of socioeconomic status (Crnic, Gaze, & Hoffman, 2005; Huang, Costeines, Kaufman, & Ayala, 2014; Misri et al., 2010; Raikes & Thompson, 2005), and has particularly strong links to child maladjustment during the preschool period (e.g., Goldberg et al., 1997).

Undoubtedly, the relations among parenting stress and children's poor psychosocial functioning are transactional, with each influencing the other over time (Woodman, Mawdsley, & Hauser-Cram, 2015). To best understand these complex processes, it is important to first identify individual factors impacting the links between parenting stress and child adjustment problems. Thus, the goal of this study is to examine child characteristics

that might make them more or less sensitive to the effects of parenting stress within the frameworks of diathesis-stress and differential susceptibility models.

Traditional diathesis-stress models posit that individuals with a given vulnerability factor (e.g., genetic risk), compared to individuals lacking this vulnerability factor, are more likely to experience negative outcomes as a result of exposure to adverse environmental contexts (for a review, see Zuckerman, 1999). In contrast, the differential susceptibility framework suggests that susceptibility variables render individuals more sensitive to the environment in a “for better *and* for worse” way (Ellis, Boyce, Belsky, Bakermans-Kranenburg, & van IJzendoorn, 2011, p. 14). To date, research has found support for both diathesis-stress and susceptibility models, depending on the constructs involved, the methods used to assess those constructs, and the developmental period studied (e.g., Conradt, Measelle & Ablow, 2013; Kochanska, Boldt, Kim, Yoon, & Philibert, 2015; Kochanska, Kim, Barry, & Philibert, 2011; Morris et al., 2002; Obradovi , Bush, Stamperdahl, Adler, & Boyce, 2010; Slagt, Dubas, Dekovi , & van Aken, 2016). Further, the majority of research has examined children’s sensitivity to the environment via a single construct, though some investigators have examined two constructs (e.g., Kochanska et al., 2015). No study could be identified that assessed child sensitivity at genetic, physiological, and behavioral levels. Given that the mixed support for diathesis-stress versus differential susceptibility frameworks could be due to variability in the level of analysis used in the extant literature (i.e., whether sensitivity was examined at the behavioral, physiological, or genetic level), it is important to address child sensitivity at each of these levels in the same investigation. The present study used a multi-systems, multi-method approach to study how preschoolers’ genetic (i.e., status on the serotonin transporter linked polymorphic region known as 5-HTTLPR), physiological (i.e., baseline respiratory sinus arrhythmia; RSA), and behavioral (i.e., negative emotionality) sensitivity factors interact with parenting stress to impact maternal perceptions of child adjustment across three domains: internalizing, externalizing, and sleep problems. Such research can aid in identifying children who are more or less at risk for maladjustment in the context of parenting stress, thereby benefitting prevention and intervention planning.

Genetic, Physiological, and Behavioral Sensitivity to Parenting Stress

Parenting stress arises from pressures to juggle parenting tasks with employment and other obligations (Roxburgh, 2012), as well as from variations in child and parent characteristics. For instance, parenting stress is exacerbated when caring for a child with a developmental disability or emotional or behavioral problems (Bode, George, Weist, Stephan, Lever, & Youngstrom, 2016; Merwin, Smith, & Dougherty, 2014; Woodman et al., 2015). Regardless of the sources, parenting stress likely relates to poor outcomes for children via decrements in effective parenting practices (e.g., Deater-Deckard, 1998; Morgan, Robinson, & Aldridge, 2002). Empirical work has demonstrated that children’s exposure to parenting stress can have serious, negative implications for youth development (Anthony et al., 2005; Coplan, Bowker, & Cooper, 2003; Costa, Weems, Pellerin, & Dalton, 2006; Crnic et al., 2005). For example, in a sample of preschoolers in a Head Start program, greater parenting stress was associated with poorer teacher ratings of social competence and greater internalizing and externalizing problems (Anthony et al., 2005). Importantly, outcomes of parent-focused interventions for child behavior problems are enhanced when parenting stress is addressed

(Kazdin & Whitley, 2003). Because parenting stress tends to be stable over time (Koch, Ludvigsson, & Sepa, 2010), when not addressed, it is likely to have a lasting impact on child outcomes.

Given the prevalence and persistence of parenting stress and its adverse impact on effective parenting, it is important to identify factors that exacerbate risk for, and can protect against, child adjustment problems in the context of parenting stress. Despite strong theoretical and empirical support for a multi-systems approach, to our knowledge, no study has examined child sensitivity to parenting stress at the genetic, physiological, and behavioral levels in one investigation. Examining sensitivity factors at these three levels in tandem is necessary to disentangle the contributions of each factor and their relevance to diathesis-stress and differential susceptibility frameworks. Presumably, child baseline RSA and 5-HTTLPR could function according to either a diathesis-stress or a differential susceptibility framework in the context of maternal parenting stress; however, it is most likely that negative emotionality follows a diathesis-stress model.

Genetic sensitivity

The serotonin transporter gene, (*SLC6A4*), is an important regulatory element for serotonergic neurotransmission. The promoter region of the gene, also referred to as 5-HTTLPR, is highly polymorphic, resulting in two main variants, a short (*s*) 14-repeat allele and a long (*l*) 16-repeat allele. The short variation leads to less transcription of *SLC6A4*. Though the short allele of 5-HTTLPR has been a focus of research on gene-environment interactions, we did not find any research that examined interactions between 5-HTTLPR and mothers' parenting stress. However, limited research has included parenting stress as part of life stress composites. For example, Lavigne et al. (2013) found a significant gene-environment interaction involving life stress and 5-HTTLPR. Four-year-olds with two copies of the long allele, compared to children with one or two copies of the short allele, demonstrated the greatest levels of oppositional defiant disorder symptoms when family stress was high but the lowest levels when stress was low. The findings by Lavigne et al. (2013) are in contrast to most other work examining 5-HTTLPR that suggests one- or two-copies of the short allele confer susceptibility (for a review, see Belsky & Pluess, 2009), or vulnerability (e.g., Caspi et al., 2003), to environmental contexts. In particular, the short allele of 5-HTTLPR has been found to interact with a number of environmental factors (e.g., bullying victimization, mother-child attachment style) to predict a host of adjustment problems in youth populations (e.g., emotional problems, difficulties with self-regulation; Kochanska, Philibert, & Barry 2009; Sugden, et al., 2010). In other related investigations, the short allele of 5-HTTLPR was found to increase the likelihood that youth would benefit from exposure to low-risk environments and be more susceptible to the negative effects of adverse environments (Bogdan, Agrawal, Gaffrey, Tillman, & Luby, 2014). Bogdan et al. (2014) found that preschoolers who were homozygous for the short allele of 5-HTTLPR exhibited fewer depressive symptoms than their peers with long alleles when exposed to low levels of stressful life events but demonstrated higher symptom levels in the context of greater levels of stressful life events.

Physiological sensitivity

From an evolutionary perspective, calibration of the stress response is of key importance when considering the impact of the environment on the individual (Boyce & Ellis, 2005). Respiratory sinus arrhythmia (RSA), a marker of the parasympathetic nervous system's control over heart rate, is noteworthy because of its proposed role in stress sensitivity and reactivity (Porges, 1992). Generally speaking, lower resting RSA has been linked with poor emotion regulation and psychopathology (Beauchaine, 2001; Calkins, Graziano, & Keane, 2007; Mezzacappa et al., 1997; Pine et al., 1998; Shannon, Beauchaine, Brenner, Nehaus, & Gatzke-Kopp, 2007). In contrast, higher resting RSA has been associated with adaptive outcomes, including emotion regulation and social competence (Beauchaine, 2001; Fabes, Eisenberg, & Eisenbud, 1993), and recent research has also provided evidence for the notion that higher RSA (i.e. higher vagal tone) might be a protective factor in the link between adversity and youth psychopathology (McLaughlin, Rith-Najarian, Dirks & Sheridan, 2015). Other literature suggests that child resting RSA may function differently depending on the quality of the caregiver-child relationship, such that infants with higher resting RSA have shown the lowest levels of problem behavior in positive caregiving environments and the highest levels of problem behavior in the context of negative environments (Conradt et al., 2013). These findings underscore physiology as a potential moderator of parental effects on child outcomes.

Behavioral sensitivity

In terms of behavioral sensitivity factors, some research has demonstrated that child emotion dysregulation (Scott & O'Connor, 2012) and related constructs (e.g., difficult temperament; Pluess & Belsky, 2010) confer greater sensitivity to the environment. For instance, Pluess and Belsky (2010) demonstrated that children with more difficult temperaments (e.g., greater negative emotionality, difficulties with adaptability) exhibited the highest levels of behavior problems and teacher-child conflict when childcare quality was low and the lowest scores on these two outcomes when childcare quality was high. In Kim and Kochanska (2012), infant negative emotionality moderated the link between parent-child mutuality and child self-regulation in a manner consistent with a differential susceptibility framework. Kochanska et al. (2015) examined child biobehavioral risk, which they defined as having the short allele of 5-HTTLPR and high levels of anger proneness, and found that support for diathesis-stress and differential susceptibility models varied across parenting dimensions and child outcomes. For instance, children with high biobehavioral risk exhibited the lowest levels of negative attitudes towards substance use at age 10 when they were exposed to lower levels of positive parenting from 25 to 80 months of age. However, when exposed to optimal, positive parenting environments, these high-risk children had higher levels of negative attitudes towards substance use than their low-risk peers, consistent with a differential susceptibility framework. All other interactions involving parenting variables (both positive and negative) and biobehavioral risk followed a diathesis-stress pattern, regardless of the child outcome being examined (i.e., callous-unemotional traits, internalization of parental values, and cooperation with parental monitoring). A recent meta-analysis by Slagt et al. (2016) found that negative emotionality functioned according to a differential susceptibility model, but only when emotionality was measured before age 1. Therefore, we would not expect negative emotionality to follow a differential susceptibility

framework in the present study involving preschoolers. Importantly; however, Slagt et al. (2016) mention that their results did not withstand sensitivity analyses that account for the possibility of publication bias. Despite some evidence for negative emotionality functioning in accordance with a differential susceptibility framework, oftentimes, variables reflecting difficult temperament (e.g., child negative affect and emotional lability) function as risk factors for a host of poor outcomes in variety of contexts (Han & Shaffer, 2013; Muris & Ollendick, 2005; Shields & Cicchetti, 2001). For example, Morris and colleagues (2002) found support for the diathesis-stress model; child negative emotionality (i.e., irritability) functioned as a vulnerability factor when combined with negative parenting for first and second graders.

The Inclusion of Sleep as a Key Developmental Outcome

Research on parenting stress and child adjustment has frequently focused on children's internalizing or externalizing problems (e.g., Anthony et al., 2005). The present study sought to expand upon the extant literature by also examining sleep problems, given that difficulties in this area during the preschool period are associated with a variety of externalizing behavior problems (e.g., inattention and hyperactivity; Hiscock, Canterford, Ukoumunne, & Wake, 2007) and have been linked to poorer adjustment, including lower teacher-reported school adjustment (Bates, Viken, Alexander, Beyers, & Stockton, 2002). Moreover, sleep problems in childhood longitudinally predict internalizing symptoms and disorders in adolescence and even into adulthood (Gregory et al., 2005; Ong, Wickramaratne, Tang, & Weissman, 2006). Scant research has examined the relation between parenting stress and child sleep problems (Meltzer & Mindell, 2007). In a pilot study of mothers and their children aged 3 to 14, Meltzer and Mindell (2007) found that mothers of children with clinically significant sleep disruptions reported more parenting stress than mothers of children who were below the clinical cutoff. Caregivers who are experiencing high levels of stress may find it difficult to implement strategies conducive to their children's sleep development. Thus, mild sleep difficulties may develop into chronic ones that have long-lasting implications for development. Continued research on factors that contribute to children's sleep difficulties, particularly early in childhood, is crucial.

The Current Study

The current study builds upon the extant literature by: (1) examining sensitivity to parenting stress, a variable relevant to all families; (2) using a multi-method approach to examine child sensitivity (i.e., genetic, physiological, and behavioral) to parenting stress; and (3) incorporating child sleep problems, in addition to internalizing and externalizing problems, as a key outcome of interest.

It was hypothesized that children's genetic (i.e., having at least one short allele of 5-HTTLPR), physiological (i.e., higher baseline RSA), and behavioral (i.e., higher levels of negative emotionality) sensitivity would moderate the positive associations between maternal parenting stress and mothers' perceptions of child internalizing, externalizing, and sleep problems. In light of the mixed literature, we did not hypothesize whether our findings involving child baseline RSA and 5-HTTLPR would be most consistent with a diathesis-

stress or a differential susceptibility framework. Because the literature has consistently identified children's negative emotionality as a risk factor for psychopathology, we anticipated that the moderation results involving this variable would follow a diathesis-stress pattern. Specifically, it was predicted that when both parenting stress and child negative emotionality were higher, adjustment problems would be higher than when parenting stress was lower.

Method

Participants

Participants included 108 mothers ($M_{age} = 30.68$ years, $SD_{age} = 6.06$.) and their preschool-aged biological children ($M_{age} = 3.50$ years, $SD_{age} = .51$, 61% boys) who were recruited through flyers posted at local businesses and Head Start centers. Due to budget constraints, genetics data was only collected for the first 98 families. Inclusion criteria required that mothers and children were fluent in English. Pregnant mothers were excluded because pregnancy can alter women's typical physiological responses. Children with developmental disabilities that could hinder participation were not included in the present study. All mothers were required to have lived with their children for at least two years.

The sample was economically- and racially-diverse. Nearly half (47%) of the women identified as Black; approximately 43% were Caucasian; about 1% were Asian; about 5% were Hispanic; and about 5% identified as "other." The majority of families (52%) indicated they had a total household income of less than \$30,000; 15% were between \$30,000 and \$49,999; and 33% had a total income above \$50,000. Nearly half (43%) of mothers reported they had never been married; 46% indicated they were currently married; and 12% were separated, divorced, widowed, or engaged.

Procedures

Mothers participated in a phone screening with a research assistant and, if eligible, were mailed a packet of measures to complete before visiting the lab. Mothers completed unfinished measures at the lab visit. Mothers provided written consent as well as permission for their child to participate, and children provided verbal assent. To collect RSA data, electrodes were placed on the child before the behavioral observation tasks. The present study focused on RSA data collected during a 4-minute baseline task where children and their mothers were instructed to remain quiet and sit still with their hands resting on the table. Children provided saliva samples for the genetic assays. Mothers were compensated \$100 and children chose a small prize. All study procedures were in accordance with the sponsoring university's Institutional Review Board.

Measures

Parenting stress

Parenting Stress Index-Short Form (PSI-SF; Abidin, 1995): The PSI-SF consists of 36 items and allows for the calculation of a Total Stress score and three subscale scores, each consisting of 12 items rated on a 5-point scale from 1 (strongly disagree) to 5 (strongly

agree). This study utilized the Total Stress scale, which measures the degree to which the caregiver experiences stress due to his/her role as a parent ($\alpha = .91$).

Child sensitivity factors

Genetic sensitivity: Child genetic sensitivity was assessed via 5-HTTLPR. Children provided DNA samples using Oragene DNA kits (DNA Genotek; Kanata, Ontario, Canada). Children sucked on buccal swabs to fill the Oragene vials with 4 ml of saliva. The vials were sealed and mailed to the Psychiatric Genetics Laboratory in Iowa City, Iowa. Genotyping for 5-HTTLPR involved the primers F-GGCGTTGCCGCTCTGAATGC and R-GAGGACTGAGCTGGACAACCAC, standard *Taq* polymerase and buffer, standard dNTPs with the addition of 100 μ m M7-deaza GTP, and 10% dimethyl sulfoxide. Next, the polymerase chain reaction products underwent electrophoresis on a 6% nondenaturing polyacrylamide gel and DNA was then visualized via silver staining. Two individuals who were blind to the study hypotheses and unaware of information regarding the participants determined the children's genotype statuses. Samples were prepared in accordance with the manufacturer's guidelines and the frequency distribution for 5-HTTLPR ($\chi^2 = 1.87$, $df = 1$, $p = .17$) was in Hardy-Weinberg equilibrium. With regard to 5-HTTLPR, 56.60% had one or two copies of the short allele and 43.40% were homozygous for the long allele. To control for potential differences in dependent variables due to child race, this variable was entered as a covariate in all moderation analyses. Based on prior research examining effects of race on gene expression (Vijayendran et al., 2012), there was no expectation of further moderation of GxE effects by race. However, to directly rule out moderation by race, exploratory analyses were conducted. These analyses resulted in non-significant effects for externalizing and sleep problems, but a significant three-way interaction for internalizing problems. We explicate the three-way interaction in supplemental material available from the authors, noting that the GXE effect is significant for Black individuals, but not for White participants, in this case.

Similar to procedures outlined in the extant literature (e.g., Brody et al., 2013), the short allele of 5-HTTLPR was treated as the genotype that confers sensitivity to the environment. Therefore, children who were homozygous for the long allele of 5-HTTLPR were assigned a code of "0" and those with one or two copies of the short allele were given a "1".

Physiological sensitivity: Physiological sensitivity was assessed via children's resting RSA. RSA data were collected during the baseline task using MindWare BioLab 3.0.6 software and analyzed using MindWare HRV 3.0.17 software (MindWare Technologies, Ltd., Gahanna, OH.). RSA data was collected in 30-second epochs following recommendations of the Society for Psychophysiological Research Committee on Heart Rate Variability (Berntson et al., 1997). Electrodes were placed on the right collarbone (i.e., the right clavicle area), in the cleft of the throat (i.e., below the Adam's apple), at the base of the rib areas on the left and the right sides of the body, near the xiphoid process, midway down the back, and below the base of the skull upon the back. Respiration was monitored by impedance cardiography (Ernst, Litvack, Lozano, Cacioppo, & Berntson, 1999) and the respiratory frequency band was set to include frequencies between 0.12 and 0.40 Hz. To derive the interbeat interval series, which was ultimately used in the calculation of RSA values,

MindWare used a peak-identification algorithm and calculated a 4 Hz time series via interpolation. The residual series was tapered via a Hamming window and then submitted to a Discrete Fourier transformation (DFT) or to a fast Fourier transformation (FFT) through the LabVIEW module (National Instruments, Austin, TX), resulting in the spectral distribution (MindWare HRV Module, Gahanna, Ohio). The EKG signal was digitized at 1000 Hz. Within MindWare HRV 3.0.17, RSA values were calculated using the integral power within the respiratory frequency band (i.e., the statistical variance of the interbeat interval time series within the specified respiratory frequency band). Visual inspection and an algorithm developed by Berntson, Quigley, Jang, and Boysen (1990), were used to identify and remove artifact peaks. We removed 30-second epochs in which greater than 10% of peaks needed to be edited (e.g., Perry et al., 2013). In the current analyses, mean scores for children's RSA during the baseline task were computed across all available epochs for that task. To calculate the mean, children were required to have at least two clean 30-second epochs (i.e., epochs in which no more than 10% of the data points needed to be edited) for the baseline task.

Behavioral sensitivity: Mothers completed the Emotion Regulation Checklist (ERC; Shields & Cicchetti, 1997), which assesses children's adaptive emotion regulation and emotion dysregulation. The present study relied on the Lability/Negativity subscale (15 items), which captures the degree to which a child is inflexible, emotionally labile, and displays dysregulated negative affect (e.g., "Is easily frustrated"). Responses are provided on a 4-point Likert scale (1 = *never*, 4 = *always*). Cronbach's alpha for the present study was .73.

Child adjustment

Child Behavior Checklist (CBCL; Achenbach & Rescorla, 2000): Mothers reported on their children's adjustment problems during the past 6 months using the CBCL. Unstandardized scores were used in analyses and higher scores indicated greater levels of problems. On the Sleep Problems subscale ($\alpha = .68$; 7 items) about 7% of the sample fell in the borderline (*T* score of 65–69) or clinical (*T* scores greater than 70) ranges. Whereas the Internalizing Problems scale ($\alpha = .90$; 36 items) indicated children's levels of anxious, depressed, and withdrawn behaviors as well as somatic complaints, the Externalizing Problems scale ($\alpha = .87$; 24 items) assessed delinquent and aggressive behaviors. On the Internalizing and Externalizing Problems Scales, 11% and 10% of children were in the borderline (*T* score of 60–63) or clinical (*T* scores greater than 63) ranges, respectively.

Demographics

Demographics questionnaire: Caregivers provided background information (e.g., child race, child sex, total household income, maternal education and maternal marital status) on a demographics questionnaire.

Missing Data

In total, 94 children had sufficient baseline RSA data to calculate mean scores. Missing RSA data was due to a number of factors, including technological difficulties (particularly early in data collection), failure of children to participate in the video tasks, as well as the stringent

data editing methods used. Seventy-six children provided saliva samples that could be genotyped for 5-HTTLPR. Missing genetics data was due either to difficulties in the collection of saliva samples or in the genotyping process. Overall, 106 mothers filled out the CBCL and PSI-SF and reported on their child's sex, and 105 mothers reported on their child's race. We were able to compute the ERC Lability/Negativity scale for 104 families. Missing data techniques were utilized to maximize the number of participants included in the moderation analyses. Little's MCAR was not statistically significant $\chi^2(16) = 13.60$, $p = .63$, indicating that the data were missing completely at random (Little, 1988). To handle missing data, multiple imputation was implemented only for continuous, primary study variables (i.e., child baseline RSA as well as CBCL, PSI-SF, and ERC scores). A total of 10 imputations were conducted, and pooled values were then used in the moderation analyses.

Analytic Plan

Descriptive statistics were run and Pearson bivariate correlations were calculated to examine relations between the main study variables (See Table 1). Single moderation models were run for each of the dependent and moderator variables separately using the publicly-available PROCESS SPSS macro plug-in (<http://processmacro.org/index.html>; Hayes, 2013). In PROCESS, mean centering was implemented to reduce nonessential multicollinearity between the independent variable, moderator variable, and interaction term (Aiken & West, 1991), but was only employed in the models involving baseline RSA and negative emotionality so as to preserve the dichotomous coding of the genetics variable. Significant moderation occurred when the interaction term between the predictor and moderator was significant and the 95% confidence interval did not include zero. For the genetics models, all interactions were probed by examining conditional effects for children in the high (at least one short allele of 5-HTTLPR) and low (zero short alleles of 5-HTTLPR) genetic sensitivity groups. For moderation models involving child baseline RSA and negative emotionality, interaction terms were probed by examining conditional effects at low (-1 SD below the mean) and high ($+1$ SD above the mean) levels of the moderator.

Significant interactions were probed further by first examining the value of the cross-over point, or the point on the independent variable (X_1) at which regression lines for different values of the moderator (X_2) converged (Widaman et al., 2012). Both point and interval estimates of the cross-over point were derived (Widaman et al., 2012). When the cross-over point is within the range of observed values of X_1 in the sample, this is suggestive of a disordinal interaction (i.e., more likely reflective of differential susceptibility than diathesis-stress; Widaman et al., 2012). Alternatively, cross-over values that fall outside of the range of X_1 are typically indicative of an ordinal interaction, and therefore, are more in line with a diathesis-stress model (Widaman et al., 2012). Whereas the point estimate for the cross-over point can be calculated based on a standard regression equation, the interval estimate of the cross-over point requires a re-parameterized regression equation (Widaman et al., 2012). In the re-parameterized equation, the independent variable is centered at the cross-over point to yield a standard error, which is then used to calculate the 95% confidence interval of the cross-over point (i.e., the interval estimate of the cross-over point; Widaman et al., 2012).

When considered together, point and interval estimates of the cross-over point can yield four main outcomes (Widaman et al., 2012). First, a disordinal interaction can occur when the point estimate of the cross-over point falls within the range of the independent variable and the interval estimate falls completely within that range. Second, a disordinal interaction can occur when the cross-over point estimate is within the range of the independent variable but the interval estimate falls partly outside of this range. Third, an ordinal interaction can include a point estimate of the cross-over term that falls outside of the range of the independent variable but has an interval estimate partly within the range. Lastly, an ordinal interaction can occur when both the point and interval estimates of the cross-over point fall outside of the range of the independent variable. All re-parameterized regression equations were run using the nonlinear regression function in SPSS.

Results

The simple correlation between the genetics and parenting stress variables was not significant (see Table 1), suggesting that any observed significant gene-environment interactions were not attributable to gene-environment correlation. For all moderations, child race was entered as a covariate to statistically control for potential differences based on this demographic characteristic (Belsky & Beaver, 2011; 1 = Caucasian, 2 = Black, 3 = Asian, 4 = Hispanic/Latino, and 5 = Other). Also, because CBCL raw scores were used as the dependent variables in analyses, gender was included as a covariate in all models.

Moderation Findings

Child genetic sensitivity—Children's 5-HTTLPR status significantly moderated the positive association between maternal parenting stress and child sleep problems, $b = .07$, $t = 2.05$, $p < .05$, 95% CI [.002, .13]. Simple slopes analyses indicated that parenting stress was only significantly, positively associated with child sleep problems for children high in genetic sensitivity (see Table 2 and Figure 1, Panel A). There was not a significant main effect for genetic sensitivity, $b = -4.42$, $t = -1.97$, $p = .05$, 95% CI [-8.89, .05], or parenting stress, $b = .01$, $t = .59$, $p = .56$, 95% CI [-.04, .06]. Neither child race, $b = .04$, $t = .20$, $p = .84$, 95% CI [-.39, .47], nor child sex, $b = .12$, $t = .21$, $p = .84$, 95% CI [-1.02, 1.26], served as significant covariates in the model. The point ($\hat{C} = 67.03$) and interval ($SE = 8.46$, 95% CI [50.45, 83.61]) estimates of the cross-over point both fell within the range of the parenting stress variable, thus indicating the interaction was disordinal and the results were most in line with a differential susceptibility framework.

Children's 5-HTTLPR status also significantly moderated the positive association between maternal parenting stress and child internalizing problems, $b = .18$, $t = 2.02$, $p < .05$, 95% CI [.002, .36]. A significant simple slope was found at high levels of genetic sensitivity (see Table 2). For children carrying at least one copy of the short allele, parenting stress was significantly and positively associated with child internalizing problems (see Figure 1, Panel B). There was not a significant main effect for genetic sensitivity, $b = -9.63$, $t = -1.56$, $p = .12$, 95% CI [-21.99, 2.72], or parenting stress, $b = .14$, $t = 1.97$, $p = .05$, 95% CI [-.002, .27]. Neither child race, $b = .64$, $t = 1.07$, $p = .29$, 95% CI [-.44, 1.82], nor child sex, $b = -.29$, $t = -.18$, $p = .86$, 95% CI [-3.44, 2.86], served as significant covariates in the model.

Again, the point ($\hat{C} = 53.73$) estimate of the cross-over point fell within the range of the parenting stress variable. The lower bound of the interval estimate of the cross-over point ($SE = 10.96$, 95% CI [32.25, 75.21]) fell just outside the range of the parenting stress variable; however, the upper bound of the interval estimate was within the range of parenting stress scores. Collectively, these results lend support for a differential susceptibility model.

Child 5-HTTLPR status did not serve as a significant moderator of the association between maternal parenting stress and child externalizing problems, $b = .06$, $t = .57$, $p = .57$, 95% CI [-.14, .25]. There was not a significant main effect for genetic sensitivity, $b = -2.17$, $t = -.32$, $p = .75$, 95% CI [-15.55, 11.20] but there was a significant main effect for parenting stress, $b = .18$, $t = 2.36$, $p < .05$, 95% CI [.03, .33]. Neither child race, $b = -.17$, $t = -.27$, $p = .79$, 95% CI [-1.46, 1.11], nor child sex, $b = -1.08$, $t = -.63$, $p = .53$, 95% CI [-4.49, 2.33], served as significant covariates in the model.

Child physiological sensitivity—Child baseline RSA significantly moderated the positive association between maternal parenting stress and child sleep problems, $b = .03$, $t = 2.27$, $p < .05$, 95% CI [.004, .06], such that for children with higher levels of baseline RSA, maternal parenting stress was significantly and positively associated with child sleep problems (see Table 2 and Figure 1, Panel C). There was a significant main effect for parenting stress, $b = .06$, $t = 4.08$, $p < .001$, 95% CI [.03, .08], but not child baseline RSA, $b = .17$, $t = .84$, $p = .40$, 95% CI [-.23, .58]. Neither child race, $b = -.07$, $t = -.37$, $p = .29$, 95% CI [-.44, .30], nor child sex, $b = .01$, $t = .02$, $p = .98$, 95% CI [-.92, .94], served as significant covariates in the model. Both the point ($\hat{C} = -5.57$) and interval ($SE = 7.20$, 95% CI [-19.68, 8.54]) estimates of the cross-over point fell outside of the range of the parenting stress variable, thus indicating the interaction was ordinal and the results were most in line with a diathesis-stress framework.

Child baseline RSA also moderated the association between maternal parenting stress and child internalizing problems, $b = .09$, $t = 2.51$, $p < .05$, 95% CI [.02, .16]. Significant simple slopes were found at higher and lower levels of child baseline RSA (see Table 2); for children with higher and lower levels of baseline RSA, there was a significant, positive association between parenting stress and internalizing problems (see Figure 1, Panel D). There was a significant main effect for parenting stress, $b = .24$, $t = 7.03$, $p < .001$, 95% CI [.17, .31], but not child baseline RSA, $b = .03$, $t = .07$, $p = .95$, 95% CI [-1.01, 1.08]. Neither child race, $b = .52$, $t = -1.09$, $p = .28$, 95% CI [-.43, 1.47], nor child sex, $b = .08$, $t = .07$, $p = .95$, 95% CI [-2.31, 2.48], served as significant covariates in the model. Because the point ($\hat{C} = -.39$) and interval ($SE = 5.97$, 95% CI [-12.09, 11.31]) estimates of the cross-over point were outside the range of the parenting stress variable (i.e., an ordinal interaction was present), these results are consistent with a diathesis-stress model.

Child baseline RSA was not a significant moderator of the association between maternal parenting stress and child externalizing problems, $b = .07$, $t = 1.85$, $p = .07$, 95% CI [-.01, .15]. There was a significant main effect for parenting stress, $b = .22$, $t = 5.60$, $p < .001$, 95% CI [.14, .30], but not child baseline RSA, $b = .05$, $t = .09$, $p = .93$, 95% CI [-1.14, 1.24]. Neither child race, $b = -.03$, $t = -.05$, $p = .96$, 95% CI [-1.11, 1.05], nor child sex, $b = -1.47$, $t = 1.07$, $p = .29$, 95% CI [-4.20, 1.26], served as significant covariates in the model.

Child behavioral sensitivity—Children's negative emotionality significantly moderated the association between maternal parenting stress and child internalizing problems, $b = .01$, $t = 2.47$, $p < .05$, 95% CI [.002, .02]. The simple slope was significant at higher levels of negative emotionality such that the positive association between maternal parenting stress and child internalizing problems only held for children higher in negative emotionality (see Table 2 and Figure 2, Panel A). There was a significant main effect for parenting stress, $b = .16$, $t = 4.33$, $p < .001$, 95% CI [.09, .24], and child negative emotionality, $b = .33$, $t = 3.28$, $p < .01$, 95% CI [.13, .54]. Neither child race, $b = .43$, $t = .95$, $p = .34$, 95% CI [−.47, 1.32], nor child sex, $b = 1.35$, $t = 1.13$, $p = .26$, 95% CI [−1.03, 3.73], served as significant covariates in the model. Both the point ($\hat{C} = -29.51$) and interval ($SE = 15.56$, 95% CI [−60.01, .99]) estimates of the cross-over point fell outside of the bounds of the parenting stress variable, indicating the interaction was ordinal. In turn, these results were in line with a diathesis-stress model.

Children's negative emotionality also served as a significant moderator in the association between maternal parenting stress and child externalizing problems, $b = .01$, $t = 2.18$, $p < .05$, 95% CI [.001, .02]. The simple slope was significant at higher levels of negative emotionality such that the positive association between maternal parenting stress and child externalizing problems was significant only for children higher in negative emotionality (see Table 2 and Figure 2, Panel B). There was a significant main effect for parenting stress, $b = .09$, $t = 2.33$, $p < .05$, 95% CI [.12, .17], and child negative emotionality, $b = .62$, $t = 6.02$, $p < .001$, 95% CI [.42, .83]. Neither child race, $b = -.27$, $t = -.58$, $p = .56$, 95% CI [−1.18, .64], nor child sex, $b = .40$, $t = .33$, $p = .74$, 95% CI [−2.03, 2.83], served as significant covariates in the model. Similar to the results for internalizing problems, the point ($\hat{C} = -61.19$) and interval ($SE = 30.67$, 95% CI [−121.30, −1.08]) estimates of the cross-over point were outside of the range of the parenting stress variable and, therefore, results were in line with a diathesis-stress framework.

Lastly, child negative emotionality was not a significant moderator of the association between parenting stress and child sleep problems, $b = .0002$, $t = .08$, $p = .94$, 95% CI [−.004, .004]. There was a significant main effect for parenting stress, $b = .04$, $t = 2.44$, $p < .05$, 95% CI [.01, .07], and child negative emotionality, $b = .12$, $t = 2.78$, $p < .01$, 95% CI [.03, .20]. Neither child race, $b = -.08$, $t = -.42$, $p = .67$, 95% CI [−.44, .29], nor child sex, $b = .18$, $t = .37$, $p = .72$, 95% CI [−.79, 1.15], served as significant covariates in the model.

Discussion

Parenting stress is a common phenomenon and, irrespective of its origins, is associated with child maladjustment (Anthony et al., 2005; Crnic, Gaze, & Hoffman, 2005). Our study expands upon the extant literature by demonstrating the ways that children's genetic, physiological, and behavioral sensitivity factors moderate the positive associations between maternal parenting stress and mothers' perceptions of child internalizing, externalizing, and sleep problems.

Consistent with hypotheses, child genetic sensitivity moderated the associations between parenting stress and child internalizing and sleep problems. These findings were in line with

a differential susceptibility framework and thus were largely consistent with recent research that has examined gene-environment interactions in relation to outcomes (e.g., Bogdan et al., 2014; van IJzendoorn, Belsky, & Bakermans-Kranenburg, 2012). In particular, maternal parenting stress was significantly, positively associated with child sleep and internalizing problems only for children who were high in genetic sensitivity. Though prior work has examined the role of 5-HTTLPR in internalizing symptoms (e.g., Benjet, Thompson, & Gotlib, 2010), no prior work to our knowledge has examined preschoolers' sleep problems as an outcome in studies of gene-environment interactions using either diathesis-stress or differential susceptibility frameworks. Given the potential regulatory and protective functions of sleep (Michels, et al., 2013; Silk et al., 2007), and the fact that sleep problems have been related to a host of adjustment problems across the developmental spectrum (Gregory et al., 2005; Hiscock et al., 2007), understanding variables that influence sleep quality, particularly during the preschool years, is important. Our findings, though preliminary, suggest that preschoolers' 5-HTTLPR status contributes to sleep quality in the context of parenting stress.

Though children's 5-HTTLPR status did not moderate the association between maternal parenting stress and child externalizing problems, the results followed a pattern similar to those found for internalizing and sleep problems. Of note, findings on the role of 5-HTTLPR in child externalizing problems have been mixed, with some studies indicating the effect of family adversity on child externalizing problems is greater for carriers of the short allele, and other research either yielding the opposite pattern or null results (for a review, see Weeland, Overbeek, Castro, & Matthys, 2015). Weeland and colleagues (2015) highlight the methodological differences (i.e., sample size and composition, conceptualization, and power) across studies on gene-environment interactions and child externalizing problems, which likely contribute to the inconsistencies in findings throughout the extant literature.

The pattern of findings examining child RSA was largely consistent with a diathesis-stress model. Maternal parenting stress was significantly and positively associated with sleep problems only for children with higher baseline RSA; parenting stress was associated with child internalizing problems for children with higher and lower levels of baseline RSA. The present findings suggest that maternal parenting stress is a potent risk factor during the preschool period, particularly for children with higher physiological sensitivity (i.e., RSA). High baseline RSA reflects greater openness to, and engagement with, the environment (Beauchaine, 2001). Greater engagement with a high-stress environment may increase children's exposure to negative parenting behaviors and experiences, thereby increasing the risk for poor outcomes such as internalizing or sleep problems.

Children's baseline RSA did not moderate the association between maternal parenting stress and child externalizing problems. Research on the direct relation between baseline RSA and child externalizing problems is mixed with some findings indicating that lower baseline RSA is associated with greater externalizing problems (e.g., Calkins & Dedmon, 2000; Beauchaine, Gatzke-Kopp, & Mead, 2007), while other research demonstrates the opposite (e.g., Dietrich et al. 2007) or finds no relationship between these variables (e.g., Calkins et al. 2007; El-Sheikh & Whitson, 2006). These mixed findings suggest that the effects of RSA on child outcomes likely vary depending on context, and the present results indicate that in

the context of parenting stress, child RSA may be more closely linked to internalizing and sleep problems rather than externalizing problems. Regardless, it will be important for future research to continue to explore child RSA in context in relation to child externalizing problems to develop a more nuanced understanding of the unique roles that child RSA plays in this domain of child maladjustment under various environmental conditions.

Finally, children's negative emotionality moderated the association between maternal parenting stress and child internalizing and externalizing problems in ways consistent with a diathesis-stress model. These results corroborate previous findings (e.g., Morris et al., 2002) and extend the literature by demonstrating the vulnerability function of child negative emotionality in the associations between maternal parenting stress and child internalizing and externalizing problems. Alternatively, child negative emotionality was not a significant moderator of the association between maternal parenting stress and child sleep problems. The bivariate relations among variables suggest that these variables are directly related to one another and in fact, are likely reciprocally related (Bell & Belsky, 2008). The results indicate sleep adjustment may be most impacted by maternal parenting stress for preschoolers who are more sensitive to their environment due to their genetic makeup and physiology.

Overall, the present analyses provide evidence of child genetic, physiological, and behavioral sensitivity to parenting stress, but limitations are noted. The design was cross-sectional and, though important for establishing preliminary relations among variables, future work should incorporate the variables identified here into a longitudinal analysis. A longitudinal design would allow for an examination of reciprocal relations over time, extending previous research that has shown that parenting stress and child behavior problems tend to influence each other mutually (Neece, Green, & Baker, 2012). Additionally, longitudinal analyses would allow for the exploration of possible mechanisms (e.g., parenting behaviors) that are likely implicated in the relations between parenting stress and child adjustment problems. We relied on rigorous statistical tests to differentiate between differential susceptibility and diathesis-stress (Widaman et al., 2012) but acknowledge that other approaches could have been implemented (e.g., Roisman et al., 2012; Del Giudice, in press). The current study used mothers' reports of child internalizing and externalizing problems and future research should include other reports (e.g., daycare teacher) and/or behavioral observations. Future research could also include multiple assessments of sleep problems (e.g., actigraphs). Though the sample size was comparable to, or even larger than, samples used in some other studies that have examined gene-environment interactions in youth (Benjet et al., 2010; Sheese, Rothbart, Voelker, & Posner, 2012), it was still relatively small and somewhat restricted in the range of child adjustment problems. Accordingly, the results are best interpreted in the context of the extant literature. It will be beneficial for future research with larger sample sizes to more directly examine the unique contributions of each sensitivity factor by determining whether effects for a given sensitivity factor hold when controlling for the others.

Despite these limitations, this study moves the literature forward by documenting interactions between preschoolers' genetic, physiological, and behavioral sensitivity and mothers' perceived parenting stress in an economically- and racially- diverse sample. The

study also advances the literature by examining sleep adjustment, given the critical role of this process in child development (Alfano & Gamble, 2009; Dewald, Meijer, Oort, Kerkhof, & Bögels, 2010). Findings from the present study demonstrate how factors across genetic, physiological, and behavioral levels may make children more or less sensitive to the adverse effects of parenting stress during the preschool period. The relative independence of the three moderators examined suggests that effects of parenting stress on the interrelated outcomes of internalizing, externalizing, and sleep problems may be buffered or moderated by a number of different vulnerability and susceptibility factors. Results suggest that it is important for prevention and intervention efforts to target mothers' parenting stress to help them promote their children's optimal adjustment. In particular, future research may explore the benefit of providing effective parenting strategies for caregivers of more and less genetically, physiologically, and behaviorally sensitive youth as a means of differentially countering the impact of parenting stress on healthy child development.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.

Maternal parenting stress was positively associated with child sleep (Panel A) and internalizing (Panel B) problems when children were high in genetic sensitivity. For children with high levels of physiological sensitivity, maternal parenting stress was positively associated with child sleep (Panel C) and internalizing (Panel D) problems. The positive relation between parenting stress and child internalizing problems was also significant for children with low levels of physiological sensitivity.

Figure 2.

Maternal parenting stress was positively associated with child internalizing (Panel A) and externalizing (Panel B) problems, only when children were high in behavioral sensitivity.

Table 1

Intercorrelations and Descriptive Statistics for Main Study Variables

Variable	1	2	3	4	5	6	7	M (SD)	Range
1. Maternal Parenting Stress	—	.23*	.07	.49**	.41**	.58**	.50**	66.61 (17.52)	36–131
2. Child Baseline RSA		—	.10	.25*	.21	.18	.16	6.19 (1.23)	3.00–9.08
3. Child Genetic Sensitivity			—	-.001	.05	.18	.12	.57 (.50)	0–1
4. Child Negative Emotionality				—	.42**	.52**	.65**	28.56 (6.55)	15–46
5. Child Sleep Problems					—	.51**	.52**	3.34 (2.55)	0–11
6. Child Internalizing Problems						—	.65**	7.81 (7.39)	0–50
7. Child Externalizing Problems							—	10.37 (8.04)	0–36

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

Simple Slopes of Maternal Parenting Stress on Child Sleep, Internalizing, and Externalizing Problems at Low and High Levels of Child Genetic, Physiological, and Behavioral Sensitivity

Sensitivity Factor													
Genetic (5-HTTLPR; N = 74)							Physiological (Baseline RSA; N = 108)						
Outcome Variable	b (SE)	t	R ²	R ²	F	95% CI	b (SE)	t	R ²	R ²	F	95% CI	95% CI
Sleep Problems			0.20	.05	3.32**				0.21	.04	5.32**		
Low Sensitivity	.01 (.03)	0.59				-.04, .06	.02 (.02)	.91				-.02, .06	-.01, .08
High Sensitivity	.08 (.02)	4.01**				.04, .12	.09 (.02)	4.42**				.05, .13	.004, .07
Internalizing Problems			0.38	.04	8.20**				0.38	.04	12.20**		
Low Sensitivity	.14 (.07)	1.97				-.002, .27	.14 (.05)	2.61*				.03, .25	-.01, .19
High Sensitivity	.32 (.06)	5.67**				.20, .43	.35 (.05)	6.54**				.24, .45	.15, .32
Externalizing Problems			0.25	.004	4.60**				0.29	.03	7.84**		
Low Sensitivity	.18(.07)	2.36*				.03, .33	.13 (.06)	2.19*				.01, .26	-.08, .13
High Sensitivity	.23 (.06)	3.86**				.11, .35	.31 (.06)	5.10**				.19, .43	.07, .24

Note. R^2 = change in R^2 due to interaction term. $F = F$ value for the overall model.

^{**}
 $p < .01$.^{*} $p < .05$