Early Parasympathetic Activity Predicts Later Childhood Social Functioning as Mediated by Emotion Regulation

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Abstract

Theories of emotion regulation and social engagement indicate that resting and reactive respiratory sinus arrhythmia (RSA), which reflect vagal activity, in early childhood can inform the development of social and emotional behaviors later in life. Low RSA at baseline and during a stressful task have been associated with symptoms of ED and disorders characterized by social impairments. The current study examined the mediating role of ED at 24-months-old (mo) on the prospective association between early infant resting and reactive RSA at 5 mo on social functioning outcomes at 48 mo, and the mediating role of social functioning at 24 mo on infant RSA at 5 mo and ED at 48 mo in 237 healthy children. It was hypothesized that ED would mediate the relationship between infant RSA and later childhood social function. Results largely indicated no support of the hypotheses and that there is no mediating effect of childhood ED on early RSA on later childhood social behavior; however, there was a significant relationship between infant resting and reactive RSA and later ED. Limitations and future directions for improving the methodology are addressed.

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General Audience Abstract

Early childhood heart rate has been thought to influence the development of later child emotional and social development. The Polyvagal Theory suggests that low variability in heart rate, as measured by respiratory sinus arrhythmia (RSA), is related to greater difficulties in emotional and social behavior. Finding an underlying biological reason for emotional and social development can be important for understanding childhood psychological disorders. This research study examined healthy children at three different time points during development: 5 months old (mo), 24 mo, 48 mo. RSA was measured at 5 mo, and frustration levels and social abilities at 24 and 48 mo. It was hypothesized that low RSA at 5 mo predicts low social abilities at 48 mo because of high frustration levels at 24 mo. To rule out an alternate hypothesis, this study also tested if low RSA at 5 mo predicts high frustration levels at 48 mo because of low social abilities at 24 mo. The results of this study did not support the predictions and there was no evidence of emotional abilities affecting how RSA predicts later social abilities. Possible explanations for the lack of findings and ideas for future research were discussed.

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Introduction

Activity of the parasympathetic nervous system has been posited as an indicator of emotion regulation during dynamic tasks and implicated in a wide range of psychological disorders in childhood as well as social behavior (Appelhans & Luecken, 2006; Porges, 2003). The current study examined respiratory sinus arrhythmia (RSA), a measure of heart rate variability (HRV), in healthy, typically developing infants and whether emotion dysregulation mediates the prospective relationship of early RSA on later childhood social functioning.

Social and Emotional Functioning

The ability to interact with other children and adults is a critical part of healthy child development. The National Research Council (2000) states that early childhood social development influences outcomes well beyond childhood. The American Academy of Pediatrics (Hagan Jr. et al., 2017) recommends guidelines for promoting the health of infants, children and adolescents. An important component of optimal functioning is achieving developmental milestones related to social connections, competence, autonomy, empathy, and coping skills. Attainment of early life developmental skills is critical for lifelong learning and have been known to provide the best estimate of "readiness to learn" in early childhood (e.g., Denham, 2006; Scharf et al., 2016). Researchers who study at-risk children and families have found that healthy social development protects against negative exposure to risk and promotes resilience (Domitrovich et al., 2017). Furthermore, measuring social-emotional competence in children can be integral for developing interventions designed for promoting positive mental health (Carter et al., 2004).

Impairments in social functioning are key components of a range of childhood psychopathology (e.g., internalizing, neurodevelopmental, personality, externalizing).

Internalizing disorders are often referred to as emotional and behavior disorders and feature high levels of negative affect. Although social difficulties are not a core feature of internalizing disorders such as anxiety or depression, it is often a source of clinical impairment. In a sample of 2981 adults, those with anxiety and depressive disorders experienced social dysfunction and had residual social impairments even after remission of affective psychopathology (Saris et al., 2017). Moreover, in this study, prospective analyses indicated that perceived social impairment was predictive of clinical anxiety or depression two years later. Keenan-Miller and Miklowitz, (2011) conducted a review of studies of children with bipolar disorder (BD) and found that children with BD were more likely to have poor social skills, such as low social competence and high social withdrawal, and fewer friends compared to children with attention-deficit/hyperactivity disorder (ADHD) and typically-developing peers; additionally, the authors found that social impairments predict worse prognosis of children with BD (e.g., facial affect recognition). Personality disorders are long-term distinct patterns of pervasive behavior and thinking. The *International Statistical Classification of Diseases and Related Health Problems* (11^{th} ed; ICD-11; World Health Organization, 2018) considers interpersonal dysfunction, such as inability to understand other's perspective, difficulty in developing and maintaining relationships, and difficulty in managing conflict in relationships, that cause impaired patterns of emotional experience and expression as a main domain of impairment for personality disorders. Domes et al. (2009) conducted a review of emotion recognition in borderline personality disorder and suggested that impaired facial emotion recognition, such as not noticing subtle basic emotions, negativity bias, sensitivity to negative emotions, causes the impairment in interpersonal functioning.

Many neurodevelopmental disorders such as autism spectrum disorder (ASD) and ADHD are also characterized by deficits in social skills. A core diagnostic symptom of ASD is the presence of social impairments that include difficulties with social-emotional reciprocity, nonverbal communicative behavior, and developing and maintaining social relationships (American Psychiatric Association [APA], 2013). Although poor social-emotional skills are not a core feature of an ADHD diagnosis, they often cause clinical impairment (e.g., Kats-Gold et al., 2007; Nixon, 2001). Longitudinal analyses have found that children with hyperactivity are more likely to develop antisocial behavior problems as adults (Lilienfeld & Waldman, 1990). Peer relationships are often impacted by symptoms of inattentiveness and impulsivity and around 52% of children with ADHD failed to develop reciprocal friendships (Hoza, 2007; Hoza et al., 2005), while girls with ADHD especially show marked deficits in interpersonal ability (Greene et al., 2001).

Poor social and emotional function is also present in children with externalizing disorders, such as conduct disorder (CD) and oppositional defiant disorder (ODD). The *Diagnostic and Statistical Manual of Mental Disorders* (5th ed; DSM-5) categorizes ODD as the persistent pattern of irritability, argumentativeness, and vindictiveness, and CD for individuals with more severe behaviors of aggression, destruction, and violation of rules (APA, 2013). Extant research has found that children with externalizing disorders experience more social impairment, such as peer rejection and low social competence (e.g., Asarnow, 1988; Hartup, 1983), compared to typically developing children and children with internalizing disorders. Cross-sectional studies have elucidated the link between emotion function and externalizing disorders and suggested the prospective role that poor emotional functioning has on later externalizing symptoms (Mullin & Hinshaw, 2007).

The Rothbart model of temperament states that individual differences in emotional reactivity and regulation are evident in early development, suggesting a strong underlying biological etiology (Rothbart & Bates, 1998). Emotional reactivity is defined as the basic emotional response to elicited stimuli, whereas regulation is defined as the ability to modulate the reactivity through cognitive and behavior control (Rothbart & Bates, 1998). The relationship between emotion regulation and externalizing symptoms is intertwined; children with externalizing symptoms, such as conduct problems and impulsivity, have unique biomarkers (i.e. autonomic reactivity patterns) of emotion regulation and emotion regulation can moderate the risk for developing more severe externalizing psychopathology (Beauchaine, 2012). In a review of longitudinal studies, ED is shown repeatedly to be a risk factor for developing later aggressive behavior (Röll et al., 2012).

Taken together, there is evidence that highlights the importance of understanding the relationship between emotion regulation and social outcomes. Furthermore, these relationships may have implications for clinical disorders.

The Parasympathetic Nervous System, Emotion Regulation, and Social Behavior

The nervous system is the main regulatory and communicating system of the body and consists of two separate physiological systems: central and peripheral. The central nervous system consists of the brain and spinal cord and is responsible for integrating and responding to sensory information. The peripheral nervous system is responsible for the communication of the nerves that exist outside of the central nervous system and is made up of the somatic and autonomic nervous system. The somatic nervous system is largely responsible for the delivery of afferent and efferent neuron activity to and from the central nervous system. The autonomic nervous system (ANS) contains two branches, sympathetic and parasympathetic, that work in collaboration or in opposition to each other in regulating core, involuntary bodily functions such as cardiac activity and respiration to adapt to dynamic internal and environmental demands (Richerson, 2017).

The vagus nerve is the tenth cranial nerve (X) that originates in the brainstem and innervates other viscera (e.g., heart, gastrointestinal tract) in the body. The vagus nerve is subserved by the parasympathetic branch of the ANS. The relationship between cardiac and brain stem activity as regulated by the vagus nerve is referred to as cardiac vagal tone, which can be measured by RSA. RSA, a non-invasive measure of beat-to-beat variability in heart rate during respiration, is an index of cardiac vagal tone via myelinated vagal efferent pathways that emerge from the nucleus ambiguus of the brainstem to the sinoatrial node (i.e., pacemaker) of the heart. Importantly, RSA provides a window into the neural mechanisms involved during stressful and emotional challenges (Porges, 1995a).

ANS activity has been proposed as a means to link physiological activity and psychological behavior. In review conducted in 2015, Scarpa discussed a variety of physiological models of explaining interpersonal and emotional functioning, which in turn can lead to maladjustment (Scarpa, 2015). The Polyvagal Theory posits a neural basis for psychological processes and proposes an adaptive, hierarchical response strategy that mammals have during periods when not exposed to stress (Porges, 1995a, 1995b, 1998) and also in response to environmental stressors (Porges, 2001). There is a phylogenetic adjustment of the ANS to adapt to new environmental demands. In mammals, this complex system is called the ventral vagal complex. Porges states that the ventral vagal complex exerts influence on cardiac activity such that it can act as a "brake" to inhibit sympathetic nervous activity, commonly known as "fight or flight" behaviors, and encourage more social affiliative behaviors, such as appropriate emotional responses and social communication, in response to sudden environmental stressors to achieve homeostasis (Porges, 2001). Porges (2003) theorized that activation of the vagus nerve promotes effective social engagement through its coordination with five cranial nerves (V, VII, IX, X, XI), which together form the Social Engagement System. As such, RSA is an output of this system and is considered to be a valid biomarker of psychological behavior that is commonly used in measuring emotion regulation and social behavior in clinical populations and can be examined at resting state or in periods of reactivity (Bal et al., 2010; Beauchaine, 2015).

Resting RSA is indexed when the vagus nerve acts to slow cardiac activity in the absence of environmental stressors or demands (Porges et al., 1996). Previous studies support that low resting RSA is associated with symptoms of both internalizing and externalizing psychopathology as well as disorders characterized by social dysfunction (Beauchaine, 2012; Beauchaine et al., 2001; Hinnant & El-Sheikh, 2009; Patriquin et al., 2013; Vasilev et al., 2009; Zhang et al., 2017). For example, a study by Beauchaine et al. (2001) indicated that those with comorbid ADHD and CD had lower resting RSA and reactive RSA than the control group during a baseline period and in response to videos of peer conflict in adolescents with ADHD. Beauchaine (2012) presented a model for the ANS, specifically low resting RSA, as a biological vulnerability for developing later externalizing psychopathology. In a longitudinal study of 8-12-year-old children with depressive symptoms and conduct problems, resting RSA that increased over three years was related to fewer self-reported emotion regulation difficulties at the final time point (Vasilev et al., 2009). In a nonclinical sample, Patriquin et al. (2015) found two divergent developmental trajectories of children, such that those with consistently low RSA from 5-48 months exhibited greater childhood problems at four years old (i.e., increased withdrawal, aggressive behavior, pervasive developmental problems, and oppositional defiant problems) than those with consistently high RSA, which may provide support for RSA as a biological vulnerability for future psychopathology.

Porges' polyvagal theory suggests the adaptive nature of the parasympathetic nervous system to support different behavioral activities (Porges, 1995a; Porges et al., 1996). In the presence of environmental demands, cardiac activity is either increased through the withdrawal of the vagus nerve or lowered through the augmentation of the vagus nerve in order to mobilize physical resources quickly and effectively as needed. Reactivity of RSA is calculated as the change between RSA at rest and during stressors (Butler et al., 2006). When exposed to environmental "threat" demands, vagal withdrawal results in decreased RSA activity which speeds up the heart and allows for SNS activity to dictate "fight or flight' behaviors (Porges, 1995a). The decrease in RSA (i.e., vagal withdrawal) is theorized to reduce the coordination of cranial nerves involved in the Social Engagement System which leads to difficulties in maintaining prosocial behaviors (e.g., eye contact, joint attention, conventional gestures, social responsivity; Bal et al., 2010; Patriquin et al., 2013; Van Hecke et al., 2009). Conversely, vagal augmentation results in increased RSA activity, which reflects increased cardiac vagal activity (i.e., parasympathetic nervous system) activity that is useful when an individual must utilize more socially appropriate behaviors (Porges, 1995b). As such, the ventral vagal complex reflects the adaptive ability for the body to respond appropriately to the environmental stress or demands (Porges, 1995b). Nine-month old infants who had more difficulty with decreasing RSA reactivity in response to challenging social tasks (i.e., less vagal withdrawal) were more likely to have difficulty in exhibiting appropriate social reciprocity and engagement during social/attention tasks as part of a cognitive test at three years old (Porges et al., 1996). Calkins et al. (2002) found that easily frustrated infants also had more difficulty with decreasing RSA during a frustration task with their mothers. Further, literature shows that low RSA reactivity, specifically less vagal withdrawal, predicts externalizing and internalizing symptoms and lower prosocial behavior in children and is associated with clinical samples, such as those with or at risk for externalizing disorder (e.g., Beauchaine et al., 2013; Calkins et al., 2007; Graziano & Derefinko, 2013).

Emotion Dysregulation and Social Behavior

In the Rothbart and Bates (1998) temperament model, regulation refers to the ability to modulate behaviors in response to elicited stimuli. A component of the Rothbart and Bates (1998) model is the ability to demonstrate effortful control, which refers to the ability to inhibit a dominant response in order to exhibit a more preferred, subdominant response (Posner & Rothbart, 2000). Rothbart and Sheese (2006) later integrated emotional processing as part of the self-regulatory process in the initial temperament model of regulation; emotional processing is not distinct from temperament, nor is it a result of one another. In this updated model, emotion regulation is defined as the inhibition, activation, or graded modulation of an emotional reaction, such that down/up regulation refers to the reduction/increase in the activation of emotion-related neural systems. The current study refers to the Rothbart and Sheese (2006) definition of emotion regulation when discussing ED. In relation to emotion regulation, effortful control can be conceptualized as the behavioral response to emotionally charged stimuli; for example, aggressive behavior is inhibited when angered (Eisenberg et al., 2016). Emotion regulation has been found to aid in the development and maintenance of prosocial behavior in children (e.g., Calkins et al., 1999; Eisenberg et al., 1995). In a longitudinal study, school-aged children who consistently inhibited inappropriate emotional behaviors (i.e., impulsivity, inattentiveness) demonstrated sociable behavior in school (i.e., teacher reported popularity) over the course of two years (Eisenberg et al., 1995). Early emotion regulation behaviors in toddlers during a frustration task, such as thumb-sucking or hair-twirling presumably used to self-soothe anxiety, predicted both social participation and conflict such that dysregulation in toddlers significantly predicted aggressive behavior towards peers (Calkins et al., 1999). Overall, the ability to regulate certain negative emotions, such as distress or anger, is critical for later application in social situations.

The Current Study

The current study aims to assess whether early peripheral parasympathetic activity, specifically resting and reactive RSA, can predict later emotion dysregulation (ED) and social functioning, and to assess whether the effect of RSA on social functioning is mediated by ED. Taken together, resting and reactive RSA were used as measures of parasympathetic activity to predict later social functioning as mediated by ED. To determine specificity of the causal relationship, the current study included secondary analyses of alternative models suggesting that social functioning mediates the relationship between early RSA and later ED.

Factors such as crying and sex may confound the effects of RSA. Specifically, crying interferes with respiration and may confound parasympathetic activity. With regard to sex differences, there is some evidence to suggest that resting RSA may be higher in boys than in girls (El-Sheikh, 2005; Salomon, 2005); however, many of these previous studies look at samples of older aged children. To adjust for these potential influences, crying and sex were included as potential covariates to the models. Although there is some support for a negative association between body mass index (BMI) and resting RSA (El-Sheikh, 2005), the current study did not collect current height and weight; therefore, was not able to control for the effect of BMI.

The current study hypothesized that ED in toddlerhood during stressful parent-child interaction mediates the relationship between infant parasympathetic activity and later childhood social function. In particular, I hypothesized that low resting RSA and low reactive RSA under stress in infancy would be related to higher levels of ED during frustrating parent-child interactions in toddlerhood and to lower scores in social functioning later in childhood. Considering previous literature that links regulatory processes (behaviorally and physiologically) that occur in response to negative stimuli with appropriate social behavior during frustrating situations, I hypothesized that reactive RSA would be a stronger predictor of later social-emotional functioning compared to resting RSA. The current study analyzed data collected from three separate time points to test the following hypotheses, after controlling for potential confounds (i.e., crying and sex):

1) Low resting RSA during baseline conditions and less reactive RSA during stressful parent-child interaction in infancy (five-months old) will be significantly associated with:
    a. Lower scores in parent reported social functioning in childhood (48-months old), and
    b. Higher levels of ED during stressful parent-child interaction in toddlerhood (24-months old).
2) Higher levels of ED during stressful parent-child interaction in toddlerhood (24-months old) will be significantly related to lower scores in parent reported social functioning in childhood (48-months old).

3) There is an indirect effect of resting and reactive RSA in infancy (five-months old) on parent reported social functioning in childhood (48-months old) through ED during stressful parent-child interaction in toddlerhood (24-months old).
4) The association of reactive RSA during stressful interactions to later social functioning as mediated by ED will be a stronger relationship than the association of resting RSA at baseline to later social functioning as mediated by ED.

Method

Participants

The current study used data collected as part of an ongoing multi-site (UNC-Greensboro, Virginia Tech) longitudinal study examining individual differences in cognitive and emotional processes across development (e.g., Broomell et al., 2019; Perry et al., 2016). Across three cohorts, 410 infants and their biological mothers were recruited to complete an in-person laboratory visit. Participants from each cohort were evaluated at three separate time points when they were 5-months, 24-months, and 48-months old. Cohort 1 (n = 106) was recruited three years prior to cohorts 2 and 3, and did not complete the social functioning questionnaires at 24 and 48 months because it was not part of the protocol at the time of their visits; given this, participants from cohort 1 were excluded from the current analyses resulting in a sample of 304 participants across cohorts 2 (n = 105) and 3 (n = 199). To follow, 21 infants were excluded from the current analyses if they were born with low birth weight (< 5lbs 8oz) and/or prematurely (> 28 days) or later diagnosed with a developmental delay resulting in 283 healthy, full-term born infants. Furthermore, participants with noisy ECG data (i.e., movement artifacts) or who did not complete the task had missing RSA recordings. Sixteen participants were excluded due to missing baseline RSA data, and an additional 30 participants without at least one interaction task RSA recording were removed from the sample; the resulting total sample for the current analyses was 237.

Of the total current sample, there were 126 (53.2%) females and 111 (46.8%) males. 177 (74.7%) identified their racial group as white and 60 (25.3%) as not white. 220 (92.8%) identified their ethnicity as not Hispanic and 17 (7.2%) as Hispanic.

Procedures

Procedures for this study were approved by the university Institutional Review Boards at each research location (UNC-Greensboro, Virginia Tech), and were identical between both locations. The research assistants from both locations were trained to administer the study's protocols and use behavioral and psychophysiological coding and scoring schemes by the same principal investigator. To ensure that protocol administration and coding procedures were identical, the Virginia Tech research team periodically reviewed recordings and psychophysiological data files and conducted reliability coding of psychophysiological data collected by the UNC-Greensboro research team.

Recruited 5-month-old infants and their mothers were invited to the research laboratory where research assistants collected informed consent from the mothers. After consenting, heart rate electrodes were placed on the participants while they sat on their mothers' laps and spent five minutes warming up to the laboratory space and procedures. Then, the participants completed the laboratory tasks that examined cognitive, emotional, and maternal-child interaction behaviors. Participants and their mothers were invited to subsequent research session visits when they turned 24- and 48-months old. Prior to these later visits, mothers were mailed a packet of questionnaires to complete and bring to their upcoming visit. At their 24-month visit, participants completed a battery of executive function, emotion regulation, and maternal-child interaction tasks while wearing physiological sensors (e.g., electrocardiogram, electroencephalogram). For their 48-month time point, participants completed a similar battery of cognitive, emotional, and maternal-child tasks while wearing physiological sensors. The participant's mothers were compensated $50 for each laboratory visit.

Measures

Independent Variables

To derive RSA, electrocardiogram (ECG) signals were acquired using a modified limb Lead II configuration with two disposable electrodes placed on the infant's right clavicle and lower left rib. The ground electrode was placed near scalp electrode site Fz of the international 10/20 system (Stern et al., 2001). ECG data were collected during a baseline recording procedure and several maternal interaction tasks. The cardiac signals were amplified using a SA Instrumentation Bioamp (San Diego, CA) and were bandpass filtered from 0.1 to 100 Hz. During recording, the QRS complex was displayed on the acquisition computer monitor display and digitized at 512 Hz. Raw data were collected using Snapshot-Snapstream (HEM Data Corp.; Southfield, MI) and were stored for later R-peak detection and RSA analyses. To prepare for analysis, ECG data were analyzed using the IBI Analysis System software developed by James Long Company (Caroga Lake, NY)(Bar-Haim et al., 2000). The first step in preparing the ECG data was to detect R-peaks with a four-pass peak detection algorithm that resulted in a data file with onset times for each detected R-peak. Next, tick marks were placed on the peak waves to indicate the onset times of the IBI software detected R-peaks. The tick marks were inserted manually if there were undetected visible and obscured R-peaks. If three consecutive R-peaks were missing, the data were marked as an artifact. All artifacts were subsequently removed from the dataset. The final marked R-peak was then converted to an index reflecting score time between heart beats (heart period). Movement artifacts were defined as the absence of three or more consecutive R-waves and any epochs with these artifacts were removed from the final calculations. RSA was then calculated as the spectral power value in the high frequency (HF) bandwidth of the heart period data by using a 16-second Hamming windowing function, which were submitted to a fast Fourier transform with 50% overlap. The HF band of RSA was 0.24 – 1.04 Hz, which is consistent with recommendations of examining ECG data in infants (Bar-Haim et al., 2000). To meet assumptions of normality, the RSA data were computed as the natural-logged spectral power value of the HF band and reported as $\ln(\text{ms})^2$.

Resting RSA. A baseline ECG recording was collected using a commonly used procedure employed for infant electrophysiology research (e.g., Bell, 2012; Cuevas & Bell, 2011). During the baseline recording, ECG was recorded for one minute while the infant sat on their mother's lap and a research assistant played with a brightly colored toy 1.1 meters in front of the infant. Mothers were instructed to remain quiet and not talk to their infants during this recording. The purpose of this activity was to quiet the infant and minimize gross motor movement. Resting RSA was averaged over the baseline period. In the current sample, the average resting RSA was 4.00 $\ln(\text{ms})^2$ (SD = 1.29, range = 1.06-11.11, N = 237).

Reactive RSA. Besides resting RSA, the present study was also focused on the analysis of reactive RSA during stressful parent-child interaction. As such, ECG data were recorded from infants during parent-child interaction. Mothers were instructed to play with their infant during four separate two-minute tasks, including toy play, free play, toy removal, and arm restraint. The toy play and peek-a-boo tasks were intended to be playful maternal interaction tasks, while the toy removal and arm restraint tasks were intended to elicit mild distress. Only the stressful interaction tasks of toy removal and arm restraint will be used for the current study to measure reactive RSA. Reactive RSA was calculated as the change in RSA from baseline to task (i.e. task minus resting RSA scores).

During the toy removal task, mothers were instructed to play for 30 seconds with a toy, then hold the toy out of their infant's reach while maintaining a still face and silence. Mothers were instructed to withhold the toy for 120 seconds or until the infant cried for more than ten seconds. If the infants cried for ten seconds or more, the mothers were told to not administer the arm restraint task. Conversely, if the infants did not cry for more than ten seconds during the toy removal task, the mothers were instructed to continue administering the toy removal task for the full 120 seconds and administer the arm restraint task. For the current sample, the average RSA for the toy removal task was 4.32 $\ln(ms)^2$ (*SD* = 1.17, range: 1.36-9.78) During the arm restraint task, mothers were instructed to gently restrain their infant's arms to restrict their free arm movements while simultaneously maintaining a still face and silence for 120 seconds. If the infants cried for ten seconds or more, the mothers did not continue the arm restraint task. The average RSA for the arm restraint task was 4.38 $\ln(ms)^2$ (*SD* = 1.47, range: 1.77-10.53). RSA recordings during the toy removal and arm restraint tasks were averaged to create an index of RSA during stressful situations across the two tasks. To calculate reactive RSA, I subtracted resting RSA from the overall average RSA taken during the toy removal and arm restraint tasks. Negative change values represent a decrease in RSA values from baseline to task, whereas positive change values represent an increase in RSA values from baseline to task (Alkon et al., 2001). The average change between baseline and overall mean task RSA was 0.33 $\ln(ms)^2$ (*SD* = 1.34, range = -4.61-6.07).

Crying. To account for the interference of crying on respiration during the ECG recordings, I calculated a two level categorical variable for "cry"/"did not cry" based on a continuous measure of overall mean negative affect. During administration of the toy removal and arm restraint tasks, research assistants rated behaviors of "Global Affect" in 30-second epochs on a Likert scale of 0 to 5 where higher scores indicate higher negativity as adapted from Emde and Easterbrooks (1985) and Stifter and Braungart (1995). These scores were summed across up to eight epochs, then divided by the number of epochs, to get an overall mean value for the toy removal and arm restraint tasks (0 = *Neutral or even positive face and voice*; 1=

Concentration frown or sobering of face with a brief, negative vocalization; 2 = *Pouting, pre-cry face or clearly distinguishable frown and brief negative vocalizations---grunt, protest, frustration sounds that tend to be in single bursts with strident tone or vocal tension*; 3 = *Whimpering or fussing with at least one sob with appropriate facial expression*, *both fuss and whimper involve a string of negative vocalizations, not just single vocalizations*; 4 = *Marked distress in face and voice*, *Full blown cry accompanied by appropriate facial expressions---screwing up face, closed eyes, maybe tears*; 5 = *Escalated crying with at least one shriek*). Participants who cried for more than 10 seconds during the toy removal task immediately discontinued the task and did not continue on to complete the arm restraint task; therefore all scores for global affect were averaged across up to eight epochs. Those with gross motor movement have been excluded from calculations of RSA, and therefore those with higher levels of Global Affect (extreme crying/distress) do not have movement artifacts. I further coded participants as 0 = *did not cry (0-2)* or 1 = *cried (3-5)* based on their mean global affect score. In the current sample during the reactive RSA recordings, 51 participants cried and 186 did not. Crying, as derived by the "Global Affect" variable, was analyzed as a possible confound variable for measuring task RSA. However, the study did not code for "Global Affect" during the baseline recording so crying was not considered as a possible confound in analyses involving resting RSA.

Mediating Variables

Emotion Dysregulation. Infants and their mothers who were seen at the five-month time point were invited back to the research study when infants were 24-months old. During this visit, ED was measured during a play-based parent-child interaction task. Children were asked to independently assemble an age in-appropriate puzzle (1-2-3) for two minutes and mothers were instructed to ignore their child's requests for help .

Research assistants coded videos of the parent-child interaction in 30-second epochs on how much frustration the child expressed during the task. Behaviors of frustration included anger towards parent, use of tone of voice, facial expressions, and aggressive behaviors. Behaviors were coded on a Likert Scale of 1 to 4 where higher scores indicated higher frustration: 1 = *The child was not angry nor demonstrated hostility or aggression*, 2 = *The child was mildly frustrated and had only one bout of such behaviors*, 3 = *The child was somewhat frustrated and had several bouts of frustration*, 4 = *The child was consistently and/or intensely frustrated, negative, hostile, or aggressive*. A total frustration score was averaged across four epochs which resulted in a continuous variable of ED. For the current sample, the average score for frustration at the 24-month time point was 1.51 (SD = 0.69, range = 1.0-4.0, n = 184); 53 participants of the total sample did not complete the 1-2-3 puzzle and, therefore, were not included in the analyses.

Social Functioning. Social functioning was measured by the Vineland Adaptive Behavior Scales – Second Edition, Survey Parent/Caregiver Rating Form (Vineland-II; Sparrow et al., 2005) when infants returned for their 24-month old time point. The Vineland-II is a semi-structured parent-report questionnaire of current adaptive behavior and is composed of four domains that yield a standard score (M = 100, SD = 15) normed from birth to 90 years: communication, daily living skills, socialization, and motor skills (Sparrow et al., 2005). Each domain is comprised of three subdomains. Given the scope of the current study, I conducted analyses using only the scores from the three subdomains of the Socialization domain, which included: (a) Interpersonal Relationships; (b) Play and Leisure Time; and (c) Coping Skills. The Vineland-II asks parents to rate the frequency of specific behaviors (e.g., smiles in response to another person's smile or voice, play with other children their own age) on a three point Likert scale that their child currently does on a day to day basis where higher scores indicate greater adaptive skill: 0 = *Never*, 1 = *Sometimes or Partially*, 2 = *Usually*.

The Interpersonal Relationship subdomain consists of 38 items that assess for how well the child interacts with others (e.g., "Answers when familiar adults make small talk"). The Play and Leisure Time subdomain consists of 31 items that inquire about how the child plays and uses leisure time (e.g., "Chooses to play with other children"). The Coping Skills subdomain consists of 30 items that measure how a child demonstrates responsibility and sensitivity to others (e.g., "Controls anger or hurt feelings when he or she does not get his or her way"). The domain score represents a standard score for overall social behavior whereas each subdomain yields a *v*-scale score and represents a subtype of social behavior. The current analyses used the standard score of the Socialization domain to determine overall level of social functioning in participants seen at the 24-month time point. The average score for social functioning at the 24-month time point as measured by the Vineland-II Socialization was 111.82 (*SD* = 13.89, range = 82-156, *n* = 183); 54 of the total 237 person sample had missing standard scores because they were missing one or more of the subdomain scores at 24 months.

Dependent Variables

Social Functioning. Children seen at the 24-month time point were invited to return to the research site with their mother at 48 months. Social functioning was measured by the Vineland-II, a parent-report questionnaire that assesses for current adaptive behavior. Mothers completed the three subdomains of the Socialization domain of the Vineland-II: Interpersonal Relationships, Play and Leisure Time, Coping Skills. Data from this time point yielded a standard Socialization domain score (*M* = 100, *SD* = 15). The average score for social functioning at the 48-month time point as measured by the Vineland-II Socialization was 111.97 (*SD* = 14.26, range = 72-155, *n* = 169); 68 of the total 237 person sample had missing standard scores because they were missing one or more of the subdomain scores at 48 months.

Emotion Dysregulation. ED was coded during a frustrating parent-child interaction at the 48-month old time point. Children were asked to independently assemble an age-inappropriate puzzle (i.e., animal jigsaw puzzle) for two minutes and mothers were instructed to ignore their child's requests for help. Similarly to their 24-month visit, behavior was coded on the same Likert scale of 1-4 per 30 second epoch where higher scores indicated higher frustration: 1 = *The child was not angry nor demonstrated hostility or aggression*, 2 = *The child was mildly frustrated and had only one bout of such behaviors*, 3 = *The child was somewhat frustrated and had several bouts of frustration*, 4 = *The child was consistently and/or intensely frustrated, negative, hostile, or aggressive*. A total frustration score was averaged across four epochs which resulted in a continuous variable of ED. For the current sample, the average score for frustration at the 48-month time point was 1.49 (*SD* = 0.67, range = 1.0-4.0, *n* = 159); 78 participants of the total sample did not complete the animal puzzle and, therefore, were excluded from analyses.

Analytic Plan

Although the current sample consists of 237 participants with complete data for their independent variables (resting and reactive RSA), there were up to 98 participants with missing data for their mediating variables (frustration scores = 53; Vineland-II scores = 54) or dependent variables (Vineland-II scores = 68; frustration scores = 78). Participants with incomplete data for their mediating and/or dependent variables were not included in the mediational analyses. The resulting sample sizes for the mediational analyses: models 1 and 2, *n* = 154; models 3 and 4, *n* =

139. Regarding the missing data, I conducted chi-square analyses to examine significant differences in the demographic makeup of the participants who were included in the mediational analyses and those who were not. In addition, I performed independent sample *t*-tests to compare group differences between their resting and reactive RSA scores and global affect scores. Results are reported along with their corresponding analyses below.

I conducted descriptive analyses and group comparisons on demographic variables. Independent sample *t*-tests were performed between demographic variables (sex, race, ethnicity) and RSA (resting and reactive) and crying with reactive RSA. I performed analyses using SPSS 26 (IBM, 2019) with a two-tailed alpha level of 0.05. Sensitivity analyses using G*Power (v3.1.9.7; Faul et al., 2007) demonstrated that the current sample was large enough to detect significant differences between groups (sex, race, ethnicity, crying) that exceeded medium effect sizes (Hedges's $g = 0.67$-0.71). In addition, I conducted two-tailed Pearson correlation analyses between all of the study variables.

For hypothesis testing, I examined the data using two mediational models (one for resting RSA and one for reactive RSA), as depicted in Figure 2. Models 1 and 2 predicted the effect of parasympathetic activity, as measured by RSA (resting and reactive), on later social functioning as mediated by ED. As shown in Figure 1, pathways *a* represent the effect of RSA, the independent variable, on ED at 24-months-old, the mediating variable, and pathways *b* represent the effect of ED at 24-months-old on social functioning at 48-months-old, the dependent variable. The indirect effect of RSA on social functioning through ED is represented as the product of pathways *a* and *b* (*ab*) and the direct effect that RSA had on social functioning is represented by pathway *c'*. The total effect of the mediation is represented by *c*, or the sum of the direct and indirect effect ($c' + ab$).

An alternative set of models were tested to rule out the possibility that early parasympathetic activity predicts ED, as mediated by social functioning (Figure 3). Models 3 and 4 predicted the effect of parasympathetic activity, as measured by resting and reactive RSA, on later ED mediated by social functioning. As shown in Figure 2, pathways *a* represent the effect of RSA, the independent variable, on social functioning at 24-months-old, the mediating variable, and pathways *b* represent the effect of social functioning at 24-months-old on ED at 48-months-old, the dependent variable. The indirect effect of RSA on ED through social functioning is represented as the product of pathways *a* and *b* (*ab*) and the direct effect that RSA had on ED is represented by pathway *c'*. The total effect of the mediation is represented by *c* (*c'* + *ab*).

To test the mediational hypotheses, I conducted ordinary least squares (OLS) regression analyses using the PROCESS macro model 4 for SPSS (PROCESS version 3.4.1; SPSS version 26.0; Hayes, 2017). Using G*Power (v3.1.9.7; Faul et al., 2007), I conducted multiple sensitivity analyses for a linear multiple regression fixed model, R^2 deviation from zero at an alpha level of 0.05 and power of 0.80 with 2-3 predictors (independent and mediational variable, and/or covariate) and found that the current samples for model 1 with 2 predictors ($n = 154$), model 2 with 3 predictors ($n = 154$), model 3 with 2 predictors ($n = 139$), and model 4 with 3 predictors ($n = 139$) are powered to detect small-to-medium effects (Cohen's $f^2 = 0.06\text{-}0.08$).

RSA, which was collected from infants at the five-month time point during the baseline condition (i.e., resting) and during the Arm Restraint and/or Toy removal tasks (i.e., reactive), were the independent variables for all models. ED, coded as the total average score of frustration scores, was measured during the frustrating parent-child interaction completed at the participant's 24-month and 48-month time points. Social functioning was measured by parent-reported Vineland-II Socialization domain standard scores completed at the participant's 24-

month and 48-month time points. All predictor variables were continuous measures and mean-centered when added to the PROCESS macro analyses.

Covariates, like crying (dichotomized between infants who cried and those who did not during the parent-child interaction tasks during the ECG recording at 5-months) and sex, were included in each model if they significantly related to resting or reactive RSA. An independent sample *t*-test between crying and reactive RSA was conducted to determine whether crying should be entered as a covariate for models 2 and 4. Similarly, independent sample *t*-tests between sex and RSA were conducted to determine if sex should be entered as a covariate in all four models. If covariates were significantly related to the outcome, then they were included in each model via the PROCESS macro to predict the mediating variables, using pathways *f*, and indirectly predict the dependent variables with pathways *g* (Figures 1 and 2).

Results

Demographic Effects

I conducted group comparisons between sex (males, females), race (white, non-white) and ethnicity (Hispanic, non-Hispanic) on resting and reactive RSA, frustration levels, and Vineland-II scores. No significant group differences emerged for sex (resting: *t*[235] = -0.84, *p* = .401; reactive: *t*[235] = 0.29, *p* = .774), race (resting: *t*[235] = -0.09, *p* = .928; reactive: *t*[235] = 0.80, *p* = .427) and ethnicity (resting: *t*[235] = -0.22, *p* = .829; reactive: *t*[235] = 1.16, *p* = .247) on either resting or reactive RSA (Table 1). Since no significant sex differences emerged for either RSA measures, sex was not added as a covariate in the mediational models. However, participants who cried during the interaction tasks, as derived by the Global Affect variable (cried, *n* = 51, *M* = -0.18 $\ln[ms]^2$, *SD* = 1.54; did not cry, *n* = 186, *M* = 0.46 $\ln[ms]^2$, *SD* = 1.25), had significantly lower reactive RSA scores, *t*(235) = 3.09, *p* = .002, Hedges's *g* = 0.49. Thus, crying was added as a covariate in all mediational analyses that looked at RSA reactivity.

There were no group differences by sex (24mo: *t*[182] = -0.74, *p* = .458; 48mo: *t*[157] = -0.57, *p* = .568), race (24mo: *t*[182] = -0.31, *p* = .754; 48mo: *t*[157] = -0.58, *p* = .560) and ethnicity (24mo: *t*[182] = -1.04, *p* = .299 48mo: *t*[157] = -0.09, *p* = .932) on frustration scores at 24 or 48 months old (Table 2). Table 2 shows no group differences by sex, (24mo: *t*[181] = -1.71, *p* = .089; 48mo: *t*[167] = -1.69, *p* = .093), race (24mo: *t*[181] = -1.25, *p* = .214; 48mo: *t*[167] = -0.59, *p* = .555) and ethnicity (24mo: *t*[181] = 1.13, *p* = .261; 48mo: *t*[167] = -0.45, *p* = .653) on Vineland-II Socialization standard scores at 24 or 48 months old.

Table 3 shows that resting, toy removal and arm restraint RSA were positively correlated with each other. Reactive RSA was negatively correlated with resting RSA indicating that an increase in vagal reactivity during the stressful parent-child interaction tasks was correlated with low vagal activity at baseline. However, reactive RSA was positively correlated with the toy removal and arm restraint RSA suggesting that an increase in vagal reactivity during the stressful parent-child interaction tasks was correlated with having high vagal activity at during those tasks. Resting RSA was negatively correlated with Frustration levels at 24 months such that low vagal activity during baseline was related to high emotion dysregulation. In addition, frustration levels were positively correlated at 24 and 48 months, and so were Vineland-II scores (Table 3).

Missing Data

For the mediational analyses that examined ED at 24-months-old and social functioning at 48-months-old, a total of 83 participants were excluded due to missing data: 15 missing frustration scores at 24-months-old only, 30 missing Vineland-II data at 48-months-old only, 38 missing both frustration and Vineland-II data. The resulting working sample for mediational models 1 and 2 consisted of complete data from 154 participants. There were no differences in sex ($\chi^2[1, n = 237] = 0.62, p = .433$) or ethnicity ($\chi^2[1, n = 237] = 0.001, p = .980$) between those with ($n = 154$) and without ($n = 83$) complete data for models 1 and 2, but there were differences between racial groups such that a significantly greater proportion of white participants (69%) had complete data than their non-white peers (53%; $\chi^2[1, n = 237] = 4.48, p = .029$). No group differences emerged between participants who were included in the mediational analyses for models 1 and 2 and those who were not on resting ($t[235] = -1.44, p = .151$) and reactive RSA scores ($t[235] = 1.43, p = .154$) or their crying($\chi^2[1, n = 237] = 1.81, p = .178$).

For models 3 and 4, which examined social functioning at 24-months-old and ED at 48-months-old, a total of 98 participants were excluded due to missing data: 44 missing Vineland-II data at 24-months-old only, 20 missing frustration scores at 48-months-old only, 34 missing both Vineland-II and frustration data. The resulting working sample for models 3 and 4 consisted of complete data from 139 participants. Similarly to the missing data in models 1 and 2, there were no differences in (χ^2[1, *n* = 237] = 0.25, *p* = .616) or ethnicity (χ^2[1, *n* = 237] = 0.25, *p* = .620) between those with (*n* = 139) and without (*n* = 98) complete data but racial group differences such that white participants (63%) had a significantly greater proportion of complete data than non-white peers (47%; χ^2[1, *n* = 237] = 4.76, *p* = .026). No group differences emerged between participants who were included in the mediational analyses for models 3 and 4 and those who were not on resting (*t*[235] = -0.38, *p* = .702) and reactive RSA scores (*t*[235] = -0.19, *p* = .852) or their crying (χ^2[1, *n* = 237] = 1.12, *p* = .290).

Mediational Models

Model 1 – Resting RSA predicting Vineland-II scores as mediated by Frustration levels.

Model 1 tested the hypothesis that ED (frustration level) mediates the relationship between resting RSA and social functioning (Vineland-II score; Figure 3). There was a significant small effect such that participants with low resting RSA at 5 months were more likely to have greater frustration levels at 24 months (*a* = -0.09, *p* = .041, f^2 = 0.03; Table 4). There was no evidence indicating that frustration levels significantly predicted later Vineland-II scores (*b* = 3.03, *p* = .058; Table 4). There was no additional support that resting RSA directly predicted Vineland-II scores (*c'* = 0.53, *p* = .528), though the nonsignificant trend was in the direction of greater 24 month frustration being related to better 48 month social functioning (opposite to what was predicted; Table 4). Regarding the total effect, frustration levels at 24-months old did not mediate the association between resting RSA at 5-months old and Vineland-II scores at 48-months old (*c* = 0.27, *p* = .751).

Model 2 – Reactive RSA predicting Vineland-II scores as mediated by Frustration levels.

Model 2 tested the hypothesis that ED (frustration level) mediates the relationship between reactive RSA and social functioning (Vineland-II score; Figure 4). There was a significant small effect that participants with high RSA reactivity at 5 months were more likely to have high frustration levels at 24 months (a = 0.09, p = .039, f^2 = 0.10; Table 5) when controlling for crying (f = 0.31, p = .022). Frustration levels did not predict later Vineland-II scores (b = 3.05, p = .060; Table 5), though the nonsignificant trend was in the direction of greater 24 month frustration being related to better 48 month social functioning (opposite to what was predicted). There was no additional support that reactive RSA directly predicted Vineland-II scores (c' = -0.64, p = .447; Table 5). Crying at 5-months-old did not predict 48-month Vineland-II scores (g = -0.25, p = .928; Table 5). In total, frustration levels at 24-months old did not mediate the association between reactive RSA at 5-months old and Vineland-II scores at 48-months old (c = -0.37, p = .655).

Model 3 – Resting RSA predicting Frustration levels as mediated by Vineland-II scores.

As modeled in Figure 5, the next mediational model depicted the hypothesis that social functioning (Vineland-II score) mediates the relationship between resting RSA and ED (frustration level). Resting RSA at 5 months was not significantly associated with Vineland-II scores at 24 months (a = 0.70, p = .430) and Vineland-II scores were not related to later frustration levels (b = 0.001, p = .867; Table 6). There was no additional support that resting RSA directly predicted frustration levels (c' = -0.01, p = .758; Table 6). Regarding the total mediation, Vineland-II scores at 24-months old did not mediate the association between resting RSA at 5-months old and frustration levels at 48-months old (c = -0.01, p = .758).

Model 4 – Reactive RSA predicting Frustration levels as mediated by Vineland-II scores.

In the final mediational model (Figure 6), I tested the hypothesis that social functioning (Vineland-II score) mediates the relationship between reactive RSA and ED (frustration level). Reactive RSA at 5 months was not significantly associated with Vineland-II scores at 24 months ($a = -0.53$, $p = .549$) and Vineland-II scores did not relate to later frustration levels ($b = 0.001$, $p = .774$; Table 7). There was no additional support that reactive RSA directly predicted frustration levels ($c' = 0.07$, $p = .102$; Table 7). When I added the effect of the covariate crying variable, there was no association of whether participants cried during the tasks with their frustration level ($f = -1.66$, $p = .558$) and Vineland-II scores ($g = 0.22$, $p = .106$; Table 7). Taken together, Vineland-II scores at 24-months old did not mediate the association between reactive RSA at 5-months old and frustration levels at 48-months old ($c = 0.07$, $p = .103$).

Discussion

This study explored the role of early physiological predictors (i.e., resting and reactive RSA) on ED and social functioning outcomes. As guided by Porges' Polyvagal Theory (Porges, 1995a) and observed in findings from previous studies, significant associations with low resting RSA or low reactive RSA with emotion or social impairments would demonstrate the limited flexibility of the vagus nerve in those with compromised emotional or social abilities. In addition, the Rothbart and Bates (1998) temperament model emphasizes an underlying biological etiology to emotion regulation and that emotion regulation contributes to the development and maintenance of pro-social processes.

The results of the current analyses did not support the hypotheses that I previously specified with the exception of hypothesis 1b, which predicted that low resting RSA during baseline conditions at 5-months old would be significantly associated with higher levels of ED during stressful parent-child interaction at 24-months old. In the literature, there is strong existing evidence for the relationship of low resting RSA with ED in children (Beauchaine, 2015; Beauchaine et al., 2007; Gentzler et al., 2009), which supports the current result that low resting RSA at 5 months is negatively associated with ED at 24 months. In addition, the results showed a significant medium-sized effect that greater reactivity at 5 months (i.e., increase in RSA from the baseline to parent-child interaction tasks) significantly predicted greater frustration levels at 24 months when controlled for crying during the parent-child interaction tasks; this was converse to what I hypothesized which was that less reactive RSA would predict high ED at 24 months. Although the other relationships in the current study were not significant, there was some indication of a trend suggesting that increased 24 month ED is associated with increased 48 month socialization (Models 1 and 2; *b*s = 3.03-2.84, *p*s = .058-.076). The results mainly indicated no significant associations between infant resting RSA and later childhood emotional or social dysfunction. Since there were no significant mediational models of both resting and reactive RSA onto later frustration and Vineland-II scores, I did not compare the difference between those models to determine if one mediation was stronger as proposed in hypothesis 4.

Theoretical Implications

While there are no biological measures for diagnosing any disorders characterized by atypical social behavior, assessments of parasympathetic nervous system activity can be informative for later clinical outcomes (Beauchaine, 2015). The Social Engagement System (Porges, 2003) suggests that the vagus nerve, in coordination with other cranial nerves, promotes social engagement such that prosocial behavior can be indexed by RSA; however, the current study generally did not yield results in support of this theory. While there was a significant relationship between resting RSA and 24 month frustration levels, results yielded support in the opposite direction than what I hypothesized for reactive RSA and frustration such that greater vagal reactivity predicted later ED. However, these unsuspecting findings are consistent with the relationship between resting RSA and frustration levels such that the participants who experienced a significantly greater positive change during the tasks would have had lower resting RSA, thus more room for vagal reactivity than participants with higher resting RSA.

There was no significant association between 24 month frustration levels and later Vineland-II scores. In fact, though not significant, the trend indicated the exact opposite – that higher 24 month frustration level was related to higher Vineland-II scores at 48 months. These observed relationships are incongruent to my initial hypotheses. An alternative explanation, however, is that the expression of frustration itself can be a form of social-communicative behavior if the child has yet to master fluent speech and if their mother typically assists them when they express distress. Additionally, Bertollo et al. (2020) found that more negative affect during a frustrating task is a better indicator of later adaptive social skills than negative affect during a less frustrating task; this suggests the context-dependent adaptive nature of infant reactivity. If interpreted in this way, then these findings provide some limited support for the Social Engagement System theory, at least with respect to 5-month RSA and 24-month frustrative social communication during a stressful parent-child interaction. However, this interpretation should be met with caution since I did not examine contextual influences.

Other theories are also consistent with my hypothesized models. The neurovisceral integration model (Thayer & Lane, 2000), for example, posits a model of attentional regulation and affective processes that may provide some explanation for the current study's hypothesized mediation of emotion regulation for the relationship between parasympathetic activity and social functioning. In this model, HRV indexes self-regulation arising from the integration of the central and autonomic nervous systems through neural feedback mechanisms. Although I did not examine at the role of social context in the current mediations, Scarpa (2015) highlighted how environmental stressors (e.g., parental interactions, family context) can influence physiological and psychological processes, like the ones examined in the current study. I did not analyze the effects of maternal response on participant's frustration levels; however, prior research has examined the maternal socialization of emotion regulation and physiological arousal in children (Eisenberg et al., 1998; Shipman et al., 2007; Williams & Woodruff-Borden, 2015). Although there could be a different theoretical explanation for the study's hypotheses, the current results did not support the Social Engagement System or the Rothbart temperament model with respect to either infant RSA or toddler-aged ED predicting child socialization. I suggest alternative methodological considerations below.

Limitations and Suggestion for Future Directions.

For the most part, the hypotheses were not supported, and I have some considerations for these results. The sensitivity analyses suggested that this sample was not powered enough to detect effect sizes smaller than $f^2 = 0.06$ so the majority of the effects may have been too small to be detected and should therefore be explored further in future research with larger samples. Excluding up to 98 participants from the mediational analyses due to missing data from their 24- and 48-month time points significantly reduced the power of the study. The study also lacked sample diversity such that the majority (75%) of the sample was white and a significantly greater proportion of non-white participants compared to their white peers were missing data. In consideration of these differences, the results of the current study may not generalize to non-white children and should be interpreted with caution. Future child development research should not only aim to recruit larger samples, but also to examine these processes in racially diverse families.

Other than a limited sample size, I speculate that the lack of supported hypotheses may have been due to the temporal gap between 5-month old and the 24-month and 48-month time points. Kopp (1982) defined distinct developmental stages of control and regulation in infants and that a child's ability to voluntarily manipulate their movements in response to stimuli is under development before 12 months; thus, a 5 month timepoint may have been too distal to examine physiological activity to predict later, modulated behavior. Morasch and Bell (2012) examined infants at 5-months and 10-months and found that the relationship between negative affect and regulation was stronger for when the infant was older, and that the foundation of self-regulation is determined in the last-half of a child's first year. Future analyses could benefit from examining data collected within a smaller time frame of development and slightly older children, such as modeling 24-month old RSA data onto 36-month and 48-month emotional and social functioning.

While infant RSA did not predict later social and emotional functioning in the current study, participants may have been excluded from analyses due to their own dysregulation. Specifically, I excluded 46 participants who were too overactive and/or distressed and could not produce reliable ECG data resulting in a conservative sample of the least dysregulated participants for the analyses. During the toy removal and arm restraint tasks, less than a quarter of participants cried and the average overall level of negative affect was 1.99 (*SD* = 1.13, range = 0-5), suggesting that the current sample demonstrated mostly neutral to some negative affect.

Crying was dichotomized between those who cried and those who did not based on an averaged overall level of global affect across all 30-second epochs during two tasks that could last up to two minutes each. Some participants may have been coded as "did not cry" if their overall mean global affect score was less than 3, however this does not preclude them from have ever cried during the task. Given this method of dichotomizing participants who cried, there may have likely been an over estimation of categorizing infants who did not cry. Future analyses should revisit how crying was calculated in order to control for the effects of crying on respiration more accurately. This is particularly salient given that one of the two significant findings from the current analyses was accounted for after controlling for this two level crying variable.

The Vineland-II may have contributed to the lack of significant findings. While the Vineland-II is a widely used questionnaire for measuring adaptive social behavior, it rates a limited number of prescribed skills that may be present in wide age range and does not get at the nuances of specific social affiliative behavior (e.g., only asks if their child shows interests in other children but does not assess for the quality of the initiation or interaction which may be a more accurate indicator of poor social function). Specifically, out of the 38 items for the Interpersonal subdomain, eleven skills are targeted for children aged 0-4 years old, nine items out of 31 for children aged 0-7 years old within the Play and Leisure subdomain, and that none of the 30 items in the Coping Skills subdomain specify between different ages in those early years of childhood. The study may have seen a floor effect with the Vineland-II given its limited specificity in early childhood social functioning. I suggest that future analyses instead use an observed measure of social behavior similar to how the emotional dysregulation data were based on observed behavioral codes.

Another consideration for the null findings may have been that I used a nonclinical normative sample, which may be too "healthy" to detect any significant abnormal trajectories. The analyses purposely excluded participants who were born with low birthweight or prematurely, or those who later developed a developmental delay (e.g., ASD). The average level of social functioning on the Vineland-II at both time points (24-months = 111.82 [*SD* = 13.89]; 48-months = 111.97 [*SD* = 14.26]) was above the average levels of functioning for most 24- and 48-month old children (*M* = 100, *SD* = 15). Also, the ED data from the frustration tasks demonstrated relatively low levels of frustration (*M* = 1.49-1.51, possible range = 1.0-4.0). Most of the existing literature for examining the association of RSA with later outcomes have usually only been addressed in the context of clinical levels of dysfunction (Beauchaine, 2012; Beauchaine et al., 2001; Hinnant & El-Sheikh, 2009; Patriquin et al., 2013, 2015; Vasilev et al., 2009; Zhang et al., 2017). The lack of support for the prospective power of early parasympathetic activity on later outcomes from this study indicates that examining biological processes in a healthy, typically developing sample may not provide enough specificity for the underlying mechanisms of future psychopathology.

Although some previous research has elucidated underlying physiological activity in a non-clinical sample (Patriquin et al., 2015), these findings revealed that consistently low resting RSA over time (5 to 48 months) predicted abnormal social behavior at 48 months whereas the current study only examined the association of RSA and social behavior at a single time point of 5 months. In addition, there could be possible moderating influences (e.g., severity of function, intellectual impairment) that could explain the differences within a more neurodiverse sample (Patriquin et al., 2019). Further research is needed on the longitudinal outcomes of samples of vulnerable children with a greater likelihood of developing abnormal levels of function (e.g., recruiting children with elevations in measures that screen for autism or with reported developmental delays or challenging behaviors).

Conclusions

The current study aimed to examine infant resting and reactive RSA as predictors of later childhood socialization behavior or ED as mediated through ED or socialization, respectively, in a healthy, typically developing sample of participants recruited from Greensboro, North Carolina and Blacksburg, Virginia, United States. For the most part, I failed to reject the null hypotheses, with the exception of lower resting RSA at 5-months old predicting greater frustration levels at 24-months old. I was underpowered to detect sufficiently sized effects; however, I made several suggestions for future analyses and studies such as utilizing more proximal timepoints, improving the measurement of social behavior, including clinical samples, and examining the role of neurodiversity or severity of functioning as potential moderators.

Although these findings were not significant, future research that identifies unique physiological markers of later pathology may elucidate understanding of the mechanisms of a wide range of psychopathology and help with the differential diagnosis of several psychological disorders and guide treatment planning. Some psychological disorders, such as ASD, benefit from early intervention, and having a reliable assessment of early risk factors may contribute to the development of intervention and resource planning. In the future, potentially significant findings would align with burgeoning research nosological initiatives such as the NIMH Research Domain Criteria (Insel, 2014), which provides an alternative, dimensional model for characterizing psychological conditions.

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Tables

Table 1

RSA by Demographic Variables

	Resting RSA ln(ms)^2					Reactive RSA ln(ms)^2				
	N	*n*	*M*	*SD*	range	*N*	*n*	*M*	*SD*	range
Sex	237					237				
Male		111	3.93	1.13	1.58-9.27		111	0.35	1.35	-4.61-3.66
Female		126	4.07	1.41	1.06-11.11		126	0.30	1.37	-3.39-6.07
Race	237					237				
White		177	4.01	1.38	1.06-11.11		177	0.28	1.30	-4.61-3.73
Non-White		60	3.99	0.96	1.91-6.17		60	0.44	1.46	-2.80-6.07
Ethnicity	237					237				
Hispanic		17	3.94	0.73	2.28-4.83		17	0.69	1.14	-0.86-3.66
Non-Hispanic		220	4.00	1.32	1.06-11.11		220	0.30	1.35	-4.61-6.07

Note: Reactive RSA = TR and AR RSA minus resting RSA; ln = natural log; ms = millisecond.

Table 2

Frustration and Vineland-II scores by Demographic Variables at 24- and 48-months-old

	24 months old					48 months old				
	N	*n*	*M*	*SD*	range	*N*	*n*	*M*	*SD*	range
					Frustration Scores					
Sex	184					159				
Male		85	1.47	0.63	1.00-3.50		78	1.46	0.61	1.00-3.50
Female		99	1.54	0.74	1.00-4.00		81	1.52	0.73	1.00-4.00
Race	184					159				
White		143	1.51	0.71	1.00-4.00		126	1.51	0.71	1.00-4.00
Non-white		41	1.48	0.59	1.00-3.00		33	1.43	0.52	1.00-2.75
Ethnicity	184					159				
Hispanic		14	1.32	0.64	1.00-2.50		10	1.48	0.85	1.00-3.75
Non-Hispanic		170	1.52	0.69	1.00-4.00		149	1.49	0.66	1.00-4.00
					Vineland-II Socialization Standard Scores					
Sex	183					169				
Male		85	109.94	12.80	82-153		83	110.10	14.41	72-155
Female		98	113.45	14.65	82-156		86	113.78	13.96	81-146
Race	183					169				
White		140	112.53	13.76	82-156		131	112.32	14.16	74-148
Non-white		43	109.51	14.25	82-153		38	110.76	14.73	72-155
Ethnicity	183					169				
Hispanic		13	116.00	16.75	91-153		11	110.09	14.69	85-128
Non-Hispanic		170	111.50	13.66	82-156		158	112.10	14.27	72-155

Table 3

Pearson's r Correlations for Study Variables

Variable	*n*	1	2	3	4	5	6	7	8	9
1. Resting RSA	237	1	-	-	-	-	-	-	-	-
2. Toy removal RSA	235	0.28**	1	-	-	-	-	-	-	-
3. Arm restraint RSA	135	0.44**	0.36**	1	-	-	-	-	-	-
4. TR and AR RSA	237	0.41**	0.89**	0.88**	1	-	-	-	-	-
5. Reactive RSA	237	-0.60**	0.49**	0.41**	0.49**	1	-	-	-	-
6. Frustration, 24 mo	184	-0.15*	-0.05	0.01	-0.02	0.12	1	-	-	-
7. Vineland-II, 24 mo	183	0.09	0.09	0.13	0.11	0.01	0.09	1	-	-
8. Frustration, 48 mo	159	-0.04	-0.01	0.13	0.08	0.11	0.21**	0.01	1	-
9. Vineland-II, 48 mo	169	0.07	0.004	0.12	0.02	-0.06	0.15	0.38**	0.002	1

Note. TR and AR RSA = Toy removal and arm restraint overall mean RSA; Reactive RSA = TR and AR RSA minus resting RSA; mo = months old
*p < .05 (two-tailed). **p < .01 (two-tailed).

Table 4

Model 1 Resting RSA onto Vineland-II Through Frustration

		Consequent									
		MV (Frustration)					*DV* (Vineland-II)				*n*
Antecedent		Coeff.	*SE*	CI	*p*		Coeff.	*SE*	CI	*p*	
IV (Resting RSA)	*a*	-0.09	0.04	-0.17, -0.004	.041	*c'*	0.53	0.84	-1.13, 2.20	.528	154
MV (Frustration)		-	-	-	-	*b*	3.03	1.59	-0.10, 6.17	.058	
Constant		1.54	0.06	1.43, 1.65	<.001		112.29	1.11	110.09, 114.49	<.001	
		R^2 = 0.03					R^2 = 0.02				
		$F(1,152) = 4.26, p = .041$					$F(2,151) = 1.88, p = .156$				

Note: IV = Independent Variable; MV = Mediator Variable; DV = Dependent Variable; CI = Confidence Interval

Table 5

Model 2 Reactive RSA onto Vineland-II Through Frustration

		Consequent										
		MV (Frustration)					*DV* (Vineland-II)					*n*
Antecedent		Coeff.	*SE*	CI	*p*		Coeff.	*SE*	CI	*p*		
IV (Reactive RSA)	*a*	0.09	0.14	0.005, 0.17	.039	*c'*	-0.64	0.84	-2.29, 1.01	.447		154
MV (Frustration)		-	-	-	-	*b*	3.05	1.61	-0.13, 6.23	.060		
CV (Crying)	*f*	0.31	0.14	-0.05, 0.58	.022	*g*	-0.25	2.74	-5.66, 5.16	.928		
Constant		1.47	0.07	1.34, 1.60	<.001		112.35	1.30	109.79, 114.91	<.001		
		$R^2 = 0.05$					$R^2 = 0.03$					
		$F(2,151) = 3.92, p = .022$					$F(3,150) = 1.31, p = .273$					

Note: IV = Independent Variable; MV = Mediator Variable; DV = Dependent Variable; CV = Covariate; CI = Confidence Interval

Table 6

Model 3 Resting RSA onto Frustration Through Vineland-II

		Consequent									*n*
		MV (Vineland-II)					*DV* (Frustration)				
Antecedent		Coeff.	*SE*	CI	*p*		Coeff.	*SE*	CI	*p*	
IV (Resting RSA)	*a*	0.70	0.89	-1.05, 2.46	.430	*c'*	-0.01	0.04	-0.10, 0.07	.758	139
MV (Vineland-II)		-	-	-	-	*b*	0.001	0.004	-0.01, 0.01	.867	
Constant		112.37	1.17	110.05, 114.70	<.001		1.52	0.06	1.41, 1.64	<.001	
		$R^2 = 0.005$					$R^2 = 0.001$				
		$F(1,137) = 0.63, p = .430$					$F(2,136) = 0.06, p = .943$				

Note: IV = Independent Variable; MV = Mediator Variable; DV = Dependent Variable; CI = Confidence Interval

Table 7

Model 4 Reactive RSA onto Frustration Through Vineland-II

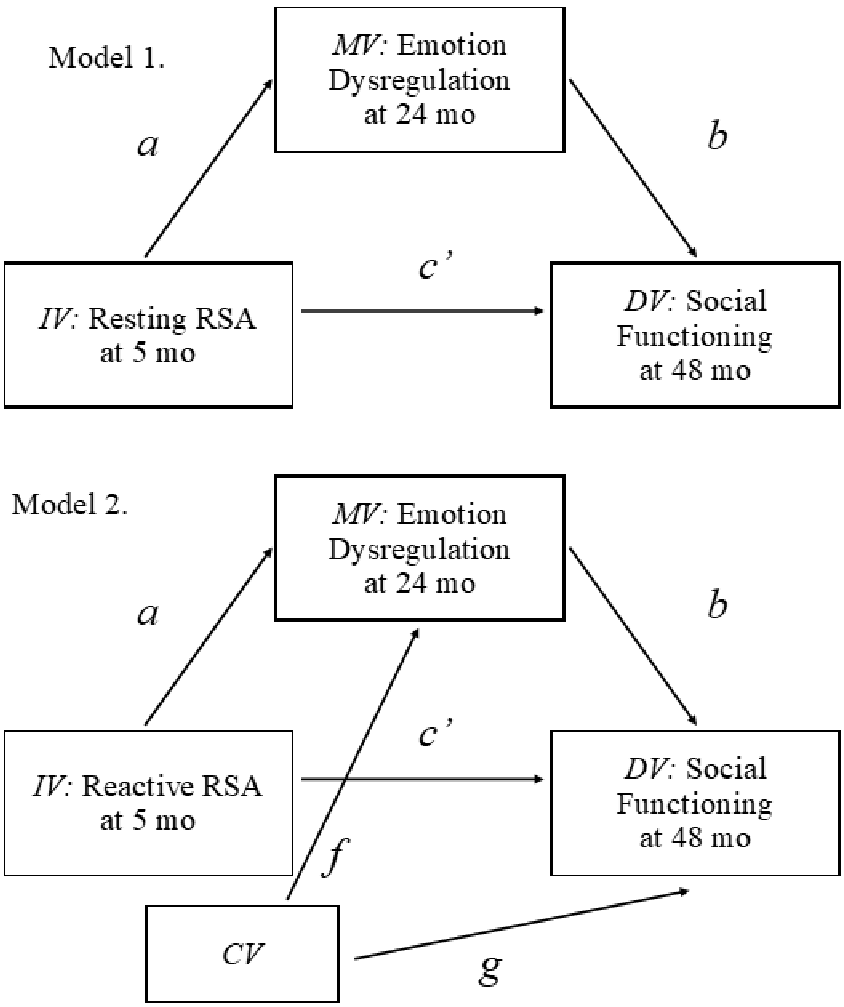
		Consequent									*n*
		MV (Vineland-II)					*DV* (Frustration)				
Antecedent		Coeff.	*SE*	CI	*p*		Coeff.	*SE*	CI	*p*	
IV (Reactive RSA)	*a*	-0.53	0.89	-2.29, 1.22	.549	*c'*	0.07	0.04	-0.01, 0.16	.102	139
MV (Vineland-II)		-	-	-	-	*b*	0.001	0.004	-0.01, 0.01	.774	
CV (Crying)	*f*	-1.66	2.83	-7.26, 3.93	.558	*g*	0.22	0.14	-0.05, 0.50	.106	
Constant		112.77	1.36	110.09, 115.45	<.001		1.47	0.07	1.34, 1.60	<.001	
		$R^2 = 0.004$					$R^2 = 0.03$				
		$F(2,136) = 0.29, p = .745$					$F(3, 135) = 1.50, p = .218$				

Note: IV = Independent Variable; MV = Mediator Variable; DV = Dependent Variable; CI = Confidence Interval

Figures

Figure 1

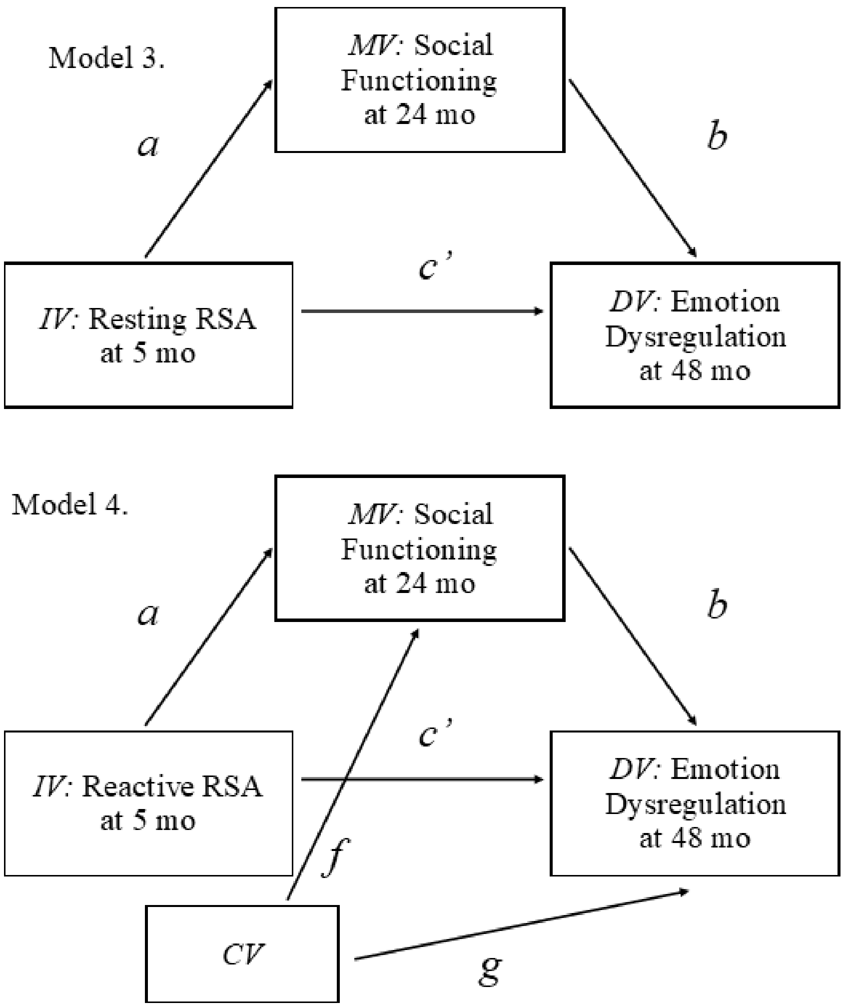
Models 1 and 2 of ED Mediating the Relationship Between RSA and Social Functioning



Note: *IV* = independent variable; *MV* = mediating variable; *DV* = dependent variable; *CV* = covariate.

Figure 2

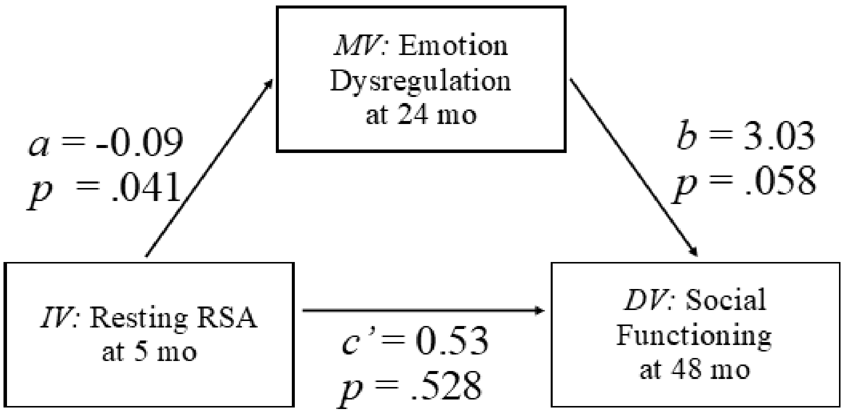
Models 3 and 4 of Social Functioning Mediating the Relationship Between RSA and ED



Note*: IV* = independent variable; *MV* = mediating variable; *DV* = dependent variable; *CV* = covariate.

Figure 3

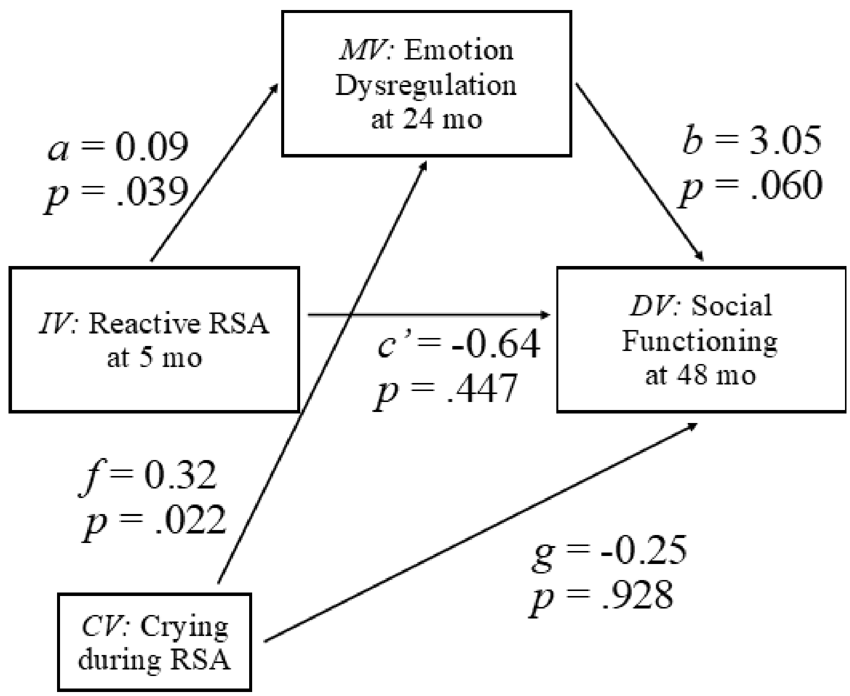
A Statistical Diagram of Model 1 for Resting RSA onto Social Functioning



Note: *IV* = independent variable; *MV* = mediating variable; *DV* = dependent variable.

Figure 4

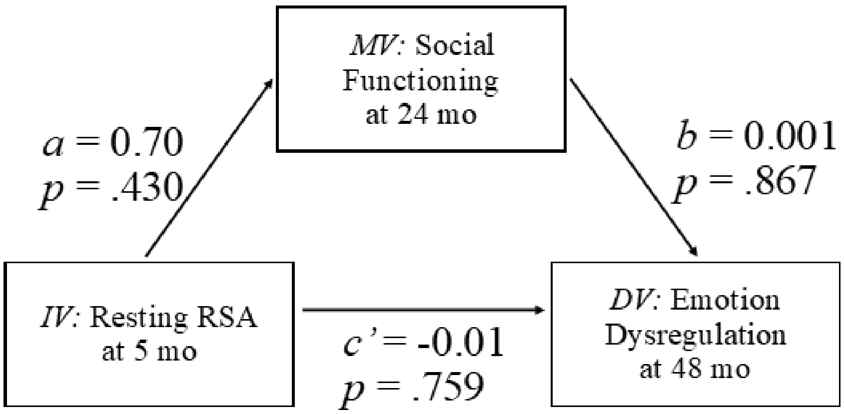
A Statistical Diagram of Model 2 for Reactive RSA onto Social Functioning



Note: *IV* = independent variable; *MV* = mediating variable; *DV* = dependent variable; *CV* = covariate.

Figure 5

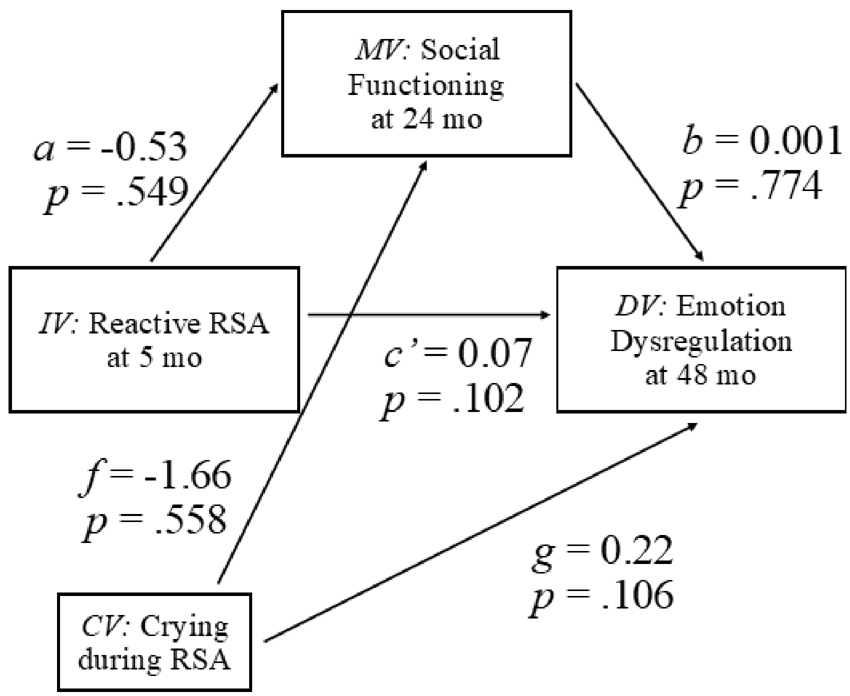
A Statistical Diagram of Model 3 for Resting RSA onto ED



Note: *IV* = independent variable; *MV* = mediating variable; *DV* = dependent variable.

Figure 6

A Statistical Diagram of Model 4 for Reactive RSA onto ED



Note: *IV* = independent variable; *MV* = mediating variable; *DV* = dependent variable; *CV* = covariate.

Appendix

Appendix A

Vineland-II Survey Parent/Caregiver Rating Form

Social Skills and Relationships

Response Options: **2** = Usually, **1** = Sometimes or Partially, **0** = Never, **DK** = Don't Know

Relating to Others

Start	No.	Item					Circle "?" If You Have a Question
0–4 ☛	1	Looks at face of parent or caregiver.	2	1	0	DK	?
	2	Watches (that is, follows with eyes) someone moving by crib or bed for 5 seconds or more.	2	1	0	DK	?
	3	Shows two or more emotions (for example, laughs, cries, screams, etc.).	2	1	0	DK	?
	4	Smiles or makes sounds when approached by a familiar person.	2	1	0	DK	?
	5	Makes or tries to make social contact (for example, smiles, makes noises, etc.).	2	1	0	DK	?
	6	Reaches for familiar person when person holds out arms to him or her.	2	1	0	DK	?
	7	Shows preference for certain people and objects (for example, smiles, reaches for or moves toward person or object, etc.).	2	1	0	DK	?
	8	Shows affection to familiar persons (for example, touches, hugs, kisses, cuddles, etc.).	2	1	0	DK	?
	9	Imitates or tries to imitate parent's or caregiver's facial expressions (for example, smiles, frowns, etc.).	2	1	0	DK	?
	10	Moves about looking for parent or caregiver or other familiar person nearby.	2	1	0	DK	?
	11	Shows interest in children the same age, other than brothers or sisters (for example, watches them, smiles at them, etc.).	2	1	0	DK	?
5–15 ☛	12	Imitates simple movements (for example, claps hands, waves good-bye, etc.).	2	1	0	DK	?
	13	Uses actions to show happiness or concern for others (for example, hugs, pats arm, holds hands, etc.).	2	1	0	DK	?
	14	Shows desire to please others (for example, shares a snack or toy, tries to help even if not capable, etc.).	2	1	0	DK	?
	15	Demonstrates friendship-seeking behavior with others the same age (for example, says, "Do you want to play?" or takes another child by the hand, etc.).	2	1	0	DK	?
	16	Imitates relatively complex actions as they are being performed by another person (for example, shaving, putting on makeup, hammering nails, etc.).	2	1	0	DK	?
	17	Answers when familiar adults make small talk (for example, if asked, "How are you?" says, "I'm fine"; if told, "You look nice," says, "Thank you"; etc.).	2	1	0	DK	?
	18	Repeats phrases heard spoken before by an adult (for example, "Honey, I'm home"; "No dessert until you clean your plate"; etc.).	2	1	0	DK	?
	19	Uses words to express own emotions (for example, "I'm happy"; "I'm scared"; etc.).	2	1	0	DK	?
	20	Has best friend or shows preference for certain friends (of either sex) over others.	2	1	0	DK	?
	21	Imitates relatively complex actions several hours after watching someone else perform them (for example, shaving, putting on makeup, hammering nails, etc.).	2	1	0	DK	?
16+ ☛	22	Uses words to express happiness or concern for others (for example, says, "Yeah! You won"; "Are you all right?"; etc.).	2	1	0	DK	?
	23	Acts when another person needs a helping hand (for example, holds door open, picks up dropped items, etc.).	2	1	0	DK	?
	24	Recognizes the likes and dislikes of others (for example, says, "Chow likes soccer"; "Susie doesn't eat pizza"; etc.).	2	1	0	DK	?
	25	Shows same level of emotion as others around him or her (for example, does not downplay or overdramatize a situation, etc.).	2	1	0	DK	?
	26	Keeps comfortable distance between self and others in social situations (for example, does not get too close to another person when talking, etc.).	2	1	0	DK	?

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Social Skills and Relationships, continued

Response Options: 2 = Usually, 1 = Sometimes or Partially, 0 = Never, DK = Don't Know

Relating to Others, *continued*

						Circle "?" If You Have a Question
27	Talks with others about shared interests (for example, sports, TV shows, summer plans, etc.).	2	1	0	DK	?
28	Starts small talk when meets people he or she knows (for example, says, "How are you?"; "What's up?"; etc.).	2	1	0	DK	?
29	Meets with friends regularly.	2	1	0	DK	?
30	Chooses not to say embarrassing or mean things or ask rude questions in public.	2	1	0	DK	?
31	Places reasonable demands on friendship (for example, does not expect to be a person's only friend or to have the friend always available, etc.).	2	1	0	DK	?
32	Understands that others do not know his or her thoughts unless he or she says them.	2	1	0	DK	?
33	Is careful when talking about personal things.	2	1	0	DK	?
34	Cooperates with others to plan or be part of an activity (for example, a birthday party, sports event, etc.).	2	1	0	DK	?
35	Demonstrates understanding of hints or indirect cues in conversation (for example, knows that yawns may mean, "I'm bored," or a quick change of subject may mean, "I don't want to talk about that"; etc.).	2	1	0	DK	?
36	Starts conversations by talking about things that interest others (for example, "Tyrone tells me you like computers"; etc.).	2	1	0	DK	?
37	Goes on group dates.	2	1	0	DK	?
38	Goes on single dates.	2	1	0	DK	?

Playing and Using Leisure Time

							Circle "?" If You Have a Question
0–7 ☛	1	Responds when parent or caregiver is playful (for example, smiles, laughs, claps hands, etc.).	2	1	0	DK	?
	2	Shows interest in where he or she is (for example, looks or moves around, touches objects or people, etc.).	2	1	0	DK	?
	3	Plays simple interaction games with others (for example, peekaboo, patty-cake, etc.).	2	1	0	DK	?
	4	Plays near another child, each doing different things.	2	1	0	DK	?
	5	Chooses to play with other children (for example, does not stay on the edge of a group or avoid others).	2	1	0	DK	?
	6	Plays cooperatively with one or more children for up to 5 minutes.	2	1	0	DK	?
	7	Plays cooperatively with more than one child for more than 5 minutes.	2	1	0	DK	?
	8	Continues playing with another child with little fussing when parent or caregiver leaves.	2	1	0	DK	?
	9	Shares toys or possessions when asked.	2	1	0	DK	?
8–15 ☛	10	Plays with others with minimal supervision.	2	1	0	DK	?
	11	Uses common household objects or other objects for make-believe activities (for example, pretends a block is a car, a box is a house, etc.).	2	1	0	DK	?
	12	Protects self by moving away from those who destroy things or cause injury (for example, those who bite, hit, throw things, pull hair, etc.).	2	1	0	DK	?
	13	Plays simple make-believe activities with others (for example, plays dress-up, pretends to be superheroes, etc.).	2	1	0	DK	?

Response Options: 2 = Usually, 1 = Sometimes or Partially, 0 = Never, DK = Don't Know

Playing and Using Leisure Time, *continued*

							Circle "?" If You Have a Question
	14	Seeks out others for play or companionship (for example, invites others home, goes to another's home, plays with others on the playground, etc.).	2	1	0	DK	?
	15	Takes turns when asked while playing games or sports.	2	1	0	DK	?
	16	Plays informal, outdoor group games (for example, tag, jump rope, catch, etc.).	2	1	0	DK	?
	17	Shares toys or possessions without being asked.	2	1	0	DK	?
	18	Follows rules in simple games (relay races, spelling bees, electronic games, etc.).	2	1	0	DK	?
	19	Takes turns without being asked.	2	1	0	DK	?
	20	Plays simple card or board game based only on chance (for example, Go Fish, Crazy Eights, Sorry™, etc.).	2	1	0	DK	?
	21	Goes places with friends during the day with adult supervision (for example, to a shopping mall, park, community center, etc.).	2	1	0	DK	?
16+ ☛	22	Asks permission before using objects belonging to or being used by another.	2	1	0	DK	?
	23	Refrains from entering group when nonverbal cues indicate that he or she is not welcome.	2	1	0	DK	?
	24	Plays simple games that require keeping score (for example, kickball, pickup basketball, etc.).	2	1	0	DK	?
	25	Shows good sportsmanship (that is, follows rules, is not overly aggressive, congratulates other team on winning, and does not get mad when losing).	2	1	0	DK	?
	26	Plays more than one board, card, or electronic game requiring skill and decision making (for example, Monopoly™, Cribbage, etc.).	2	1	0	DK	?
	27	Goes places with friends in evening with adult supervision (for example, to a concert, lecture, sporting event, movie, etc.).	2	1	0	DK	?
	28	Follows rules in complex games or sports (for example, football, soccer, volleyball, etc.).	2	1	0	DK	?
	29	Goes places with friends during the day without adult supervision (for example, to a shopping mall, park, community center, etc.).	2	1	0	DK	?
	30	Plans fun activities with more than two things to be arranged (for example, a trip to a beach or park that requires planning transportation, food, recreational items, etc.).	2	1	0	DK	?
	31	Goes places with friends in evening without adult supervision (for example, to a concert, lecture, sporting event, movie, etc.).	2	1	0	DK	?

Response Options: 2 = Usually, 1 = Sometimes or Partially, 0 = Never, DK = Don't Know

Adapting

		Item					Circle "?" If You Have a Question
1+ ☛	1	Changes easily from one at-home activity to another.	2	1	0	DK	?
	2	Says "thank you" when given something.	2	1	0	DK	?
	3	Changes behavior depending on how well he or she knows another person (for example, acts differently with family member than with stranger, etc.).	2	1	0	DK	?
	4	Chews with mouth closed.	2	1	0	DK	?
	5	Says "please" when asking for something.	2	1	0	DK	?
	6	Ends conversations appropriately (for example, says, "Good-bye"; "See you later"; etc.).	2	1	0	DK	?
	7	Cleans or wipes face and hands during and/or after meals.	2	1	0	DK	?
	8	Responds appropriately to reasonable changes in routine (for example, refrains from complaining, etc.).	2	1	0	DK	?
	9	Says that he or she is sorry for unintended mistakes (for example, bumping into someone, etc.).	2	1	0	DK	?
	10	Chooses not to taunt, tease, or bully.	2	1	0	DK	?
	11	Acts appropriately when introduced to strangers (for example, nods, smiles, shakes hands, greets them, etc.).	2	1	0	DK	?
	12	Changes voice level depending on location or situation (for example, in a library, during a movie or play, etc.).	2	1	0	DK	?
	13	Says he or she is sorry after hurting another's feelings.	2	1	0	DK	?
	14	Refrains from talking with food in mouth.	2	1	0	DK	?
	15	Talks with others without interrupting or being rude.	2	1	0	DK	?
	16	Accepts helpful suggestions or solutions from others.	2	1	0	DK	?
	17	Controls anger or hurt feelings when plans change for reason(s) that cannot be helped (for example, bad weather, car trouble, etc.).	2	1	0	DK	?
	18	Keeps secrets or confidences for longer than one day.	2	1	0	DK	?
	19	Says he or she is sorry after making unintentional mistakes or errors in judgment (for example, when unintentionally leaving someone out of a game, etc.).	2	1	0	DK	?
	20	Shows understanding that gentle teasing with family and friends can be a form of humor or affection.	2	1	0	DK	?
	21	Tells parent or caregiver about his or her plans (for example, what time he or she is leaving and returning, where he or she is going, etc.).	2	1	0	DK	?
	22	Chooses to avoid dangerous or risky activities (for example, jumping off high places, picking up a hitchhiker, driving recklessly, etc.).	2	1	0	DK	?
	23	Controls anger or hurt feelings when he or she does not get his or her way (for example, when not allowed to watch television or attend a party; when suggestion is rejected by friend or supervisor; etc.).	2	1	0	DK	?
	24	Follows through with arrangements (for example, if promises to meet someone, meets that person; etc.).	2	1	0	DK	?
	25	Stops or stays away from relationships or situations that are hurtful or dangerous (for example, being bullied or made fun of, being taken advantage of sexually or financially, etc.).	2	1	0	DK	?
	26	Controls anger or hurt feelings due to constructive criticism (for example, correction of misbehavior, discussion of test score or grade, performance review, etc.).	2	1	0	DK	?
	27	Keeps secrets or confidences for as long as needed.	2	1	0	DK	?
	28	Thinks about what could happen before making decisions (for example, refrains from acting impulsively, thinks about important information, etc.).	2	1	0	DK	?
	29	Is aware of potential danger and uses caution when encountering risky social situations (for example, binge drinking parties, Internet chat rooms, personal ads, etc.).	2	1	0	DK	?
	30	Shows respect for co-workers (for example, does not distract or interrupt others who are working, is on time for meetings, etc.).	2	1	0	DK	?