

REPORT

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Maternal sensitivity as a predictor of change in respiratory sinus arrhythmia activity from infancy to toddlerhood

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Abstract

This study examined whether parental sensitivity during distressing and non-distressing mother–infant interactions predicts changes in young children's respiratory sinus arrhythmia (RSA) activity. Baseline RSA levels were collected from 83 children (49% female, 51% male) when children were 7 and 18 months old. Children's RSA reactivity and RSA recovery during the still-face paradigm were collected when children were 7 months and during the strange situation procedure at 18 months. Controlling for stability of RSA activity over time, maternal sensitivity during distressing interactions at 7 months predicted changes in children's baseline RSA levels ($\beta = -0.30$) and children's RSA recovery ($\beta = 0.25$). Young children who experienced higher levels of sensitivity at 7 months had lower resting RSA levels and exhibited greater RSA recovery at 18 months. These results suggest that changes in young children's RSA activity are meaningfully related to their early caregiving experiences.

Highlights

- We examined whether maternal sensitivity during infancy predicts changes in children's RSA activity from infancy to toddlerhood.

- Children who experienced higher levels of maternal sensitivity during infancy showed greater RSA recovery from a stressor during toddlerhood.
- Children who experienced higher levels of maternal sensitivity during infancy had lower resting RSA levels during toddlerhood.

KEYWORDS

maternal sensitivity, respiratory sinus arrhythmia, still-face paradigm, strange situation procedure

1 | INTRODUCTION

Respiratory sinus arrhythmia (RSA) is an index of parasympathetic nervous system activity and is commonly conceptualized as a marker of emotional adjustment, self-regulation, and interpersonal functioning (for reviews, see Shaffer et al., 2014; Smith et al., 2020). Levels of RSA while at rest (i.e., baseline) are thought to reflect a general capacity for effective self-regulation (Porges, 2007; Thayer et al., 2009). RSA levels typically decrease in response to a challenging event, especially if it evokes negative emotions (Beauchaine et al., 2019). These changes are referred to as RSA reactivity and are thought to facilitate sympathetic innervation of the cardiac tissue to effectively adapt to the environmental stressor (Porges, 2007; Shaffer et al., 2014; Smith et al., 2020). At a psychological level, both blunted and exaggerated RSA declines in response to challenging tasks have been suggested to reflect problematic emotion regulation (Beauchaine, 2015; Porges, 2007). RSA levels tend to increase following the removal of a stressor. These changes are referred to as RSA recovery and reflect the rate and degree to which individuals' parasympathetic activity returns to homeostatic levels after the challenging event has passed (Smith et al., 2020).

During the first few years of life, the early development and functioning of the parasympathetic nervous system, and particularly RSA, is theorized to be shaped by young children's experiences within parent-child attachment relationships (Propper & Holochwost, 2013). Responding in a timely and appropriate manner (i.e., parental sensitivity) to infants' distress cues is thought to be particularly influential in shaping infants' emerging emotion regulation strategies and skills (Leerkes et al., 2009; Sroufe, 1997; Thompson, 2014). Specifically, parental sensitivity in response to infant distress helps soothe the infant, potentially facilitating RSA recovery to baseline levels. The repetition of these parent-child interactions over time may program infants' stress physiology by enabling parasympathetic activation to cope after environmental challenges (Alen et al., 2022). In contrast, insensitive parental responses when infants are upset (e.g., rejecting, dismissing, or ignoring infants' distress cues) may exacerbate infants' distress and program infants' stress physiology to exhibit a lack of RSA recovery.

Most research examining potential parental contributions to child RSA activity has focused on children's baseline RSA levels and their RSA reactivity to a stressor but not RSA recovery. For instance, a meta-analysis of the associations between parenting and child autonomic nervous system activity identified 74 studies focusing on baseline parasympathetic nervous system activity and 50 studies focusing on parasympathetic reactivity to a stressor (Alen et al., 2022). The authors of this meta-analysis noted that it was not possible to meta-analytically examine whether parenting was associated with recovery processes because of the scarcity of studies.

We are aware of only three studies that have examined whether maternal sensitivity is associated with young children's RSA recovery, and the results have not been consistent. For example, Conradt and Ablow (2010) reported that infants who experienced higher levels of maternal sensitivity when distressed exhibited greater RSA recovery during the reunion episode of the still-face paradigm. In contrast, Moore et al. (2009) found that higher levels of maternal sensitivity during a non-distressing free-play interaction were associated with greater decreases in RSA from baseline to reunion episode of the still-face paradigm. Further, Enlow et al. (2014) reported that measures of

maternal sensitivity during distressing or non-distressing interactions were not significantly associated with infants' RSA levels during the still-face paradigm. Importantly, all three of these studies examined associations between maternal sensitivity and RSA recovery at a single time point (Conradt & Ablow, 2010; Enlow et al., 2014; Moore et al., 2009). As a result, little is known about whether maternal sensitivity has sustained associations with young children's RSA outcomes, especially RSA recovery after a stressful task. To address this gap, longitudinal data are needed to test whether the associations between maternal sensitivity and young children's RSA activity persist over time.

The aim of the present study was to investigate whether maternal sensitivity during distressing and non-distressing mother–infant interactions at 7 months predicts changes in children's RSA activity from 7 to 18 months. We hypothesized that higher levels of maternal sensitivity in the context of infant distress at 7 months would predict greater RSA recovery at 18 months, even after controlling for RSA recovery to a similar task at 7 months. The analyses examining the associations between maternal sensitivity and young children's baseline RSA levels and RSA reactivity at 18 months were exploratory based on the meta-analytic evidence that experiences with parents have non-significant overall associations with children's resting parasympathetic levels and parasympathetic reactivity (Alen et al., 2022).

2 | METHOD

2.1 | Participants

This study draws on longitudinal data from 162 women and their children. Recruitment for this study was carried out from January 2016 to October 2018 in the Mountain West region of the United States. Pregnant women receiving prenatal care at OBGYN clinics associated with the University of Utah were recruited for the study in person. Pregnant women were also recruited through flyers, brochures, and social media posts. After responding to the recruitment efforts, interested women completed a screening process, which involved over-sampling for ethnic and racial minorities as well as high levels of maternal emotion dysregulation. More information on specific recruitment criteria is described in Lin et al. (2019).

Mother–child dyads were followed from the mother's third trimester of pregnancy through the child's third year postnatal. The current study included data collected when children were approximately 7 months ($M = 6.68$, $SD = 0.63$) and 18 months ($M = 17.54$, $SD = 0.75$). The study focused on the subsample of 83 participants whose toddlers had useable RSA data available at the 18-month assessment. Among those who were not included in the sample, 31 could not be contacted or had moved out of state, 12 provided questionnaire data but did not participate in the lab visit for reasons other than COVID-19, 25 did not participate in lab visits due to COVID-19, 8 provided RSA data, but the data could not be used due to technical difficulties, and 3 had withdrawn prior to the 18-month lab visit. Attrition analyses indicated no significant differences between the subsample included in the analyses and the excluded participants with respect to maternal education, income, age, or marital status at the time of the prenatal visit. However, there was a significant difference with respect to maternal race/ethnicity. The analytic sample included a larger percentage of women who identified as being a person of colour at the prenatal visit than the sample of participants who were not included in the analyses (54% and 38%, respectively; $r = 0.16$, $p = 0.04$). Information on the demographic characteristics of the 83 mother–child dyads that were the focus of the current study is provided in Table 1.

2.2 | Procedure

The University of Utah's IRB approved all study procedures, and mothers completed informed consent at the start of each visit. Women and their infants were invited to participate in a laboratory-based research visit when infants

TABLE 1 Demographic characteristics of the sample.

Child biological sex assigned at birth	
Female	49%
Male	51%
Child race/ethnicity	
White	48%
Multiracial	23%
Hispanic/Latino	19%
Black/African American	1%
Asian	2%
Other race	1%
Missing data	5%
Mothers' marital status at the 7-month visit	
Married	80%
Single and never married	17%
Separated or divorced	4%
Maternal education at the 7-month visit	
Less than 12th grade	4%
High school graduate or equivalent	12%
Junior college graduate or some technical school	30%
College graduate	30%
Any post-graduate school	20%
Missing data	4%
Household annual income at the 7-month visit	
Under \$9000	2%
\$9000–\$14,999	4%
\$15,000–\$19,999	5%
\$20,000–\$24,999	6%
\$25,000–\$29,999	4%
\$30,000–\$39,999	11%
\$40,000–\$49,999	10%
\$50,000–\$79,999	27%
\$80,000–\$99,999	13%
\$100,000 or more	11%
Missing data	8%

Note: $N = 83$.

were approximately 7 months old. At this visit, electrodes intended to measure cardiac activity were placed on mothers and their infants using a standard three-lead spot electrode placement (i.e., right clavicle, lowest left rib, and a ground in the centre of the chest). Infants were placed in a highchair, and the dyads watched a 2-min clip of a Baby Einstein video for a resting baseline. Mothers were then instructed to complete the still-face paradigm while video cameras recorded their behaviours.

The still-face paradigm consists of three, 2-min episodes and was designed by Tronick et al. (1978) to elicit distress responses from children 2–9 months of age (Adamson & Prick, 2003). During the initial play episode, the mother was instructed to engage with her child as she normally would. Following this, the mother was instructed to hold a neutral facial expression (unresponsive), which usually elicited infant distress. Lastly, during the recovery episode, the mother was instructed to respond to the infant as they usually would, which often involved trying to soothe them. In the current study, dyads completed an extended version of the still-face paradigm, which includes a second 2-min still-face episode followed by a second 2-min reunion episode. This extended version of the still-face paradigm tends to elicit a stronger stress response from infants (Jones-Mason et al., 2018). The extended length of the still-face paradigm also allows for a more direct comparison to the 18-month assessment.

Women and their 18-month-old toddlers were invited to participate in a second laboratory-based research visit. Again, electrodes intended to measure cardiac activity were placed on mothers and their toddlers using the same standard three-lead spot electrode placement from the 7-month visit. Toddlers were placed in a highchair, mothers were asked to sit next to their child, and the dyads watched a 3-min clip of a Baby Einstein video to capture a resting baseline. The toddler was then taken out of the highchair and mother–toddler dyads completed the strange situation procedure, which was designed to elicit separation and stranger anxiety in 1-year-old infants (Ainsworth et al., 1978).

The strange situation procedure consists of eight episodes that last up to 3 mins. During the initial episode, the mother was instructed to sit in a chair, let her child play with toys, and only interact with their child if they sought her attention. During the stranger episode, a stranger entered the room and quietly sat for 1 min, engaged the mother in conversation for another minute, and then tried to interact with the toddler for the last minute of the episode. During the separation episode, the mother was instructed to leave the room. The stranger tried to play, comfort, or distract the child as needed, and the episode was terminated if the child could not be comforted. During the first reunion episode, the mother re-entered the room and comforted the child if needed. During this time, the stranger left the room. During the second separation episode, the mother was instructed to leave the room, this time leaving the child alone to continue playing with toys for the entire episode unless they became too distressed. During the third separation episode, the stranger re-entered the room and attempted to comfort or distract the child if needed. This episode and the preceding one were terminated before 3 mins if the child was inconsolable. During the final reunion episode, the mother re-entered the room and comforted the child as needed.

2.3 | Measures

2.3.1 | Infant physiological activity

At the 7-month visit, electrocardiogram (ECG) data were recorded continuously during a video baseline task and during the still-face paradigm (see also Gao et al., 2022). ECG data were sampled at 500 Hz using MindWare Technology mobile devices (MindWare Technologies Ltd.; Biolab software version 3.1), and electrocardiograph activity was monitored throughout the task to ensure accurate data collection. After data collection, MindWare Technologies' Heart Rate Variability (HRV) software was used to score the ECG data. The software automatically identified R peaks within the QRS complex and flagged R peaks that have an interbeat interval that deviates from the expected range. These R peaks were visually inspected and corrected if needed by trained research assistants. Using MindWare's software, spectral analysis was used to decompose the variability in beat-to-beat intervals in 30-s intervals into very low frequency (0.003–0.04 Hz), low frequency (0.04–0.12 Hz) and high frequency power (0.12–0.42 Hz; MindWare Technologies, 2014). As is standard, RSA was calculated as the natural log of the high frequency power spectrum. RSA data were inspected for outliers or other anomalous values. Each 30-s time interval RSA estimate during the video baseline was averaged. Likewise, average RSA levels during each of the five episodes of the still-face paradigm were calculated.

2.3.2 | Toddler physiological activity

At the 18-month visit, ECG data were continuously recorded during a video baseline task and during the strange situation procedure. As with the 7-month visit, the ECG data were sampled using MindWare Technology mobile devices and inspected by trained research assistants using MindWare Technologies' Heart Rate Variability (HRV) software. Each of the 30-s time interval RSA estimates was averaged during the video baseline and during each of the strange situation episodes.

2.3.3 | Maternal sensitivity during infant distress

Video recordings of the mothers' behaviours during the still-face paradigm at the 7-month visit were coded using an adapted version of the Observational Record of the Caregiving Environment by a team of trained research assistants (NICHD Early Child Care Research Network, 1996). Consistent with Speck et al. (2023), two 5-point scales were used for the current study. The *sensitivity to non-distress* scale focuses on the degree to which the mother observes and responds appropriately and promptly to the child's social gestures, expressions, and signals. Markers of sensitivity to non-distress include acknowledging the child's affect and encouraging the child's efforts. The *sensitivity to distress* scale focuses on the degree to which the mother responds to the child's cues of sadness, fear, or anger in a timely and appropriate manner. Behavioural markers of sensitivity to distress include gently rubbing the child's hands or legs, acknowledging their distress, and speaking softly. Mothers' sensitivity to infant non-distress and infant distress were double-coded by research assistants, and disagreements in coding decisions of a point or greater were conferenced. The intraclass correlations for coders' ratings of maternal sensitivity to infant non-distress and infant distress were 0.69 and 0.66, respectively. The ratings of maternal sensitivity to distress and non-distress were significantly correlated with each other during both reunion episodes ($r = 0.46$, $p = 0.043$ and $r = 0.54$, $p = 0.009$) and, therefore, were averaged to create a single measure of maternal sensitivity in the context of infant distress ($\alpha = 0.74$).

2.3.4 | Maternal sensitivity during infant non-distress

Maternal behaviours were also assessed during a 15-min mother–infant play interaction that took place immediately after the still-face paradigm at the 7-month visit. Mothers were asked to interact with their infant as they normally would without toys present for 5 min. Then, they were provided with toys and asked to continue interacting with their infant as they normally would for 10 mins. A subset of 89 participants also completed a second laboratory visit where they participated in the 15-min free-play task a second time. All these videotaped interactions were coded using an adapted version of the Observational Record of the Caregiving Environment (NICHD Early Child Care Research Network, 1996). Specifically, mother's behaviours were rated using 5-point scales capturing maternal sensitivity to non-distress. All interactions were double-coded by research assistants, and disagreements in coding decisions of one point or greater were conferenced. The intraclass correlations for coders' ratings of maternal sensitivity to non-distress during the no-toy and toy interactions at all completed visits ranged from 0.76 to 0.91. Maternal sensitivity ratings during the no-toy and toy interactions during both free-play interactions were averaged to create an overall score.

2.3.5 | Potential covariates

Consistent with other research on the associations of early sensitivity for individuals' autonomic nervous system functioning (e.g., Raby et al., 2015), child biological sex assigned at birth (0 = male, 1 = female), child race/ethnicity (0 = White and non-Hispanic, 1 = person of colour), and family socioeconomic status at the time of the 7-month

visit were considered as potential covariates. A composite measure of family socioeconomic status was created by standardizing and averaging measures of maternal educational attainment, family income, and ratings of family occupational prestige (Hout et al., 2016) collected at the 7-month visit.

2.3.6 | Missing data

Approximately 23% of the infant RSA data were missing at the 7-month visit. Ten infants were missing baseline RSA data, 13 were missing RSA data during the play episode, 14 were missing RSA data during the first still-face, 17 were missing RSA data during the first reunion, 29 were missing RSA data during the second still-face, and 31 were missing RSA data during the second reunion. Approximately 13% of the toddler RSA data were missing at the 18-month visit. Three participants were missing RSA data during the video baseline, four were missing RSA data during the initial play episode, five were missing RSA data during the stranger episode, 13 were missing RSA data during the first separation, five were missing RSA data during the first reunion episode, 31 were missing RSA data during the second separation, 15 were missing RSA data during the stranger return episode, and seven were missing RSA data during the second reunion. Thirteen participants were missing maternal sensitivity to distress, and eight were missing maternal sensitivity to non-distress at the 7-month visit. For the potential covariates, six participants were missing infant age at the 7-month visit, five were missing family socioeconomic status information, and four were missing child race/ethnicity information. Full information maximum likelihood was used to address these missing data.

3 | RESULTS

3.1 | Preliminary analyses

Infants' RSA levels during the video baseline and the still-face paradigm at the 7-month visit are presented in Figure 1. Consistent with other research (Jones-Mason et al., 2018), infants' RSA levels decreased during the two still-face episodes and slightly increased during the two reunion episodes. A similar pattern of mean scores was also

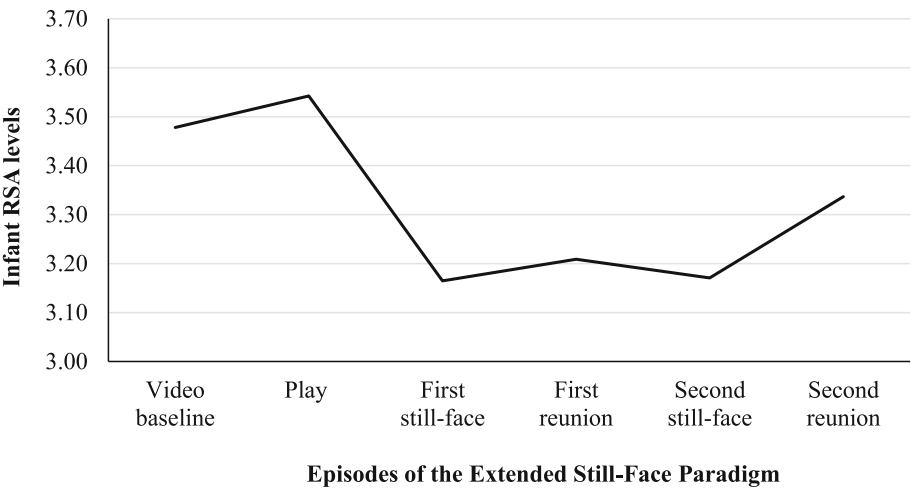


FIGURE 1 Average infant respiratory sinus arrhythmia (RSA) levels during the still-face paradigm at 7 months.

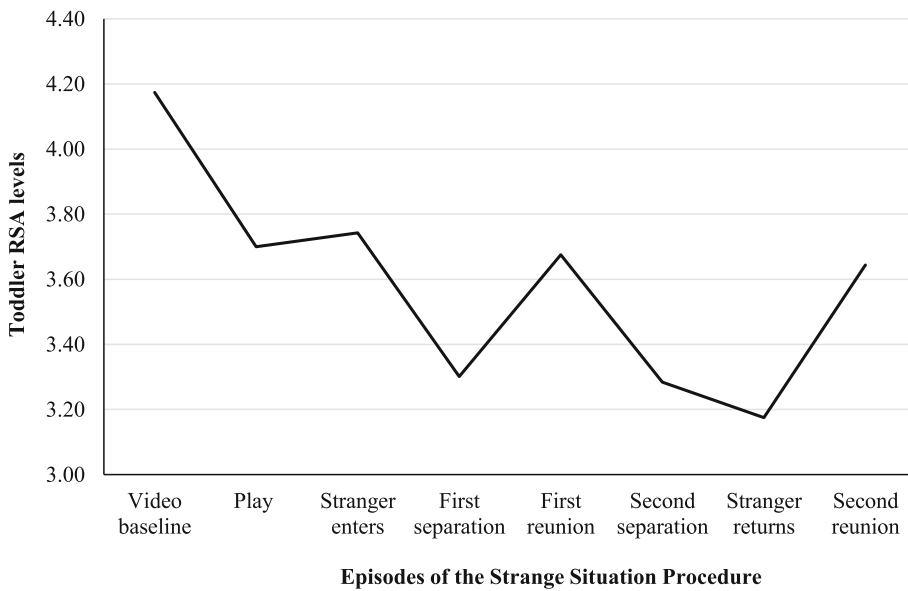


FIGURE 2 Average toddler respiratory sinus arrhythmia (RSA) levels during the strange situation procedure at 18 months.

observed at the 18-month visit (see Figure 2). Specifically, toddlers' RSA levels decreased during the three episodes in which they were separated from their mothers, and toddlers' RSA levels increased during the two episodes in which they were reunited with their mothers.

We devised a strategy for creating measures of baseline RSA, RSA reactivity, and RSA recovery at the 7-month time-point and the 18-month time-point that were consistent with approaches used in prior research on children's RSA activity during the still-face paradigm and during the strange situation procedure (e.g., Groh & Narayan, 2019; Propper et al., 2008). Specifically, at both 7 and 18 months, *baseline RSA* levels were calculated by averaging scores collected during the video baseline episode. Infant *RSA reactivity* at the 7-month visit was calculated by subtracting average RSA levels during the two still-face episodes from average RSA levels during the video baseline episode. Likewise, toddler RSA reactivity at the 18-month visit was calculated by subtracting average RSA levels during the three separation episodes of the strange situation from average RSA levels during the video baseline episode. In this way, for both RSA reactivity scores, a low numeric value indicates large decreases in RSA relative to baseline (i.e., high RSA reactivity). Infant *RSA recovery* at the 7-month visit was calculated by subtracting average RSA levels during the two still-face paradigm reunion episodes from average RSA levels during the video baseline episode. Likewise, toddler RSA recovery at the 18-month visit was calculated by subtracting average RSA levels during the two strange situation episodes from average RSA levels during the video baseline episode. As with RSA reactivity, a low numeric value for the RSA recovery variables indicates large decreases in RSA relative to baseline (i.e., a lack of RSA recovery).

Descriptive statistics and correlations among study variables are presented in Table 2. Regarding the potential covariates, family socioeconomic status was positively correlated with maternal sensitivity during infant non-distress. Child sex assigned at birth and child race/ethnicity were not significantly correlated with the measures of infant RSA activity at 7 months, toddler RSA activity at 18 months, or maternal sensitivity. Therefore, only family socioeconomic status was included as a covariate in the analyses focused on maternal sensitivity as a predictor of change in RSA activity.

TABLE 2 Descriptive statistics and correlations among the variables.

	1	2	3	4	5	6	7	8	9	10	11
Potential covariates											
1. Child sex assigned at birth	-										
2. Child race/ethnicity	0.08	-									
3. Family socioeconomic status	-0.28*	-0.16	-								
Infant RSA at 7 months											
4. Baseline RSA	0.04	0.01	0.17	-							
5. RSA reactivity	0.10	-0.02	-0.19	-0.55*	-						
6. RSA recovery	-0.01	-0.13	0.01	-0.31*	0.66*	-					
Toddler RSA at 18 months											
7. Baseline RSA	0.17	0.15	-0.05	0.33*	0.02	-0.02	-				
8. RSA reactivity	0.10	-0.08	-0.02	-0.37*	0.31*	0.15	-0.44*	-			
9. RSA recovery	-0.15	-0.23	0.14	-0.33*	0.13	0.16	-0.70*	0.36*	-		
Maternal sensitivity at 7 months											
10. Sensitivity during infant distress	-0.07	-0.07	0.19	0.01	0.12	0.04	-0.19	0.09	0.25*	-	
11. Sensitivity during free play	-0.14	-0.10	0.31*	0.07	-0.06	-0.17	0.05	-0.04	-0.11	0.17	-
M or %	49%	48%	-0.03	3.50	-0.39	-0.36	4.18	-0.90	-0.54	3.06	3.14
SD	-	-	0.95	0.97	1.26	1.31	1.06	1.39	0.92	0.75	0.83
Minimum	0.00	0.00	-2.71	0.89	-4.02	-4.48	1.96	-5.22	-4.68	1.12	1.25
Maximum	1.00	1.00	2.41	6.46	3.18	3.27	7.48	2.26	1.34	4.83	5.00
Skewness	0.02	0.02	-0.44	0.25	-0.08	-0.22	0.56	-0.55	-1.25	-0.30	0.04

Note: N = 83. Child sex assigned at birth was coded as male = 0, female = 1. Child race/ethnicity was coded as White and non-Hispanic = 0, person of colour = 1. Abbreviation: RSA, respiratory sinus arrhythmia. **p* < 0.05.

TABLE 3 Results from multiple regression analyses of predicting 18-month toddler respiratory sinus arrhythmia (RSA) from 7-month infant RSA and maternal sensitivity.

	18-month baseline RSA			18-month RSA reactivity			18-month RSA recovery		
	β	SE	<i>p</i>	β	SE	<i>p</i>	β	SE	<i>p</i>
Model 1									
7-month infant baseline RSA	0.17	0.08	0.062	–	–	–	–	–	–
7-month infant RSA reactivity	–	–	–	0.37*	0.11	0.001	–	–	–
7-month infant RSA recovery	–	–	–	–	–	–	0.17	0.09	0.061
Maternal sensitivity during distress	–0.30*	0.10	0.004	0.04	0.12	0.767	0.27*	0.11	0.016
Maternal sensitivity during free play	0.08	0.11	0.458	0.05	0.13	0.692	–0.10	0.12	0.408
Model 2									
7-month infant baseline RSA	0.16	0.09	0.080	–	–	–	–	–	–
7-month infant RSA reactivity	–	–	–	0.36*	0.11	0.001	–	–	–
7-month infant RSA recovery	–	–	–	–	–	–	0.16	0.09	0.084
Maternal sensitivity during distress	–0.30*	0.11	0.005	0.04	0.13	0.765	0.25*	0.12	0.032
Maternal sensitivity during free play	0.12	0.12	0.319	0.03	0.13	0.797	–0.16	0.12	0.190
Family socioeconomic status	–0.07	0.12	0.539	0.03	0.13	0.788	0.14	0.12	0.228

Note: *N* = 83.

Abbreviation: RSA, respiratory sinus arrhythmia.

**p* < 0.05.

3.2 | Maternal sensitivity as a predictor of change in RSA activity

A set of multiple regression analyses were used to test whether maternal sensitivity in the context of infant distress and infant non-distress when infants were 7 months are associated with changes in RSA activity between 7 and 18 months (see Table 3). After accounting for stability of baseline RSA levels between 7 and 18 months, maternal sensitivity in the context of infant distress was negatively associated with toddlers' baseline RSA levels at 18 months. Maternal sensitivity in the context of infant distress was also negatively associated with toddlers' RSA recovery at 18 months. However, toddlers' RSA reactivity at 18 months was not significantly predicted by maternal sensitivity in the context of infant distress or during the non-distressing free-play interactions. All decisions about the statistical significance of the associations remained unchanged when socioeconomic status was included as a covariate in the model (see Table 3).

4 | DISCUSSION

The present study examined whether maternal sensitivity during distressing and non-distressing mother–infant interactions predicted changes in children's RSA activity between infancy and toddlerhood. The results supported the theoretically-driven hypothesis that maternal sensitivity measured in the context of infant distress predicts toddler RSA recovery after a social stressor nearly a year later. Infants at 7 months who experienced higher levels of maternal sensitivity immediately after a distressing event exhibited greater RSA recovery during the reunion episodes of the strange situation procedure at 18 months. Importantly, this longitudinal association with children's RSA recovery was unique to maternal sensitivity during distressing mother–infant interactions. This finding is consistent with the theoretical notion that nurturing parental responses to infants' distress may program infants' stress physiology to activate the parasympathetic nervous system when coping following a stressful event (Sroufe, 1997;

Thompson, 2014). To our knowledge, this is the first study to provide evidence for the predictive validity of maternal sensitivity to young children's RSA recovery.

Neither maternal sensitivity during distressing nor non-distressing interactions significantly predicted changes in children's RSA reactivity levels. This null result is consistent with meta-analytic evidence that experiences with parents are not associated with children's parasympathetic reactivity to stressful events (Alen et al., 2022). On the other hand, changes in young children's baseline RSA levels were predicted by maternal sensitivity in the context of infant distress. The direction of this association was negative, meaning that toddlers who previously had experienced relatively high levels of maternal sensitivity when they were distressed had lower baseline RSA levels at 18 months than toddlers who had experienced relatively low maternal sensitivity. This direction of effect is surprising given that many studies have reported that positive experiences with parents are associated with higher resting parasympathetic nervous system activity among children (Alen et al., 2022). In the current sample, children's average resting RSA levels increased from infancy to toddlerhood, and the bivariate correlation between the two resting RSA measures demonstrated significant test–retest stability. These results are consistent with other research on the ontogeny of resting RSA levels during infancy and toddlerhood (Wagner et al., 2021) and support the view that resting RSA levels reflect a general capacity for effective self-regulation (Porges, 2007; Thayer et al., 2009). It is possible that toddlers with fewer self-regulatory abilities (as indexed by low resting RSA) elicited more sensitive caregiving during infancy. Although we attempted to control for that possibility by including a measure of resting RSA during infancy as a covariate, future research that includes additional physiological indices of self-regulation, such as the sympathetic nervous system and the hypothalamic–pituitary–adrenal axis (e.g., Holochwost et al., 2021), would provide a more comprehensive examination of potential bidirectional effects between early caregiving experiences and young children's early physiological development.

Strengths of this study include the longitudinal design and the use of two commonly used and well-validated laboratory-based stressors. In addition, the assessment of maternal sensitivity in the context of infant distress and during a non-distressing free-play interaction allowed for assessing whether these two aspects of the early caregiving environment have unique implications for young children's RSA activity. The current study also has some limitations. The first is the modest sample size, which was because a large proportion of participants could not be contacted, moved out of state, or could not participate in the follow-up visit due to the COVID-19 pandemic. Future longitudinal research that utilizes larger samples would have greater statistical power and, therefore, would be able to detect smaller effect sizes. Second, to accommodate children's developmental changes, two distinct procedures were used to assess children's RSA reactivity at different ages. Although both the still-face paradigm and strange situation procedure expose children to the stressful loss of responsiveness from their primary caregiver, the still-face is conducted while infants are sitting, whereas the strange situation allows children to walk freely. Variations in posture and physical movement may alter parasympathetic functioning (Houtveen et al., 2005). This methodological limitation could be addressed by future research that uses the same stressful task at multiple ages.

In summary, the present study suggests that maternal sensitivity in the context of infant distress has unique consequences for young children's RSA activity. In particular, young children who experienced higher levels of sensitivity during infancy had lower resting RSA levels and exhibited greater RSA recovery nearly a year later. These results suggest that children's early experiences within the parent–child relationship are meaningfully related to the development of young children's RSA activity.

AUTHOR CONTRIBUTIONS

Tracey Tacana: Conceptualization; formal analysis; writing – original draft; writing – review and editing. **Bailey Speck:** Methodology; writing – review and editing. **Jennifer Isenhour:** Methodology; writing – review and editing. **Elisabeth Conradt:** Funding acquisition; investigation; writing – review and editing. **Sheila E. Crowell:** Funding acquisition; investigation; writing – review and editing. **K. Lee Raby:** Conceptualization; data curation; formal analysis; supervision; writing – original draft; writing – review and editing.

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PEER REVIEW

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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