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Sex Differences in the Contribution of Respiratory Sinus Arrhythmia and Trauma to Children's Psychopathology

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Abstract

Respiratory sinus arrhythmia (RSA), a marker of parasympathetic activity, has been shown to moderate the relation between adversity and child behavioral outcomes; however, this work has been conducted in primarily Caucasian samples and limited in focus to family-level adversity. The current analysis extends the previous literature to examine the co-contribution of exposure to potentially traumatic events (PTEs), baseline RSA, and RSA withdrawal to internalizing and externalizing behavior in a sample of primarily African American youth (n = 92) recruited using neighborhood mapping techniques from communities high in epidemiological indicators of adversity. Exposure to PTEs was associated with lower baseline RSA. Complex interactions were observed between sex of the child, baseline RSA and RSA withdrawal, and PTE exposure predicting to internalizing behaviors. Among girls with high (4+) levels of PTEs, high baseline RSA and RSA withdrawal predicted higher internalizing; for RSA withdrawal only, the inverse was observed for girls with low PTE exposure, for whom high RSA withdrawal predicted *lower* internalizing. No associations were observed from RSA to externalizing, or among boys to internalizing. Findings are consistent with distinct patterns among primarily African American samples and suggest the need for sex-specific conceptualizations of the link between environmental adversity, physiological reactivity, and internalizing behaviors.

Keywords

Respiratory Sinus Arrhythmia; vagal tone; psychopathology; trauma; sex differences

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Compliance with Ethical Standards: All procedures were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study (informed consent from all caregivers and assent for children over age 8 years).

Early exposure to environmental adversity, including exposure to potentially traumatic events (PTEs), is a well-documented predictor of negative behavioral and health outcomes across the lifespan (Felitti et al., 1998). Notably, not all children exposed to PTEs develop psychopathology, a basic developmental psychopathology tenet that has led to a body of research inquiring about what factors at multiple levels of analysis (physiological, psychological, environmental, group differences such as sex) may in isolation and interaction predict resilient or vulnerable outcomes (Cicchetti, 2010; Del Giudice, Ellis & Shirtcliff, 2011; Ellis & Boyce, 2008). Deficits in self-regulatory processes in particular are suggested to be one pathway linking adversity and maladaptation. Therefore, integrating psychophysiological measures of regulation with psychological and environmental measurement may better illuminate these relations. The present study investigates the moderating role of one such psychophysiological marker of regulation – respiratory sinus arrhythmia (RSA) – in the relation between children's exposure to trauma and their behavioral outcomes, examining sex-differentiated patterns.

Critical to self-regulation, as well as the integration of physiology and behavior, the autonomic nervous system (ANS) supports an individual's reaction to and coping with environmental challenges by balancing sympathetic (SNS) activation of physiological arousal, preparing for "fight or flight," and parasympathetic (PNS) activation, responsible for the modulation of sympathetic arousal and promotion of homeostasis. The ANS plays a critical role in biobehavioral regulatory processes, including regulating a wide range of involuntary bodily functions, such as heart rate and blood pressure. The ANS is also considered part of the complex stress response systems that includes other physiologic pathways such as the hypothalamic pituitary axis and the immune system, which are all implicated in stress reactivity. Respiratory sinus arrhythmia (RSA), or high-frequency variability in heart period oscillations during the respiratory cycle, is a reliable index of PNS activity and has emerged as a physiological marker of self-regulatory capacity (Porges, 2007).

Polyvagal theory (Porges, 2007) differentiates between RSA indexed while the organism is at rest and RSA withdrawal in response to challenges in the environment. Baseline measures of RSA during resting states are reflective of both the potential responsiveness to the environment and the individuals' ability to maintain homeostasis, as the PNS exhibits an inhibitory influence on sympathetic activity, including heart rate. When confronted with a challenge, the individual prepares him or herself by disengaging this inhibitory function (RSA withdrawal) and activating the SNS. RSA withdrawal is thought to facilitate attentional and behavioral control in the context of an environmental challenges and index the efficiency of cardiovascular adaptation, also potentially serving as a biological indicator of the organism's social and emotional regulatory capacity (Porges, 2007).

Baseline RSA

High baseline RSA is considered a marker of high tonic parasympathetic influence of the heart. Higher baseline RSA has been linked to a range of adaptive outcomes across domains of functioning, including cognitive (Feldman, 2009; Staton, El-Sheikh & Buckhalt 2009), emotional (Beauchaine, 2001), and social (Calkins & Keane, 2004) domains. Conversely,

lower baseline RSA has been associated with less adaptive outcomes, including deficits in emotion and attentional regulation (Blandon, Calkins, Keane & O'Brien, 2008; Hansen, Johnson, & Thayer, 2003). Correspondingly, in terms of psychopathology outcomes, lower baseline RSA is typically associated with elevated externalizing behaviors (Beauchaine, 2001), although these patterns are not always observed (Calkins, Graziano, Keane, 2007). Lower baseline RSA is also typically associated with internalizing disorders (Forbes, Fox, Cohn, Galles, & Kovacs, 2006; Shannon, Beauchaine, Brenner, Neuhaus, & Gatzke-Kopp, 2007), though again, findings have been inconsistent (Hinnant & El-Sheikh, 2009). Together, the literature suggests that children with high baseline RSA have more adaptive functioning, but considerable variability exists.

RSA Withdrawal in Response to Stressors

A recent meta-analysis examining the relation between RSA withdrawal and child outcomes across 44 studies, with children ranging in age from infancy to 18 years, reported that greater RSA withdrawal in the context of a stressor was associated with fewer externalizing and internalizing behaviors (Graziano & Derefinko, 2013). However, in this meta-analysis, among clinical or at-risk samples, higher RSA withdrawal was actually associated with *higher* problem behavior. Race but not age or gender (% female) moderated the relation between RSA and behavioral outcomes. Among children at risk for psychopathology, extreme RSA withdrawal may indicate an over-vigilance or over-reactivity to environmental threats (Beauchaine, 2001). Thus, although RSA withdrawal can be adaptive, excessive RSA withdrawal may instead index a vulnerability to psychopathology (Thayer, Hansen, Saus-Rose & Johnsen, 2009). Indeed, findings relating RSA withdrawal to psychopathology outcomes are not always consistent, with some evidence that internalizing problems in particular may be associated with the pattern of *extreme* RSA withdrawal (Boyce et al., 2001; Beauchaine, 2001; Calkins, Graziano, & Keane, 2007; Hinnant & El-Sheikh, 2009).

RSA and Adversity

Conceptually, given that RSA reflects the body's self-regulation and response to challenge, RSA may index cumulative stress exposure. This model is in line with an allostatic load perspective, whereby children repeatedly exposed to stressors demonstrate repeated activation of physiological stress responses that, while adaptive in short-term situations, likely lead to long-term negative outcomes (McEwen & Stellar, 1993). RSA baseline and RSA withdrawal then, particularly in cross-sectional studies, may thus reflect the cumulative impact of a range of environmental stressors. Indeed, there is evidence that exposure to adversity results in long-term changes in children's RSA. Specifically, among children, experiences of adversity have been linked to lower levels of resting RSA (Skowron et al., 2011), and early adversity has been linked to lower RSA withdrawal (Conradt et al., 2014). The link between RSA and early life adversity may have particular relevance given the established links between adverse childhood events (ACEs) and cardiovascular health across the lifespan (Felitti et al., 1998). Unpacking these associations requires research that examines patterns at high as well as low adversity. As such, this study targets children under-represented in the bulk of this research, specifically children from high-risk communities who are primarily African American and exposed to a range of adversity.

Following the large body of research documenting the ways in which children's biological risk interacts with environmental factors to predict outcomes, RSA also has been examined as a moderator of the relations between environmental adversity and child psychopathology. Corresponding to theories and research documenting how individual differences in physiological reactivity contribute to how the environment influences development and behavior (Boyce & Ellis, 2005), RSA has been shown to moderate the relation between environmental influence and behavioral outcomes.

For example, high RSA at baseline has been shown to buffer young children against externalizing behavior in contexts of marital hostility (Katz & Gottman, 1995). Similarly, RSA withdrawal appears to buffer negative impacts of hostile co-parenting on children's peer relations in middle childhood (Leary & Katz, 2004). In these and other moderation studies, RSA is more strongly associated with psychopathology outcomes among children from high-adversity environments (McLaughlin, Najarian, Dirks, & Sheriden, 2015; El-Sheikh, Harger, & Whitson, 2001). In other samples, these positive associations from high RSA baseline and higher withdrawal are only observed in contexts of *low* adversity. For example, among preschool-aged children, greater RSA withdrawal in the context of a challenge was associated with more adaptive social-emotional outcomes, but only in contexts of low family violence (Cipriano, Skowron & Gatzke-Kopp, 2011). In preschool children from families with high levels of family violence, children demonstrated poorer outcomes regardless of RSA withdrawal, suggesting a threshold level at which ANS adaptation may not be able to buffer against negative outcomes. Similarly, in a longitudinal study across the toddler-preschool period, relations from low baseline RSA to aggression were found only at low levels of adversity, as indexed by marital adjustment and socioeconomic status (Eisenberg et al., 2012); for children at higher levels of adversity, no such relations were observed.

Given the observed variability across samples and types of adversity, it may be that baseline RSA and RSA withdrawal are in fact indices of children's physiological sensitivity to their context, with higher baseline RSA and greater withdrawal serving as protective factors in low-stress environments, but not high-stress ones. Biological Sensitivity to Context theory provides one framework for understanding this variability in findings, as well as how reactivity may moderate environmental influence on child outcomes. According to this theory, individuals who are highly reactive are more sensitive to environmental influences, thriving in low stress environments but having substantial negative impacts in high stress environments (Ellis & Boyce, 2008). Evidence consistent with this for RSA has been reported in kindergarten children, where high RSA withdrawal was associated with poor outcomes in contexts of high adversity, indexed as financial and parenting stress and high conflict, but with more adaptive outcomes in contexts of low adversity (Obradovic et al, 2010).

A majority of the work examining the interaction of RSA and environmental quality has focused on the quality of the family environment, such as quality of parenting (Scheeringa, Zeanah, Myers & Putman, 2004) or family conflict (Cipriano, Skowron, & Gatzke-Kopp, 2011; El-Sheikh & Hinnant, 2011). However, the impact of family-level stressors may be unique or operate in combination with broader, community-level environmental stressors.

Those studies that have looked to stressors in children's broader environment have also found that RSA may moderate the link between community-level stressors such as exposure to community violence and child outcomes (McLaughlin, Najarian, Dirks, & Sheriden, 2015; Scarpa, Tanaka & Haden, 2008). However, these patterns are not always consistent with what has been observed among studies examining family-level adversity. For example, children with higher baseline RSA demonstrated *higher* levels of reactive aggression among children exposed to community violence, suggesting contradictory patterns to what has been observed in studies of family adversity (Scarpa, Tanaka & Haden, 2008).

The Moderating Effect of Sex

Some past research has suggested that the patterns of relation between RSA and child behavioral outcomes may differ across sex (Eisenberg et al., 2012; Beauchaine, Hong, & Marsh, 2009; Aults, Cooper, Pauletti, Jones, & Perry, 2015), though results have varied across the literature. While most studies report on baseline sex differences on RSA variables, the majority of studies to date have not examined sex as a potential moderator, testing whether patterns of relations between RSA and outcomes vary across sex. Some studies that test sex differences in patterns in relations find differences (El-Sheikh, 2005) – for example, boys with lower baseline RSA and less withdrawal appear at greater risk for vulnerable behavioral outcomes (Calkins & Dedmon, 2000; Hastings et al., 2008; El-Sheikh et al., 2011). Others have observed environment-by-RSA interactions only within girls (Eisenberg et al., 2012), and still others have not found sex differences (Obradovic, Bush, Stamperdahi, Adler, & Boyce, 2010). Relative to the relation between RSA withdrawal, environment, and child outcomes, sex moderation effects have been inconsistently reported and observed. Given the higher symptomatology following potentially traumatic exposures among females (Tolin & Foa, 2006), even in toddlers and preschoolers (Grasso, Ford, & Briggs-Gowan, 2012), studies explicitly testing sex differences in the link between RSA and child behavioral outcomes are particularly relevant in relation to early life adversity.

Race and RSA

Given the increased attention to disparities across health outcomes, it is important to note that the majority of research exploring the link between RSA and child psychopathology has been conducted in primarily Caucasian samples. This is despite evidence for racial differences in baseline RSA; African American youth typically demonstrate higher resting RSA levels (Hinnant, Elmore-Staton, El-Sheikh, 2011; Wang, Thayer, Treiber, Snieder, 2005). Additionally, patterns of prediction to child behavioral outcomes may vary by race. In Graziano & Derefinko's (2013) meta-analysis of RSA withdrawal and adaptive outcomes, for example, stronger effects were observed predicting to externalizing outcomes for samples with a higher percentage of Caucasian participants, leading the authors to call for a broader examination of RSA patterns across different groups. Work documenting relations between RSA and child outcomes within non-white samples is important to clarify whether the patterns typically observed in majority-Caucasian samples also hold for other ethnic groups. While the current study was not designed to compare across racial groups, the primarily African-American nature of this sample presents a unique contribution to the

literature on RSA and child behavioral outcomes, in which these children are generally under-represented.

The Current Study

To address several gaps in the current literature this study examines, within a primarily African American community-recruited high-risk sample, the potential moderating effect of RSA at baseline and RSA withdrawal in response to a stressor on the relation between children's exposure to potentially traumatic events (PTEs) and their internalizing and externalizing psychopathology was examined. We hypothesized that baseline RSA and RSA withdrawal would be associated with PTE exposure. We further examined whether the association between exposure to PTEs and psychological outcomes would differ by baseline RSA and RSA withdrawal. Lastly, given evidence for sex differences, we examined how sex moderated these relations, recognizing the limitations due to the sample size. Given documented developmental effects for RSA particularly in the younger years (Alkon et al., 2003) and established risk of low socioeconomic status for behavioral outcomes (Dodge, Pettit, & Bates, 1994), child age and mother's education (a proxy for SES) were examined as covariates.

Methods

Procedures

Participants were drawn from a larger study (n = 120) of the impacts of neighborhood influence on health disparities that took place between January 2012 and July 2013 designed to target children growing up in neighborhoods high in adversity. Families were recruited through street outreach and through participating schools in targeted neighborhoods, which were selected using a community identification process (Tashima, Crain, O'Reilly, & Elifson, 1996) based on epidemiological indicators of the prevalence and incidence of community violence and other social epidemiological risk factors such as poverty and concentrated disadvantage, targeting high-risk neighborhoods. Interested families contacted the research site to schedule an appointment.

Questionnaires were administered using an interview-assisted computer survey at the research site. Assent for children over the age of 8 and informed consent from all caregivers was obtained. As part of the larger study, a range of biological and physiological indicators were collected, including telomere length and cortisol (see Theall, Brett, Shirtcliff, Dunn & Drury, 2013). This report focuses on heart period data, collected by methods described below. Visits lasted approximately 2 hours. Transportation was provided as needed and caregivers were compensated for their participation and children received a small gift. All procedures were approved by a university IRB.

Participants

Children ranged in age from 5–16 and were majority African American (89%) and female (56.5%). Sixty-one percent were from single parent households, nearly all participating caregivers were children's legal guardian (96%), and most were biological mothers (83.7%).

Approximately a quarter (22%) of mothers had less than a high school education, another 23% had a high school diploma, and the remainder had some college or more.

RSA Data Acquisition

Respiratory sinus arrhythmia (RSA) was collected using equipment and software from the James Long Company. Approximately 30 minutes after arriving at the research site, electrodes were placed on the child axially on the left and right rib cage and centrally on the chest to ground the signal. To capture respiration period and timing, latex pneumatic bellows for measuring change in thoracic girth were employed. The heart period (interbeat interval, IBI) was measured with ECG data, with the bioamplifier set for bandpass filtering at frequencies of 0.1 and 1000 Hz and data digitized at a sampling rate of 1000 Hz. The rising edges of R waves were identified with an automated algorithm. All signals were visually inspected using the IBI Analysis System from James Long Company. The IBIs between R waves were prorated into equal time intervals of 125 ms. The peak-valley method, one of several acceptable methods for recording RSA, was used; this method produces values that correlate with spectral measurements of RSA (Galles et al., 2002). Respiration signals identified onset of inhalation and exhalation, and RSA was computed as change in IBI readings between these time points. Values are reported in milliseconds.

Children initially participated in a baseline soothing epoch followed by a brief scary film clip epoch that are not the subject of this report. Following those epochs, children completed a two minute baseline period, used as baseline in this report. Next, children participated in a standardized lab social stressor, the Trier Social Stress Test for children (TSST-C), a validated psychosocial stressor for youth (Buske-Kirschbaum et al., 1997). Children were told the beginning of a story and were given five minutes to prepare. They were then asked to finish telling the story as exciting as possible in front of a committee of study staff, with five minutes to finish telling the story. RSA withdrawal scores were calculated by subtracting the baseline RSA from the challenge epoch of preparation for the speech. Thus, a negative RSA withdrawal score indicates a decrease in RSA in the context of the stressor, whereas a positive withdrawal score indicates an increase in RSA (augmentation).

Measures

Caregivers reported on demographic variables, including child age and sex and parent education.

Psychopathology—Caregivers reported on the primary outcome variables, children's internalizing and externalizing behaviors, using the widely used Child Behavior Checklist (CBCL; Achenbach, 1991), a checklist of 118 behaviors that parents rate as not true (0), somewhat or sometimes true (1), or very true or often true (2) of their child over the past 5 months. Sum variables for both the internalizing and externalizing scales were used in this report.

Potentially traumatic events—Exposure to PTEs was measured using the caregiver-report Major Life Events derived from the Preschool Age Psychiatric Assessment (PAPA), a structured diagnostic interview (Egger et al., 2006) that was modified to include specific

items related to witnessing both community and family violence. Caregivers reported about children's exposure to 13 items types of events related to serious injury or potential for serious injury, including witnessing violence (domestic, family, community), motor vehicle crash, and exposure to disasters (e.g. hurricanes, fires). Responses were coded as yes or no and exposure was operationalized as a sum of exposure to PTEs (0 to 13).

Data Preparation and Analytic Procedures

Analyses were performed using SPSS version 22. Of participating families, 102 had heart rate data; ten others were excluded for missing data on the outcome variable of interest (CBCL), resulting in a final analytic sample of 92. Within this analytic sample, two outliers (i.e., +/− 3 standard deviations from mean) were identified on the CBCL internalizing scale and two on the externalizing scale; patterns of significance were similar with these outliers winsorized to within 3 standard deviations of the mean, so results are reported for raw data. All predictors and outcomes of interest were normally distributed and did not require transformation.

To examine the co-contribution of PTEs and RSA on child outcomes, a series of four linear regression analyses were conducted. Models were run separately for RSA baseline and RSA withdrawal across both externalizing and internalizing outcomes. All models controlled for child age and sex, and in models examining RSA withdrawal, baseline RSA was entered as a covariate (Graziano & Derefinko, 2013). Regression analyses were conducted hierarchically, with covariates (age, sex) and predictors entered in step one; two-way interaction terms in step two (RSA baseline or RSA withdrawal-by-sex, RSA baseline- or RSA withdrawal-by-PTE exposure, and sex-by-PTE exposure); in the final step, a three-way RSA-by-PTE-by-sex interactions term was entered. Main effects variables were mean-centered in analyses and prior to creating interaction terms. When three-way interactions were significant, data were illustrated visually in graphs separately for boys and girls. For boys and for girls, the relation between RSA and psychopathology was plotted at one standard deviation above and below the mean for exposure to PTEs, corresponding to approximately 0 exposures (-1 SD) and approximately 4 exposures (+1 SD). Then, for boys and girls separately, two-way RSA-by-PTE interactions were further decomposed using simple slopes and slope difference testing (Aiken & West, 1991; Dawson & Richter, 2006). Following Aiken & West (1991), simple slopes were estimated at three levels of PTE exposure: low (-1 SD, approximately no exposures), moderate (at mean, approximately 2 exposures), and high (+1 SD, approximately 4+ exposures).

Results

As expected given the recruitment strategy targeting high-adversity neighborhoods, most children (91%) had lifetime exposure to at least one type of PTE, with 32% experiencing one type of PTE exposure and 60% experiencing two or more. These rates are higher than those documented in national surveys; for example, a survey of adolescents indicated rates closer to 60% for at least one event and 33% for two or more (McLaughlin et al., 2013). The mean exposure level in this sample was between 2 and 3 exposures, with a standard deviation of approximately 2 exposures. Descriptive statistics are provided stratified by sex

in Table 1 and correlations between main study variables are presented in Table 2. Mothers' education, a proxy for socioeconomic risk, was also lower than national rates (Bloom, Cohen, & Freeman, 2010) but was not associated with any study variables of interest.

Consistent with hypotheses, exposure to PTEs was significantly and negatively associated with baseline levels of RSA in crude bivariate analyses; however, this relation was not observed for RSA withdrawal. Exposure to PTEs additionally was associated with higher levels of both internalizing and externalizing behaviors. No bivariate associations were observed between RSA variables and psychopathology. As expected, age was positively associated with children's exposure to PTEs and was negatively associated with baseline levels of RSA. T-tests indicated no significant differences between African American and non-African American children or between boys and girls on study variables of interest, although sex difference for baseline RSA approached significance ($t = 1.90$, $p = .06$).

Multivariable Results

RSA Baseline—For externalizing behaviors, there was a significant main effect of exposure to PTEs on children's behavior; no main effects of child sex or baseline RSA were observed (see Table 3). Baseline RSA did not moderate the relation between PTEs and externalizing behaviors, and no sex effects were observed.

For internalizing behaviors, when baseline RSA and PTEs were considered together, there was a main effect of PTE exposure on internalizing behaviors, but no main effect of baseline RSA was observed (see Table 3), consistent with previous research (McLaughlin, Rith-Najaran, Dirks, & Sheridan, 2015). However, a significant baseline RSA-by-Sex-by-PTE interaction was observed (see Table 3, Figure 1). We decomposed this interaction by examining separately for boys and girls the relation between baseline RSA and internalizing behaviors at high (approximately 4 PTEs), medium (approximately 2 PTEs), and low (approximately 0 PTEs) levels of trauma exposure. Simple slopes were only significantly different from 0 at high levels of PTE exposure and only among girls ($t = 3.68$, $p < .000$), indicating that baseline RSA was *positively* associated with internalizing behaviors at high levels of exposure to PTEs. Simple slopes did not differ significantly from 0 among boys with any level of exposure to PTE, nor among girls with low- or moderate-range exposure ($ps > .05$). Slopes difference tests indicated that the slope for girls with high PTE exposure was significantly different from those of girls and boys with low exposure to PTEs ($ps < .05$). Among girls with low or moderate exposure to PTEs and among boys with any level of exposure, there was not a significant association between RSA and internalizing behaviors.

RSA Withdrawal—For externalizing behaviors, there was again a significant main effect of exposure to PTEs, with greater PTE exposure associated with higher externalizing behaviors. There was no main effect of RSA withdrawal, nor was there a main effect of sex. A significant RSA withdrawal-by-PTE interaction was found predicting externalizing; however, the change in R^2 was not significant when two-way interaction terms were entered ($F = 2.01$, $p = .10$), suggesting that the main effect model best fits the data.

For internalizing behaviors, again, there was a significant main effect of exposure to PTEs, with higher exposure associated with higher internalizing, but no main effects of sex or RSA

withdrawal. Additionally, a significant RSA withdrawal-by-PTE interaction was observed. However, these main effects and two-way interactions must be considered in light of a significant three-way interaction between RSA withdrawal, sex, and PTE exposure, parallel to what was observed with RSA baseline and internalizing behaviors (see Table 3, Figure 2).

This interaction was again decomposed using simple slopes and slopes difference testing. We examined separately for boys and girls the relation between RSA withdrawal and internalizing behaviors at high (approximately 4 PTEs), medium (approximately 2 PTEs), and low (approximately 0 PTEs) levels of trauma exposure. For boys, simple slopes were not significantly different from 0 at any level of PTE exposure. The simple slopes test also was not significant for girls with moderate levels of PTE exposure (ps > .05). However, simple slopes tests were significant for girls with high (+1 SD, approximately 4+ exposures; t = −3.55, p = .001) and low (-1 SD, approximately 0 exposures; t = 2.84, p = .006) PTE exposure, suggesting that the association between RSA withdrawal and internalizing behaviors is negative at high levels of PTE exposure but positive at low levels of PTE exposure. Slopes difference tests suggested that the slope for girls with high levels of PTE exposure was significantly different than slopes for all other groups. Among children with low levels of PTE exposure, there was not a significant difference between boys and girls (lines 2 & 4, p = .08), and among boys, there was not a significant difference in the relation of RSA withdrawal to internalizing psychopathology between boys with low vs. high levels of PTE exposure (lines 3&4, p = .51). Taken together, slopes testing results suggest that for girls with high levels of PTE exposure, RSA withdrawal was related to *higher* levels of internalizing psychopathology; this pattern was inverted for girls with low levels of PTE exposure, for whom RSA withdrawal was linked to *lower* levels of internalizing psychopathology. For boys, higher PTEs were associated with higher internalizing psychopathology, but RSA withdrawal was not.

Discussion

This report examined the relations between children's exposure to PTEs, RSA, and internalizing and externalizing behavior in a primarily African American, community-recruited sample enriched for exposure to PTEs, unique sample features in the literature on RSA. While some patterns consistent with prior literature were observed, distinct patterns emerged, particularly in relation to internalizing behaviors among girls from high-adversity environments.

First, consistent with hypotheses, in crude bivariate models, children's exposure to PTEs was negatively associated with baseline RSA. Contrary to hypothesis, this prediction was not observed for RSA withdrawal. This pattern of effect is consistent with allostatic load, whereby children in higher-stress environments demonstrate physiological evidence of repeated activation of physiological stress responses which, while adaptive in short-term situations, may have longer-term negative outcomes (McEwen & Stellar, 1993). Lower baseline RSA among high-risk and clinical samples relative to community samples was also noted in a recent meta-analysis (Graziano & Derefinko, 2013). Prior work has documented that PNS activity is susceptible to alteration following exposure to family-level environmental stressors such as marital conflict (El-Sheikh & Hinnant, 2011). Though crude

and cross-sectional, the relation of PTEs to lower baseline RSA in this sample suggests that cumulative exposure to traumatic events is contributing to children's PNS activity. Future longitudinal work documenting the relationship between children's environment – both adverse and positive – and PNS activity over time may help to disentangle these relationships. Given the documented health links from early adversity to cardiovascular disease in later life (Felitti et al., 1998), understanding prospectively how early experiences of stress impact cardiovascular systems has implications for long-term health.

Second, in multivariable models, somewhat surprisingly, no pattern of relations was observed between RSA baseline or withdrawal and externalizing behaviors. This may be due to the differences in our sample, which was predominantly African American and is high risk in terms of parent education and higher exposures to PTEs relative to national rates of exposure (McLaughlin et al., 2013). The lack of association between RSA withdrawal and externalizing may reflect the predominantly African American subject population, as a recent meta-analysis reported a stronger association between RSA withdrawal and externalizing behavior among samples with a higher proportion of Caucasian children (Graziano & Derefinko, 2013).

With respect to internalizing outcomes, a complex three-way interaction between child sex, exposure to PTEs, and RSA at baseline and in response to a stressor were observed. These findings add to a growing body of research suggesting that both sex and PNS reactivity moderate the relation between the adversity and child outcomes (Eisenberg et al., 2012; El-Sheikh, Hinnant, & Erath 2011; McLaughlin, Rith-Najarian, Dirks & Sheridan, 2015). Patterns of slope testing indicated that for girls with high exposures to PTEs, higher baseline RSA was associated with *higher* CBCL internalizing scores. This direction of effect is the inverse of what is typically observed, where higher baseline RSA typically is associated with more adaptive outcomes.

For RSA withdrawal, among girls only, patterns are consistent with a biological sensitivity to context (Ellis & Boyce, 2008), specifying how reactivity and environment may interact to predict adaptive or maladaptive outcomes. Specifically, this theory posits how individuals who are highly physiologically reactive may be more sensitive to the impacts of environment broadly, including both the positive influences of healthy environments as well as the negative outcomes of high-stress environments (Ellis & Boyce, 2008; see Obradovic et al, 2010). As such, as seen in this pattern of findings, high physiological reactivity may be maladaptive only within contexts of high adversity, whereas low-reactive children may be generally less susceptible to the impact of environment, either high- or low-quality. In this sample, for girls with low exposure to PTEs (low adversity environments), high RSA withdrawal predicted lower internalizing scores – suggesting that among these girls from low adversity environments, high withdrawal was protective. In contrast, in this sample, for girls with high PTE exposure, *low* reactivity, indexed as low RSA withdrawal, appeared protective, predicting lower internalizing scores. Notably, though, this sensitivity to context finding was not observed among boys, nor was it observed for baseline levels of RSA, where relations were observed only for girls with high levels of exposure.

Whereas in some previous research, the interaction between PNS activity and environmental adversity has been observed more consistently among boys (McLaughlin, Rith-Najarian, Dirks & Sheridan, 2015), in this sample, these interactions were observed more consistently among girls. Our findings are consistent with Eisenberg et al. (2012), where high-baseline and high-withdrawal RSA girls demonstrated stronger links between PTE exposure and internalizing outcomes. The finding that high levels of RSA withdrawal are associated with increased internalizing behaviors among girls suggests that high RSA withdrawal in this context may be reflective of a general altered reactivity. Beauchaine (2001) has suggested that excessive RSA withdrawal in response to a challenge, the pattern observed in girls with high PTE exposure, may reflect overall greater lability. These findings parallel studies documenting higher RSA withdrawal among women with Post-Traumatic Stress Disorder compared to matched controls (Keary, Hughes, & Palmieri, 2009) and studies demonstrating an association between higher RSA withdrawal and internalizing behaviors in children (Hinnant & El-Sheikh, 2009; Boyce et al., 2001). They additionally speak to how optimal levels of RSA withdrawal may vary depending on the context which the child is developing, suggesting that the role of RSA in relation to psychopathology differs based on the level of adversity in the environment.

Previous studies have found that the association between RSA and child outcomes have been strongest at low adversity (e.g., Cipriano, Skowron, & Gatzke-Koppe, 2011) while others have reported greatest association at high adversity (McLaughlin, Najaraian, Dirks, & Sheriden, 2015). In this sample, patterns were most consistently observed among girls from high adversity environments, though inverse patterns were observed for RSA withdrawal among girls from low adversity environments. This may be because our index of adversity, exposure to potentially traumatic events, differs from previous studies, which have focused on the family context. Moreover, the levels of adversity experienced by this sample are higher than among many extant studies in the literature given our targeted recruitment strategy, suggesting that both the “low” and “high” exposed groups may differ from previous low- or high-exposed groups.

Study limitations include a cross-sectional design. A critical question from the framework of developmental psychopathology is whether stress reactivity impacts how life events are integrated into child development; whether environmental stress impacts reactivity directly (e.g., allostatic load); or perhaps most likely, whether the environment, physiological reactivity, and behavior affect one another interactively across the lifespan. Preliminary longitudinal findings suggested that high baseline RSA is protective in high-quality environments (Eisenberg et al., 2012). Research that conceptualizes the environment beyond the family to include both direct individual level exposures and neighborhood level factors, may help to further illuminate these pathways (McLaughlin, Rith-Najaran, Dirks, & Sheridan, 2015). The extent to which physiological regulation and environmental influences work in concert to impact behavioral functioning across development, as well as how these patterns relate to observed sex differences, are important areas of inquiry for continued research. Moreover, the wide age range of children limits our ability to draw inferences about specific developmental periods. Previous work suggest that even across childhood, developmental difference exist, with baseline RSA typically higher among older children. However, in a previous meta-analysis, age did not moderate the relation between RSA

withdrawal and child behavioral outcomes (Graziano & Derefinko, 2013). Additionally, despite the significant pattern of findings, our sample size was small, limiting power to detect effects.

Despite these limitations, the current study has several strengths, including contributions to understanding of sex differences in relations between adversity, RSA, and child behavioral outcomes. Additionally, we documented patterns among a population under-represented in the literature (primarily African American; Graziano & Derefinko, 2013). Moreover, our sampling technique targeted children from high-adversity communities that were not recruited for clinical symptoms. It may be that the patterns observed in this sample, some of which contradict typical prediction patterns, are more typical of African American children from communities higher in adversity who are less represented in RSA research to date, suggesting a need for further research among diverse populations. The direct testing of moderation by the sex of the child represents another unique strength of the current study. This testing revealed sex-specific patterns in the relations between environmental adversity, RSA, and behavioral outcomes. While the sex-specific relations documented in this sample were not identical to what has been observed in other samples (c.f. McLaughlin, Rith-Najarian, Dirks & Sheridan, 2015), they nonetheless call for continued consideration of sex as a moderator in the link between PNS activity and child outcomes, particularly given sex-differentiated patterns in psychopathology across the lifespan.

In summary, these results provide evidence that children's baseline RSA is a marker of exposure to environmental stressors, in line with an allostatic load perspective. Additionally, our results support a model of risk for internalizing behaviors among girls that is characterized by the interaction of physiological reactivity and environmental stress parallel with a Biological Sensitivity to Context (Ellis & Boyce, 2008), where high RSA withdrawal represents a vulnerability for girls from high-stress environments but a potential marker of adaptation for girls with low exposure to PTEs. This pattern was not observed among boys or for externalizing behaviors and is unique from patterns observed in primarily Caucasian samples, suggesting that even within these models about differential responsiveness to the environment, other group differences, such as sex or race, may influence patterns. On a broader level, taking children's exposure to community stressors into account can help to further specify our models of the link between children's physiology and their behavior, in ways that may be unfolding according to sex-specific patterns. Continued integration of the ways in which physiology, environment, and behavior relate to one another in girls and boys is critical to understanding children's vulnerability for maladaptive outcomes, as well as how resilient adaptation occurs under contexts of stressful environments (Cicchetti, 2010). Such models may ultimately allow us to identify children at highest risk for vulnerability, as well as inform interventions to support resilience across development.

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References

Achenbach, TM. Integrative guide for the 1991 CBC/4-18, YSR, and TRF profiles. University of Vermont: Department of Psychiatry; 1991.

Aiken, LS., West, SG. Multiple Regression: Testing and Interpreting Interactions. London: Sage; 1991.

Alkon A, Goldstein LH, Smider N, Essex MJ, Kupfer DJ, Boyce WT. Developmental and contextual influences on autonomic reactivity in young children. Developmental Psychobiology. 2003; 42(1): 64–78. [PubMed: 12471637]

Aults CD, Cooper PJ, Pauletti RE, Jones NA, Perry DG. Child sex and Respiratory Sinus Arrhythmia reactivity as moderators of the relation between internalizing symptoms and aggression. Applied Psychophysiology and Biofeedback. 2015; 40(4):269–276. [PubMed: 26159768]

Beauchaine T. Vagal tone, development, and Gray's motivational theory: Toward an integrated model of autonomic nervous system functioning in psychopathology. Development and psychopathology. 2001; 13(02):183–214. [PubMed: 11393643]

Beauchaine TP, Hong J, Marsh P. Sex differences in autonomic correlates of conduct problems and aggression. Journal of the American Academy of Child and Adolescent Psychiatry. 2009; 47(7): 788–796.

Blandon AY, Calkins SD, Keane SP, O'Brien M. Individual differences in trajectories of emotion regulation processes: the effects of maternal depressive symptomatology and children's physiological regulation. Developmental psychology. 2008; 44(4):1110. [PubMed: 18605838]

Bloom B, Cohen RA, Freeman G. Summary health statistics for U.S. children: National health interview survey, 2010. National Center for Health Statistics. Vital Health Statistics. 2011; 10(250)

Boyce WT, Ellis BJ. Biological sensitivity to context: I. An evolutionary-developmental theory of the origins and functions of stress reactivity. Development and psychopathology. 2005; 17(2):271–301. [PubMed: 16761546]

Boyce WT, Quas J, Alkon A, Smider NA, Essex MJ, Kupfer DJ. Autonomic reactivity and psychopathology in middle childhood. The British Journal of Psychiatry. 179(2):144–150.

Buske-Kirschbaum A, Jobst S, Wustmans A, Kirschbaum C, Rauh W, Hellhammer D. Attenuated free cortisol response to psychosocial stress in children with atopic dermatitis. Psychosomatic Medicine. 1997; 59(4):419–426. [PubMed: 9251162]

Calkins SD, Blandon AY, Williford AP, Keane SP. Biological, behavioral, and relational levels of resilience in the context of risk for early childhood behavior problems. Development and psychopathology. 2007; 19(03):675–700. [PubMed: 17705898]

Calkins SD, Dedmon SE. Physiological and behavioral regulation in two-year-old children with aggressive/destructive behavior problems. Journal of Abnormal Child Psychology. 2000; 28(2): 103–118. [PubMed: 10834764]

Calkins SD, Keane SP. Cardiac vagal regulation across the preschool period: Stability, continuity, and implications for childhood adjustment. Developmental psychobiology. 2004; 45(3):101–112. [PubMed: 15505799]

Calkins SD, Graziano PA, Keane SP. Cardiac vagal regulation differentiates among children at risk for behavior problems. Biological Psychology. 2007; 74(2):144–153. [PubMed: 17055141]

Cicchetti D, Cicchetti D. Resilience under conditions of extreme stress: a multilevel perspective. World Psychiatry. 2010; 9(3):145–154. [PubMed: 20975856]

Cipriano EA, Skowron EA, Gatze-Kopp LM. Preschool children's cardiac reactivity moderates the relation between exposure to family violence and emotional adjustment. Child Maltreatment. 2011; 16(3):205–215. [PubMed: 21593016]

Conradt E, Degarmo D, Fisher P, Abar B, Lester BM, Lagasse LL, Hammond JA. The contributions of early adverse experiences and trajectories of respiratory sinus arrhythmia on the development of neurobehavioral disinhibition among children with prenatal substance exposure. Development and psychopathology. 2014; 26(4pt1):901–916. [PubMed: 24909973]

Dawson JF, Richter AW. Probing three-way interactions in moderated multiple regression: Development and application of a slope difference test. Journal of Applied Psychology. 2006; 91(4):917–926. [PubMed: 16834514]

Del Giudice M, Ellis BJ, Shirtcliff EA. The adaptive calibration model of stress responsivity. Neuroscience & Biobehavioral Reviews. 2011; 35(7):1562–1592. [PubMed: 21145350]

Dodge KA, Pettit GS, Bates JE. Socialization mediators of the relation between socioeconomic status and child conduct problems. Child Development. 1994; 65(2):649–665. [PubMed: 8013245]

Egger HL, Erklani A, Keeler G, Potts E, Walter BK, Angold A. Test-retest reliability of the Preschool Age Psychiatric Assessment (PAPA). Journal of the American Academy of Child and Adolescent Psychiatry. 2006; 45:538–549. [PubMed: 16601400]

Eisenberg N, Sulik MJ, Spinrad TL, Edwards A, Eggum ND, Liew J…, Hart D. Differential susceptibility and the early development of aggression: Interactive effects of respiratory sinus arrhythmia and environmental quality. Developmental Psychology. 2012; 48(3):755–568. [PubMed: 22182294]

El-Sheikh M. Does poor vagal tone exacerbate child maladjustment in the context of parental problem drinking? A longitudinal examination. Journal of Abnormal Psychology. 2005; 114(4):735–41. [PubMed: 16351394]

El-Sheikh M, Harger J, Whitson SM. Exposure to interpersonal conflict and children's adjustment and physical health: The moderating role of vagal tone. Child Development. 2001; 72(6):1617–1636. [PubMed: 11768136]

El-Sheikh M, Hinnant JB. Marital conflict, respiratory sinus arrhythmia, and allostatic load: Interrelations and associations with the development of children's externalizing behavior. Developmental Psychopathology. 2011; 23(3):815–829.

El-Sheikh M, Hinnant JB, Erath S. Developmental trajectories of delinquency symptoms in childhood: the role of marital conflict and autonomic nervous system activity. Journal of abnormal psychology. 2011; 120(1):16–32. [PubMed: 20919788]

Ellis BJ, Boyce TW. Biological sensitivity to context. Current Directions in Psychological Science. 2008; 17:183–187.

Feldman R. The development of regulatory functions from birth to 5 years: Insights from premature infants. Child Development. 2009; 80(2):544–561. [PubMed: 19467010]

Felitti VJ, Anda RF, Nordenberg D, Williamson DF, Spitz AM, Edwards V, Marks JS. Relationship of childhood abuse and household dysfunction to many of the leading causes of death in adults: The Adverse Childhood Experiences (ACE) Study. American journal of preventive medicine. 1998; 14(4):245–258. [PubMed: 9635069]

Galles SJ, Miller A, Cohn JF, Fox NA. Estimating parasympathetic control of heart rate variability: two approaches to quantifying vagal tone. Psychophysiology. 2002; 39(Suppl.1):S37.

Grasso DJ, Ford JD, Briggs-Gowan MJ. Early life trauma exposure and stress sensitivity in young children. Journal of Pediatric Psychology. 2012; 38(1):94–103. [PubMed: 23008502]

Graziano P, Derefinko K. Cardiac vagal control and children's adaptive functioning: A meta-analysis. Biological psychology. 2013; 94(1):22–37. [PubMed: 23648264]

Hansen AL, Johnsen BH, Thayer JF. Vagal influence on working memory and attention. International Journal of Psychophysiology. 2003; 48(3):263–274. [PubMed: 12798986]

Hastings PD, Nuselovici JN, Utendale WT, Coutya J, McShane KE, Sullivan C. Applying the polyvagal theory to children's emotion regulation: Social context, socialization, and adjustment. Biological Psychology. 2008; 79:299–306. [PubMed: 18722499]

Hinnant JB, El-Sheikh M. Children's externalizing and internalizing symptoms over time: The role of individual differences in patterns of RSA responding. Journal of Abnormal Child Psychology. 2009; 37(8):1049–1061. [PubMed: 19711181]

Hinnant JB, Elmore-Staton L, El-Sheikh M. Developmental trajectories of respiratory sinus arrhythmia and preejection period in middle childhood. Developmental Psychobiology. 2011; 53(1):59–68. [PubMed: 20882584]

Katz LF, Gottman JM. Vagal tone protects children from marital conflict. Development & Psychopathology. 1995; 7(1):83–92.

Keary TA, Hughes JW, Palmieri PA. Women with posttraumatic stress disorder have larger decreases in heart rate variability during stress tasks. International Journal of Psychophysiology. 2009; 73(3): 257–264. [PubMed: 19374925]

Leary A, Katz LF. Coparenting, family-level processes, and peer outcomes: The moderating role of vagal tone. Developmental Psychopathology. 2004; 16(3):593–608.

McEwen BS, Stellar E. Stress and the individual: mechanisms leading to disease. Archives of internal medicine. 1993; 153(18):2093–2101. [PubMed: 8379800]

McLaughlin KA, Koenen KC, Hill ED, Petukhova M, Sampson NA, Zaslavsky AM, Kessler RC. Trauma exposure and posttraumatic stress disorder in a national sample of adolescents. Journal of the American Academy of Child & Adolescent Psychiatry. 2013; 52(8):815–830. [PubMed: 23880492]

McLaughlin KA, Rith-Najarian L, Dirks MA, Sheridan MA. Low vagal tone magnifies the association between psychosocial stress exposure and internalizing psychopathology in adolescents. Journal of Clinical Child & Adolescent Psychology. 2015; 44(2):314–328. [PubMed: 24156380]

Obradovic J, Bush NR, Stamperdahi J, Adler NE, Boyce T. Biological sensitivity to context: The interactive effects of stress reactivity and family adversity on socioemotional behavior and school readiness. Child Development. 2010; 81(1):270–289. [PubMed: 20331667]

Porges SW. The polyvagal perspective. Biological Psychology. 2007; 74(2):116–143. [PubMed: 17049418]

Santucci AK, Silk JS, Shaw DS, Gentzler A, Fox NA, Kovacs M. Vagal tone and temperament as predictors of emotion regulation strategies in young children. Developmental Psychobiology. 2008; 50:205–216. [PubMed: 18335488]

Scarpa A, Tanaka A, Haden SC. Biosocial bases or reactive and proactive aggression: The roles of community violence exposure and heart rate. Journal of Community Psychology. 2008; 36:969–988.

Scheeringa MS, Zeanah CH, Myers L, Putnam F. Heart period and variability findings in preschool children with posttraumatic stress symptoms. Biological Psychiatry. 2004; 55(7):685–691. [PubMed: 15065300]

Shannon KE, Beauchaine TP, Brenner SL, Neuhaus E, Gatzke-Kopp L. Familial and temperamental predictors of resilience in children at risk for conduct disorder and depression. Development and psychopathology. 2007; 19(03):701–727. [PubMed: 17705899]

Staton L, El-Sheikh M, Buckhalt JA. Respiratory sinus arrhythmia and cognitive functioning in children. Developmental Psychobiology. 2009; 51(3):249–258. [PubMed: 19107730]

Skowron EA, Loken E, Gatzke-Kopp LM, Cipriano-Essel EA, Woehrle PL, Van Epps JJ, Ammerman RT. Mapping cardiac physiology and parenting processes in maltreating mother-child dyads. Journal of Family Psychology. 2011; 25(5):663. [PubMed: 21842991]

Tashima N, Crain C, O'Reilly K, Elifson CS. The community identification (CID) process: a discovery model. Qualitative Health Research. 1996; 6:23–48.

Thayer JF, Hansen AL, Saus-Rose E, Johnsen BH. Heart rate variability, prefrontal neural function, and cogntiive performance: The neurovisceral intergration perspective on self-regulation, adaptation, and health. Annals of Behavioral Medicine. 2009; 39:255–266.

Theall KP, Brett ZH, Shirtcliff EA, Dunn EC, Drury SS. Neighborhood disorder and telomeres: Connecting children's exposure to community level stress and cellular response. Social Science & Medicine. 2013; 85:50–58. [PubMed: 23540366]

Tolin DF, Foa EB. Sex differences in trauma and posttraumatic stress disorder: A quantitative review of 25 years of research. Psychological Bulletin. 132(6):959–992.

Wang X, Thayer JF, Treiber F, Snieder H. Ethnic differences and heritability of heart rate variability in African-and European American youth. The American Journal of Cardiology. 2005; 96(8):1166–1172. [PubMed: 16214458]

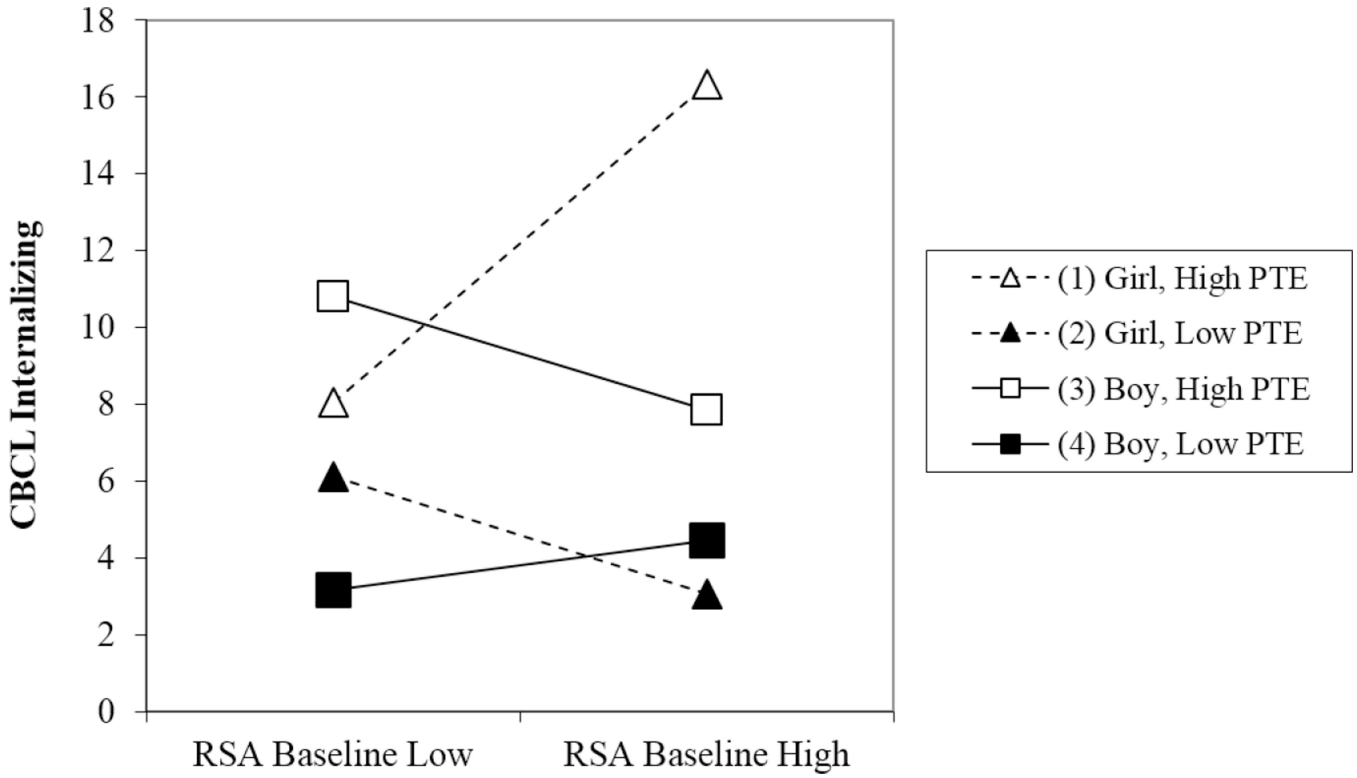

Figure 1.
Girls with high PTE exposure show unique relation between baseline RSA and internalizing problems.

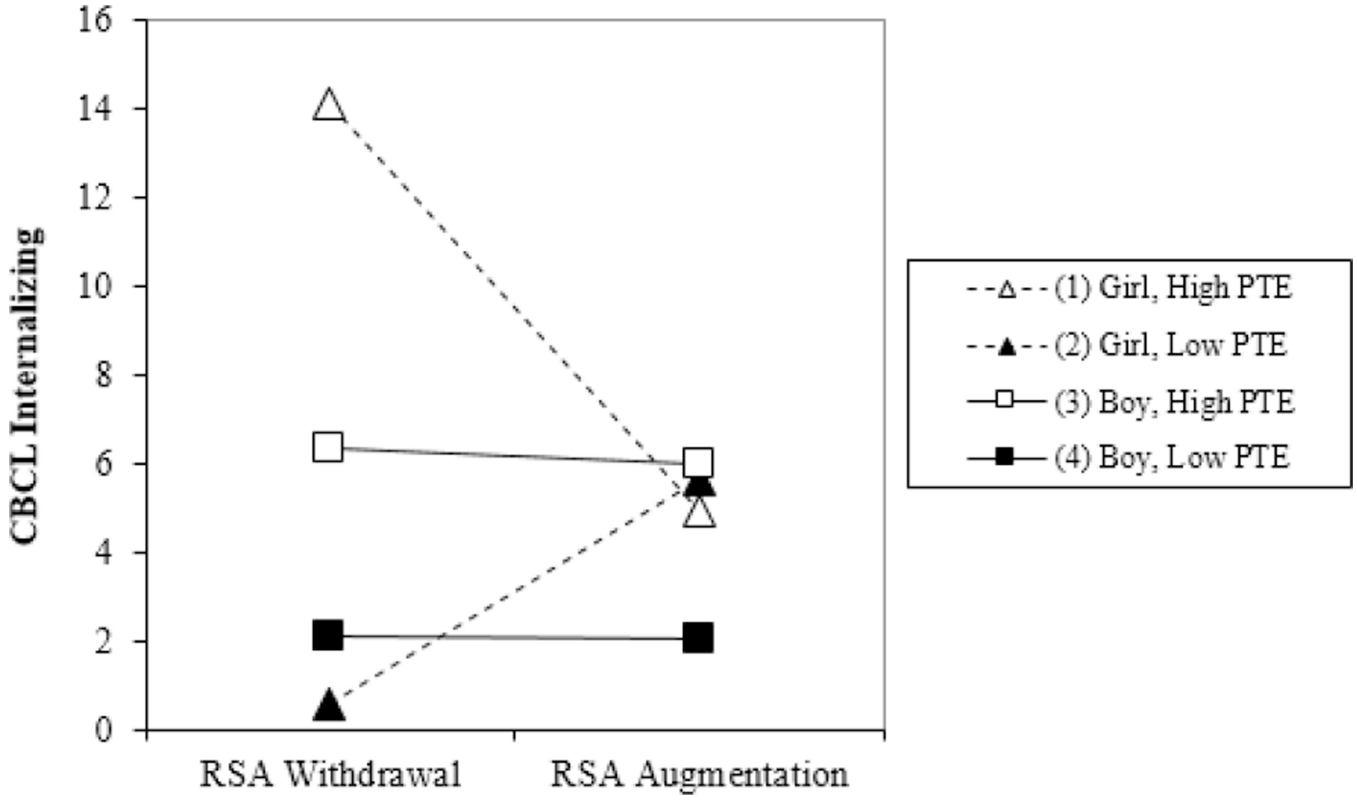

Figure 2.
Girls with high and low PTE exposure show unique relations between RSA withdrawal and internalizing problems

Table 1

Descriptive Statistics for Study Variables by Sex

	Male (*n* = 40) M (SD)	**Female (*n* = 52) M (SD)**	**Range**
Child age	10.70 (3.40)	9.71 (2.81)	5–16
Number of PTEs	2.40 (2.01)	2.63 (1.97)	0–8
Baseline RSA (ms)	71.33 (49.46)	95.67 (68.67)	5–315
RSA Withdrawal	−3.33 (36.95)	−13.04 (39.12)	−141–111
CBCL Internalizing Sum	4.43 (5.87)	6.27 (6.61)	0–29
CBCL Externalizing Sum	6.12 (8.15)	7.19 (7.22)	0–37

Table 2

Correlations Between Study Variables

	Sex	Age	PTEs	RSA Base	RSA Withdrawal	CBCL Internalizing	CBCL Externalizing
Child Sex	--						
Child Age	−.16						
Number of PTEs	.06	.38***					
Baseline RSA	.20	−.28**	−.20*				
RSA Change	−.13	.13	.19	−.61***			
CBCL Internalizing	.15	.09	.45***	−.009	−.07		
CBCL Externalizing	.07	−.02	.41***	.07	.02	.70***	
Parent education	.02	−.03	−.12	−.14	.18	.09	−.02

Note.

* $p < .05$;

** $p < .01$;

*** $p < .001$.

Lower RSA change indicates withdrawal. PTE = Potentially Traumatic Events; CBCL = Child Behavior Checklist; child sex coded male 1, female 2; correlations with child sex (dichotomous) are point-biserial and with education (ordinal) are Spearman's rank-order.

Table 3

Standardized Regression Coefficients for Models Testing Effects of RSA, Potentially Traumatic Events, and Sex on Internalizing and Externalizing Behavior

	RSA Baseline					
	Externalizing			**Internalizing**		
	β	***t*(91)**	***P***	**B**	***t*(91)**	***P***
Age	−.16	−1.54	.13	−.05	−.43	.67
Sex	−.01	−.07	.94	.10	1.03	.31
PTEs	**.49*****	4.75	.000	**.47*****	4.55	**.000**
RSA_b	.11	1.11	.27	.05	.47	.64
Δ R^2		*.21****			*.22****	
RSA_b × Sex	.01	.05	.35	.15	1.30	.20
RSA_b × PTE	.11	.94	.35	.09	.87	.39
PTE × Sex	.05	.43	.67	.09	.87	.39
Δ R^2		*.01*			*.01*	
RSA_b × Sex × PTE	.12	1.06	.29	**.24***	2.13	**.04***
Δ R^2		*.01*			*.04**	
Total R^2		*.23*			*.28*	
	RSA Withdrawal					
	Externalizing			**Internalizing**		
	β	*t*(91)	***P***	B	*t*(91)	***P***
Age	−.11	−.98	.33	−.02	.14	.89
Sex	.02	.23	.82	.19	1.90	.06
PTEs	**.53*****	4.73	**.000**	**.44*****	4.38	**.000**
RSA_b	.24	1.77	.08	−.01	−.06	.95

	RSA Baseline					
	Externalizing			Internalizing		
	β	*t*(91)	*P*	Β	*t*(91)	*P*
RSA Δ	.19	1.46	.15	−.14	−1.12	.26
Δ R^2		*.21***			*.24****	
RSA Δ × Sex	.00	.04	.97	−.10	−1.06	.29
RSA Δ × PTE	**−.34***	−2.60	**.01**	**−.35****	−2.77	**.007**
PTE × Sex	.05	.48	.63	.10	.96	.34
Δ R^2		*.05*			*.03*	
RSA Δ × Sex × PTE	−.13	−1.00	.32	**−.36****	−2.93	**.004**
Δ R^2		*.01*			*.07***	
Total R^2		*.26*			*.34*	

Note.

* $p < .05$;

** $p < .01$;

*** $p < .001$.

RSA_b = Baseline RSA; RSA Δ = RSA Change; PTEs = Potentially Traumatic Events. All variables were centered prior to creation of interaction terms. Sex coded as 1 = male, 2 = female.