# The relation between maternal emotional support and child physiological regulation across the preschool years

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**Abstract:**

Trajectories of baseline RSA (respiratory sinus arrhythmia), an index of reactivity, and vagal withdrawal, an index of regulation, across the preschool period were examined. In addition, maternal emotional support was investigated as a potential time-varying predictor of these trajectories. Physiological measures were obtained during frustration tasks, and a maternal emotional support measure was assessed via maternal report and direct observation. Children's baseline RSA and vagal withdrawal scores were moderately stable across the preschool period. Growth models indicated that children's baseline RSA scores changed linearly over the preschool years, and there was significant variability in withdrawal trajectories. Greater maternal emotional support predicted higher initial withdrawal levels and lower emotional support was associated with the greatest increase in withdrawal over time. This suggests that children of higher emotionally supportive mothers reached higher levels of physiological regulation earlier in development and therefore did not show the same increase across preschool as children of less supportive mothers. Maternal emotional support was not significantly related to trajectories of baseline RSA.

**Keywords:** vagal withdrawal | vagal tone | emotion regulation | physiological regulation | maternal sensitivity | RSA | preschool | emotional support

**Article:**

## INTRODUCTION

The regulation of emotion, especially during early childhood, has received extensive attention in the field of developmental psychology. Developmentalists have linked the ability to regulate emotion (particularly negative emotions) to development in other critical domains such as cognitive development, social development, and psychological adjustment (Deater-Deckard & Mullineaux, 2010; Hill, Degnan, Calkins, & Keane, 2006; Mendez, Fantuzzo, & Cicchetti, 2002). For example, preschoolers' ability to adapt flexibly and appropriately to emotionally challenging situations has been found to predict better school adjustment, academic readiness, and overall social competence (Denham et al., 2003; Rubin, Coplan, Fox, & Calkins, 1995). Therefore, understanding developmental trajectories of emotion regulation during the preschool years, as well as predictors of these trajectories, is potentially informative for predicting children's academic success and adaptive social functioning.

Emotion regulation is a multidimensional construct composed of behavioral and biological components and has been found to be influenced by environmental factors such as parenting (Calkins, 1994; Calkins, Graziano, Berdan, Keane, & Degan, 2008; Hoffman, Crnic, & Baker, 2006). One of the most common parental measures associated with children's emotion regulation is sensitive and supportive responses to emotional situations (Feldman, Greenbaum, Yirmiya, 1999; Kochanska, Aksan, Prisco, & Adams, 2008). Mothers who consistently respond to their children with warm accepting behavior are likely to create emotionally supportive contexts in which children feel comfortable, thus promoting self-regulation (Karreman, van Tuijl, van Aken, & Dekovic, 2006). Further, negative emotions such as anger, fear, and sadness are more developmentally challenging for young children and are manifested through changes in arousal and autonomic activity (Hastings & De, 2008; Ramsden & Hubbard, 2002). Parenting that is supportive and responsive to positive and negative emotion is likely to reduce autonomic arousal and promote children's physiological regulation during emotionally charged contexts, which in turn promotes children's future physiological self-regulation. Therefore, in order to best understand the development of emotion regulation, intrinsic child (i.e., physiological responses to challenge) and extrinsic environmental (i.e., maternal emotional support) factors should be examined (Fox & Calkins, 2003). The first aim of the current project was to identify trajectories of child physiological regulation across the preschool period during challenging situations that require regulation of emotions and emotional responding. The second aim of this work was to examine how maternal emotional support may influence these trajectories of child physiological regulation across the preschool years.

## PARASYMPATHETIC CARDIAC ACTIVITY AND EMOTION REGULATION

Previous research has documented the importance of physiological regulation in development and its influence on other domains of functioning such as emotion understanding, behavioral regulation, social competence, and cognitive functioning (Deater-Deckard & Mullineaux, 2010; Hill et al., 2006; Mendez et al., 2002). Being physiologically regulated earlier in life allows children to engage in higher quality play, acquire more literacy skills (Suess & Bornstein, 2000), better control emotional displays (Calkins, 1997), and express emotions more appropriately (Cole, Zahn-Waxler, Fox, Usher, & Welsh, 1996) than less regulated peers. These skills, in turn, enable children to develop social, emotional, and cognitive abilities at an earlier age, which has been associated with better developmental trajectories, such as less problem behavior (Fanti & Henrich, 2010) and greater academic achievement (Leeson, Ciasrrochi, & Heaven, 2008; Wentzel & Caldwell, 1997) over time.

Emotion regulation theories that include physiological aspects of regulation assume that advanced and adaptive emotion regulation behaviors are, in part, a result of the maturation of biological systems across childhood (Calkins & Hill, 2007). Parasympathetic nervous system functioning has been the focus of the majority of research on physiological aspects of emotion regulation and emotional development because parasympathetic nervous system maturation is thought to play an important role in individuals' ability to regulate their state, activity, and emotional experiences (Berntson, Lozano, & Chen, 2005, Calkins, Graziano, & Keane, 2007;

Kreibig, 2010). Porges's (1995) polyvagal theory identified an index of the functional status of the parasympathetic nervous system, which reflects the vagal control of the heart as a measurable organismic variable that accounts for differences in the development of emotional expression and regulation. Porges's method measures the amplitude and period of the oscillations associated with inhalation and exhalation and therefore is a measure of the variability in heart rate that occurs at the frequency of breathing (respiratory sinus arrhythmia, RSA) and is thought to index the parasympathetic influence on heart rate by way of the vagus nerve. Specifically, the myelinated vagus nerve sends input to the heart and causes changes in cardiac activity that allow the body to transition between sustaining metabolic processes and generating responses to the environment (Porges, 2007). Although there are other components of heart rate variability, the RSA measure has been identified as ideal to study the physiological basis for behavioral functioning (Stifter & Fox, 1990; Suess, Porges, & Plude, 1994).

### Baseline RSA

Developmental studies using RSA measures have primarily examined baseline RSA and decreases in RSA (vagal withdrawal) in response to challenge as predictors of emotion regulation abilities. Baseline RSA has been proposed to be a measure of an individual's characteristic level of arousal and, as such, it may reflect temperamental reactivity, which is commonly considered to be a trait-like measure that predicts an individual's capacity for responding to their environment, including challenging situations (Blandon, Calkins, Keane, & O'Brien, 2010; Propper & Moore, 2006; Stifter & Fox, 1990). The majority of studies find higher baseline RSA to be associated with better developmental outcomes such as greater sociability, appropriate emotional reactivity, and expressivity (Cole et al., 1996; Eisenberg, Fabes, Murphy, & Maszk, 1995; Fabes, Eisenberg, & Eisenbud, 1993; Gottman & Katz, 2002), better regulation/soothability (Calkins, 1997; Calkins & Fox, 2002; Stifter & Fox, 1990) good attentional ability (Richards, 1985, 1987; Suess et al., 1994), and fewer behavior problems (Calkins & Howse, 2004; Huffman et al., 1998) in infants and children. However, there have been exceptions to this pattern (Burgess, Marshall, Rubin, & Fox, 2003).

Previous work has provided evidence of developmental change in baseline RSA as physiological systems become more mature and stable over time, such that, in general, baseline RSA has been found to increase with age until middle childhood (Alkon et al., 2003; Bornstein & Suess, 2000; Marshall & Stevenson-Hinde, 1998). However, although the majority of studies find baseline RSA to increase in a stable fashion through middle childhood (Doussard-Roosevelt, Montgomery, & Porges, 2003; El-Sheikh, 2005; Hinnant, Elmore-Staton, & El-Sheikh, 2011), a few studies have reported instability in samples of children as early as the first year (Porter, Bryan, & Hsu, 1995; Stifter, Fox, & Porges, 1989). The current study aimed to add to this literature by examining the trajectory and stability of baseline RSA across the preschool period.

Developmental theory proposes that caregivers affect infants' physiological functioning through both the caregiving environment and hereditary factors (Propper & Moore, 2006). Although small number of studies have provided support for a link between caregiving behavior and child baseline RSA (e.g., Conradt & Ablow, 2010; Gottman & Katz, 2002) the majority do not. For example, Kennedy, Rubin, Hastings, and Maisel (2004) found that children's early RSA predicted mothers' subsequent parenting however the converse association was not significant. Similarly, in a study investigating observed maternal sensitivity and vagal functioning of infants, Propper et al. (2008) found no relation between observed sensitivity and baseline RSA. The lack of relation between maternal behavior and baseline RSA may suggest that baseline RSA is linked to temperamental characteristics intrinsic to the child and is relatively insensitive to environmental variation. To date, however, this association between caregiving and the trajectory of baseline RSA within the preschool period has not been examined and may provide important insight into the mixed results regarding the association between baseline RSA and the caregiving environment. Thus, a secondary goal of the current study was to assess whether maternal emotional support predicted the trajectory of baseline RSA across the preschool period.

## Vagal Withdrawal

During emotionally challenging situations in which active coping is required for the expression of adaptive and appropriate behavioral responses, vagal withdrawal (as indexed by a decrease in RSA during a task) has been identified as a measure of cardiac activity that may be more directly related to regulatory behaviors than baseline RSA in early childhood (Calkins & Keane, 2004; Porges, 2001, 2003). Vagal withdrawal is thought to be indicative of adaptive physiological functioning such that it allows children to transition from maintaining homoeostasis to increasing the demand on internal resources necessary for generating coping strategies to control behavioral and affective expression during emotionally charged situations (Calkins & Keane, 2004). Thus, vagal withdrawal is a physiological mechanism that allows for an increased attention span and adaptive coping behaviors that are thought to be mediated by the parasympathetic nervous system (Porges, 1996; Wilson & Gottman, 1996) and necessary for self-regulation. Although most research has found high levels of vagal withdrawal to be most beneficial (e.g., Calkins & Dedmon, 2000; Gentzler, Santucci, Kovacs, & Fox, 2009), some recent research suggests moderate levels of vagal withdrawal and vagal augmentation are most adaptive in some social, emotional, and cognitive contexts (Calkins et al., 2007; Gazelle & Druhen, 2009; Hastings et al., 2008; Marcovitch et al., 2010).

The stability and developmental trajectory of vagal withdrawal to challenge is still relatively unclear, although much less work has been conducted in this area. To our knowledge, only four studies to date have investigated the stability of vagal withdrawal over time, and they have revealed mixed findings. Bornstein and Suess (2000) measured vagal withdrawal during attention tasks when children were 2 months and again at 5 years and found it to be unstable across these two ages. Further, in a short-term longitudinal study Doussard-Roosevelt et al. (2003) measured 5- and 6-year-old children's vagal withdrawal during a negative affect task across three 2-week intervals and also found this measure to be unstable across assessments. In contrast, other studies have found mild to moderate stability in vagal withdrawal when measured at 3, 6, and 12 months (Feldman, 2009), and at 2 and 4.5 years of age (Calkins & Keane, 2004).

In addition to inconsistencies in previous results, prior studies investigating stability of vagal withdrawal during the preschool period have assessed children at only two time points. The use of three assessment points in the current study will help to clarify the trajectory of vagal withdrawal with development, which has demonstrated variability across studies. For example, Calkins and Keane (2004), found a significant decrease in the magnitude of vagal withdrawal with age. This led to a hypothesis that as children become better emotional and behavioral regulators, they begin to rely less and less on physiological regulation to help them achieve a regulated state. This is in contrast to the idea that physiological regulation capabilities increase as a result of maturation and children become “better” physiological regulators with age. Given these inconsistencies, a more systematic investigation of physiological regulation in the preschool years is necessary to help elucidate the nature of developmental change in physiological regulation.

Infants' physiological self-regulatory abilities are very immature and therefore very young children are reliant on environmental resources to achieve and maintain a regulated state (Spangler & Grossmann, 1993). Thus, caregivers play a crucial role in helping children achieve physiological homeostasis during emotionally arousing situations. Research investigating the link between caregiving and children's physiological functioning has revealed somewhat mixed findings. For example, Kennedy et al. (2004) found no link between parental socialization and vagal regulation, and Calkins, Smith, Gill, and Johnson (1998) found that positive maternal support was uncorrelated with physiological measures. In contrast, infants of sensitive mothers showed greater vagal withdrawal during the still-face procedure compared to infants of less sensitive mothers (Moore et al., 2009). Likewise, mother–child relationship quality during toddlerhood was found to predict the degree of children's vagal withdrawal at 5 years, even after controlling for behavior problems and vagal withdrawal at age 2, such that children with poorer mother–child relationships displayed significantly poorer vagal regulation (Calkins et al., 2008). Thus, there is accumulating evidence that sensitive and emotionally supportive parenting plays a role in children's physiological development, specifically with regard to vagal withdrawal.

## THE CURRENT STUDY

The first goal of the current study was to examine the stability and trajectories of baseline RSA and RSA change, or vagal withdrawal, across the preschool period in children 3, 4, and 5 years of age. A second goal of this work was to examine the potential relation between maternal emotional support and trajectories of baseline RSA and vagal withdrawal. We expected baseline RSA to be moderately stable and increase linearly as children get older. With regard to children's trajectories of vagal withdrawal, based on the only previous investigation of vagal withdrawal stability within this age range (Calkins & Keane, 2004), we expected that modest stability would be observed across the three time points.

Finally, the relation between maternal emotional support and cardiac activity across the preschool period was examined. Given the somewhat mixed findings of prior research regarding the association between caregiving and baseline RSA, our analysis regarding the effect of maternal emotional support on children's baseline RSA was exploratory and we did not have a clear hypothesis. However, based on the associations linking sensitive and supportive caregiving to children's vagal regulation, it was hypothesized that children of emotionally supportive mothers would display greater vagal withdrawal earlier and maintain higher levels of withdrawal throughout the preschool years. Additionally, maternal emotional support was predicted to be more strongly related to vagal withdrawal at age 3 when children's internal regulatory abilities are still relatively immature, than at later ages when the nervous system is more mature.

## METHODS

### Participants

The participants in this project were part of a longitudinal study of early cognitive and emotional precursors to school success. Children were recruited from childcare centers and preschools in a mid-sized Southeastern city. Families were enrolled in the study when children were 3 years old and returned when children were 4 and 5 years of age. Of the 263 families that participated at age 3, 244 families had data available at the 4-year visit, and 228 had available data at the 5-year visit (87% retention rate). There were no significant differences by child gender or family income-to-needs ratio (total family income divided by the poverty threshold for a particular family size) between families who did and did not have data available at age 4 or 5. Families lost to attrition were more likely to be ethnic minority ($\chi^2[1, N = 263] = 3.89, p < .05$). The current sample included 226 children with RSA data available at the age 3 assessment, 197 of whom had RSA data at age 4, and 209 of whom had RSA data at age 5. Vagal tone data was primarily missing due to the child's refusal to wear the electrode stickers. However, the necessity of conducting home visits, equipment failure, and experimenter error also prevented the collection of usable physiological data in some cases.

**Procedure**

The laboratory visits lasted approximately 2 h. Mothers provided written consent, completed questionnaires, and engaged in a parent–child interaction task during the sessions. Children were videotaped while engaging in multiple tasks, either with an experimenter or with their mothers. Approximately 30 min into the visits, children were asked to wear heart rate electrode stickers and children who complied wore the electrodes for close to an hour while they completed cognitively and emotionally challenging tasks. Families received $40 for the 3-year visit, $60 for the 4-year visit, and $80 for the 5-year visit. Children selected a toy at the end of each visit as thanks for their participation.

**Measures**

*Demographics.* Mothers completed a demographic questionnaire including child gender and race, maternal age, parents' marital status, and family income. Updated demographic information was obtained at each year's visit.

*Parasympathetic Cardiac Measures.* EKG was recorded during a baseline procedure in which children watched an emotionally neutral 5-min video and during the frustration tasks. Two electrodes were placed on children's chest and stomach and connected to a preamplifier, the output of which was processed through a vagal tone monitor (Series, 2000 Mini-Logger, Mini Mitter Co., Inc. Bend, OR) for *R*-wave detection. Editing the files consisted of examining for outlier points and dividing or summing them so that they would be consistent with the surrounding data. Data files that required editing of more than 10% of the data were not included in the analyses.

Estimates of RSA were calculated using Porges' (1985) method of analyzing interbeat interval (IBI) data. This method applies an algorithm to the sequential heart period (HP) data. The algorithm uses a moving 21-point polynomial to detrend periodicities in HP slower than RSA. A band-pass filter then extracts the variance of HP within the frequency band of spontaneous respiration (.24–1.04 Hz) in young children. Although lower frequency bands may be studied, research with young children has consistently examined this band and identified associations with child functioning (Huffman et al., 1998; Stifter & Fox, 1990). RSA was calculated every 30 s for the baseline period and every 30 s for the frustration tasks. These epoch durations were used to maximize the use of available data from each task and are typical for studies of short-duration tasks with a developmental population (Calkins & Dedmon, 2000; Calkins & Keane, 2004; Doussard-Roosevelt et al., 2003; Huffman et al., 1998; Marcovitch et al., 2010). To generate measures of cardiac activity to derive baseline RSA (baseline vagal tone) and RSA withdrawal (baseline RSA-challenge RSA = vagal withdrawal) IBI files were edited and analyzed using MXEDIT software (Delta Biometrics, Inc., Chicago, IL).

*Frustration tasks.* At the 3-year, 4-year, and 5-year visits children also participated in the Impossibly Perfect Green Circles laboratory task adapted from Goldsmith and Reilly (1993). During the Green Circles task, children were given a sheet of white paper and a green marker. In a neutral tone, an experimenter repeatedly (for 3.5 min) asked the child to draw a perfect green circle and gently criticized previous circles drawn. Critiques did not provide the child with enough information to fix the problem, but they were specific (e.g., too small or too bumpy). When the task was over the children received positive comments and the experimenter told the child that the last circle was perfect.

At the 3-year and 5-year visits, children participated in the Attractive Toy in a Locked Box task ("Locked Box"). The child was seated at a small table and offered a choice of two highly desirable toys to play with. After the child made a selection, the toy was placed in a transparent box that was locked with a padlock. The experimenter supplied the child with a large ring of keys, none of which were the correct key, and instructed the child to find the right key to open the box in order to play with the toy. The experimenter then left the room for 3 min while the child attempted to open the box. When the experimenter re-entered the room, he/she presented the correct key to the child and allowed the child to open the box and play with the toy for 1 min.

At the 4-year visit only, children participated in the Frustrating Puzzles Task. The child was seated at a small table and given a wooden toy with many holes. The toy had a string laced through the holes; however, the middle of the string was glued to the inside of the toy, so that it was impossible to untangle it completely. The experimenter asked the child to untangle the toy and left the room. After 3 min, the experimenter re-entered the room and gave the child a second unglued puzzle that the child could solve.

Pearson correlations between the vagal withdrawal scores in the two tasks given at each year ranged from .59 to .60 ($p$s < .01). Vagal withdrawal scores for the frustration tasks were averaged as an index of regulation. Scores were not standardized prior to averaging due to the fact that we were interested in change.

*Maternal Emotional Support.* Maternal emotional support was measured from two mother–child interaction tasks and a mother-report questionnaire during each visit. Emotional responsiveness, representing the emotional quality of the interaction between mother and child, was coded by trained coders from a board game task and storybook reading task; it was rated on a scale of 1 (little dyadic involvement or sensitivity shown by the mother) to 5 (the mother was highly sensitive, clearly enjoyed being with the child). The board game and storybook were slightly different each year, though the overall goals of each task were identical. To establish reliability, approximately 25% of the videotapes were coded by two coders (3-year ICCs = .85, .83; 4-year ICCs = .83, .73; 5-year ICCs = .75, .84). The mother-report questionnaire included in the emotional support composite was the Supportive subscale of the Coping with Children's Negative Emotions Scale (CCNES; Fabes, Eisenberg, & Bernzweig, 1990). The supportive subscale includes three types of parental reactions: problem-focused, emotion-focused, and expressive encouragement (Fabes, Poulin, Eisenberg, & Madden-Derdich, 2002). The CCNES has demonstrated adequate test–retest reliability and construct and predictive validity (Fabes et al., 2002). It includes 12 common situations in which the child is distressed and asks mothers to rate the likelihood that they would respond in each of 6 possible ways (i.e., 3 supportive and 3 non-supportive) on a 7-point scale (1 = *very unlikely*, 7 = *very likely*). The average internal reliability across the 3 supportive reaction subscales was .85 at age 3, .86 at age 4, and .86 at age 5. The average correlation between both observed maternal responsiveness scores and the 3 reported emotional supportive parenting reactions was .30 at age 3, .32 at age 4, and .32 at age 5, all $p < .001$. The average reliability was calculated from the five variables included in the composite and was .65 at age 3, .68 at age 4, and .61 at age 5 (Cronbach's alpha). Thus, scores for maternal emotional support were averaged across the standardized maternal emotional responsiveness and emotional support variables.

## RESULTS

### Preliminary Analyses

Preliminary analyses were conducted to examine descriptive information and correlations between study variables (shown in Tab. 1). Children's baseline RSA and vagal withdrawal scores were correlated within each age. Children's vagal withdrawal at age 3 and baseline RSA at age 5 were the only cardiac measure correlated with maternal emotional support. Child gender and family income-to-needs ratio were examined as possible covariates[1]; these demographic characteristics were unrelated to children's cardiac activity at all time points and therefore were excluded from analyses.

**Table 1.** Descriptive Information and Correlations for Study Variables

| | **Descriptives** | | | | **Correlations** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ***M*** | ***SD*** | **Range** | **Skew (*SE*)** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| 1. Baseline vagal tone 3 years | 6.41 | 1.32 | 1.70–9.06 | −.37 (.16) | | | | | | | | |
| 2. Baseline vagal tone 4 years | 6.64 | 1.08 | 3.96–9.23 | −.18 (.17) | .34** | | | | | | | |
| 3. Baseline vagal tone 5 years | 7.01 | 1.21 | 3.84–10.10 | −.25 (.17) | .34** | .52** | | | | | | |
| 4. Vagal withdrawal 3 years | .92 | .68 | −1.53–2.72 | −.21 (.16) | .57** | .09 | .09 | | | | | |
| 5. Vagal withdrawal 4 years | 1.07 | .62 | −.52–2.87 | −.03 (.17) | .12 | .45** | .23** | .35** | | | | |
| 6. Vagal withdrawal 5 years | .96 | .60 | −.63–2.50 | .13 (.17) | −.09 | .09 | .36** | .12 | .27** | | | |
| 7. Maternal support 3 years | .01 | 1.51 | −7.05–2.82 | −.91 (.15) | −.03 | .03 | −.15* | .11 | .06 | −.02 | | |
| 8. Maternal support 4 years | .00 | 1.54 | −6.24–2.74 | −.63 (.16) | .02 | .02 | −.15* | .18** | −.06 | −.08 | .66** | |
| 9. Maternal support 5 years | .02 | 1.46 | −4.64–3.19 | −.33 (.16) | −.08 | −.07 | −.13 | .01 | −.10 | −.05 | .57** | .63** |

* $p < .05$.
** $p < .01$.

### Stability and Mean Change

*Baseline RSA.* Stability and mean-level change of baseline RSA at the three time points were examined. As seen in Table 1 correlations, children's baseline RSA was moderately to highly stable from age 3 to age 4, from age 4 to age 5, and from age 3 to age 5. A repeated-measures analysis of variance (ANOVA) showed a significant difference in mean baseline RSA scores ($F(2, 170) = 11.48$, $p < .01$, age 3, $M = 6.45$, $SD = 1.23$; age 4, $M = 6.60$, $SD = 1.06$; age 5, $M = 6.93$, $SD = 1.22$). Consistent with previous research, children's mean baseline RSA increased over time; the age 5 mean was significantly higher than the age 3 and the age 4 mean.

[1] In addition to examining child gender as a covariate, gender was also examined as a potential moderating factor; however, no significant moderation effects were found.

*Vagal Withdrawal.* Correlations shown in Table 1 demonstrated that children's mean vagal withdrawal was moderately stable from age 3 to age 4, and from age 4 to age 5, although withdrawal scores at age 3 were unrelated to withdrawal at age 5. A repeated-measures ANOVA revealed that the vagal withdrawal means at 3 ($M = .96$, $SD = .62$), 4 ($M = 1.06$, $SD = .59$), and 5 ($M = .98$, $SD = .58$) years were not significantly different from one another, $F(2, 159) = 1.83$, $p = .17$.

## Trajectory Analyses

Trajectories of children's baseline RSA and vagal withdrawal using scores at ages 3, 4, and 5 were examined. Three growth models for each dimension of cardiac activity were tested using Mplus v5 (Muthén & Muthén, 1998–2011): a level-only model testing no change, a linear change model, and a latent basis model testing varying change. Full information maximum likelihood (FIML) was used to account for missing data. Results are presented in Table 2.

**Table 2.** Baseline RSA and Vagal Withdrawal Growth Analyses

| | **B (*SE* B)** |
|---|---|
| Baseline RSA | |
| Intercept | |
| Mean | 6.42 (.08)** |
| Variance | .87 (.16)** |
| Maternal emotional support 3 years | −.03 (.20) |
| Slope | |
| Mean | .57 (.10)** |
| Variance | .66 (.27)* |
| Maternal emotional support 3 years | −.22 (.17) |
| Maternal emotional support 4 years | −.30 (.16) |
| Maternal emotional support 5 years | −.08 (.17) |
| Intercept × Slope | −.39 (.17)* |
| Vagal withdrawal | |
| Intercept | |
| Mean | .96 (.04)** |
| Variance | .22 (.05)** |
| Maternal emotional support 3 years | .26 (.12)* |
| Slope | |
| Mean | .04 (.06) |
| Variance | .20 (.09)* |
| Maternal emotional support 3 years | −.20 (.10)* |
| Maternal emotional support 4 years | −.22 (.09)* |
| Maternal emotional support 5 years | −.01 (.10) |
| Intercept × slope | −.15 (.06)** |

* $p < .05$.
** $p < .01$.

*Baseline RSA.* A model estimating linear growth in children's baseline RSA across the preschool years had marginal fit to the data, RMSEA = .11 [90% CI = .05–.18], CFI = .89, $\chi^2(3) = 12.59$, $p < .01$. However, the linear model fit the data significantly better than the level-only model, which assumes no change in baseline RSA scores across time, $\chi^2(3) = 43.94$, $p < .01$, or the latent basis model, which suggests change occurs, but in a nonlinear fashion, $\chi^2(1) = 9.77$, $p < .01$. Together, these findings indicated that children's baseline RSA scores changed over the preschool years and that this change tended to be linear. As seen in Table 2, the linear growth model indicated that there was significant variation in children's initial baseline RSA at age 3. Baseline RSA scores increased linearly with age and there was significant variation in how children's baseline scores changed over time, meaning that baseline RSA did not increase in the same way for all children. Baseline scores decreased for approximately 37% of children, stayed very similar for 6% of children, and increased over time for approximately 57% of children.

*Vagal Withdrawal.* The linear change model also fit the vagal withdrawal data significantly better than the level-only model of no change, $\chi^2(3) = 9.19$, $p < .05$, and had adequate fit to the data, RMSEA = .08 [90% CI = .00–.15], CFI = .86, $\chi^2(3) = 7.60$, $p = .06$. The latent basis model of nonlinear change did not significantly add to the prediction of change in vagal withdrawal over the linear change model, $\chi^2(1) = .01$, $p = .91$. Results from the linear model indicated that as a group, children's vagal withdrawal scores did not change in the same direction on average (see Tab. 2). However, there was significant variation between children in initial 3-year withdrawal scores and in how scores changed over time. Together, these findings indicated that when children's individual vagal withdrawal scores changed over the preschool years, this change tended to be linear. Withdrawal scores decreased over time for approximately 46% of children, remained very similar for 8% of children, and increased over time for approximately 46% of children. There was also a significant relation between the intercept and slope; children with lower initial withdrawal scores tended to have a faster rate of withdrawal increase over time, $b = -.15$, $p < .01$.

### Maternal Emotional Support as a Predictor of Children's Trajectories

To address the second aim of the study, we tested whether maternal emotional support predicted variation in children's initial cardiac activity and change in cardiac activity over time using the linear change model. Emotional support at the 3-year assessment was used to predict the baseline RSA and vagal withdrawal intercepts. Emotional support scores at 3, 4, and 5 years were included as time-varying predictors of the baseline RSA and vagal withdrawal slopes. Results are shown in Table 2.

*Baseline RSA.* Although relations between maternal emotional support and children's baseline RSA were not hypothesized, emotional support was included in the growth curve analyses as a predictor of initial baseline RSA and change in RSA over time. Consistent with the prediction, maternal emotional support at 3 years was not significantly related to initial baseline RSA, and emotional support at 3 years, 4 years, and 5 years were not related to changes in baseline RSA (see Tab. 2).

*Vagal Withdrawal.* Next, maternal emotional support was used to predict children's vagal withdrawal scores. The model had adequate fit to the data, RMSEA = .06 [90% CI = .00–.12], CFI = .88, $\chi^2(12) = 51.30$, $p < .01$. As seen in Table 2, higher maternal emotional support when children were 3 years old significantly predicted higher initial withdrawal levels in children. Emotional support at age 3 and age 4 also predicted change in children's withdrawal scores over time, with lower emotional support at age 3 and age 4 associated with increases in withdrawal. Maternal emotional support at age 5 was not associated with changes in withdrawal.[2]

For illustrative purposes we grouped children based on their mothers' 3-year supportiveness scores into halves and graphed vagal withdrawal scores for the high emotional support and low emotional support groups. As seen in Figure 1, children with highly supportive mothers experienced little change in vagal withdrawal in response to frustration across the preschool years. However, children with unsupportive mothers experienced gains in withdrawal, suggesting that their regulatory abilities increased over time ending at a similar level as children of supportive mothers by age 5. Indeed, ANOVA indicated that the supportiveness groups were significantly different from one another in vagal withdrawal at 3 years, $F(1, 225) = 359.28$, $p < .01$, with children of more supportive mothers having higher withdrawal scores. At age 4, mothers in the high support group again had children with significantly higher withdrawal, $F(1, 196) = 7.59$, $p < .01$. There were no significant differences between children's withdrawal scores at age 5 based on 3-year maternal emotional support.

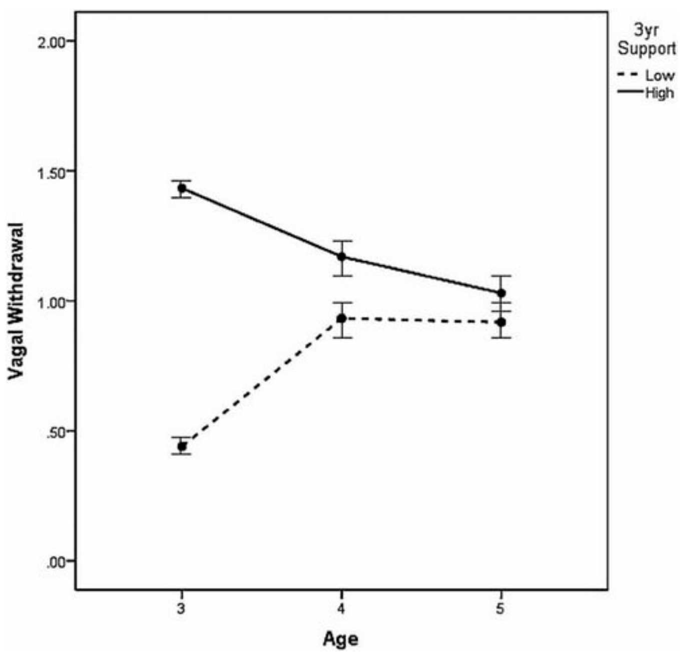


**Figure 1**. Maternal emotional support at age 3 predicting trajectories of Children's vagal withdrawal across the preschool years.

## DISCUSSION

The current study examined trajectories of physiological regulation during a frustration challenge, as indexed by baseline RSA and vagal withdrawal, across the preschool years. A second aim was to examine the role of maternal emotional support in predicting change in children's physiological regulation to frustration. Our design was advantageous over previous research in that it allowed us to examine changes across three time points that have been implicated as integral in the development of self-regulation abilities (Kopp, 1982). A further

[2] The results were identical when also controlling for baseline RSA.

advantage of the current study was that it utilizes a supportive parenting measure that encompasses mother's emotionally responsive and supportive reactions to children's negative and positive emotions, which is important due to the fact that parents have been shown to respond differently to child distress versus nondistress, and responses to distress may be especially important in relation to the development of emotion regulation (Leerkes, Blankson, & O'Brien, 2009).

In accordance with previous research, our results indicated that baseline RSA was moderately to highly stable and increased from age 3 to age 5. In accordance with our hypothesis, trajectory analyses revealed that a linear growth model fit the baseline RSA data best. There was significant individual variation in initial baseline RSA and significant change in baseline RSA with age that tended to be linear. Interestingly, although the linear model fit the data best, model fit statistics suggested a somewhat marginal fit. There was significant variation in how baseline RSA changed over time, meaning that baseline RSA did not increase in the same way for all children. This finding highlights the need to investigate trajectories of baseline RSA further to tease apart what might be accounting for the significant variation in baseline RSA over time.

Vagal withdrawal was also moderately stable from age 3 to 4 and from age 4 to 5; in contrast to baseline RSA, vagal withdrawal means were not significantly different from one another across the preschool years for the entire sample. Therefore, while baseline RSA values increased on average, as a group children's average physiological reaction in response to frustration was stable over time from age 3 to age 5. This finding suggests that children's physiological response to a frustrating challenge is, on average, well developed by the age of 3. Thus, the rapid development of children's self-regulatory behaviors during the preschool years may be building on an already established physiological base. While the results of this study suggest such a hypothesis, the current data cannot speak to this question. Future work would benefit from examining vagal withdrawal at earlier ages specifically in relation to self-regulatory behaviors exhibited by children during frustration.

The second aim of this study was to examine whether maternal emotional support predicted variation in children's initial cardiac activity and change in cardiac activity over time. Maternal emotional support was not significantly related to initial baseline RSA at age 3, or to changes in baseline RSA scores across the preschool years. This finding fits with the notion that baseline RSA is a trait-like characteristic reflective of child temperament, and is therefore less sensitive to environmental influences such as sensitive and supportive caregiving. However, the fact that trajectory analyses revealed significant variation in baseline RSA change over time suggests that there may be other environmental and/or child factors that might influence this variation that could be investigated in future research.

In contrast, maternal emotional support across the preschool years was a significant predictor of initial vagal withdrawal levels at 3 years. Specifically, greater maternal support was associated with higher initial levels of vagal withdrawal to frustration at age 3. Early in development children have rudimentary physiological self-regulatory abilities in place and are therefore reliant on external sources to achieve and maintain a regulated state (Spangler & Grossmann, 1993). Thus, parents of young children play a crucial role in helping children achieve physiological homeostasis during emotionally arousing situations. It has been proposed, and empirically supported, that warm, supportive, responsive, and sensitive parenting may facilitate the organization of physiological systems to achieve regulation (Moore & Calkins, 2004; Moore et al., 2009; Panksepp, 2001). It is likely that parents who are emotionally supportive help children regulate and reduce emotional arousal during emotionally charged situations and thereby facilitate cardiac vagal withdrawal. Over time, the facilitation of cardiac vagal withdrawal may act to shape the development of the autonomic nervous system in such a way that physiological regulation is activated even when the child is without parental support.

Maternal emotional support also predicted the way in which children's withdrawal scores changed over time such that maternal emotional support earlier in the preschool years had a greater impact on children's concurrent and future physiological regulation. Maternal emotional support when children were 3 and 4 years of age predicted children's withdrawal trajectories, and levels of emotional support differentiated children's withdrawal scores at age 3 and age 4 only. The results suggest that as children gain increasing control over their own regulatory abilities, maternal emotional support may not be as influential for children's physiological regulation. Sroufe (1996) has described the course of emotional development as a movement from dyadic regulation in the context of social interaction to more independent self-regulation by the child. Others have described this as a shift from other-regulation (i.e., regulation in which the caregiver plays the dominant role) to self-regulation (Sameroff, 2010; Sameroff & Fiese, 2000). By the second year, toddlers have come to understand that arousal does not necessarily lead to disorganization (Sroufe, 1996), and in the event the child is not able to regulate his or her own arousal the parent will serve as a reliable source of support in arousal reduction. As children age they become more confident in their ability to regulate their own emotions, with little reliance on their caregivers. Therefore, it is possible that emotionally sensitive and supportive parenting has a stronger influence on children's physiological regulation when internal regulatory abilities are immature. Over time, as children's physiological functioning develops as a result of maturation, the influence of parents on children's physiological functioning may be more likely decrease. Children in our sample with less supportive mothers and lower initial levels of withdrawal showed increases in withdrawal across time, perhaps as a result of the natural course of maturation of the parasympathetic nervous system. In contrast, children with more supportive mothers had higher initial levels of vagal withdrawal and did not show increases over time. One explanation for this finding is that children of emotionally supportive mothers reach a higher level of physiological regulatory functioning earlier in development than children with less supportive mothers. It may be that children of less emotionally supportive mothers show lower levels of vagal withdrawal to a frustrating challenge at 3 years of age when they are more reliant on external sources (e.g., the mother) to help them achieve a regulated state during a challenge, but that as the parasympathetic nervous system matures and they become better able to regulate on their own, they show a rapid increase in vagal withdrawal across the preschool period to eventually catch up to their peers. Future research is needed to probe the nature of this relationship.

Finally, in accordance with the hypothesis proposed by Calkins and Keane (2004), it may be that by age 5 natural maturation of the parasympathetic nervous system allows all children greater abilities in their individual physiological functioning and that, with age, children begin to vary more in terms of behavioral regulation and less on physiological regulation abilities. It should be noted however, that this hypothesis is in direct contrast to studies that have found vagal regulation is associated with emotion regulation and/or other adjustment indices in children and adolescents (e.g., Mezzacappa, Tremblay, Kindlon, & Saul, 1997; Vögele, Sorg, Studtmann, & Weber, 2010). Thus, a direction for future research is to investigate whether the link between physiological regulation and optimal socio-emotional and cognitive outcomes that has been found in previous work is perhaps mediated by behavioral regulatory abilities at older ages.

It is important to note that our sample was not a high-risk sample and very few of our mothers showed high levels of unsupportive behavior. Therefore, we are focused here on the effect of relatively small variations in maternal emotional support in typically developing low-risk children who have not been exposed to extreme environmental stressors and therefore are likely showing typical physiological development. Further, it is important to note that our stressors are not particularly extreme. Thus, different results may surface in a more threatening or emotionally intense situation or if a higher risk population experiencing extremely insensitive, neglectful, or even abusive parenting was used. While the current study was an important first step in examining these relationships, there are other limitations. First, we cannot be sure that the frustration tasks were equally emotionally challenging across time, which may give some insight into why children with less supportive mothers appeared to reach similar physiological levels as children with more emotionally supportive mothers. For example, it may be that 5 year-old children did not experience high levels of frustration therefore reducing the ability to observe individual differences in vagal withdrawal. However, we do believe the tasks continue to provide a valid measure of withdrawal during an emotionally challenging situation at age 5 due to the fact that we have substantial variability in the scores at this time point. Second, there also may be some regression toward the mean, which could also provide insight into the explanation of children's vagal withdrawal trajectories of less emotionally supportive mothers. However, it is unlikely that this explains the large increase in the group of children that had mothers who were low on emotional support and increased over time.

Future research should investigate additional aspects of sensitive and supportive caregiving across a variety of situations and examine whether specific features of maternal emotional support (i.e, touch, affect) are distinctly related to the child's physiological regulation to support the current findings. Finally, we investigated one specific aspect of parenting and its relative contributions to a single physiological measure of children's regulation over time. Although we found that maternal emotional support was not related to older children's vagal withdrawal, this is not evidence that all environmental factors become inconsequential to children's physiological functioning over time. For example, previous research has found that greater maternal depressive symptomatology was associated with a decline in the trajectories of behavioral emotion regulation in a sample of 4–7 year olds (Blandon, Calkins, Keane, & O'Brien, 2008). Future research should examine additional aspects of children's environments and of children's own individual characteristics in predicting physiological functioning to further explore the shift from dyadic regulation to self-regulation (Sameroff, 2010) as children mature.

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