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Attachment Status and Mother-Preschooler Parasympathetic Response to the Strange Situation Procedure

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Abstract

Background—Early attachment relationships are important for children's development of behavioral and physiological regulation strategies. Parasympathetic nervous system activity, indexed by respiratory sinus arrhythmia (RSA), is a key indicator of self-regulation, with links to numerous developmental outcomes. Attachment-related changes in and associations between mother and child RSA during the Strange Situation procedure (SSP) can elucidate individual differences in physiological response to stress that are important for understanding the development of and intervention for psychopathology.

Methods—A sample of 142 at-risk mothers and preschool-age children participated in the SSP and provided time-synchronized RSA data during the 7 episodes, which included 2 separations and 2 reunions. Attachment classifications were obtained using the Cassidy and Marvin (1992) coding system. Linear mixed-effects models were constructed to examine attachment-related change in RSA during the SSP and the concordance between mother and child RSA over time.

Results—Findings demonstrated attachment-related differences in children's RSA. Secure children's RSA was relatively stable over time, whereas insecure–avoidant children showed RSA increases during the first separation and insecure–resistant children's RSA declined across the SSP. Mothers showed RSA withdrawal during separation regardless of child's attachment

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classification. Mother–child RSA showed a positive concordance that was strongest in the insecure–resistant group, compared with the other groups.

Conclusions—Results support attachment theories concerning parasympathetic response to stress and the role of the mother–child relationship in physiological regulation. Our findings advance previous research by focusing on at-risk mother–preschooler dyads within diverse attachment classifications.

Keywords

attachment; preschool; respiratory sinus arrhythmia; dyadic concordance; strange situation

INTRODUCTION

Children's physiological regulation in stressful situations has critical implications for the development of psychopathology (Aldao, Nolen-Hoeksema, & Schweizer, 2010; Calkins & Dedmon, 2000; Calkins & Fox, 2002; Chaplin & Cole, 2005; Cicchetti, Ackerman, & Izard, 1995; Eisenberg, 2000; Eisenberg, Spinrad, & Eggum, 2010; Keenan, 2000) and for prosocial adaptation (Gottman, Katz, & Hooven, 1997; Graziano, Reavis, Keane, & Calkins, 2007; Halberstadt, Denham, & Dunsmore, 2001; Posner & Rothbart, 2000, 2007). Contemporary biosocial models (Calkins & Hill, 2007; Hofer, 2006; Shipman & Zeman, 2001), which are supported by empirical studies (Calkins, Smith, Gill, & Johnson, 1998; Crockenberg & Leerkes, 2004; Rosenblum, McDonough, Muzik, Miller, & Sameroff, 2002), hold that children learn physiological and behavioral regulation in the context of early attachment relationships. Polyvagal theory (Porges, 2003, 2007) provides a neurovisceral model that links attachment and arousal modulation, as indexed by respiratory sinus arrhythmia (RSA). RSA reflects the action of the parasympathetic nervous system (PNS) on the heart via the 10th cranial (vagus) nerve (Hirsch & Bishop, 1981; Porges, 1986). PNS stimulation, or vagal activation, results in a lowering of heart rate (HR) and greater variation in the time between heart cycles. Thus, PNS stimulation downregulates HR, and higher RSA indicates greater PNS stimulation. PNS regulation of HR variability, indexed by RSA, can serve as a physiological indicator of self-regulation in children (Porges, 2007).

Porges (1991, 2009) and others (e.g., Appelhans & Luecken, 2006) have argued that the physiological regulatory function provided by the ventral vagal complex may mediate regulation following arousal. Empirical evidence supports the notion that change in RSA is an important physiological indicator of self-regulation and adaptive developmental correlates (Blair, 2003; Calkins & Keane, 2004; Graziano & Derefinko, 2013). Collectively, the research suggests that variability in RSA in response to challenge and recovery may reflect healthy physiological regulation. A decrease in RSA from baseline (withdrawal) reflects attention to threat (Porges, 2007) and efforts at active coping (Porges, 1995), whereas an increase in RSA reactivity (augmentation) (Porges, 2009) is associated with emotion regulation, particularly in social contexts (Butler, Wilhelm, & Gross, 2006). In a recent meta-analysis examining the relation between cardiac vagal control and children's adaptive functioning, Graziano and Darefinko (2013) concluded that healthy, well-developing children show parasympathetic withdrawal during challenge. Conversely, Beauchaine (2001) and others have observed that high levels of vagal withdrawal can be related to negative behavioral and mental health outcomes. Withdrawal in response to challenge has been linked to positive regulatory outcomes from infancy to school age (Calkins, 1997; Huffman et al., 1998; Porges, Doussard- Roosevelt, Lourdes Portales, & Suess, 1994; Stifter & Corey, 2001; Suess, Porges, & Plude, 1994), particularly in low-risk samples (Graziano & Derefinko, 2013). However, RSA withdrawal is not uniformly adaptive, according to an increasing number of studies that have documented risk associated with RSA withdrawal (Calkins, Graziano, & Keane, 2007; Obradović, Bush, Stamperdahl, Adler, & Boyce, 2010; Skowron, Cipriano-Essel, Benjamin, Pincus, & Van Ryzin, 2013; Skowron, Cipriano-Essel, Gatzke-Kopp, Teti, & Ammerman, 2014; Skowron et al., 2011), particularly in higher-risk samples. A growing body of research suggests that the implications of RSA withdrawal and augmentation may be highly context specific (Conradt, Measelle, & Ablow, 2013; Quas, Bauer, & Boyce, 2004), with changes in RSA modulated by the type of challenge and the context in which each occurs. For example, children and adults typically show RSA augmentation in social contexts and situations where they experience relatively neutral affect (Bazhenova, Plonskaia, & Porges, 2001; Butler et al., 2006; Hastings, Kahle, & Nuselovici, 2014; Lorber & O'Leary, 2005). However, when affect is highly negative, evidence suggests that less RSA withdrawal is associated with better cognitive functioning (Healy, Treadwell, & Reagan, 2011).

Physiological Response to the Strange Situation Procedure

A child's early attachment experiences shape lifelong physiological regulation strategies (Bowlby, 1969/1982, 1998; Bretherton & Munholland, 1999; Johnson, Dweck, & Chen, 2007) and attachment accounts for individual differences in RSA (Burgess, Marshall, Rubin, & Fox, 2003; Del Giudice, Ellis, & Shirtcliff, 2011; Hill- Soderlund et al., 2008). The Strange Situation procedure (SSP; Ainsworth, Blehar, Waters, & Wall, 1978b) is a well-established paradigm for activating the attachment system. The SSP comprises 7 episodes and includes 2 separations from and reunions with the mother (Episode 1: mother–child; 2: mother–child–stranger; 3: child–stranger [Separation 1]; 4: mother–child [Reunion 1]; 5: child alone [Separation 2]; 6: child–stranger; 7: mother–child [Reunion 2]). Observers then classify the child into 1 of 3 organized attachment categories (secure, insecure–avoidant, and insecure–resistant(secure, insecure–avoidant, and insecure–resistant; Müller, Bütefisch, Seitz, & Hömberg, 2007)) or a disorganized group, on the basis of behavior during the procedure (Main & Solomon, 1990). Given the critical importance of attachment-related differences to child development noted earlier, the SSP is ideal for examining patterns of physiological regulation under systematically varied conditions, including two timed separations from the mother designed to activate the child's attachment system (Ainsworth, Blehar, Waters, & Wall, 1978a). Thus, use of the SSP procedure allows for examination of attachment-related variation in physiological responses over time as the child plays near the mother, as the child's attachment system is activated via separation, and as the dyad interacts during reunion immediately following activation of the attachment system.

Classification via the SSP is determined primarily on the basis of children's differing responses to reunion with the mother. Secure children, regardless of behavioral distress upon separation, are more likely to use mother-oriented behavioral regulation strategies upon reunion than are the other groups (Cassidy, 1994; Spangler & Grossmann, 1993; Zelenko et al., 2005). Infants classified as insecure–avoidant are more likely to use self-soothing or exploration in response to distress, and they appear less distressed behaviorally in SSP reunions despite showing increased HR (Zelenko et al., 2005) and higher cortisol during separations than secure children show (Spangler & Grossmann, 1993; Zelenko et al., 2005). However, it is unclear whether the physiological response of insecure–avoidant children is specific to separation from the caregiver or if it generalizes across episodes of engagement with the caregiver and/or stranger. Most studies of autonomic physiology during the SSP have focused simply on HR (Calkins & Hill, 2007), which is jointly affected by both sympathetic and parasympathetic response in nonsystematic ways. For example, although infants' HR tends to increase during the separation episodes, securely attached children show a faster return to baseline than do insecure children upon reunion (Sroufe & Waters, 1977), and only disorganized children show increased HR in the second separation (Spangler & Grossman, 1999).

Surprisingly little research has examined links between attachment and episode related *change* in RSA during the SSP. Given the importance of attachment patterns in predicting adaptation and mental health throughout the lifespan, examination of the physiological responses associated with these patterns may help to inform models of early regulation and dysregulation. Hill-Soderlund and colleagues (2008) compared trajectories of RSA in the SSP for typically developing secure and insecure–avoidant infants. They found a significant interaction whereby insecure–avoidant infants showed RSA withdrawal in 3 episodes: the first reunion with the mother, when completely alone, and when alone with the stranger. Securely attached infants had a flatter profile during these episodes, perhaps indicating more efficient parasympathetic modulation through the SSP or that the task was no longer a challenge. Notably, the findings of Hill-Soderlund and colleagues were more consistent with the meta-analytic findings of Beauchaine (2001) than with the findings of Graziano and Darefinko (2013), in that it was the insecure-avoidant infants, relative to secure infants, who showed greater withdrawal of RSA. Hill-Soderlund and colleagues were able to examine RSA for infants only in the secure and insecure–avoidant groups because of a lack of participants classified as insecure–resistant or disorganized, a significant limitation given that the latter classes are at the greatest risk for adverse outcomes. Nevertheless, this study was a significant step forward because RSA, rather than HR alone, was used as an index of PNS activation.

Little is known about attachment-related patterns of RSA for preschool-age children. Marshall and Stevenson-Hinde (1998) compared these patterns among high- and low-inhibition preschoolers by using a modified SSP that comprised a 25-minute separation and a single reunion. No attachment-related RSA effects were found. Rather, findings indicated that only secure children showed heart period (the interval between heartbeats) increases at reunion, whereas insecure children showed heart period declines during episodes with the stranger, corresponding to heart rate declines and increases, respectively. Second, in a small sample of low-risk preschoolers, Oosterman and Schuengel (2007) found evidence of RSA withdrawal during separations but no attachment-related differences. These findings indicate the need for further research with larger samples and the complete SSP.

Maternal Physiological Regulation While Parenting and Mother–Child Concordance

Historically overlooked in research on children's RSA is the role of maternal physiological regulation while parenting. Two notable studies have examined maternal RSA and attachment-related associations; both have documented that maternal separations from one's child are associated with RSA withdrawal. For example, Mills-Koonce and colleagues (2007) found that RSA declined during separations in the SSP for all mothers regardless of their child's attachment security, suggesting that separation is challenging for caregivers. Hill-Soderlund and colleagues (2008) found that mothers of secure infants showed lower RSA during the final reunion of the SSP than did mothers of insecure–avoidant infants, interpreted as evidence of greater efforts to engage in interactive repair with a distressed child among mothers of secure infants. Evidence from animal research has demonstrated the importance of maternal physiological regulation for active attention, engagement with the needs of offspring, and parenting behaviors (Campbell, 2008; Hansen, Bergvall, & Nyiredi, 1993; Insel, 2000; Lonstein & Gammie, 2002). Research has indicated that caregivers' positive parenting behaviors of distressed infants and preschoolers is typically associated with short-term decreases in RSA (Mills- Koonce et al., 2009; Moore et al., 2009). A handful of studies that have examined RSA during the act of parenting has suggested that RSA augmentation occurs in the context of positive social engagement and self-regulation (Hill- Soderlund et al., 2008; Skowron et al., 2011). For example, RSA augmentation is observed in mothers who achieve greater positive interactive synchrony with their child regardless of risk status (Giuliano, Skowron, & Berkman, 2015).

A growing body of research suggests that the extent of mother–child physiological concordance, or synchrony – defined here as the temporal coordination of RSA – may influence or shape a child's development of regulatory processes (Champagne, 2008). The development of self-regulation occurs in the context of self and other (dyadic) interactions, primarily between the child and significant caregiver (Calkins & Leerkes, 2004). We need to understand the physiological mechanisms associated with different dyadic interaction patterns to elucidate the developmental processes of children's self-regulation and dysregulation. Co-regulation of mother and child are important because theorists have argued that the biological synchrony between the caregiver and child allows the child to develop adaptive self-regulation (Field, 1996; Hofer, 2006) and there is empirical evidence that physiological concordance is linked to mothers' behavioral attunement to their children (Ham & Tronick, 2009; Moore & Calkins, 2004; Moore et al., 2009).

Yet, studies of concordance in mother and child autonomic physiology, including studies of HR and RSA, have produced equivocal findings. Feldman and colleagues (2011) found a time-lagged heart rhythm concordance between low-risk mothers and their 4-month-old infants. Likewise, we have observed significant concordance in mother and preschooler contemporaneously measured resting HR and RSA, such that greater maternal HR was associated with greater child HR and lower child RSA (Creaven, Skowron, Hughes, Howard, & Loken, 2014). In a prospective study of 76 mother–infant dyads, Bornstein and Suess (2000) found no associations between mothers and children at 2 months or at 5 years in either resting HR or RSA, although RSA withdrawal in response to challenge showed positive between-dyad associations by age 5.

Researchers have also investigated mother–child physiological concordance during the SSP. An early study showed HR concordance for mothers and secure infants, whereas data for mothers of insecure infants did not (Donovan & Leavitt, 1985). Zelenko and colleagues (2005) found that mothers and insecure–resistant infants demonstrated lower dyadic consistency in their HR changes during the SSP, compared with secure dyads. Hill-Soderlund and colleagues (2008) found no evidence of concordance in RSA levels nor in Salivary α-Amylase (a marker of sympathetic activation) during the SSP for either secure or insecure–avoidant dyads.

This Study

We measured RSA during the SSP in an at-risk sample of preschool-age children and their mothers to clarify attachment-related patterns of physiological responding. We characterized patterns of mother and child RSA withdrawal and augmentation and examined dyadic concordance by child attachment classification during the course of the SSP. On the basis of the findings of Hill-Soderlund et al. (2008), we expected the insecure-avoidant children to show significant RSA withdrawal in response to the stress of separation. Second, we expected the insecure-avoidant children to show RSA withdrawal during reunions and during the course of the SSP, which would indicate arousal without successful augmentation in the presence of the caregiver. Further, we explored whether RSA patterns differed by attachment classification, overall. We expected to see maternal RSA withdrawal during separation episodes and augmentation during reunion, as has been found in previous studies (Hill- Soderlund et al., 2008). Again, we examined differences in maternal RSA by the attachment classification of their preschooler. Last, we explored whether mother–child dyads would evidence RSA concordance across the SSP and whether such concordance would vary as a function of children's attachment status.

METHODS AND MATERIALS

Participants

The sample consisted of 142 mothers (age 19–45 years, $M = 29.4$, $SD = 5.6$) and their 3- to 5-year-old children ($M = 3.79$, $SD = .74$; 51% female; 80% Caucasian) with coded data for the SSP. Mean maternal education was 13.4 years. Dyads were recruited from Child Protective Services (CPS), the Department of Public Welfare, and a university database, and were eligible to participate if the mother was age 18 years or older, spoke fluent English, and lived with her preschooler. In keeping with the at-risk nature of the sample, a subsample of mothers ($N = 64$, 45%) in the study was involved with CPS. Among the CPS-involved families, 22.4% of mothers had perpetrated physical abuse, 62.7% were physically neglectful, 10.4% were identified as emotionally maltreating, and 4.5% were involved with CPS but had no documented evidence of child maltreatment. Comparisons between CPS and non-CPS dyads revealed no significant differences in terms of child age, gender, or ethnicity; mother's relationship status; or child attachment classification. CPS dyads were significantly lower with respect to mother years of education, $t(1,142) = 6.17$, $p <.001$, and household income, $\chi^2(4, N = 142) = 26.71$, $p <.001$. Fifty-three percent of mothers reported having a high school diploma or less and 70% of the sample reported an annual household income of less than $30,000, which is substantially lower than the countywide median household income level of $50,000 at the time of study enrollment (United States Census Bureau, 2015).

Procedure and Measures

Two trained interviewers conducted a 3-visit protocol with mothers and their children during a 2- to 3-week period that consisted of two 2-hour home visits and 1 laboratory visit (approximately 2.5 hours). During the home visits, mothers completed a series of psychosocial assessments and provided demographic information, and mothers and children each completed a cognitive assessment. During the laboratory visit, mothers and children participated in the SSP (Ainsworth, 1979) and a series of joint teaching tasks, and mothers completed questionnaires while children participated in a series of individual self-regulation tasks. Mothers' and children's electrocardiography (ECG) was monitored during all laboratory procedures. Families were paid $150 for protocol completion. Transportation, snacks, and small toys/gifts for the child were provided.

Attachment Classification—Mothers and their children participated in the SSP for preschool children and their mothers (Cassidy et al., 1992) Episode 1 (mother-child; 3 minutes): child plays with toys while mother watches but does not initiate play or conversation with her child. Episode 2 (mother-child-stranger, 3 min): a stranger enters the room, greets the mother, and then plays with the child. At the end of this episode, the mother leaves the room. Episode 3 (separation 1; 3 min): child in the room with the stranger; stranger does not initiate play or conversation with child. Episode 4 (reunion 1; 3 min): mother returns to the room and greets her child, but does not initiate play or conversation with child; stranger leaves room. Episode 5 (separation 2; 3 min): mother leaves the room and the child is left alone. Episode 6 (child-stranger; 3 min): the stranger enters the room; does not initiate play or conversation. Episode 7 (reunion 2; 5 min): the stranger leaves the room while mother re-enters and engages with her child. Mothers did not observe the child when not in the room. Two graduate students and one expert coder classified children from videotapes of the SSP by using Cassidy and Marvin's (1992) preschool-age coding system. The expert coder was employed to determine initial reliability and also classified 3 difficult cases to ensure accuracy. Biweekly meetings were convened to counter drift. Intraclass correlation coefficients (Cicchetti, 1994) revealed excellent agreement on primary attachment classifications (.80) from a random sample of 28 (20%) double-coded tapes. Results indicated 63 (44%) children were classified as secure, 23 (16%) as insecure–avoidant, 15 (11%) as insecure–resistant, and 41 (29%) as insecure–disorganized (N = 23) or insecure–other (N = 18).

Mother and Child RSA—At the beginning of the laboratory visit, mothers' and children's cardiac physiology was monitored during a 5-min neutral children's video and during the SSP. Three electrodes were placed in a modified Lead II placement on the child and mother. Data were acquired via Mindware© (Gahanna, OH) ambulatory ECG MW 1000A and sampled at 500HZ. Data were transmitted through a wireless signal to a computer equipped with data acquisition software and monitored by a research assistant. HR data were processed offline using Mindware Technologies HRV 3.0.10 analysis program, and trained research assistants visually inspected the data. Erroneously identified, or missing heart beats were manually deleted or inserted as appropriate. The resulting inter-beat interval time series was subjected to a fast-Fourier transformation, and power in the respiratory frequency band was derived from the spectral density function. The RSA frequency bands were set between 0.24 to 1.04 for children and between 0.12 and 0.40 for mothers in the sample. RSA was calculated every 30 seconds. Then, the mean RSA of all 30-second epochs within each episode of the Strange Situation was used in subsequent analyses, resulting in 7 RSA scores each for mothers and children. Across 142 mother and child dyads, RSA data were unavailable for 12 children. The majority of children (N = 90) provided data for all 7 episodes. Similarly, 8 mothers were missing RSA data for all episodes and 91 provided data for all episodes. Data for 1 mother whose RSA values were >3 SDs below average were dropped from analysis.

Analytic Plan—Data analysis proceeded in two phases. In the first phase, we constructed two independent linear mixed effects models to predict child RSA and maternal RSA respectively. Measures of mother RSA and child RSA were collected repeatedly across the SSP. Mixed models were employed because they allow one to account for the dependencies created by nesting of repeated measures within dyads and within SSP episodes by incorporating the covariance structure for these dependencies into the model (Littell, Pendergast, & Natarajan, 2000). Moreover, mixed models employ maximum likelihood estimation, a state-of-the-art means of handling missing data (Schafer & Graham, 2002). For both child and maternal RSA, several candidate covariance structures were compared using Akaike's Information Criterion, the Bayesian Information Criterion, log-likelihood comparisons, and covariance plots to identify the structure that best fit the data.[93] After identifying the best fitting covariance structure, the following covariates were entered as main effects in the models: minority status, child gender, household income, maltreatment status, child age. Non-significant covariates were trimmed from the models before entering the attachment group variable, SSP episode, and an interaction term for the relationship between attachment group and SSP episode. These terms were categorical, given our interest in examining within-person changes in RSA associated with the distinct challenges of each SSP episode. Therefore, the intercept for each model reflects RSA of the secure group in SSP episode 1 and other model estimates reflect the difference from this intercept as a function of the predictor. Non-significant interaction terms were dropped from the models in a backward trimming approach to arrive at a final, parsimonious model for both child and mother RSA. Models were constructed using restricted maximum likelihood and the Kenward-Roger correction was applied for more robust standard errors (Arnau, Bono, & Vallejo, 2009). Pseudo R^2 statistics (percent variance explained) were calculated by subtracting the residual variance for models with predictors included relative to models with no predictors.

In the second phase of analyses, we extended the models to examine concordance between maternal and child RSA in relation to attachment status and SSP episode. Using child RSA as a dependent variable, we included a between-person centered variable representing the mother's average RSA relative to the mean RSA of all mothers in the sample. In the same model, we also included a within-person centered variable to describe episode-to-episode fluctuations in a mother's RSA relative to her own mean (Hoffman, 2007). A similar model was then constructed with maternal RSA as the dependent variable and child between- and within-person RSA as predictors.

RESULTS

Change in Child RSA

Table 1 presents the means and standard deviations of RSA for mothers and children during the 7 SSP episodes. Comparisons of candidate covariance structures showed that child RSA was best modeled using a random intercept to reflect general individual differences in RSA in SSP episode 1 and an autoregressive covariance structure to reflect relatively stronger correlations between SSP episodes that were closer together in time (Littell, Miliken, Stroup, Wolfinger, & Schabenberger, 2006). None of the tested covariates were significant, so all except child age were dropped from the final model as presented. Table 2 shows estimates for the final child RSA model. As shown, while there were no main effects of SSP episode or attachment group, there were significant interactions between attachment group and SSP episode. Contrasts of mean levels of RSA were used to probe significant interactions evident for the avoidant group in Episode 3 and the resistant group in Episode 5 to determine the way in which these two significant effects differed from the mean of the other groups or from other episodes. As illustrated in Figure 1, children in the avoidant attachment group showed higher RSA relative to the mean of all the other groups when they were left alone with a stranger in Episode 3, γ(SE) = .99 (.33), $p = .003$. A similar effect was evident when children were again left with the stranger in Episode 6 such that the avoidant group showed higher RSA, relative only to the resistant group in this episode, γ(SE) = .95 (.48), $p = .049$. The resistant group showed significant decreases in RSA over time (Episodes 1 and 2 vs. Episodes 5 and 6, γ(SE) = −.85 (.41), $p = .03$). Model predictors explained 1.4% of the variance in child RSA.

Change in Maternal RSA

Next, changes in maternal RSA during the course of the SSP were examined. The best fitting unconditional model for maternal RSA included a random intercept and an antedependent covariance matrix. Minority ethnicity, household income, and child maltreatment status were not significantly related to maternal RSA and were dropped from the model. Unlike the models for child RSA, there was no significant attachment group by SSP episode interaction, nor was there a main effect of attachment status. There was, however, a significant main effect of episode, $F(6, 171) = 10.72$, $p <.001$ (see Table 3). As illustrated in Figure 2, mothers showed significantly lower RSA during Episodes 3, 5, and 6, when they were separated from their children. The model explained 14% of the variance in maternal RSA.

Concordance of RSA in Mother–Child Dyads

Within-person fluctuations in maternal RSA did not predict changes in child RSA during the course of the SSP, although there was a main effect of between-mother variation in average RSA. Specifically, higher maternal RSA correlated with higher child RSA in general, regardless of SSP episode or attachment status, γ(SE) = .21(.09), $p = .03$. Likewise, within-child fluctuations did not predict changes in maternal RSA during the course of the SSP, providing no support for dyadic concordance in RSA associated with the SSP. There was, however, an interaction between attachment status and the between-person variation in child RSA, $F(3, 115) = 2.43$, $p = .03$, whereby mothers and children in the insecure–resistant group generally had a higher correlation in average RSA relative to dyads in the other attachment groups, $\gamma(SE) = .61 (.29)$, $p = .04$. Figure 3 illustrates the varying levels of correlation between maternal and child RSA in each of the attachment groups, particularly the significant correlation between maternal and child RSA in the resistant group.

DISCUSSION

We examined attachment-related change in children's and mother's RSA during the preschool SSP. This is the first study to examine these relations in the SSP with mother–preschooler dyads, and it extends previous work with infants (Hill- Soderlund et al., 2008) and preschool children (Oosterman & Schuengel, 2007) by using a more at-risk sample, thus affording greater variation in attachment classification and increasing the clinical relevance of the findings. Understanding the factors that contribute to individual differences in physiological regulation could illuminate intervention targets to prevent maladjustment and psychiatric conditions (Izard, 2002; Southam-Gerow & Kendall, 2002).

Contrary to previous research grounded in Porges' (2007) polyvagal theory, children classified as securely attached showed no significant pattern of RSA change over time in the secure group during the SSP. Previous research has shown secure children's behavioral coping strategies, expressed through positive social engagement that uses the mother as a secure base (Bowlby, 1998; Crugnola et al., 2011), to be mirrored in an underlying physiology of greater infant and child RSA (Bazhenova et al., 2001; Skowron et al., 2011), yet we did not find such an effect. Similarly, we did not find that secure children show RSA withdrawal when separated and RSA augmentation upon reunion.

In contrast to secure children, the insecure–resistant children showed a pattern of RSA withdrawal over time, indicating decreasing parasympathetic tone as the SSP unfolded. Given that insecure–resistant children are characterized by high levels of behavioral distress upon reunion and low levels of positive engagement with the mother (Braungart-Rieker, Garwood, & Stifter, 1997; Crugnola et al., 2011), these results are consistent with the notion that they experience hyperarousal in response to stress and are not easily soothed (Bazhenova et al., 2001).

Insecure–avoidant children showed a steep increase in RSA during the first separation of the SSP while with the stranger, and augmentation again during the second separation from mother. Together, the RSA augmentation pattern suggests that avoidant children may be attempting to self-soothe or emotionally regulate while the mother is absent whether in the novel social context with a stranger or alone. However, it is unclear yet whether these RSA increases during maternal separations are associated with adaptive or maladaptive outcomes for avoidant children. Other research indicates that insecure–avoidant children display higher RSA compared with other groups during the SSP (Burgess et al., 2003). It could be that for this group, RSA augmentation may reflect an adaptive response to finding oneself alone or with an unfamiliar adult, relative to being with a mother who may be experienced as unengaged. Such an interpretation would be consistent with other behavioral observations of insecure–avoidant children in the SSP (Braungart & Stifter, 1991), though more research is needed to better understand the nature of this augmentation.

Disorganized preschoolers showed relatively flat RSA profiles that were not significantly different from the profiles for secure children. This finding was somewhat surprising given the odd behaviors of disorganized preschoolers typically observed during the SSP (e.g., controlling the mother) and evidence from meta-analysis linking disorganized attachment and heightened risk for psychopathology compared with other attachment groups (van IJzendoorn, Schuengel, & Bakermans-Kranenburg, 1999). It stands to reason that the SSP should be experienced as stressful for disorganized preschool children, as evidenced by their unusual behavior. However, their parasympathetic response appears blunted or flat. This finding is interesting in light of our observations that physically abusive and neglectful parents show a similar, blunted RSA response and less predictable behavior while interacting with their preschooler in a joint challenge task, relative to nonmaltreating parents (Skowron et al., 2013). Perhaps disorganized children attempt to maintain a steady physiological state during the SSP, resulting in little RSA variation across episodes, results in compromised social behavior, as is observed in physically abusive parents (Skowron et al., 2013). Further research that includes simultaneous examination of RSA and microsocial coding of behavior during the SSP using intensive, repeated measures design may help us understand patterns of biobehavioral responding in disorganized children during the SSP. Given that infants with disorganized attachment tend to show cortisol elevations during the SSP (Hertsgaard, Gunnar, Erickson, & Nachmias, 1995; Spangler & Grossmann, 1993), future research also is needed to examine change in RSA as well as preejection period and measures of cortisol reactivity to clarify the physiological effects of exposure to very high and prolonged stress levels—a distinguishing experience of disorganized children.

Consistent with our hypotheses and previous research (Hill- Soderlund et al., 2008; Mills-Koonce et al., 2007), maternal RSA withdrawal occurred during episodes of separation for all mothers, regardless of child attachment classification. This indicates that even though the SSP is not explicitly intended to distress the mother, separation from their young child is challenging for mothers of preschoolers. Contrary to the findings of Hill-Soderlund et al., (2008) no attachment-related differences in maternal RSA emerged.

Last, higher maternal RSA generally was associated with higher concurrent child RSA for all attachment groups, suggesting some mutual parent and child sensitivity to one another's physiological states. This relationship was strongest in the insecure–resistant group; levels of RSA concordance across the insecure–avoidant, disorganized, and secure groups did not differ from one another. The strong positive correlation for insecure–resistant mother–child dyads is consistent with Zelenko et al.'s findings (2005), and relative to other groups, may reflect the hyperactivating regulation strategies associated with resistance (Cassidy, 1994), which suggests that both mothers and children in resistant dyads are overly attuned to one another in a maladaptive manner. In sum, our study replicated the findings of Hill-Soderlund et al. (2008) with respect to dyadic concordance.

Conclusions and Implications

Our study results indicate that RSA patterns reflect the emotional and behavioral regulation strategies associated with each of the attachment classifications; specifically, the deactivating strategies of insecure–avoidant children, the hyperactivation and overattunement to the attachment figure of insecure–resistant children, and the blunted PNS response of disorganized children. However, effect sizes were small and further inquiry is needed. Despite the significant step forward that this study represents in the literature through examining RSA differences by attachment classification across the four groups and across all seven episodes of the SSP, we had limited power to detect effects, and increased likelihood of Type II error. For this reason, and because so little is known about physiological differences by attachment classification and SSP episode, we elected to probe interactions at the standard alpha level without adjustment (e.g., Bonferroni correction). Larger samples, particularly with children classified as insecure–resistant and disorganized, with multiple physiological indices of arousal and regulation will be necessary in the next stages of this research. Unquestionably, the attachment relationship is critical to children's development of effective biobehavioral coping strategies. Early intervention programs that increase maternal sensitivity and children's attachment security effectively improves parent–child relationship dynamics and reduces children's problem behaviors (Bakermans-Kranenburg, van IJzendoorn, & Juffer, 2003; Van Zeijl et al., 2006). Translational research bridging basic physiological findings with intervention is needed to better understand the ways in which parenting and relational factors can be altered in the service of change.

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Highlights

- We examined attachment-related differences in RSA in mothers and preschoolers.
- RSA was relatively flat over time for secure and disorganized children.
- Insecure–avoidant children showed increases in RSA during first separation.
- Insecure–avoidant children showed declining RSA over time.
- Results are consistent with theory and significantly advance previous research.

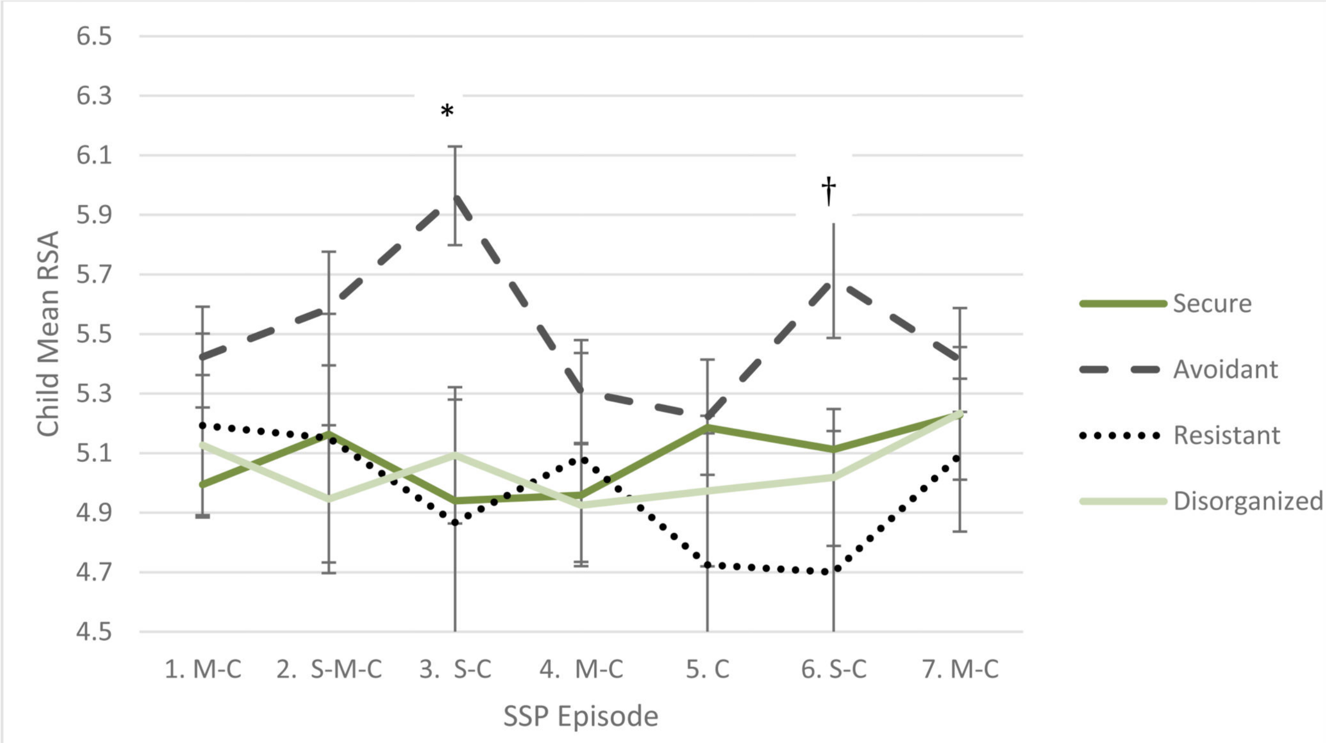

Figure 1. Mean child RSA during the Strange Situation procedure as a function of attachment status

Notes. Error bars show the standard error of the mean. Strange Situation Procedure (SSP) episode labels: M = Mother; C = Child; S = Stranger. * insecure–avoidant vs. secure, insecure–resistant, and insecure–disorganized groups, respectively, $p < .05$. † insecure–avoidant vs. insecure–resistant group, $p < .05$.

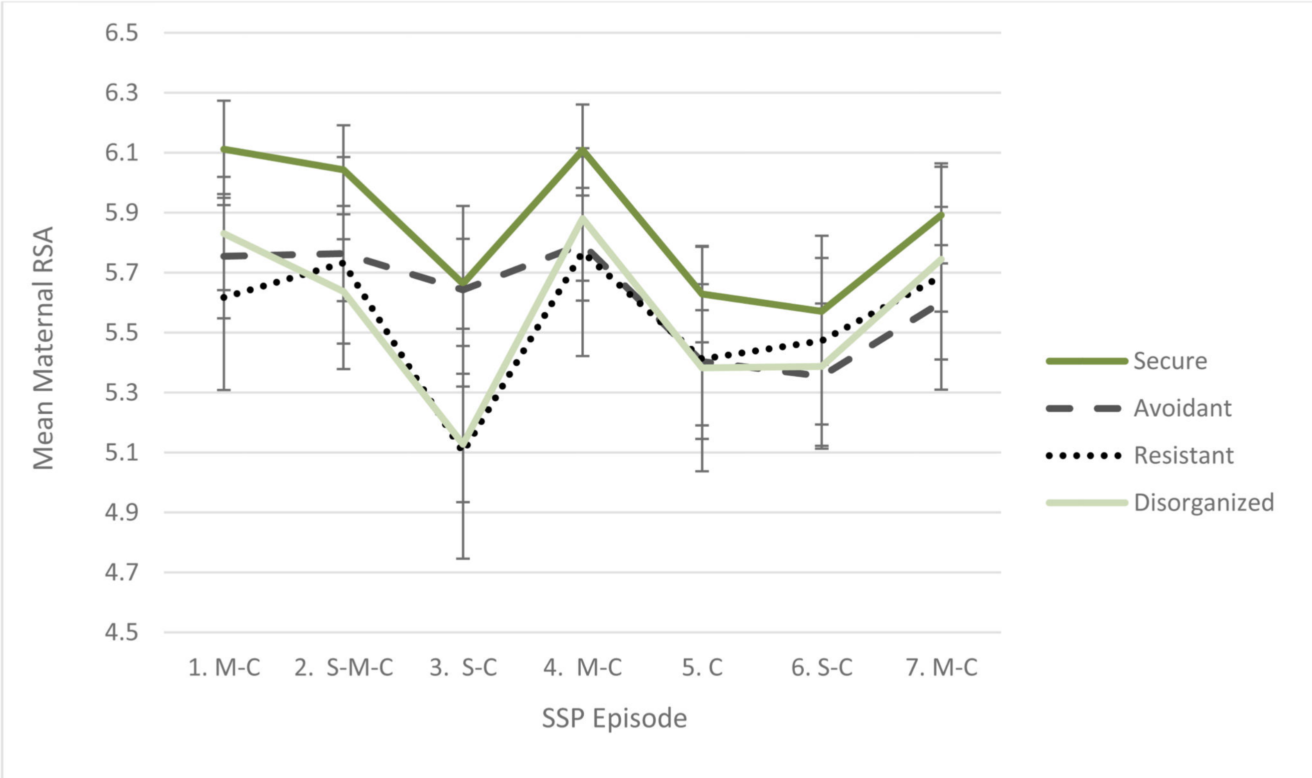

Figure 2. Mean maternal RSA during the Strange Situation Procedure as a function of child attachment status

Notes. Error bars show the standard error of the mean. Strange Situation Procedure (SSP) episode labels: M = Mother; C = Child; S = Stranger.

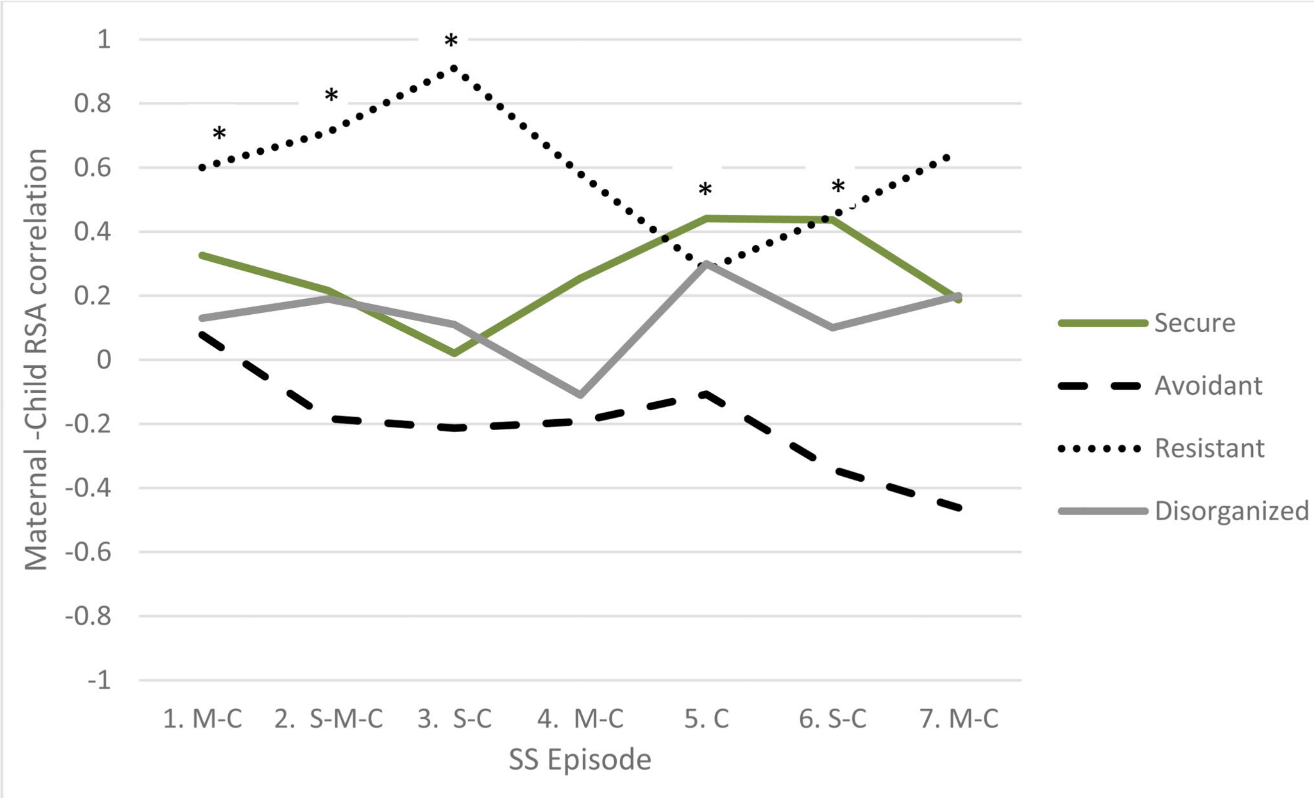

Figure 3. Correlations between maternal and child RSA during the Strange Situation procedure

Notes. Strange Situation Procedure (SSP) episode labels: M = Mother; C = Child; S = Stranger. *Significant correlation between maternal and child RSA, $p < .05$.

Table 1

Mean RSA Values for Preschool Children and Their Mothers During the Strange Situation Procedure

	Child RSA (N = 130)								Maternal RSA (N = 134)							
	Secure (n = 58)		Insecure–Avoidant (n = 19)		Insecure–Resistant (n = 13)		Insecure–Disorganized/Other (n = 40)		Secure (n = 58)		Insecure–Avoidant (n = 19)		Insecure–Resistant (n = 15)		Insecure–Disorganized/Other (n =40)	
Episode	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**
1	4.99	1.24	5.42	1.58	5.19	1.11	5.13	1.15	6.11	1.26	5.75	0.88	5.98	1.15	5.83	1.35
2	5.16	1.40	5.59	1.48	5.15	1.45	4.95	1.07	6.04	1.14	5.76	0.67	6.14	1.28	5.64	1.45
3	4.94	1.21	5.96	1.70	4.88	1.49	5.09	1.17	5.66	1.12	5.64	1.15	5.83	1.28	5.13	1.31
4	4.96	1.22	5.31	1.53	5.09	1.21	4.93	1.30	6.11	1.12	5.79	0.75	5.93	1.25	5.88	1.21
5	5.19	1.38	5.22	1.31	4.72	1.47	4.97	1.07	5.63	1.18	5.40	0.97	5.69	1.30	5.38	1.45
6	5.11	1.38	5.68	1.39	4.70	1.50	5.02	1.13	5.57	1.31	5.35	0.91	6.32	1.16	5.39	1.34
7	5.23	1.26	5.41	1.38	5.09	0.81	5.23	1.05	5.89	1.17	5.60	0.71	5.92	1.13	5.74	1.34

Table 2

Change in Child RSA During the Strange Situation Procedure as a Function of Attachment Status

	Estimate (SE)
Fixed Effects	
Intercept - Secure status group at SSP interval 1	4.822*** (.558)
Age	.053 (.137)
Insecure–avoidant status	.396 (.341)
Insecure–resistant status	.178 (.397)
Insecure–disorganized/other	.099 (.268)
SSP Episode 2 (stranger, mother & child)	.107 (.113)
SSP Episode 3 (stranger with child)	.007 (.121)
SSP Episode 4 (mother with child)	−.082 (.124)
SSP Episode 5 (child alone)	.105 (.124)
SSP Episode 6 (stranger with child)	.078 (.125)
SSP Episode 7 (mother with child)	.191 (.124)
Insecure–avoidant × SSP Episode 2	.124 (.223)
Insecure–avoidant × SSP Episode 3	**.535* (.236)**
Insecure–avoidant × SSP Episode 4	.037 (.242)
Insecure–avoidant × SSP Episode 5	−.208 (.252)
Insecure–avoidant × SSP Episode 6	.264 (.250)
Insecure–avoidant × SSP Episode 7	−.013 (.253)
Insecure–resistant × SSP Episode 2	−.130 (.260)
Insecure–resistant × SSP Episode 3	−.332 (.273)
Insecure–resistant × SSP Episode 4	−.071 (.282)
Insecure–resistant × SSP Episode 5	**−.590* (.290)**
Insecure–resistant × SSP Episode 6	−.469 (.296)
Insecure–resistant × SSP Episode 7	−.434 (.296)
Insecure–disorganized/other × SSP Episode 2	−.238 (.178)
Insecure–disorganized/other × SSP Episode 3	−.114 (.190)
Insecure–disorganized/other × SSP Episode 4	−.070 (.193)
Insecure–disorganized/other × SSP Episode 5	−.153 (.198)
Insecure–disorganized/other × SSP Episode 6	−.122 (.196)
Insecure–disorganized/other × SSP Episode 7	−.063 (.194)
Random Effects	
Intercept	1.26 *** (.170)
Fit statistics	
−2 Log likelihood	1928.9
AIC	1934.9
BIC	1943.7

Note.

BIC = Bayesian Information Criterion. AIC = Akaike Information Criterion. Estimates reflect the change in RSA associated with the predictor relative to the secure attachment group in episode 1. For example, each 1 year increase in child age predicts a .05 point increase in child RSA.

* $p < .05$,

** $p < .01$,

*** $p < .001$.

Table 3

Change in Maternal RSA During the Strange Situation Procedure as a Function of Child Attachment Status

Effect	Estimate (SE)
Fixed effects	
Intercept	7.222*** (.495)
Insecure–avoidant status	−.290 (.279)
Insecure–resistant status	−.535 (.307)
Insecure–disorganized/other status	−.276 (.216)
SSP Episode 2 (stranger, mother & child)	−.072 (.059)
SSP Episode 3 (stranger with child)	−.474*** (.077)
SSP Episode 4 (mother with child)	.045 (.061)
SSP Episode 5 (child alone)	−.455*** (.071)
SSP Episode 6 (stranger with child)	−.462*** (.077)
SSP Episode 7 (mother with child)	−.151 (.071)
Random effects	
Intercept	1.054*** (.138)
Fit statistics	
−2 LL	1783.9
AIC	1801.9
BIC	1828.5

Note.

* $p <.05$,

** $p <.01$,

*** $p <.001$