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An intervention that increases parental sensitivity in families referred to Child Protective Services also changes toddlers' parasympathetic regulation

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Abstract

Experiencing maltreatment in early childhood predicts poor parasympathetic regulation, characterized by low baseline parasympathetic activity and strong withdrawal of parasympathetic influence in response to tasks. The *Promoting First Relationships*® (PFR) program improves parental sensitivity toward young children in families identified as maltreating. Using a subsample from a randomized control trial, we examined whether parental participation in PFR had lasting effects on toddlers' parasympathetic regulation, as measured by respiratory sinus arrhythmia (RSA), relative to a resource and referral control condition. In addition, we examined whether parental sensitive and responsive behavior mediated or moderated associations between parent treatment group and children's RSA. More than 6 months after completing treatment, 29 families in the PFR condition and 30 families in the control condition were visited at home, and toddlers' RSA was assessed at baseline and during 5 moderately challenging tasks. Groups did not differ in baseline RSA, but differed in RSA reactivity to the tasks. Across tasks, toddlers of parents in the control condition manifested significantly larger RSA decreases than toddlers of parents in the PFR condition. Parental behavior showed divergent associations with RSA change for toddlers of parents in the PFR versus control condition, with PFR treatment predicting RSA change ranging from small decreases to increases in toddlers of parents who showed the most sensitive, responsive behavior in the 6 months following treatment. This preliminary study showed that the same intervention that improved parenting also improved toddlers' parasympathetic regulation in response to everyday activities, warranting further experimental investigation.

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Keywords

Maltreatment; intervention; randomized control trial; parenting; parasympathetic regulation; respiratory sinus arrhythmia

Sensitive and responsive parenting behavior has been associated with better physiological and behavioral self-regulation in children (Feldman, 2012). Conversely, children of parents who have engaged in maltreatment manifest self-regulatory deficits in their autonomic (Miskovic, Schmidt, Georgiades, Boyle, & MacMillan, 2009), adrenocortical (Cicchetti & Rogosch, 2012), neural (Strang, Hanson, & Pollack, 2012) and psychological functioning (Sousa, Klika, Herrenkohl, & Packard, 2016). These are interdependent competencies, with impacts on children's physiology likely contributing to the adverse effects of maltreatment on children's psychosocial adjustment (Frenkel & Fox, 2015). There has been considerable research on the centrality of the regulatory functions of the parasympathetic nervous system (PNS) for supporting children's social-emotional adjustment and well-being (Beauchaine, 2015; Calkins, 2007; Hastings, Kahle, & Han, 2014). In this paper, we report on experimental evidence for the socialization of children's parasympathetic regulation, as measured by baseline respiratory sinus arrhythmia (RSA) and RSA changes in response to tasks, in the context of an intervention targeting sensitive and responsive caregiving behavior of parents referred to Child Protective Services that included random assignment to treatment and control groups.

Parasympathetic regulation

According to Porges' polyvagal theory (Porges, 2007; 2011), flexibly adaptive behavioral responses to varying situational demands and social cues are supported by rapid fluctuations in parasympathetic enervation of cardiac activity via the myelinated vagus nerve. The vagus nerve extends from the nucleus ambiguus but is regulated by a network of sub-cortical and cortical regions involved in threat detection and emotion regulation (Beauchaine & Thayer, 2015; Thayer, Ahs, Fredrikson, Sollers, & Wagner, 2012). This network includes the amygdala, activity of which tends to suppress PNS and increase cardiac arousal, and multiple regions in the medial prefrontal cortex (mPFC) which have been shown to inhibit amygdala activity and thereby promote PNS control in adults (Thayer & Lane, 2009). The myelinated vagus nerve is an integral part of the social engagement system and is involved in regulating orientation, attention and emotional expression (Porges, 2007; Porges & Furman, 2011). Mild to moderate augmentation of parasympathetic influence (indicated by RSA increases) supports calm engagement with social partners in contexts that are perceived as safe. Mild to moderate withdrawal of parasympathetic influence (indicated by modest RSA decreases) in response to challenges facilitates orienting and active coping responses without requiring engagement of the sympathetic nervous system (SNS). Stronger parasympathetic withdrawal and corresponding larger decreases in RSA allow for more SNS control and mobilization of resources for defensive action in response to threats or danger cues (fight-or-flight) (Kahle & Hastings, 2015). Many lab-based challenges that are used in developmental research constitute modest challenges to which some decrease in RSA would be expected to be an appropriate reaction, and modest RSA decreases to such tasks has typically been found to characterize well-functioning children (Graziano & Derefinko, 2013).

Conversely, it has been posited that larger RSA decreases to challenges that are used in laboratory studies with children may be a biomarker for emotion dysregulation and psychopathology (Beauchaine, 2015). For example, Utendale and colleagues (2014) found that larger RSA decreases in response to inhibitory control tasks characterized children who both performed more poorly on the tasks and had more externalizing problems. However, neither polyvagal theory nor empirical research supports a simple, linear interpretation of RSA change as reflecting better (or worse) self-regulation (Miller & Hastings, 2016). For example, in typically developing samples, Obradovic and colleagues (2010) observed that kindergarteners showed, on average, mild RSA decreases to social and taste challenges but mild RSA increases to cognitive and emotional challenges, and Marcovitch and colleagues (2010) observed that preschoolers who manifested mild RSA decreases in response to executive function tasks performed better on the tasks than children who showed *either* RSA increases or larger RSA decreases. Hastings and colleagues (2008a) reported that preschoolers who reacted to meeting unfamiliar peers with moderate RSA increases, suggesting perceived safety, had better behavioral self-regulation and fewer behavioral problems than children who reacted with moderate RSA decreases, suggesting perceived challenge. Whether, and to what extent, increases or decreases in RSA from baseline to task should be expected to reflect an adaptive physiological reaction depends on the context and stimuli to which one is responding (Hastings, Kahle, & Han, 2014; Zisner & Beauchaine, 2016).

We contend that any given biological response cannot be simply or linearly equated with a complex psychological construct like self-regulation. Rather, in accord with the principals of allostasis (Berntson & Cacioppo, 2007; Sterling & Eyer, 1988), effective neurobiological support for self-regulation is reflected in patterns of physiological change that support adaptive behavioral responses to the particular demands of a given stimulus or context. In this investigation, we examined young children's parasympathetic reactivity to challenges which, on average, have elicited modest RSA decreases in typically developing and well-adjusted children.

Maltreatment, socialization and parasympathetic regulation

Research suggests that the quality of caregiving experiences can profoundly affect the neurobiological development of offspring (Miller & Hastings, 2016; in press). Infants and toddlers have limited cognitive and behavioral competencies for regulating their own states of arousal, and are highly dependent upon their caregivers acting as external sources of regulation. Through mechanisms that are likely related to the attachment system (Grusec & Davidov, 2015), sensitive and responsive parenting provides this regulation and becomes internalized in young children's developing capacity for emotional (Denham, Bassett, & Wyatt, 2015) and physiological (Feldman, 2012) self-regulation. Some studies have shown that such parenting is associated with children's patterns of PNS regulation that are considered healthy and normative, as reflected in higher baseline RSA and in RSA changes appropriate for the eliciting stimuli or contexts, including both RSA increases and decreases

(Miller & Hastings, 2016; Perry, Mackler, Calkins, & Keane, 2014; Porges & Furman, 2011). For example, Shih and colleagues (2018) reported that mothers who used emotion coaching techniques and were themselves more emotionally well-regulated had children who showed better parasympathetic recovery from a disappointment task, as shown by larger RSA increases. Conversely, neglectful, harsh and violent behavior from parents has been associated with lower baseline RSA and poorer parasympathetic regulation (Hastings, Nuselovici et al., 2008a; Katz & Rigterink, 2012). For example, Skowron and colleagues (2011) found that mothers who responded in controlling and critical ways to preschoolers' displays of autonomy during a joint activity had children who displayed larger RSA decreases to the task, whereas preschoolers of less negative mothers manifested smaller RSA decreases. Lower baseline RSA and larger RSA decreases may reflect children's neurobiological adaptation to an aversive rearing context, but it may be an adaptation that comes at a cost, leaving children vulnerable to subsequent difficulties with self-regulation.

Yet, several studies have failed to provide evidence that young children's parasympathetic regulation is related to being raised in families with overt hostility, marital conflict or interparental violence, but without evidence of direct child maltreatment (Davies, Sturge-Apple, Chicchetti, Manning, & Zale, 2011; El-Sheikh, Harger, & Whitson, 2001; Obradovic, Bush, & Boyce, 2011). El-Sheikh and Erath (2011) suggested that parasympathetic activity may be expected to be related differently to the direct experience of maltreatment in abusive parent-child relationships versus exposure to family adversity without direct victimization.

This inference has received support from studies focused specifically on PNS activity in maltreated children. Lower baseline parasympathetic activity has been observed in both currently maltreated female adolescents, as identified by child protection agencies (Miskovic et al., 2009), and in adults who retrospectively reported experiencing maltreatment in childhood (Meyer et al., 2016), compared to non-maltreated youths and adults. In a prospective longitudinal study, Shenk and colleagues (2010) found that sexual maltreatment identified in late childhood predicted an asymmetrical profile of multisystem reactivity in late adolescence, with stronger parasympathetic withdrawal but weaker adrenocortical reactivity to a cognitive challenge in youths with versus without histories of maltreatment. Conradt and colleagues (2014) found that a cumulative risk index that included maltreatment prior to 3 years predicted incrementally larger RSA decreases to a cognitive challenge across annual assessments from 3 to 6 years. Thus, the profound disruption to the parent-child relationship resulting from childhood maltreatment may predict both lower baseline PNS activity and stronger withdrawal of parasympathetic influence in response to challenges, parallel to the pattern that Beauchaine (2015) contends is typical of individuals with poor emotion regulation and multiple forms of psychopathology.

Some researchers have found that maltreatment is not directly associated with measures of parasympathetic activity, but that baseline RSA or RSA change moderate associations between maltreatment and emotional and behavioral problems (Gordis et al., 2010; McLaughlin et al., 2015). This pattern is evident in a series of studies by Skowron and colleagues (Cipriano et al., 2011; Creaven et al., 2014; Skowron et al., 2011, 2014) which did not find differences in baseline or task reactive RSA between preschool-aged children of mothers identified by child protection agencies as maltreating versus non-maltreating mothers. However, Cipriano and colleagues (2011) found that it was only for preschoolers who showed larger RSA decreases to a set of four activities that severity of maltreatment and marital violence predicted children's emotional problems. Similarly, Skowron and colleagues (2014) found that there were group differences in the implications of RSA reactivity for children's behavioral self-regulation. Children of maltreating mothers who manifested lower RSA during joint mother-child activities performed less well on a subsequent test of executive function; conversely, there was a tendency for lower RSA during joint activities to be associated with better executive function performance for children of non-maltreating mothers (Skowron et al., 2014). This could suggest that those maltreated children who physiologically reacted to interactions with their mothers as if they were in challenging or threatening contexts (more parasympathetic withdrawal) were disadvantaged in their ability to cope with tasks that challenged their cognitive self-regulatory capacities.

However, this evidence for the effects of maltreatment on PNS activity is exclusively based on non-experimental procedures. Indeed, there have been very few experimental studies of the links between children's RSA regulation and even normative parental behavior (cf Feldman et al., 2010). This is a serious limitation of socialization theory and research, because even with repeated-measures longitudinal analyses (Kennedy, Rubin, Hastings, & Maisel, 2004; Miskovic et al., 2009; Perry et al., 2014), other unmeasured variables such as pre-existing individual differences, or genetic relatedness between parents and children, may account for the apparent contributions of parenting behavior to children's baseline or reactive parasympathetic activity. Even studies that have measured preschoolers' parasympathetic regulation before and after a parent-training program and shown that changes in parenting behavior mediate the effects of the intervention on children's RSA (Bell, Shader, Webster-Stratton, Reid, & Beauchaine, 2018; Graziano, Bagner, Sheinkopf, Vohr, & Lester, 2012) cannot make a strong causal inference about parenting effects, if they fail to include a comparative control group and random assignment to groups.

Well-designed intervention studies can be used as experiments to study the effects of changes in parenting on neurobiological systems in children. There is evidence from home-based interventions for the causal effects of socialization on adrenocortical activity in children (Bernard, Simons, & Dozier, 2015). Not all home visiting programs are the same, though. Some focus broadly on maternal and child health outcomes (e.g., rapid repeated pregnancy, immunization status, and linkages to services), while others focus narrowly on improving the parent-child relationship and enhancing caregivers' capacity to be sensitive and responsive to a child's emotional needs. From the evidence available, it appears that the more narrowly focused programs have the potential to alter children's physiological activity, as seen in adrenocortical functioning (Bernard, et al., 2015; Nelson & Spieker, 2013). It is plausible that other regulatory systems, including the parasympathetic system, may also be amenable to such treatment effects.

Home visitation programs for families that maltreat

The current investigation capitalized on an ongoing randomized control trial of a relationship-based parenting program, *Promoting First Relationships* ® (PFR: Kelly, Zuckerman, Sandoval, & Buehlman, 2008), a 10-week home visiting program which we called the *Supporting Parents Program*. Parent-training interventions are the primary treatment option for families in which there has been neglect or abuse of young children (DHHS, 2005). Barth et al. (2005) argued that parent training programs "are clearly a linchpin of governmental responsibility" (p. 353). The parent study, *Supporting Parents Program*, included 247 families with 10-24 month old children who had a recent open Child Protective Services investigation of child maltreatment. Families were randomly assigned to receive either the 10-week home visiting PFR service or a telephone-based 3-call resource and referral (R&R) service. Across 3 post-intervention assessments over the 6 months following the last treatment session (Oxford et al., 2016), parents in the PFR condition scored higher than families in the R&R condition in parent understanding of toddlers' social emotional needs as measured by the Raising a Baby Scale (RAB; Kelly, Korfmacher, & Buehlman, 2008) ($d = .35$) and observed parental sensitivity and responsiveness as measured by the Nursing Child Assessment Teaching Scale (NCATS; Barnard, 1994) ($d = .20$). Children in the PFR condition scored lower than children in the comparison condition on an observational measure of atypical affective communication measured by the Toddler Attachment Sort-45 (TAS-45; Kirkland, Bimler, Drawneek, McKim, & Schölmerich, 2004) ($d = .19$) and were less likely to have been placed into foster care (6% vs 13%, $p = .042$) (Oxford et al., 2016).

At 6 months post-intervention, parents were asked to indicate their willingness to participate in future studies. A subset of the parents who agreed were contacted regarding this investigation of children's baseline and reactive RSA during another home visit that included a series of challenging tasks.

Hypotheses

Given the evidence for maltreatment predicting lower baseline parasympathetic activity and stronger parasympathetic withdrawal to challenging tasks, we expected to see treatment group differences in both of these measures of children's parasympathetic regulation. Compared to children of parents who received the PFR program, children of parents assigned to the control group were expected to have lower baseline RSA and larger RSA decreases to tasks. The improvements in sensitive and responsive caregiving behavior that resulted from the PFR intervention (Oxford et al., 2016) were expected to be a key contributing factor to children's parasympathetic regulation. Thus, we examined whether sensitive and responsive parental behavior accounted for associations between PFR and children's baseline RSA and RSA change (i.e., mediation), or whether sensitive and responsive parenting was related to children's RSA differently for parents who received PFR versus the control condition (i.e., moderation).

Method

Participants

Data were obtained from a subsample of 59 children of parents enrolled in the *Supporting Parents Program* (SPP). As part of SPP, 247 birth parents with infants and toddlers were enrolled between January 2011 and January 2014, with approval from the Washington State

Institutional Review Board. Parents were eligible if they had a child between the ages of 10 and 24 months, lived in a specified catchment area, and had an open case with an allegation of maltreatment of any type recorded in the database of the regional CPS office at least two weeks prior. Participants also needed to be conversant in English and have housing. A Department of Child and Family Services (DCFS) volunteer, trained for the purpose of the study, contacted potential participants and described the study in detail. If the potential participant indicated an interest in the study, permission was obtained to forward contact information to the research team. A study research visitor (RV) then met with the family to obtain written consent and conduct the first in-home research visit. Study families were compensated between $50 and $100 after each research visit (total of $300 for the first four assessments), but received no compensation for intervention sessions. The RV and coders were blind to intervention condition.

From each family, a dyad consisting of one parent and one child were the primary participants in the interventions and were assessed at four time points: baseline, post-intervention, and 3- and 6-month follow-up. Following the first research visit, the families were randomized to receive the Promoting First Relationships (PFR) intervention (n=124) or the Resource and Referral (R&R) program (n=123), using a computer randomization program that blocked families based on race and ethnicity. At the final follow-up visit in the main study, parents were asked to sign a consent form for future contact if they were interested in learning about additional research studies; consent was received from 83% of parents, and proportions of parents providing consent did not statistically differ between intervention groups.

Funding for this RSA pilot study was obtained, and Washington State Institutional Review Board approval was secured. Participants were eligible if they (1) had completed the final follow-up visit (88% of those in the PFR condition and 82% of those in the R&R condition completed the final follow-up visit, these rates did not differ significantly), and (2) consented to be informed of future research opportunities (86% or those in PFR consented and 80% of those in R&R consented, these rates did not differ significantly), and (3) completed at least 80% of the intervention visits to which they had been randomized (98% or those in PFR *who consented* were eligible and 100% of those in R&R *who consented* were eligible). In the summer of 2013, we began approaching eligible families sequentially two weeks after they completed their final research visit for the parent study (9 months after initial enrollment, on average). Of the 62 eligible families approached between July 2013 and November 2014, all 62 families consented to participate, 31 in the R&R condition and 31 in the PFR condition. Data were not obtained for three toddlers due to complications, two in the PFR group and one in the R&R group, resulting in the final sample of 59 for current analyses. Participants received $50 subject incentive for the additional 60-minute visit in which child physiological response to stimuli were recorded.

Of the 32 boys and 27 girls in this subsample, the majority were White/Caucasian (68%) or of mixed race (27%); 34% were Hispanic. The average age of the children at the time of the RSA assessment was 27.78 months (*SD*=5.13 months). Most of the parents (92%) were female and 42% lived with a spouse/partner at enrollment in SPP. Most families were living in poverty. Mean household income in the year prior to enrollment was $23,518

(*SD*=22,346) and 78% were receiving food stamps at enrollment. Parent mean age at enrollment was 27.05 years (*SD*=5.51). As noted above, there was no evidence that the eligibility criteria differentially affected participation in the follow-up study, and there were no statistically significant differences on the demographic variables between the 59 families who participated in the follow-up study and the 188 families who did not (all $p > .05$), nor between families in the PFR and the R&R conditions in the follow-up subsample (all $p > .05$). These variables included sex, age, and race/ethnicity of child and parent; whether the parent lived with a partner and parent marital status; number of siblings; household income; maternal education; and whether the family received food stamps.

Intervention groups

Promoting First Relationships (PFR) was delivered by two providers from a community agency. Both providers were female, Caucasian, and had Master's degrees in social work or counseling. PFR was delivered in ten weekly home visits. Each visit addressed a different topic and was accompanied by handouts and "Thoughts for the Week." Parents were videotaped interacting with their child on half of the visits. On subsequent weeks, reflective video feedback was offered: the parent and provider viewed the videotape together, and the provider guided the discussion focusing on the parent's strengths and interpretation of the child's cues.

The *Resource and Referral* (R&R) program was delivered over the phone in three sessions by a social worker employed by the study. She conducted a needs assessment, compiled a packet of personalized information about services which was mailed to the families, and followed up with two check-in calls. The needs assessment call lasted approximately 30 minutes, and the follow-up calls were approximately 10 minutes. Each phone call was scheduled approximately 7 weeks apart, so that the intervention period was similar to the PFR condition. The main needs identified by study families were financial support, education, household items, housing, and parenting support. A standard resource list, developed by the study, was sent to each R&R family containing information on over 150 local services covering 19 areas of need (e.g., education, health and dental, legal assistance). In addition, the social worker included an average of six specific resources to address the needs of each individual family (range = 0 - 15).

Procedures for RSA assessment

All measures were collected in the homes of the participants. Part of the aim of this pilot study was to develop and implement a RSA measurement protocol in the homes of toddlers in child welfare given that this population is difficult to recruit into studies that require travel to universities. Prior to the visit, the primary research visitor (RV) described all procedures to the parent. In order to standardize the measurement procedure as much as possible during a home based research visit we brought a child sized table and chair set to the research visit. After reviewing procedures, attaining informed consent, and establishing rapport, the physiological apparatus was attached to the child. After allowing the child a few minutes to adjust to the monitor, the child's baseline autonomic data were recorded, and then five mildly to moderately challenging tasks were administered: Puppet Play, Teaching, Difficult Puzzle, Fear and Frustration. The parent and child sat together during all episodes except for the last two, Fear and Frustration. Prior to beginning the Fear task parents were asked to sit elsewhere within view and complete survey material. The reason for this was that during our pilot work we found that young children were less likely to engage with the task with the parent present. For example, with the frustration task toddlers would attempt to open the cookie container once and then readily hand the container to their parent for assistance.

Physiological baseline.—To record toddlers' baseline RSA, the parent and child sat at the table and viewed a *Baby Einstein: Baby Mozart* video for 2.5 minutes.

Challenge tasks.—Tasks that have been commonly used in laboratory studies to challenge young children (e.g., Buss, 2011; Goldsmith & Rothbart, 1993; Oxford & Findlay, 2013) were adapted for administration in families' homes. Five tasks were administered in fixed order, from less to more challenging. *Puppet Play*: Parents were given three small hand puppets and were instructed to play with their child using the puppets as they normally would for 2 minutes. *Teaching:* Parents were shown a list of activities and asked to select an activity that the child did not know how to do but were ready to learn, for example, button a button or point to body parts in a book. After parents chose the activity they were given the teaching materials and instructed to begin. The task could last up to 2.5 minutes, but at minimum 1 minute. If the child completed the task in less than 1 minute the parent was instructed to select another task. *Difficult Puzzle:* The task consisted of several foam puzzle squares with one differently-shaped hole in each square (for example a shape of a tree or a car), and corresponding shapes. Parents were instructed to let the child attempt the puzzle without their assistance unless the child asked for help. This activity lasted 2.5 minutes. *Fear:* To elicit fear, the child was presented with a jumping spider that the child was asked to pet. The RV sat next to the child at the child-sized table and presented a cloth bag to alert the child to the new task. Then, the RV pulled a round plastic pet habitat out of the bag. The habitat had dirt and moss as well as a plastic spider. The RV indicated to the child they had a spider and invited the child to pet the spider through the opening at the top of the habitat. As the child reached in to pet the spider the RV would make the spider jump by pressing a concealed air compression tube. The Fear Task could last up to 2.5 minutes, but if the child became too upset the task was ended. *Frustration:* To elicit frustration, the child was offered a snack that they were then unable to have. First, the child was presented with an option of two snacks, a cookie or fish crackers. Once they indicated the desired snack, the RV handed the child a container with the desired snack that was sealed shut and could not be opened. Children were encouraged to continue to try to open the container. This task lasted 2 minutes, then the RV apologized to the child that the container was "stuck" and gave them the desired snack.

RSA assessment.—Data were acquired using Mindware Technologies (Gahanna, OH) wireless, ambulatory electrocardiograph sampled at 500 HZ. Two research assistants conducted the visit, one monitored the Mindware system and the other implemented the procedures. The electrocardiogram data were collected using disposable pregelled electrodes placed on the child's right clavicle and left lower rib; a ground electrode was placed on the left lower rib. Respiration was derived via impedance cardiography, which was acquired through four additional electrodes: two on the child's chest at the top of the sternum and over the xiphisternal junction, and two on the child's back placed at one inch above and below these locations, respectively.

Data were edited using Mindware HRV Version 3.1.0, which uses spectral analysis to compute RSA in ln(ms^2). Respiration frequency bands were set to the standard range for infants and young children (.24 - 1.04). A trained editor inspected each file for artifact, edited the data if necessary, and computed RSA in 30s epochs within each task (Berntson et al., 1997).

RSA measures were created by averaging across the 30sec epochs within each task, given at least two viable epochs. In the baseline procedure, RSA was higher in the middle three epochs ($M = 5.25$, $SD = 1.10$) than in the first and last epochs ($M = 5.03$, $SD = 1.03$), $t(57) = 2.66$, $p = .01$, suggesting that toddlers may have had an initial brief period of adjusting but then grown restless after 2 minutes. Therefore, baseline RSA consisted of the average of the 2nd, 3rd and 4th baseline epochs (alpha=.83 for the three readings). For each of the five tasks, we computed the average across epochs for each task (alphas= .76-.84). In order to capture RSA reactivity, change scores were computed by subtracting baseline from each of the task measures. Thus, negative scores represent decreases in RSA, and positive scores represent increases in RSA. There are multiple ways of calculating physiological change scores (Burt & Obradovic, 2013); arithmetic change scores were used in this study to facilitate ease of interpretation of magnitude of RSA reactivity. We included baseline RSA as a covariate in the analyses of intervention group differences in RSA reactivity.

Procedures for measuring sensitive and responsive parenting

In the post-intervention, 3-month follow-up and 6-month follow-up sessions, observed parental sensitivity was measured using the Nursing Child Assessment Teaching Scale (NCATS; Barnard, 1994) with the videotaped interaction to assess parental sensitivity, responsiveness, and stimulation of the child. A single, blinded coder was trained to reliability (90%) by a certified NCATS instructor and passed regular reliability checks. A score summing 45 items, scored *yes* (1) or *no* (0), that covered sensitivity, mutuality, verbal and nonverbal interaction was computed for each session; Cronbach's alpha ranged from .68 to .72 across sessions (see Oxford et al., 2016, for more details). The mean NCATS score across the three sessions was used in analyses (single factor solution eigenvalue = 1.32, all item loadings > 0.56).

Dealing with missing data.—Some cases did not have complete RSA data for all epochs recorded. A mean RSA value was calculated if a child had at least two viable epochs (60 seconds of clean data) for a given task. One case was missing baseline due to becoming upset during the baseline procedure, and data were missing from 1 child on the Play task and 2 children on the Frustration task due to procedural or technical errors. NCATS scores were missing for 5 parents at post-intervention, 3 parents at the 3-monthe follow-up, and 5 parents at the 6-month follow-up. Given the low rates of missing data, Widaman's (2006) recommendations for imputation were implemented prior to analyses.

Results

Descriptive statistics

Table 1 shows descriptive statistics and correlations for all study variables. Children exhibited significant RSA decreases from baseline to each task (all *t*s > 2.92, all *p*s < .01). On average, RSA during the tasks represented an 8.7% decrease from baseline, and reactivity ranged from large decreases in RSA (more than 2*SD*; ΔRSA = −2.72) to moderately large increases in RSA (1.7*SD*; ΔRSA = 1.95). Boys and girls did not differ on any RSA measure. Older children exhibited higher levels of RSA in all tasks, but age was not correlated with RSA reactivity. Baseline and task RSA scores were significantly positively inter-correlated (mean $r = .74$, all $p < .01$), and baseline RSA was negatively correlated with each change score (mean $r = -.52$, all $p < .01$), indicating that children with higher baseline RSA also showed greater decreases. The correlations showed that children in the R&R condition had lower RSA in the frustration task and larger RSA decreases to the difficult puzzle and frustration tasks than children in the PFR intervention condition. Mean NCATS scores ranged from 29.67 to 41.33, and were not significantly correlated with any RSA measures.

Effect of PFR Intervention on Children's RSA

We hypothesized that children in the PFR intervention would show higher baseline RSA and smaller RSA decreases in response to the tasks. The baseline RSA of children in the R&R group was not significantly lower than the baseline RSA of children in the PFR group, $t(57) = -0.15$, $p = .88$. To examine differences in RSA reactivity, we conducted a two-factor, Group × Task mixed design ANCOVA with Group (R&R versus PFR) as a between-subjects factor predicting the five RSA reactivity scores as a repeated measures factor (Task). Baseline RSA was included as a covariate and was significant, $F(1,56) = 42.30$, $p < .001$, partial eta squared = .43.[1] The main effect for Task was not significant, $F(4,224) = 1.88$, $p = .115$, partial eta squared = .033, indicating that the magnitude of RSA reactivity did not vary significantly by task. A significant between-subjects effect of Group, $F(1,56) = 8.30$, $p = .006$, partial eta squared = .129, indicated that RSA reactivity varied by intervention type. Figure 1 shows that, on average, children who received the PFR intervention exhibited smaller decreases in RSA from baseline to tasks than children in the R&R condition. In the PFR group, the mean RSA reactivity was a 5.3% decrease from baseline, with 65.5% of children (n = 19) showing RSA decreases and 33.5% (n = 10) showing RSA increases. In the R&R group, the mean RSA reactivity was an 11.8% decrease from baseline, with 80% (n = 24) showing RSA decreases and 20% (n = 6) showing RSA increases. The Group × Task interaction term was not significant, $F(4,224) = 0.65$, $p = .627$, partial eta squared = .01, indicating that the effect of the PFR intervention on RSA reactivity was similarly evident across the five challenge tasks. Across tasks, 61% to 76% of children showed some decrease in RSA from baseline, and the majority of children (> 50%) in both groups showed some decreases in RSA to all five tasks.

[1] Preliminary analyses showed that child age and sex were not significant covariates, so they were excluded from the final model. An ANOVA excluding baseline RSA as a covariate also produced a significant main effect of Group, $F(1,57) = 4.40$, $p < .05$, partial eta squared = .072, as well as a main effect of Task, $F(4,228) = 4.34$, $p < .01$, partial eta squared = .071.

Relations between observed parenting and children's RSA

Table 2 presents the stepwise linear regression model for observed parental sensitivity and responsiveness. All predictive variables in the model were mean-centered prior to the analysis. There was no evidence that parents' NCATS scores mediated the effect of PFR intervention on toddlers' RSA reactivity. The interaction between Group and NCATS was significant, indicating that the PFR and R&R groups differed significantly in the relation between sensitive and responsive parenting, observed in the six months following intervention, and children's RSA reactivity a few weeks after that period (see Figure 2; Dawson, n.d.). The association between NCATS and RSA reactivity was of equal magnitude for the two groups but in opposite directions: Positive for PFR ($B = 0.05$, $p = .10$) and negative for R&R ($B = -.05$, $p = .10$). A regions of significance analysis (ROS; Preacher, Curran, & Bauer, 2006) determined the upper and lower bounds of parenting behavior above and below which the regression lines for the PFR and R&R groups significantly differed in RSA reactivity. Children in the R&R group evidenced significantly greater RSA decreases than children in the PFR group when the NCATS score for parents' behavior was above the upper bound of −0.32 *SD*, representing 66.1% ($n = 39$) of the sample (the shaded portion of Figure 2). The lower bound of −35.01 *SD* was beyond observed or possible differences, indicating that children in the two treatment groups manifested comparable levels of RSA change for all observable levels of parenting behavior below the upper bound (i.e., there was no evidence of a significant cross-over effect).

Discussion

Promoting First Relationships (PFR) is a relationship-based parent-training intervention program that was conducted in the home over 10 weeks that has been shown to improve sensitivity and understanding of children's social-emotional needs in parents who maltreat their children (Oxford, et al., 2016; Spieker, Oxford, Kelly, Nelson, & Fleming 2012). The present study was conducted as a first examination to examine whether PFR also would be effective at promoting adaptive changes in children's parasympathetic regulation, paralleling the effects on adrenocortical regulation that have been observed in other parent-training intervention studies (Bernard et al., 2015) including PFR (Nelson & Spieker, 2013). This effect was evident: Children of parents who received PFR differed from children of parents who received information on resources and referrals (R&R) in their parasympathetic reactions to a set of five modest challenges to their emotional, attentional and social engagement competencies. Across three tasks completed with the parent, and two tasks completed with an examiner, children in the PFR group showed an average pattern of moderate decreases in RSA that is expected of typically developing, non-maltreated children, whereas children in the R&R group showed significantly larger RSA decreases.

Thus, as expected, the children of parents who did not receive the intervention showed a pattern of stronger parasympathetic withdrawal in response to the challenge tasks that paralleled what has previously been observed in children and youths who have experienced maltreatment (Conradt et al., 2014; Miskovic et al., 2009; Shenk et al., 2010), and which has been posited to be a biomarker for emotion dysregulation (Beauchaine, 2015). Maltreatment is a broad risk factor for myriad adjustment problems and psychiatric diagnoses (Sousa et al., 2016), many of which have also been linked with strong RSA decreases in response to challenges (Beauchaine & Thayer, 2015). Further, maltreatment has been linked with disruptions to the structure and activity of prefrontal cortical regions, such as reduced orbitofrontal cortex volume (Hanson et al., 2010) and stronger electrophysiological signals of biased attention toward anger-related stimuli (Strang et al., 2012), that are functionally tied to both parasympathetic regulation and emotional, cognitive and behavioral self-regulation (Thayer & Lane, 2000; Wong, Masse, Kimmerly, Menon, & Shoemaker, 2007). If left unaddressed, the profound disruption to the primary caregiver relationship caused by maltreatment and the suboptimal socialization behavior of parents who have been identified as maltreating their children can have pervasive adverse effects across children's developing neurobiological regulatory systems and psychological well-being.

Viewed more positively, this study also showed that this pathological sequence can be interrupted. The same PFR intervention which was previously shown to improve parental sensitivity and responsiveness (Oxford et al., 2016) also produced children who showed a normative, healthy pattern of RSA reactivity to multiple challenges. Their RSA changes ranged from mild-to-moderate RSA decreases, suggestive of orientation to the task and preparedness for active responding, to mild-to-moderate RSA increases, suggestive of calm states supporting social engagement, reflecting a range of parasympathetic change consistent with appropriate and effective parasympathetic regulation of arousal given the demands of the five tasks (Beauchaine, 2015; Hastings et al., 2014). Although a prior experimental manipulation has shown that changing parents' behavior toward their infants can change infants' parasympathetic activity during that specific interaction (Feldman et al., 2010), to our knowledge, this is the first study to document evidence that an intervention that targeted sensitive and responsive parenting behavior also produced changes in children's RSA regulation that were evident months later. Although the measure of parental sensitivity and responsiveness that was found to be affected by the PFR intervention (Oxford et al., 2016) did not account for the effect of the intervention on toddlers' RSA reactivity, the fact that a parent-focused intervention had measurable effects on children is consistent with the definitions of socialization and internalization (Grusec & Hastings, 2007). This speaks to the centrality of sensitivity and responsiveness as core features of effective and appropriate parental behavior that scaffolds and facilitates infants' and toddlers' developing capacities to respond to novel challenges as non-threatening and manageable events (Feldman, 2012; Laible, Thompson, & Froimson, 2015). The lasting influences of parents on children are evident at neurobiological levels, and it is plausible that these neurobiological effects mediate the links between parental socialization and children's emotion regulation and psychological adjustment (Frenkel & Fox, 2015).

The precise proximal mechanisms of the effects of PFR on children's RSA reactivity remain uncertain. It is plausible that in addition to the observed measure of parental sensitivity and responsiveness, PFR also impacted subtler, yet unmeasured, aspects of caregiver behavior that could have implications for children's parasympathetic regulation. For example, it may be that caregivers receiving PFR adjusted their pace of interaction, stimulation, and arousal to better match that of their child, improving moment-to-moment synchrony and thereby supporting their child's developing self-regulatory capacities (Feldman, 2007), including parasympathetic regulation (Giuliano, Skowron, & Berkman, 2015). PFR may also have benefitted the parents' own physiological regulatory capacities, and the parents' ability to maintain a calm state of autonomic arousal while interacting with their child may have established physiological synchrony that supported the child's adaptive parasympathetic responsiveness (Helm, Miller, Kahle, Troxel, & Hastings, 2018; Lunkenheimer, Busuito, Brown, & Skowron, 2018). It is also plausible that PFR improved caregiver reflective capacity (Slade, 2005). During the intervention video feedback sessions, PFR providers elicited from parents their reflections on their child's underlying mental states, which can support more harmonious parent-child interactions (Hastings & Grusec, 1997) and thereby facilitate synchrony.

Although it did not mediate the intervention's effect on children's RSA reactivity, intriguingly, the measure of parental sensitivity was associated with RSA reactivity in divergent ways for children of parents who received PFR versus R&R. As we had expected, greater sensitivity and responsiveness predicted less withdrawal of parasympathetic influence during the tasks (smaller RSA decreases, on average) in toddlers of parents who received PFR, but surprisingly, the same parenting behavior predicted more parasympathetic withdrawal (larger RSA decreases) in toddlers of parents in the control group. The regions of significance analysis showed that this divergence was significant for values of sensitive and responsive parenting close to and above mean levels. Considering the effect for the treatment group first, recall that parents who received PFR, as a group, were significantly more sensitive and responsive in the six months following treatment than were parents in the control condition (Oxford et al., 2016). The current analysis suggests that of the parents in the PFR group, those who benefited most from PFR – the parents who subsequently engaged in the most sensitive, responsive parenting – had children who were most likely to show the pattern of RSA reactivity that is typical of normatively developing young children. Thus, this moderation effect could be seen as consistent with the mediation effects reported in prior non-experimental studies showing that changes in parenting behavior following an intervention statistically accounted for changes in children's parasympathetic activity from pre- to post-intervention (Bell et al., 2018; Graziano et al., 2012). Why greater sensitivity and responsiveness would predict stronger RSA reactivity in children of parents who did not receive the PFR intervention is less clear. It is possible that these parents continued to have other, unmeasured, aversive parenting practices that conveyed an ongoing context of risk to their children, and that their sensitivity served to scaffold children's adaptation to perceiving potential threats. Thus, sensitive but unskilled or otherwise negative parents may have contributed to a threat-sensitive regulatory pattern of greater parasympathetic withdrawal to novel challenges.

As well as providing evidence that an intervention that produces changes in parenting behavior also predicted changes in children's parasympathetic reactivity, these findings convey important clinical, translational and policy implications. There is consistent support for parent-training interventions being the treatment-of-choice for maltreatment (Barth et al., 2005; DHHS, 2005). In multiple samples, we have previously shown that the PFR home visiting program is efficacious for improving parents' sensitivity towards and knowledge of their children's social-emotional needs (Oxford et al., 2016; Spieker et al., 2012), decreasing children's atypical emotional communication, and decreasing need for future foster placements (Oxford et al., 2016), increasing child competence (Spieker et al., 2012) and enhancing the permanency of foster care placements (Spieker, Oxford, & Fleming, 2014).

Showing that the benefits of PFR extend to previously-maltreated children's effective parasympathetic regulation across diverse challenges to children's cognitive and emotional competencies is further proof for the strength and potential of PFR for promoting healthier developmental outcomes in this high-risk population. This information can be used to strengthen calls to legislators and social policy agencies to invest in home visit parent-training interventions. The findings also reinforce recent arguments for the need to recognize the contextually-bound nature of parasympathetic regulation (Kahle & Hastings, 2015; Miller & Hastings, 2016). Suggestions that the magnitude and direction of RSA reactivity is directly and linearly associated with the emotion regulation or mental health (Graziano & Derefinko, 2013) overlook the evidence for stronger parasympathetic withdrawal in reaction to emotional stimuli in clinical groups compared to healthy samples (Beauchaine & Thayer, 2015), and non-linear associations between RSA reactivity and well-regulated behavior in healthy samples (Marcovitch et al., 2010; Miller, Chochol et al., 2013). Increased PNS influence can support appropriate and adaptive behavior in certain contexts (Hastings et al., 2008a), such as Davis and colleagues' (Davis, Quinones-Camacho, & Buss, 2016) report that children instructed to use distraction and reappraisal coping strategies manifested greater RSA increases in response to emotional film clips, compared to children who received no instructions. In effect, we observed that, compared to toddlers of parents in the R&R condition, the toddlers of parents who received the PFR intervention were more likely, on average, to evidence modest parasympathetic withdrawal to five challenging tasks that would support biological preparedness to orient and actively respond. The individual toddlers' parasympathetic responses ranged, though, from such moderate RSA decreases to moderate RSA increases, which support being calm and socially engaged, with the latter pattern of parasympathetic augmentation being most likely in toddlers of the PFR parents who were most sensitive and responsive during observed interactions.

It is intriguing that the PFR intervention predicted changes in children's parasympathetic reactivity to various challenge tasks, but not in their baseline RSA. This mirrors prior reports that maternal sensitivity in the toddler period predicts preschoolers' RSA reactivity (Perry et al., 2014), and that exposure to domestic violence at kindergarten-age is associated with young children's parasympathetic reactivity but not baseline RSA, although domestic violence exposure predicts lower baseline RSA four years later (Katz & Rigterink, 2012). These findings may be reflective of the toddler through early childhood years being a period of rapid development of physiological and emotional self-regulation, and hence a sensitive period for the influence of socialization on regulatory efforts (Page, Conger, Guyer, Hastings, & Thompson, 2016). As children mature further, they may incorporate parasympathetic regulation of acute states into more trait-like patterns of general parasympathetic influence (Katz & Rigterink, 2012), which may be one reason why earlier studies have found childhood maltreatment to predict lower baseline RSA in adolescence and adulthood (Meyer et al., 2016; Miskovic et al., 2009).

Limitations.

Although the randomized assignment to groups, the basic control group design (Shadish, Cook, & Campbell, 2002), and the similarity of groups in the current study with respect to demographic variables, all strengthen the inference that the PFR intervention produced group differences in children's RSA reactivity, there was not a pre-treatment measurement of parasympathetic activity, and therefore we cannot infer how children's RSA reactivity changed from pre- to post-treatment. Further, collecting multiple repeated assessments of children's RSA in the post-intervention months could have revealed the time-course of the intervention's effect on parasympathetic regulation. We cannot know how RSA reactivity may have differed had the study taken place in a lab setting. The small sample may have limited our power to detect group differences in the magnitudes of RSA change to specific tasks challenging attentional and emotional competencies, or in baseline RSA, as well as our ability to detect significant mediation effects of parenting behavior. It will be important for future, larger studies to include alternative intervention programs, as well as a resource and referral control group, to determine if the observed effects on children's RSA reactivity are specific to the contents of the PFR intervention. Given that there was evidence of maltreatment in all of the families in this study, these findings should not be assumed to be applicable to families that have not engaged in child maltreatment. It will be important to document whether promoting greater parental sensitivity and responsiveness also can lead to improved neurobiological regulation in children from healthy families and from other at-risk samples.

In conclusion, this research has provided initial evidence that in addition to changing parent and child behavior in families that maltreat, participation in the PFR parent-training intervention predicted children's parasympathetic regulation. In a sub-sample of the parent study, the intervention was effective in promoting an average pattern of autonomic responding to challenges characterized by moderate parasympathetic withdrawal, akin to what would be expected in healthy, typically developing toddlers. Conversely, maltreated children of parents who did not receive the parent training showed a pattern of stronger parasympathetic withdrawal that has previously been observed in other maltreated samples, as well as in samples characterized by emotion dysregulation and psychopathology. Although observable parental sensitivity and responsiveness did not directly account for these group differences, parenting behavior predicted the divergence in parasympathetic reactivity shown by the two groups of toddlers. This preliminary study provided the first experimental evidence that promoting sensitive and responsive caregiving behavior in parents who have maltreated their children may have lasting effects on children's parasympathetic regulation. This finding warrants further examination and replication, as it may serve to strengthen arguments advocating for the implementation of home visit parent-training programs as the preferred standard of care for at-risk families.

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Research Highlights

- Past research has shown that individuals who experienced maltreatment in childhood manifest exaggerated parasympathetic reactivity, as indicated by strong decreases in respiratory sinus arrhythmia (RSA) in response to laboratory tasks.
- In a randomized control trial, a home-visitation parent-training program was implemented with families referred to Child Protective Services for maltreatment, and significantly improved parental sensitivity and responsiveness toward toddlers, relative to parents in a control group.
- Half a year post-intervention, a preliminary study of the effects of the intervention on children's parasympathetic regulation was conducted, with 29 families from the treatment group and 30 families from the control group. In home visits, toddlers' RSA was measured at baseline and during 5 activities to assess parasympathetic regulation.
- Toddlers in the treatment group manifested modest RSA decreases to the activities, typical of normative parasympathetic reactivity to such tasks, whereas toddlers in the control group manifested significantly stronger RSA decreases, which may be a biomarker for poorer emotion regulation.
- Observed levels of parental sensitivity and responsiveness moderated, but did not mediate, the association between intervention group and toddlers' parasympathetic reactivity.

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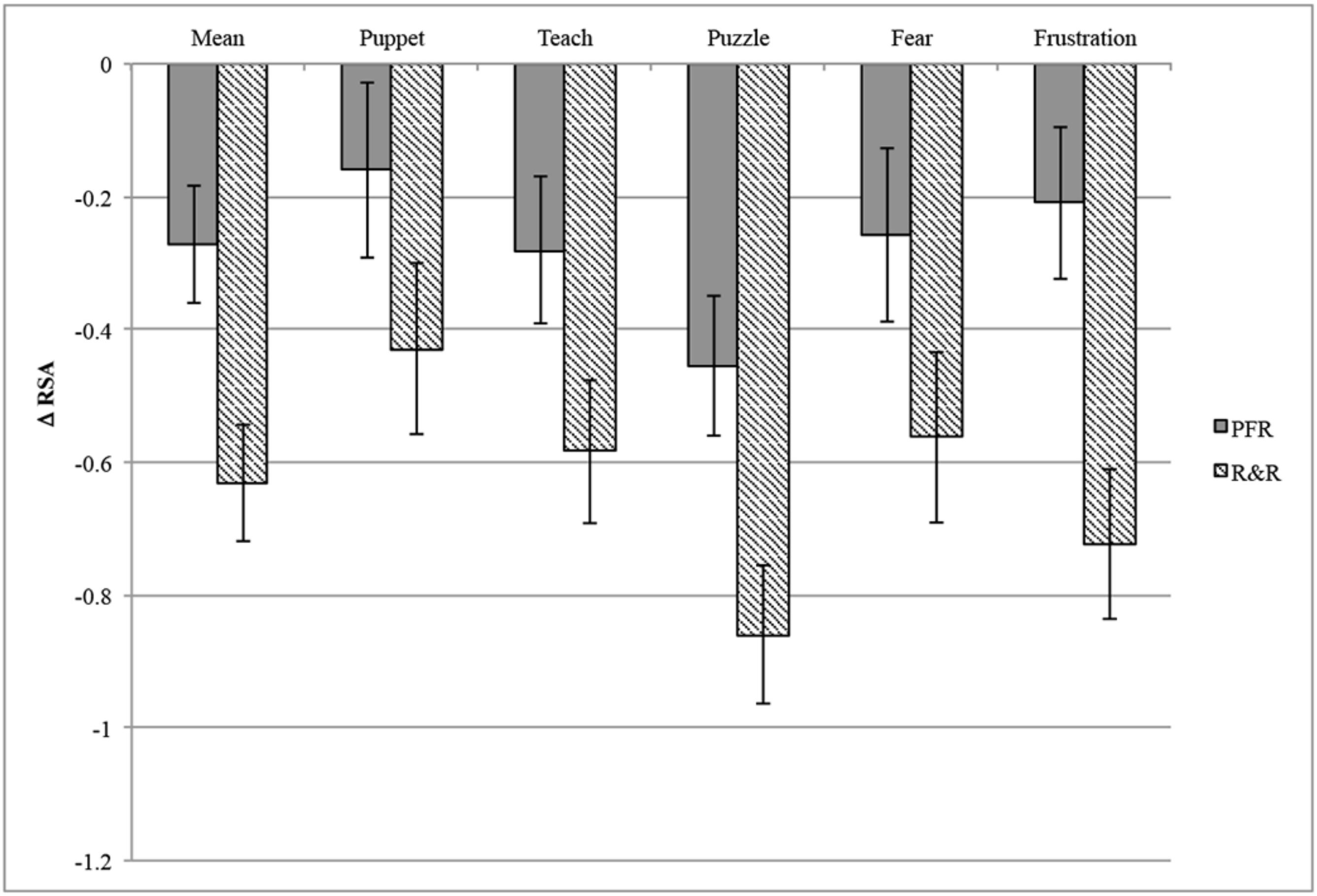

Figure 1.

Treatment group differences in children's RSA reactivity.

Note: ΔRSA = arithmetic change in respiratory sinus arrhythmia from baseline. PFR = Promoting First Relationships treatment group. R&R = Resource and Referral control group.

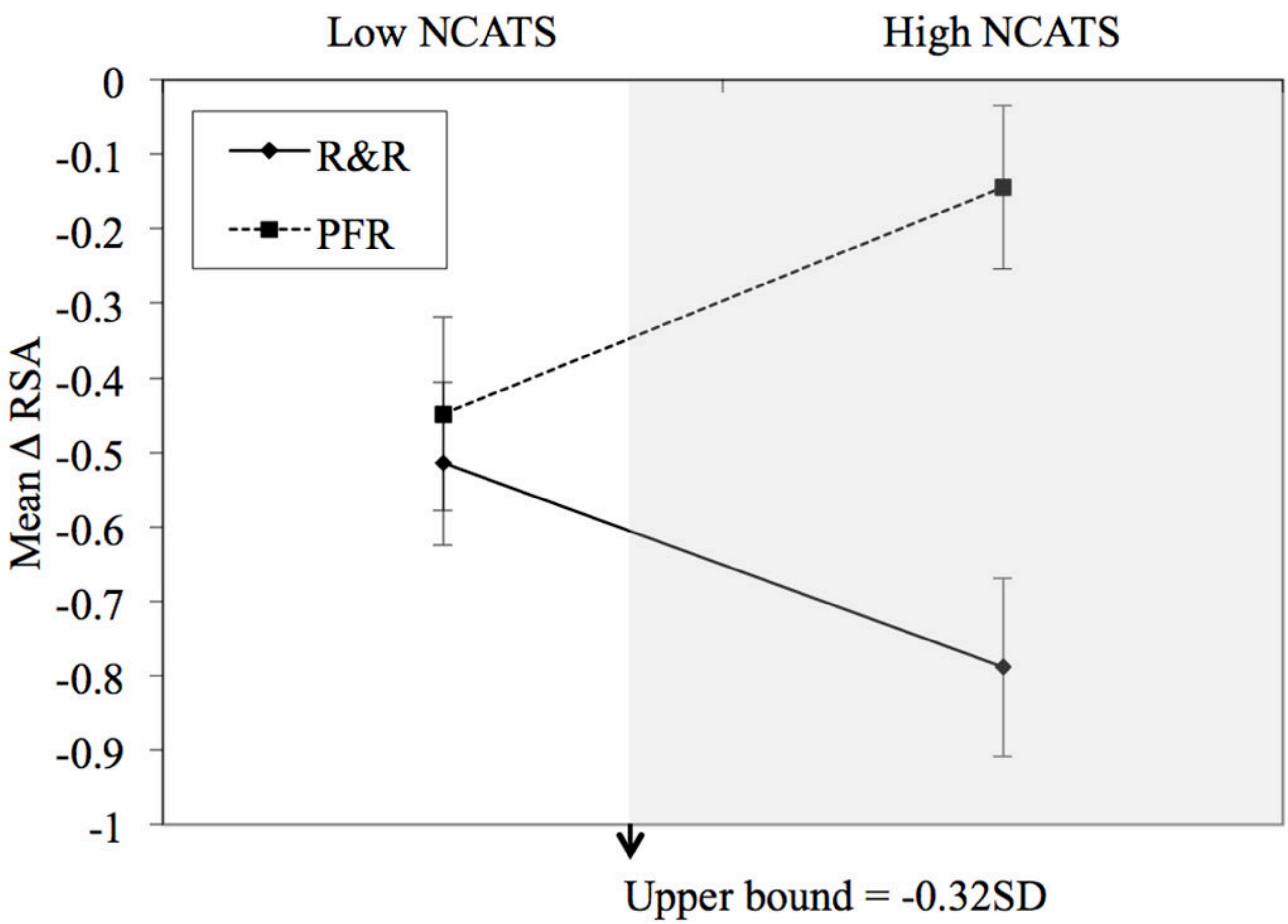

Figure 2.

Treatment group moderates the association between parental sensitivity and responsiveness and children's RSA reactivity.

Note: ΔRSA = arithmetic change in respiratory sinus arrhythmia from baseline. PFR = Promoting First Relationships treatment group. R&R = Resource and Referral control group. NCATS = Nursing Child Assessment Teaching Scale (high scores reflect greater sensitivity and responsiveness). Points are plotted at +/−1 *SD* of NCATS. Shaded region represents the NCATS values at which RSA change differed significantly for toddlers of parents in the PFR and R&R groups.

Table 1.

Descriptive statistics and correlations among study variables

Measure	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Group															
2. Age (months)	−.04														
3. Sex	−.19	−.05													
4. NCATS	.16	.06	−.25												
5. Baseline RSA	.02	**.33**	.18	−.01											
6. Puppet RSA	.14	**.30**	.17	−.01	***.74***										
7. Teach RSA	.18	**.31**	.14	.03	***.75***	***.82***									
8. Puzzle RSA	.25	**.28**	.07	.06	***.73***	***.82***	***.87***								
9. Fear RSA	.18	.22	.06	−.08	***.61***	***.68***	***.68***	***.70***							
10. Frustration RSA	**.27**	***.39***	.14	.11	***.76***	***.72***	***.79***	***.75***	***.66***						
11. Puppet ΔRSA	.17	−.05	−.02	−.01	***−.41***	**.32**	.06	.09	.05	−.10					
12. Teach ΔRSA	.20	−.10	−.08	−.05	***−.55***	−.07	.13	.01	−.07	−.14	***.68***				
13. Puzzle ΔRSA	**.26**	−.15	−.18	.07	***−.61***	−.13	−.09	.10	−.08	−.24	***.69***	***.81***			
14. Fear ΔRSA	.16	−.18	−.15	−.08	***−.60***	−.22	−.23	−.18	**.26**	**−.26**	***.55***	***.61***	***.67***		
15. Frustration ΔRSA	***.35***	.06	−.07	.16	***−.43***	−.10	−.02	−.03	.01	**−.26**	***.47***	***.63***	***.58***	***.53***	
PFR Mean		27.59	.45	36.82	5.28	5.11	4.99	4.82	5.01	5.06	−.17	−.29	−.46	−.27	−.22
PFR SD		4.74	.51	3.00	1.14	1.09	1.00	0.93	0.96	1.01	.68	.75	.78	.83	.67
R&R Mean		27.97	.63	35.87	5.24	4.81	4.66	4.38	4.68	4.52	−.42	−.58	−.85	−.55	−.72
R&R SD		5.56	.49	3.19	1.06	1.01	0.81	0.76	0.84	0.98	.85	.68	.69	.94	.72

Note. Group: 0 = control (R&R), 1 = treatment (PFR). Sex: 0 = female, 1 = male. NCATS = Nursing Child Assessment Teaching Scale, observed measure of sensitive and responsive parenting. RSA = respiratory sinus arrhythmia, measured in ln(ms^2).

Bold font $p < .05$, ***Bold italic font*** $p < .01$.

Table 2.

Contribution of parental sensitivity and responsiveness to prediction of mean RSA reactivity.

Step	ΔR^2	*p* <	Predictor	*b*	*t*	*p* <
1	.471	.001	Baseline RSA	−.63	−6.50	.001
			Group	.28	2.88	.01
2	.000	*ns*	Baseline RSA	−.63	−6.44	.001
			Group	.28	2.83	.01
			NCATS	−.01	−.06	*ns*
3	.049	.05	Baseline RSA	−.63	−6.78	.001
			Group	.28	2.91	.01
			NCATS	−.21	−1.64	*ns*
			Group × NCATS	.30	2.35	.05

Note. Group: 0 = control (R&R), 1 = treatment (PFR). NCATS = Nursing Child Assessment Teaching Scale, observed measure of sensitive and responsive parenting. RSA = respiratory sinus arrhythmia.