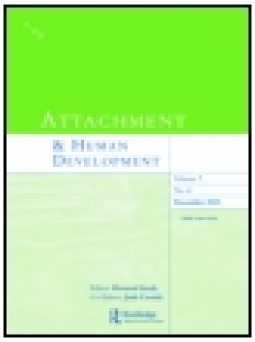

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Attachment security in infancy predicts reduced parasympathetic reactivity in middle childhood

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ABSTRACT

Children with histories of secure attachments during infancy are expected to develop healthier patterns of physiological activity at rest and in response to a stressor than children with insecure attachments. The present study examined longitudinal associations between infant attachment security and children's respiratory sinus arrhythmia (RSA) at rest and in response to a frustration task at age 9. The study focused on a sample of children referred from Child Protective Services (*N* = 97). RSA reflects the regulation of the parasympathetic branch of the autonomic nervous system, is sensitive to environmental influences, and is associated with emotion regulation. Children with histories of secure attachments during infancy exhibited less RSA withdrawal during a frustration task than children with histories of insecure attachments. Attachment security was not significantly associated with baseline RSA. Results suggest that mitigating parasympathetic reactivity during frustrating situations may be one avenue by which infant attachment security promotes emotion regulation.

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Attachment; parasympathetic nervous system; longitudinal; RSA; psychophysiology

Children's early attachment relationships are thought to provide the foundation for their developing emotion regulation abilities (Sroufe, 1996; Thompson & Meyer, 2014). When distressed, children who are securely attached to their parents seek proximity to and are easily soothed by their parents (Ainsworth et al., 1978). In contrast, children who are insecurely attached may not seek their parents despite being distressed or may be difficult to soothe (Ainsworth et al., 1978). Attachment security during infancy may also contribute to children's physiological responses to challenges, including children's parasympathetic nervous system (PNS) responses (Diamond, 2015; Groh & Narayan, 2019). In addition, the activity of the PNS is thought to have important implications for children's emotion regulation abilities (Beauchaine, 2015). Thus, secure attachment in infancy help promote the development of emotion regulation by way of promoting healthy parasympathetic activity. In order to improve our understanding of this pathway, the present study examined the longitudinal associations between attachment security in infancy and parasympathetic activity at rest and in response

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to a frustration task in middle childhood among a sample of children at high risk for emotion dysregulation due to their involvement with Child Protective Services during infancy.

Respiratory sinus arrhythmia

Respiratory sinus arrhythmia (RSA[1]) is a measure of the increases and decreases in heart rate during respiratory inspiration and expiration and is a validated index of parasympathetic control of cardiac activity (Porges, 2007). Specifically, the PNS serves as a cardiac pacemaker by either allowing or inhibiting the sympathetic innervation of the sinoatrial node (Beauchaine, 2001). Several theories have proposed that RSA activity is also an indicator of emotion regulation (Beauchaine, 2015; Beauchaine & Thayer, 2015; Porges et al., 1996). For example, baseline RSA activity is thought to reflect the individual's capacity for flexibly responding to the environment (Beauchaine, 2001; Grossman & Taylor, 2007; Holzman & Bridgett, 2017; Propper & Moore, 2006). Indeed, a high level of RSA while at rest is associated with competent emotion regulation skills and low risk for psychopathology in school-age children, adolescents, and adults (Beauchaine, 2001, 2015; Beauchaine & Thayer, 2015; Eisenberg et al., 1995).

RSA typically decreases or withdraws in response to environmental challenges, as this allows for an increase in sympathetic arousal and the fight-or-flight response (Porges, 2011; Porges et al., 1996). In low-risk samples, high RSA reactivity to challenge is thought to be protective, and high RSA reactivity in such samples has been observed to moderate relations between exposure to marital conflict and internalizing problems in middle childhood and adolescence (El-Sheikh & Whitson, 2006; Khurshid et al., 2019). Although relatively high levels of withdrawal may be adaptive in some circumstances, a high or excessive degree of RSA withdrawal in response to challenge has also been associated with emotion dysregulation and psychopathology for children and adults (Beauchaine, 2015), particularly externalizing behavior problems (at least among adults; Beauchaine et al., 2019). High RSA reactivity may be especially problematic among children at risk for dysregulation, as an association between high RSA withdrawal and problematic emotion regulation strategies has been observed among youth exposed to adversity (Calkins et al., 2007; Obradović et al., 2010; Skowron et al., 2014).

Early adversity and RSA

Children who experience early adversity such as maltreatment are at risk for physiological and behavioral dysregulation (Cicchetti & Olsen, 1990). Previous work has demonstrated that maltreated preschoolers exhibit lower resting RSA and physically abused children exhibit greater RSA reactivity during a parent-child interaction task than non-maltreated children (Skowron et al., 2011). Healthy parasympathetic regulation (i.e. high resting RSA and low-to-moderate RSA reactivity) can serve as a protective factor for children who experience early adversity (Beauchaine, 2015); thus, identifying factors that may facilitate the development of healthy PNS functioning among children with histories of early adversity is critical.

Attachment and RSA

Attachment theory suggests that children first develop regulatory skills and strategies in the context of the infant-parent attachment relationship (Cassidy, 1994). These initial strategies serve the goal of maximizing young children's proximity to their attachment figures when they are distressed (Cassidy, 1994). Indeed, infants are heavily dependent on their parents to regulate their emotions and physiological arousal because their capacities for self-regulation have not yet fully developed (Kopp, 1982). Children who are securely attached, by definition, seek proximity with their parents when distressed and are easily soothed by their parents (Ainsworth et al., 1978). Thus, securely attached children are expected to regularly experience autonomic reactivity and effective recovery, which provides the foundation for developing competent physiological self-regulation skills later in development (Sroufe, 1996).

On the other hand, children who are insecurely attached avoid contact with their parents when distressed (i.e., avoidant attachment), are not easily comforted by their parents (i.e., resistant attachment), or show confusion and disorganization (i.e., disorganized attachment) in their attachment behaviors (Ainsworth et al., 1978; Main & Solomon, 1990). As a result, insecurely attached infants are expected to experience prolonged autonomic activation without recovery in stressful environments (Sroufe, 1996). This pattern of physiological hyper-reactivity and ongoing activation may be adaptive in the short term, as it quickly prepares the young child to respond to potential threats in the environment. However, such excessive autonomic activation is thought to contribute to a host of negative mental and physical health outcomes later in development (Beauchaine, 2015; Cohen et al., 2007; Shonkoff & Garner, 2011).

A growing body of literature has examined the associations between children's attachment quality and RSA activity at rest and in response to emotionally challenging events. With regard to RSA at rest, findings are mixed. For example, in infancy, some studies find that attachment security is associated with low resting RSA concurrently (e.g., Izard et al., 1991), whereas others do not detect an association (e.g., Calkins & Fox, 1992). There have been few longitudinal studies that have examined the association between infant attachment patterns and RSA activity later in development. One rare exception is Burgess et al.'s (2003) study which indicated that children who formed avoidant attachments in infancy counter-intuitively exhibited *higher* resting RSA at age 4 than children who had formed secure or resistant attachments in infancy. Consistent with the mixed findings reviewed here, a recent meta-analysis indicated that attachment security was not significantly related to resting RSA in infancy and early childhood (Groh & Narayan, 2019).

Other research has focused on concurrent associations between attachment and resting RSA during later developmental periods. For example, self-reported attachment security has been reported to be positively associated with resting RSA levels during middle childhood and adulthood (Abtahi & Kerns, 2017; Diamond & Hicks, 2005). This set of findings raises the possibility that infant attachment security may predict baseline RSA levels later in life, perhaps beginning in middle childhood. However, these cross-sectional studies have relied on self-report measures of attachment, which are related but distinct from the classifications of attachment behavior observed during infancy. More longitudinal work is needed to determine whether infant attachment security does in fact predict baseline levels of RSA during later developmental periods.

With regard to RSA reactivity, several studies have demonstrated that secure attachment during infancy and early childhood is concurrently associated with reduced RSA reactivity during parent separation reunion tasks. For example, in a sample of low-risk infants, securely attached infants exhibited less RSA reactivity and more RSA recovery during the Strange Situation than insecurely attached infants (Hill-Soderlund et al., 2008). In a similar study with a high-risk sample, securely attached children exhibited minimal RSA reactivity during the Strange Situation, whereas insecure-avoidant children exhibited RSA augmentation (RSA increases from baseline) and insecure-resistant children exhibited prolonged RSA withdrawal (Smith et al., 2016). Although a significant association has not emerged between attachment quality and RSA reactivity during the Strange Situation in several studies (Oosterman & Schuengel, 2007; Stevenson-Hinde & Marshall, 1999), meta-analytic findings indicate there is a significant effect of infant attachment security on RSA change from baseline to reunion episodes of the Strange Situation (Groh & Narayan, 2019). Specifically, infants classified as insecure exhibited greater RSA decreases from baseline to reunion than infants classified as secure (Groh & Narayan, 2019).

To our knowledge, no study to date has examined infant attachment security as a predictor of RSA reactivity later in development. In addition, the results of studies examining the concurrent association between attachment security and RSA reactivity during other types of stressors or at later ages are inconsistent. For example, Paret et al. (2015) reported that preschool-aged children who were securely attached exhibited reduced RSA withdrawal during a social stress task than insecurely attached children. However, Abtahi and Kerns (2017) reported that children classified as secure (using a story stem task) in middle childhood did not exhibit RSA reactivity to a social stressor. RSA reactivity is known to be highly dependent on measurement context, and RSA reactivity measured in negatively valenced emotional contexts is thought to be particularly informative about broader emotional functioning (Beauchaine, 2015; Beauchaine et al., 2019). In addition, whereas individual differences in resting RSA seem to become relatively stable within the first six months of life, RSA reactivity patterns continue to develop and are not thought to stabilize until early to middle childhood (Quigley & Moore, 2018). Longitudinal work using negatively valenced, emotionally evocative tasks is necessary to understand the long-term implications of infant attachment security for children's autonomic regulation at later ages.

The present study

The present study tested the association between attachment security in infancy and RSA activity in middle childhood in a sample of children referred from Child Protective Services (CPS; i.e., at risk for maltreatment). This sample was part of a larger longitudinal study assessing the efficacy of a parenting intervention, Attachment and Biobehavioral Catch-up (ABC; Dozier & Bernard, 2019). Previous work with this sample indicated that receiving ABC in infancy was associated with higher RSA during a paced breathing task and a parent-child interaction task at age nine than receiving a control intervention (Tabachnick et al., 2019). Thus, although infant attachment security was considered the primary predictor of interest in the current study, intervention condition was also modeled as an important contextual variable. To our knowledge, this is the first longitudinal study to examine infant attachment security as a predictor of RSA in middle childhood. Further, few studies have examined associations between attachment and RSA among low-income and/or predominantly racial/ethnic minority samples (Groh & Narayan, 2019). We hypothesized that CPS-referred children with histories of secure attachments during infancy would exhibit higher resting RSA and less RSA withdrawal in a frustration task in middle childhood than children with histories of insecure attachments.

Method

Participants

Participants were 97 children (51.5% female) from a longitudinal study assessing the efficacy of a parenting intervention, Attachment and Biobehavioral Catch-up (ABC; Dozier & Bernard, 2019). When children were infants, families were referred to the study by CPS due to high risk for child maltreatment. About half of the children received the ABC intervention in infancy (n = 43) and about half of the children received a control intervention (n = 54). The ABC intervention is a 10-session home visiting program that focuses on increasing parental sensitivity and nurturance and decreasing parent frightening behaviors. The control intervention was a 10-session home visiting program focused on children's cognitive and motor development. Children's attachment security was assessed in a laboratory setting following the intervention, when children were approximately 20 months old (M = 20.16, SD = 6.24). When children were approximately nine years old (M = 9.45, SD = 0.35), autonomic nervous system data were recorded at rest and during a frustration task in a laboratory setting. All procedures were approved by the University of Delaware Institutional Review Board.

Due to missing data (described below), the analytic sample size included 85 children. Of these 85 children, 76 completed the 9-year-old lab visit with the same caregiver who received the initial intervention (two of whom were grandparents). Of the remaining nine children, four completed the visit with a different biological parent, two completed the visit with a biological grandparent, two completed the visit with an adoptive parent, and one completed the visit with a foster parent.

Based on parents' reports, most children were African American (66.9%) or multiracial (11.7%), and approximately one fifth were White (21.4%). In addition, about one fifth of the children were Hispanic (18.6%). At the time of the 9-year assessment, 35% of the parents had not completed high school, 51% had completed high school or received their GED, and 14% had completed at least some college. About half of the parents reported personal employment as a main source of income (47%), and all parents reported receiving additional financial support from family or government programs.

Procedures

Infant attachment security

When children were about 20 months old, the quality of their attachment to their parent was assessed using the Strange Situation procedure (Ainsworth et al., 1978). This video-recorded procedure includes two separations from and reunions with the parent. Children's attachment behaviors are assessed primarily during the reunion episodes. The total procedure lasts approximately 24 minutes.

Children who are classified as securely attached seek proximity to their parents and are easily soothed by their parents when they are distressed. Children who are not classified as securely attached may be categorized as having avoidant, resistant, or disorganized attachments. During reunion episodes, children with an avoidant attachment do not seek proximity to their parents when distressed and may turn away from their parents. Children with a resistant attachment are unable to be soothed by their parents when distressed and exhibit a combination of proximity seeking and resistance behaviors. Children with a disorganized attachment demonstrate a breakdown in strategy for organizing their attachment behaviors during the reunion episodes (e.g., disoriented wandering, contradictory behaviors, freezing; Main & Solomon, 1990).

One third of the videos were double coded for reliability (k =.76), and disagreements were resolved by conference. For the present study, a dichotomous attachment security variable was created by scoring infants with a secure attachment classification as 1, and scoring infants with avoidant, resistant, or disorganized attachment classifications as 0. Attachment security was selected as a predictor of interest rather than attachment organization because security is associated with consistently experiencing soothing, sensitive caregiving (Ainsworth et al., 1978) and thus physiological recovery, whereas the avoidant, resistant, and disorganized classifications are expected to be associated with prolonged physiological distress during the Strange Situation (Groh & Narayan, 2019) . Seventeen children were missing infant attachment security data, but missingness was not related to intervention condition ($\chi^2(1, N = 97) = .00, p = .99$). In the present sample, 47.5% of children were classified as securely attached to their parents.

Frustration task

When children were nine years old, their autonomic nervous system data were continuously recorded in a laboratory setting while completing the Impossibly Perfect Circles task, a standardized and widely used task designed to elicit child frustration or negative emotion by attempts to complete an impossible task (Goldsmith et al., 1999). First, each child completed a two-minute resting baseline during which they viewed a nature image accompanied by nature sounds. Next, the frustration task began. For 3.5 minutes, a research assistant gave the child one paper maze at a time and asked them to complete it perfectly. After the child completed each maze, the research assistant critiqued their maze in a neutral tone (e.g., "That one is too crooked. Try another one."). The research assistant then exited the room and left the child alone for one minute. The child was left with a stack of mazes so that he or she could continue trying to complete the perfect maze while alone. After one minute, a second research assistant joined the child and administered a brief interview about the child's emotional responses to the task. Interviews typically lasted about one minute. Altogether, each segment of this task required that the child continue working towards completing a perfect maze. The child was not released from task demands until the completion of the interview. At that time, the first research assistant re-entered the room, asked the child to complete one final maze, and then praised the child.

About one-third of the children were asked to complete perfect circles instead of perfect mazes. The task was changed from circles to mazes because the protocol was administered at the previous lab visit and children indicated that they remembered the task. Importantly, children who completed circles did not differ from those who completed mazes as a function of attachment security ($\chi^2(1, N = 70) = .07, p = .80$) or intervention condition ($\chi^2(1, N = 85) = .23, p = .63$). In addition, these same children completed a portion of an additional emotion regulation task (The Disappointing Gift; Cole, 1986) between the baseline and the frustration task. This portion of the task involved ranking a set of small toys and lasted about 2.5 minutes. Because this task was only conducted with a small subsample of participants, physiological data recorded during this task were not included in the analyses. As described below, task version was considered as a covariate because it was significantly associated with RSA during the challenge (see Table 1 for correlations).

Autonomic nervous system data collection, cleaning, and reduction

Software and hardware from the James Long Company were used for data acquisition, cleaning, and processing (James Long Company, Caroga Lake, NY, USA). RSA was calculated from heart rate and respiration data. Heart rate data were collected using two disposable electrocardiography (ECG) electrodes placed on the rib cage (one on the left and one on the right) and one grounding electrode placed on the chest (a bipolar configuration). Respiration data were collected using a pneumatic bellows belt fastened around the mid-section.

Data were collected at a sampling rate of 1,000 readings per second, using James Long Company equipment for amplification and digitization. Software provided by the James Long Company was used to process and clean ECG data for each subject. The software algorithm identified heartbeats, calculated interbeat intervals (IBIs) as the difference in milliseconds between the beats and identified IBIs with unusual values for visual verification or correction. Mis-identified heartbeats were manually corrected in the continuous ECG. Consistent with previous work with children in middle childhood (Woody et al., 2016), seven children's ECG data were excluded from analyses because 10% or more of the heart beats required manual correction. In addition, four children's data were missing due to experimenter error, and one child's data were excluded due to missing respiration data. As a result, the analytic sample size was 85. Children who were missing RSA data did not differ from the rest of the sample with respect to attachment security ($\chi^2(1, N = 97) = .54, p = .69$) or intervention group ($\chi^2(1, N = 97) = 1.09, p = .30$).

RSA was estimated using the peak-to-valley method, which quantifies the difference in IBIs during respiratory inspiration and expiration. Average RSA was calculated for each epoch of the frustration task, abbreviated as $RSA_{baseline}$, $RSA_{critique}$, RSA_{alone}, and $RSA_{interview}$. The skewness values for these four epochs were within or near acceptable limits (between 0.66 and 2.13). Because RSA values during the three challenge epochs were all significantly correlated (r's between .63 and .79; p's < .001; partial r's controlling for $RSA_{baseline}$ between .67 and .77), these epochs were averaged to create a composite score, $RSA_{challenge}$. The skewness of this variable was within acceptable limits (skewness statistic = 1.33). Finally, $RSA_{baseline}$ was subtracted from $RSA_{challenge}$ to calculate $RSA_{reactivity}$.

Covariates

Five individual difference variables were considered as potential covariates: child age, gender, race, ethnicity, and body mass index (BMI). Gender, race, and ethnicity were coded as dichotomous variables (Gender: Female = 1, Male = 0; Race: White = 1, non-

Table 1. Correlations of study variables and covariates.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Intervention condition	–													
2. Age	−.01	–												
3. Gender	.01	−.26*	–											
4. Race	−.07	.05	−.13	–										
5. Ethnicity	−.10	.03	.01	.29**	–									
6. BMI	.01	.21†	−.01	.07	−.04	–								
7. Task version	−.05	.08	.21†	.10	−.03	.07	–							
8. Attachment security	.15	−.07	.01	−.33**	−.11	−.23†	.09	–						
9. RSA – baseline	.16	−.02	.11	.03	.02	−.31**	.04	.03	–					
10. RSA – challenge	.15	.01	−.03	−.11	.15	−.13	.31**	.15	.36**	–				
11. RSA – reactivity	−.02	.02	−.13	−.12	.11	.18	.22*	.10	−.62**	.51**	–			
12. Respiration – baseline	−.12	−.03	.09	.16	−.12	−.03	−.00	.05	.25*	−.03	−.26*	–		
13. Respiration – challenge	−.11	−.15	.09	.06	.07	.06	.11	−.09	.14	.29**	.11	.39**	–	
14. Respiration – reactivity	.03	−.09	−.02	−.12	.17	.08	.09	−.13	−.13	.27*	.34**	−.67**	.42**	–

† p <.10; * p <.05; ** p <.01; *** p <.001.

For the Intervention condition variable, the Attachment and Biobehavioral Catch-up group was dummy coded as "1" and the control group was dummy coded as "0." For the Gender variable, male participants were dummy coded as "0" and female participants were dummy coded as "1." For the Race variable, White participants were dummy coded as "1" and all other participants were coded as "0." For the Ethnicity variable, Hispanic participants were dummy coded as "1" and non-Hispanic participants were dummy coded as "0." For the Task version variable, the earlier version of the task was dummy coded as "1" and the later version of the task was dummy coded as "0." For the Attachment security variable, children classified as secure were dummy coded as "1" and children classified as insecure were dummy coded as "0." BMI = Body mass index. RSA = Respiratory sinus arrhythmia.

White = 0; Ethnicity: Hispanic = 1, non-Hispanic = 0). Height and weight were measured by a research assistant during the 9-year laboratory visit, and BMI was calculated using the formula recommended by the Centers for Disease Control and Prevention (2014).

Plan of analysis

The associations between children's attachment classifications in infancy and their RSA at age 9 were examined using Mplus (Version 8.1). Attachment security was included as a predictor of $RSA_{baseline}$ and $RSA_{reactivity}$. Because the ABC intervention has been associated with infant attachment (Bernard et al., 2012) and with RSA during a parent-child interaction (Tabachnick et al., 2019), intervention condition was included as a predictor of attachment security and the two RSA variables. Respiration rate was also included as a covariate, because it is considered a potential confound when interpreting RSA values (Grossman & Taylor, 2007). $RSA_{baseline}$ was regressed on the average respiration rate during the baseline (measured in breaths per minute), and $RSA_{reactivity}$ was regressed on the difference in respiration from $RSA_{baseline}$ to $RSA_{challenge}$. Model fit was assessed using the chi-square test of model fit, the root mean square error of approximation (RMSEA), the comparative fit index (CFI), the Tucker-Lewis Index (TLI), and the standardized root mean square residual (SRMR). A model is considered to have close fit if the chi-square test is non-significant, if the RMSEA is less than .06, if the CFI and TLI are greater than or equal to .95, and if the SRMR is less than or equal to .08 (Hu & Bentler, 1999; Schreiber et al., 2006). Weighted least squares means and variance adjusted (WLSMV) estimation was used to handle missing infant attachment security data because it is considered a robust estimation technique for categorical data (DiStefano & Morgan, 2014).

Results

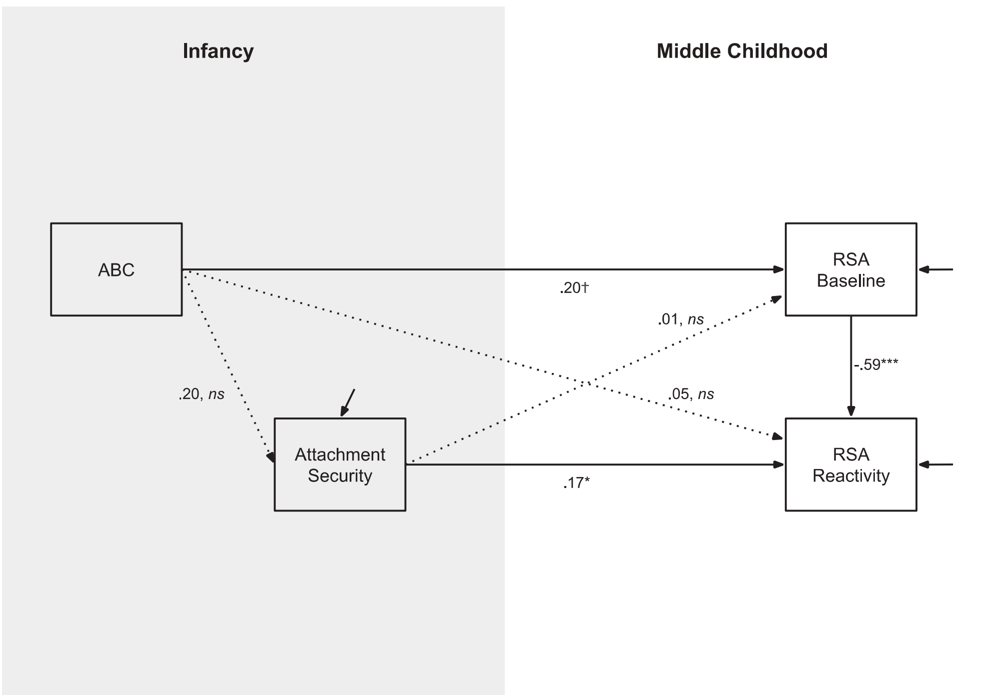
Descriptive statistics and preliminary analyses

On average, children's RSA significantly decreased from baseline ($RSA_{baseline}$: M = .13, SD = .06) to the challenge ($RSA_{challenge}$: M = .11, SD = .05; $t(84) = 3.08$, $p = .003$). Correlations of study variables are presented in Table 1. $RSA_{baseline}$ was correlated with $RSA_{challenge}$ ($r = .36$, $p = .001$), indicating that higher levels of RSA during the resting baseline were associated with higher RSA during the frustration task. In addition, $RSA_{baseline}$ was negatively correlated with $RSA_{reactivity}$ ($r = -.62$, $p < .001$), such that children with high levels of resting RSA exhibited a high degree of RSA withdrawal to the frustration task. The potential covariates of child age, gender, race, and ethnicity were not significantly associated with any of the RSA outcomes and therefore were not included in further analyses. Although BMI was significantly correlated with $RSA_{baseline}$ ($r = -.31$, $p = .006$) and task version was significantly correlated with $RSA_{reactivity}$ ($r = .22$, $p = .04$), including these variables in the regression analyses did not alter conclusions about the statistical significant of the results and so were not included in the results presented below.

Infant attachment security and RSA activity

The final model is presented in Figure 1. As described above, infant attachment security and the ABC intervention were considered the predictors of interest, and respiration was included as a covariate. Model fit was good, especially considering the relatively small sample size ($\chi^2(4, N = 85) = 2.94$, $p = .57$, RMSEA = .00 (90% confidence interval = .00, .14), CFI = 1.00, TLI = 1.07, SRMR = .14). The model accounted for 10% of the variance in $RSA_{baseline}$ ($R^2 = .098$) and 52% of the variance in $RSA_{reactivity}$ ($R^2 = .52$). Higher baseline RSA was associated with greater RSA withdrawal during the frustration task ($\beta = -.59$, $p < .001$). Respiration during baseline was positively associated with $RSA_{baseline}$ ($\beta = .27$, $p = .048$), and change in respiration from baseline to challenge was positively associated with $RSA_{reactivity}$ ($\beta = .30$, $p = .007$).

Infant attachment security was a significant predictor of $RSA_{reactivity}$ ($\beta = .17$, $p = .046$). Children who were securely attached in infancy exhibited reduced RSA withdrawal to the frustration task at age 9 relative to children who were insecurely attached in infancy. Infant attachment security was not significantly associated with $RSA_{baseline}$ ($\beta = .01$, $p = .95$). Intervention condition was a marginal predictor of $RSA_{baseline}$ ($\beta = .20$, $p = .07$),



Model fit: $\chi^2(4, N = 85) = 2.94$, $p = .57$, RMSEA = .00 (90% confidence interval = .00, .14), CFI = 1.00, TLI = 1.07, SRMR = .14.

Figure 1. When controlling for respiration (not pictured), infant attachment security predicts RSA reactivity. Standardized coefficients are presented. Respiration and RSA were measured concurrently at age 9.

Note: RMSEA = Root Mean Square Error of Approximation. CFI = Comparative Fit Index. TLI = Tucker-Lewis Index. SRMR = Standardized Root Mean Square Residual. RSA = Respiratory sinus arrhythmia. ABC = Attachment and Biobehavioral Catch-up. † p <.10; * p <.05; *** p <.001.

such that receiving ABC in infancy was associated with marginally higher resting RSA than receiving the control intervention. Intervention condition was not significantly associated with $RSA_{reactivity}$ (β = .05, *p* = .58) or with infant attachment security (β = .20, *p* = .17) in this subsample.

Discussion

The present study tested whether attachment security in infancy is longitudinally associated with RSA in middle childhood among an at-risk sample of CPS-referred children. Results indicated that children who were classified as securely attached in infancy exhibited significantly less RSA withdrawal to a frustration task in middle childhood than those classified as insecurely attached. Attachment security was not significantly associated with RSA levels while at rest.

The results from this study help advance our understanding of the potential long-term implications of infant attachment security for later physiological reactivity. Prior research indicated that infant attachment security is concurrently associated with less RSA withdrawal during parental separation-reunion tasks (Groh & Narayan, 2019). For example, infants and preschoolers with secure attachments often exhibit reduced RSA withdrawal to the Strange Situation relative to insecurely attached children (Smith et al., 2016). However, studies to date have been conducted primarily during infancy and early childhood, and often focus on RSA responses during separation-reunion tasks with parents. The findings from this study extend these results by demonstrating that, relative to insecure attachment, secure attachment also predicts less RSA withdrawal beyond early childhood and into middle childhood in a frustrating situation in which the parent was not immediately present. To our knowledge, the present study is the first to examine longitudinal associations between attachment security during infancy and RSA reactivity in middle childhood. The present study also extends previous work by demonstrating that infant attachment security may have implications for physiological regulation beyond attachment-relevant contexts.

Results support the notion that reduced RSA withdrawal to negatively valenced emotional events may be one mechanism by which attachment security promotes competent emotion regulation. Heightened RSA withdrawal during emotionally evocative tasks is associated with risk for emotion dysregulation and psychopathology (Beauchaine, 2015; Beauchaine & Thayer, 2015). In addition, in light of the heightened regulatory demands that result from experiencing maltreatment, it may be particularly important for children at risk for maltreatment to be able to recruit the parasympathetic nervous system to help them regulate (Zisner & Beauchaine, 2016). For maltreated children, who are at risk for the development of behavior problems, reduced RSA withdrawal during a frustrating event may facilitate the use of developmentally competent emotion regulation strategies and return to effective task engagement. In this way, reduced RSA withdrawal in the present study may represent "moderate" RSA reactivity that is theoretically linked to healthy emotion regulation (Beauchaine, 2015). Future research is needed to test this hypothesis.

It is plausible that children with histories of secure attachments, rather than insecure attachments, exhibit a healthier pattern of physiological regulation because their parents have consistently provided sensitive care, soothed them when they were distressed, and prevented prolonged autonomic activation (Quigley & Moore, 2018). It is also possible that low RSA withdrawal may support the development of a secure attachment in a high-risk population. Children who are less physiologically reactive to their environments may be less susceptible to negative developmental outcomes that are associated with high-risk environments (including insecure attachments) than children who are more physiologically reactive (Belsky & Pluess, 2009; Boyce & Ellis, 2005). Future research may investigate the causal direction of the association between attachment and RSA reactivity by including repeated measurements of RSA from infancy to childhood for children who vary in their exposure to risk.

The lack of a significant association between infant attachment security and resting RSA is consistent with recent meta-analytic findings focused on RSA activity during infancy (Groh & Narayan, 2019). Although a previous study reported a cross-sectional association between self-reported attachment security and higher resting RSA in middle childhood (Abtahi & Kerns, 2017), the present study measured attachment security with a different method (observational coding of the Strange Situation) during a different developmental period (infancy). That said, it may be that insecure-avoidant attachment and insecure-resistant attachment classifications have distinct effects on resting RSA, as has been previously observed in a longitudinal study from infancy to early childhood (Burgess et al., 2003). Thus, it is possible that effects of attachment security on resting RSA may by obscured by collapsing avoidant and resistant groups. It will be important for future studies to test the longitudinal association between attachment security in infancy and resting RSA later in development, and to collect a large enough sample to investigate potential differences between avoidant and resistant attachment.

The ABC intervention predicted marginally higher resting RSA than a control intervention. This result is consistent with a previous report demonstrating that the ABC intervention was associated with significantly higher resting RSA in this sample of children using a paced breathing baseline in the presence of a parent (Tabachnick et al., 2019). Experiencing pre-natal and post-natal adversity has been associated with lower resting RSA (Propper & Holochwost, 2013), but these findings suggest that the ABC intervention may compensate for the effect of early adversity on resting RSA in middle childhood.

The ABC intervention was not a significant predictor of RSA reactivity in the frustration task. It is unclear why the ABC intervention was not significantly related to RSA reactivity. The nonsignificant effect of the ABC intervention on attachment security in this subsample, despite previous findings reporting significant effects of the ABC intervention on attachment security in the larger sample (Bernard et al., 2012), suggests that the present study may be underpowered to detect potential indirect effects of the ABC intervention on RSA reactivity through attachment security.

One limitation of the current study is that it is not known whether the physiological patterns observed have meaningful implications for these children's emotion regulation abilities. Although reduced RSA withdrawal is likely protective due to the frequently observed associations between high RSA reactivity and externalizing psychopathology (see Beauchaine et al., 2019), future research is needed to test this hypothesis in this sample. In addition, the present study did not examine whether children's attachment security is related to the sympathetic influence over the heart, or cardiac impedance. Collecting these data in a future study would allow for a deeper understanding of how attachment security in infancy may affect PNS reactivity, sympathetic nervous system (SNS) reactivity, and children's cardiac autonomic balance (i.e., the relative influence of the PNS and SNS over the heart at rest; Quigley & Moore, 2018).

In addition, the longitudinal association between attachment quality and RSA reactivity should be assessed in a lower risk sample to determine whether associations are specific to a high-risk population. Further, detailed CPS referral information is not available for this sample, but future research investigating whether the consequences of infant attachment security for later RSA withdrawal depend on the type of maltreatment experienced (e.g., abuse vs. neglect) would be valuable. In addition, data are not available regarding children's exposure to maltreatment or potentially traumatic experiences in the years following the intervention, which may have important implications for children's physiological regulation and attachment to their parents. Finally, autonomic data are not available for this sample earlier in development, and so the timing of when these effects emerged is not clear.

There are several important strengths of the present study. The current study incorporated a well-validated observational assessment of infant attachment security and used a longitudinal design to predict parasympathetic regulation approximately eight years later. In addition, the present study measured RSA activity at rest and in a challenging context that is emotionally evocative and ecologically valid; children may experience similar critiques from an adult and frustration in the school setting. Context is particularly important when eliciting and interpreting RSA reactivity, and emotionally evocative tasks are ideal when researchers are interested in RSA as an index of emotion regulation (Zisner & Beauchaine, 2016). For example, externalizing behaviors are specifically linked to excessive RSA withdrawal in emotional tasks, but not in other types of tasks (Beauchaine, 2015).

Overall, results indicate that attachment security in infancy predicts reduced RSA reactivity to frustration in middle childhood among CPS-referred children. Interventions that promote attachment security in samples exposed to adversity may in turn encourage the development of healthy physiological regulation, which has important implications for physical and behavioral health.

Notes

1. For simplicity, the term RSA will be used consistently in the current paper, although some of the reviewed studies use the terms high-frequency heart rate variability or vagal tone instead of RSA.

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