Contributions of Child's Physiology and Maternal Behavior to Children's Trajectories of Temperamental Reactivity

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Abstract:

Trajectories of children's temperamental reactivity (negative affectivity and surgency) were examined in a community sample of 370 children across the ages of 4 to 7 using Hierarchical Linear Modeling. Children's physiological reactivity (respiratory sinus arrhythmia, RSA), physiological regulation (ΔRSA), and maternal parenting behavior were included as predictors of children's trajectories of temperamental reactivity. Results indicated that negative affectivity and surgency decreased from 4 to 7 years of age, however within-person changes in negative affectivity were dependent on levels of baseline RSA and not age. Increases in negative affectivity were also predicted by higher levels of earlier maternal controlling behavior. Decreases in surgency were predicted by higher levels of ΔRSA during mother-child interaction tasks and positive parenting behavior. Baseline RSA and maternal controlling parenting also accounted for interindividual differences in children's negative affectivity at age 7, while gender and children's baseline RSA accounted for interindividual differences in children's surgency at age 7. Overall, these results provide further evidence that parenting behavior and children's RSA influence the changes that occur in children's temperamental reactivity.

Article:

Individual differences in behavioral and emotional responses to novel or challenging situations are evident in early infancy and are posited to be biologically based and relatively stable over time (Goldsmith et al., 1987; Rothbart, Derryberry, & Hershey, 2000). These early temperamental differences are theorized to shape the way children respond to their environment as well as to shape the reactions they evoke from the environment, setting up patterns of interaction that can either impede or promote their social and emotional development over time. The current study is framed within Rothbart's (1989) theoretical model of temperament that focuses on individual differences in reactivity and self-regulation. This perspective posits that temperament changes across childhood as developmental changes occur in central nervous system structures and processes which underlie children's ability to moderate their emotional responses (Derryberry & Rothbart, 2001). Recently, there has been greater acknowledgement that environmental influences have important implications for the development of temperament (Rothbart & Bates, 2006). For instance, research has shown that young children's emerging ability to modulate their emotional reactivity during stressful and challenging situations is due, in part, to the strategies and behaviors that children are learning through their social interactions with caregivers (Calkins & Hill, 2007). Increasing our understanding of the developmental course of children's temperament and the child and parenting characteristics that account for changes across early childhood is important given that temperament has been identified as an underlying factor that can facilitate or inhibit children's socioemotional functioning.

Both negative and positive affectivity have been identified as two broad temperamental reactivity factors (Putnam, Ellis, & Rothbart, 2001; Rothbart et al., 2001). Negative emotionality or affectivity is the broad dimension that characterizes children's predisposition towards different negative affective states including, anger, frustration, fear, and sadness (Putnam et al., 2001). During early childhood, high levels of negative affectivity are often thought to reflect deficits in children's ability to self-regulate, increasing their risk for maladaption (Oldehinkel, Hartman, De Winter, Veenstra, & Ormel, 2004). For instance, high negative emotionality has been linked to both externalizing and internalizing behavior problems as well as lower social competence (Calkins, 2002; Merikangas, Swendsen, Preisig, & Chazan, 1998; Murphy, Shepard, Eisenberg, & Fabes, 2004).

Surgency is the dimension that reflects children's predisposition toward high levels of positive emotionality and a general tendency for children to be actively involved with their environment (Putnam et al., 2001) and has been associated with the personality dimension of extraversion (Shiner & Caspi, 2003). Specifically, this dimension includes characteristics such as high activity level, impulsivity, approach, and high intensity pleasure (Putnam et al., 2001). Children who score higher on surgency are more likely to actively explore their environment and exhibit more high level positive emotions which may be beneficial for young children's development. In some instances, however, stronger approach tendencies are linked with increased frustration and aggression particularly when children's goals are blocked (Derryberry & Rothbart, 2001). There is also evidence that aspects of surgency are associated with children's self-regulation. For instance, infants with stronger approach tendencies are more likely to exhibit lower inhibitory control later in childhood (Rothbart et al., 2000), and high positive emotionality has been associated with lower levels of effortful control (Kochanska, Aksan, Penney, & Doobay, 2007). Although it may seem counterintuitive that aspects of positive emotion are not always beneficial, if children are not able to regulate their high intensity positive emotions and approach tendencies it can disrupt their social interactions and increase their risk for behavior problems. This is also consistent with research in adults in which dysregulated positive affect has been linked with an increased risk for bipolar disorder (Gruber, Johnson, Oveis, & Keltner, 2008). Overall, this supports the notion that highly surgent children may have difficulties with regulation that increases their risk for detrimental outcomes.

DEVELOPMENT OF TEMPERAMENT ACROSS EARLY CHILDHOOD

Early temperamental theories highlighted the stability of temperament over the life course given their genetic and physiological basis (Buss & Plomin, 1984), while others have proposed that temperamental characteristics may be less stable particularly during early childhood (Goldsmith, 1987). There is evidence for long term stability. For example, children who exhibited high approach tendencies when they were 3 years old rated themselves as more impulsive, spontaneous, and careless when they were 18 years of age (Caspi & Silva, 1995). In general, stability coefficients (i.e., the extent to which children maintain their rank-order when measured over time) range from .35 to .70 depending on the method of assessment and the time period between measurements (Roberts & DelVecchio, 2000; Rothbart & Bates, 2006). However, even for specific traits where the rank-order of individuals is fairly stable there can be individual growth or change. Indeed, as children mature, they may develop new regulatory behaviors and are exposed to new environments that may alter their temperamental reactivity (Shiner, Tellegen, & Masten, 2001). Consistent with this idea, children's expression of negative emotions has been found to decrease, and their ability to regulate tends to increase across early childhood (Blandon, Calkins, Keane, & O'Brien, 2008). The developmental course of children's surgency has not been well examined. Therefore, the first aim was to explore the average developmental trajectory of children's temperamental reactivity across early childhood. We expected that both children's negative affectivity and surgency would, on average, decrease across early childhood given that children are learning to control both positive and negative emotions during this developmental period.

TEMPERAMENT AND PARENTING

Recent research has underscored the importance of the quality of parent-child interactions during emotionally eliciting situations because it is during these interactions when children learn strategies for modulating their emotional reactivity (Calkins & Hill, 2007; Propper & Moore, 2006). The strategies they learn in these contexts are, over time, expected to aid in the development of children's emotional regulation. Parental warmth and responsiveness, and negative control are dimensions of parenting that have been linked with children's reactivity and regulatory behavior (Eisenberg et al., 1999; Calkins & Hill, 2007; Dennis, 2006). During emotionally arousing situations, warm and responsive parents are more likely to teach children that the use of particular strategies may be more useful for the reduction of emotional arousal than other strategies, even if they do not immediately change the child's affect (Sroufe, 1996). In contrast, parents who utilize more controlling strategies are less likely to describe or help the child implement new regulatory strategies, given their focus on immediate compliance to parental directives; which, in turn, may actually increase children's temperamental reactivity across different situations. Over time, the cumulative effect of these parent-child interactions is expected to influence children's temperamental tendencies in emotionally-laden situations.

There is less research examining the longitudinal relations among parenting behavior and the changes that occur in children's reactivity from 4 to 7 years of age. Some investigations have found that changes in parenting behavior are associated with later changes in children's temperamental characteristics. For instance, Lengua (2006) found that higher levels of maternal rejection were predictive of increases in adolescents' fear and irritability. In addition, Halverson and Deal (2001) found children's level of persistence increased from 4 to 7 years of age when their mothers used more positive parenting practices. However, there is a paucity of research examining whether parenting characteristics may impact the development of children's surgency.

There are also methodological issues to consider, given that the research linking parenting behavior with children's negative emotionality often relies on maternal reports of both parenting behavior and children's temperament. In a recent meta-analysis exploring the link between children's negative emotionality and parenting, restrictive parenting behavior was only correlated with negative emotionality when parental reports were used, highlighting the need for studies to utilize observational measures of parenting (Paulussen-Hoogeboom, Stams, Hermanns, & Peetsma, 2007). Therefore, our second aim was to explore the link between observed maternal parenting behavior and the changes that occur in children's trajectories of temperamental reactivity from 4 to 7 years of age. Specifically, we were interested in the effect of maternal parenting on intra-individual changes across early childhood, as well as whether parenting behavior accounts for interindividual differences in children's trajectories of negative affectivity and surgency. We hypothesize that when mothers utilize positive parenting strategies children will evidence decreases in temperamental reactivity over time; whereas, negative parenting behaviors should be linked with increases in temperamental reactivity.

TEMPERAMENT AND CHILDREN'S PHYSIOLOGICAL REGULATION

There is evidence to indicate that one biological system that may account for some of the observed individual differences in temperamental reactivity is the parasympathetic nervous system. Porges' Polyvagal Theory proposes that the maturation of the parasympathetic nervous system underlies children's increased ability to regulate their states, motor activity, and emotion (Porges, Doussard-Roosevelt, & Maita, 1994; Porges, 2001, 2003). Parasympathetic nervous system functioning, as reflected in heart rate variability at the rate of respiration (i.e., respiratory sinus arrhythmia; RSA) influenced by the vagal system, has been linked to emotional reactivity and regulation. Baseline RSA has been conceptualized as a measure of an individual's characteristic level of arousal and ability to actively engage with the environment and as such, may reflect temperamental reactivity (Calkins, 1997; Gunnar, Porter, Wolf, Rigatuso, & Larson, 1995). Indeed, during infancy high baseline RSA has been associated with higher levels of emotional and behavioral reactivity, including both negative and positive emotionality (Beuchaine, 2001; Porges, 1991). By early childhood, high baseline RSA has generally been associated with appropriate observed emotional reactivity (Stifter & Fox, 1990; Beuchaine, 2001). Other studies have found, however, that higher baseline vagal tone is associated with greater negative emotional expressivity and more problem behavior (Cole, Zahn-Waxler, Fox, Usher, & Welsh, 1996; Eisenberg, et al., 1995). The biological sensitivity to context theory proposes that high biological reactivity may operate differentially depending on the context in which it occurs (Boyce & Ellis, 2005; Ellis, Essex, & Boyce, 2005). Specifically, under stressful conditions high reactivity may result in maladaptive outcomes, whereas high reactivity may be protective under less stressful conditions. For instance, children who are more physiologically reactive may be ill-equipped to deal with maternal negative control, due to their increased sensitivity to aspects of the family environment. In contrast, children who are more physiologically reactive but whose mothers utilize more responsive parenting strategies may be able to learn more effective strategies for dealing with changes in the environment.

Porges' theory further suggests that one particular measure of cardiac activity that may be more directly related to regulatory behavior is vagal regulation of the heart as indexed by a decrease in RSA (vagal withdrawal) during situations where coping or emotional and behavioral regulation is required (Porges, 2001; 2003). Evidence of vagal withdrawal during demanding tasks may reflect physiological processes that allow the child to shift focus from internal homeostatic demands to the generation of coping strategies to control affective or behavioral arousal. Considerable research suggests that greater vagal withdrawal during challenging situations is related to better state regulation, greater self-soothing, more attentional control in infancy (DeGangi, DiPietro, Greenspan, & Porges, 1991; Huffman et al., 1998) and more appropriate emotion regulation in preschool children (Calkins, 1997; Calkins & Dedmon, 2000; Calkins & Keane, 2004; Porges et al., 1996). Although, similar to results on baseline RSA, vagal withdrawal is not always consistently linked with more adaptive outcomes (Calkins, Blandon, Williford, & Keane, 2007).

Children's physiological regulation has also been found to vary across different contexts. During laboratory assessments, children exhibit better physiological regulation during tasks in which they are involved with their mother versus tasks they are instructed to complete on their own (Calkins & Dedmon, 2000). It has been proposed that the parenting strategies and behaviors which mothers use during dyadic interactions with their children over time become integrated and are evidenced in both children's physiological and behavioral responses (Calkins & Hill, 2007; Propper & Moore, 2006). The third aim of this study was to examine the link between children's early physiological responses and their trajectories of temperamental reactivity across early childhood. We were specifically interested in exploring whether there were differences in the link between physiological regulation and children's trajectories of temperamental reactivity during tasks where the child was managing a challenging situation independently and tasks where the child was engaged with their mother. We hypothesized that young children's physiological regulation during mother-child tasks at earlier ages may be particularly important for changes in temperamental reactivity at later ages. The joint contribution of supportive parenting and children's physiological regulation has recently been examined as an important predictor of children's adjustment (Hasting et al., 2008). Therefore, in exploring the predictors of interindividual differences in children's trajectories of temperamental reactivity, we also examined whether the interaction between maternal behavior and children's physiology would predict differences in children's reactivity trajectories. It was expected that more positive parenting behavior and higher baseline RSA and vagal suppression would be associated with decreasing trajectories of reactivity.

THE CURRENT STUDY

The current study addressed questions regarding the growth in two broad temperament dimensions, negative affectivity and surgency, from preschool to school age in a large community sample of children. To summarize, the three aims were: (a) to describe the normative developmental trajectories of negative affectivity and surgency from 4 to 7 years of age; (b) to examine whether maternal parenting behavior and children's physiological regulation as indexed by measures of RSA and ΔRSA account for within-person change in children's temperament; (c) to determine whether children's physiological regulation, maternal parenting behavior, and the interaction between maternal behavior and children's RSA account for interindividual differences in children's trajectories of negative affectivity and surgency.

METHOD

Recruitment and Attrition

The current study utilized data from three cohorts of children who are part of an ongoing longitudinal research project. For all cohorts, the goal for recruitment was to obtain a sample of children that was representative of the community in terms of socioeconmic status and race, and some of whom were at risk for developing future externalizing behavior problems. Therefore, recruitment was targeted to all areas of the county while oversampling for children with early evidence of externalizing behavior problems. Efforts were made to obtain approximately equal numbers of males and females. Participants were recruited through child day care centers, the County Health Department, and the local Women, Infants, and Children (WIC) program. All parents in the waiting room were approached. Potential participants for cohorts 1 and 2 were recruited at 2-years of age (cohort 1: 1994–1996 and cohort 2: 2000–2001) and screened using the Child Behavior Checklist (CBCL 2–3; Achenbach, 1992) completed by the mother in order to over-sample for externalizing behavior problems. Children were identified as being at risk for future externalizing behaviors if they received an externalizing *T* score of 60 or above. A total of 307 children were selected. Cohort 3 was initially recruited when infants were 6-months of age (in 1998) for their level of frustration based on laboratory observation and parent report (See Calkins, Dedmon, Gill, Lomax, & Johnson, 2002, for more information). Children whose mother's completed the CBCL at 2 years of age were included in the current study (n = 140). Of the entire sample (N = 447), 37% of the children were identified as being at risk for future externalizing problems at the time of recruitment. Given the different recruitment strategies for Cohort 3 versus Cohorts 1 and 2, we explored whether there were significant differences in demographic variables and behavior problems. There were no significant demographic differences between cohorts with regard to gender, χ^2 (2, N = 447) = .63, p = .73, race, χ^2 (2, N = 447) = 1.13, p = .57, or 2-year SES, F (2, 444) = .53, p = .59. Cohort 3 had a significantly lower average 2-year externalizing *T* score (M = 50.36) compared to cohorts 1 and 2 (M = 54.49), t (445) = −4.32, p = .00.

Of the 447 original screened participants, 6 were dropped because they did not participate in any 2 year data collection. At 4 years of age, 399 families participated. Families lost to attrition included those who could not be located, who moved out of the area, who declined participation, and who did not respond to phone and letter requests to participate. There were no significant differences between families who did and did not participate in terms of gender, χ^2 (1, N = 447) = 3.27, p = .07, race, χ^2 (1, N = 447) = .70, p = .40, 2-year SES, t (424) = .81, p = .42, or 2-year externalizing *T* score, t (445) = −.36, p = .72. At 5 years of age, 365 families participated including 4 that did not participate in the 4-year assessment. Again, there were no significant differences between families who did and did not participate in terms of gender, χ^2 (1, N = 447) = .76, p = .38, race, χ^2 (1, N = 447) = .17, p = .68, 2-year socioeconomic status, t (424) = 1.93, p = .06) and 2-year externalizing *T* score (t (445) = −1.73, p = .09). At 7 years of age, 350 families participated including 19 that did not participate in the 5-year assessment. Again, there were no significant differences between families who did and did not participate in terms of gender, χ^2 (1, N = 447) = 2.12, p = .15, race, χ^2 (3, N = 447) = .60, p = .90 and 2-year externalizing *T* score (t (445) = −1.30, p = .19). Families with lower 2-year socioeconomic status, t (432) = 2.61, p > .01) were less likely to continue participation at the 7-year assessment.

Participants

The current sample included 370 children (170 male, 200 female) who had temperament outcome data from at least one assessment from 4 to 7 years of age (4 year n = 370, 5 year n = 335, 7 year n = 327). Results from logistic regression models indicated that temperament and parenting variables were not predictive of missing data at the 5 and 7 year assessments. Multivariate analysis of variance was conducted for parenting and children's RSA to examine differences in parenting and RSA for those children who were missing and not missing 4-year data. The parenting model indicated no significant differences in 2-year parenting behavior (maternal positive parenting and maternal control) between children who were missing 4-year data versus those who were still in the study (F(2,424) = .26, *ns*). The model examining children's RSA (baseline RSA, ΔRSA independent tasks, and ΔRSA mother-child interaction tasks) indicated that children missing data at the 4-year assessment had higher baseline RSA scores at the 2-year assessment ($F(3,332) = 3.72$, $p < .01$).

Children were on average 31.59 months (*SD* = 3.66 months), average 53.7 months (*SD* = 3.7 months), 68.0 months (*SD* = 3.3 months) and 92.4 months (*SD* = 4.2 months) at the 2, 4, 5, and 7 year assessments respectively. At the 4 year assessment, 67% were European American, 28% were African American, 3% were biracial, and 2% were Hispanic. The children were primarily from intact families at age 4 (77%; single = 16%, divorced/separated = 7%) and families were economically diverse based on Hollingshead SES scores (*M* = 42.49, *SD* = 10.72; 1975). The 5 and 7 year SES scores were on average 43.17 (*SD* = 10.60) and 44.58 (*SD* = 11.57) respectively. Hollingshead scores that range from 40 to 54 reflect minor professional and technical occupations which are considered middle class.

Procedures

Children and their mothers participated in an ongoing longitudinal study when the children were 2, 4, 5, and 7 years of age. The current study utilized physiological data from the individual and mother-child observational tasks and observational measures of parenting from the mother-child tasks at the 2, 4, and 5 year laboratory assessments. Maternal questionnaires were completed at the 4, 5, and 7 year assessments. During each of the laboratory assessments, the children and their mothers engaged in a series of tasks designed to elicit emotional and behavioral responding (LAB-TAB, Goldsmith & Rothbart, 1993; Kochanska, Murray, Jacques, Koenig, & Vandegeest, 1996) and mother-child interaction. The 2-year laboratory assessment included a *baseline* task where the child quietly watched a Spot video; a *positive* task where the experimenter elicited positive affect with either a puppet or bubbles (2 min); a *fear* task where the experimenter played with a novel toy spider with the children (2 min); a *frustration task* that included either a toy or cookies in a locked box that the children could retrieve (2 or 3 min); and a *teaching* task where mothers were asked to help their children complete a shape sorter puzzle (4 min).

The 4-year laboratory assessment included an *effortful control* task where children were instructed to whisper while naming cartoon characters (1 min); a *frustration task* where children were instructed to draw perfect circles and then told in which ways the circles were not perfect (3 ½ min); a *teaching task* in which mothers were asked to work on 2 puzzles with increasing difficulty and assist their child when needed (4 min); and a *snack delay task* where children had to wait to eat M & M's while they were playing a game (2 min).

The 5-year laboratory assessment included an *attention task* where children were instructed to sort beads into a box (3 min); an *effortful control* task where children were instructed to draw a circle and star at different speeds (6 min); a *frustration task* where experimenters sorted candy for themselves and the child and then took the child's candy (4 min); *positive task* where the experimenter and child used a pop-up snake toy (4 min); and a *mother-child interaction task* where the child and mother worked on an art project together (6 min); a *puzzle task* in which mothers were asked to work on 2 puzzles with increasing difficulty and assist their child when needed (6 min).

Measures

Child Behavior Questionnaire. Mothers completed the short form of the Child Behavior Questionnaire to assess children's temperament when the children were 4, 5, and 7 years of age (Putnam & Rothbart, 2006). The 94 items were rated on a 7-point Likert scale ranging from "extremely untrue of your child" to "extremely true of your child." The measure yields 14 subscales. For the current study, CBQ subscale scores were composited to reflect three broad temperament dimensions (Rothbart et al., 2001): negative affectivity (discomfort, sadness, fear, anger/frustration, and soothability reverse scored), surgency (impulsivity, high intensity pleasure, activity level, and approach/positive anticipation), and effortful control (low intensity pleasure, inhibitory control, perceptual sensitivity, and attentional control). Across the 3 waves of data, alphas for negative affectivity and surgency ranged from .62 to .71 and .71 to .75 respectively. The alpha coefficients for the effortful control composite were all below .50; therefore the effortful control subscale was not used in any of the analyses.

Maternal Parenting Behavior. Global codes of maternal behavior were adapted from the Early Parenting Coding System (Winslow, Shaw, Bruns, & Kiebler, 1995). Coded behaviors included *warmth/positive affect* (displaying positive affect and warmth toward the child); *sensitivity/responsiveness* (promptly and appropriately responding to the child's bids); *strictness/punitiveness* (being too strict, demanding, or harsh relative to the child's behavior; displaying a no-nonsense attitude; constantly guiding the child and creating a very structured environment); and *hostility* (expression of anger toward the child). Each behavior was coded once for each mother-child interaction task (e.g., teaching, free-play, clean-up, and puzzle) on a 4 point scale (1 = low to 4 = high). Four coders trained on 10% of the videotaped sessions and independently coded another 10% for reliability. The average adjusted Kappa's between each pair of coders were all above .70.

To reduce the number of variables in the models composites were created such that, the individual codes were averaged across each mother-child interaction task within each assessment year. The reliabilities of the parenting codes across each mother-child task at each assessment year were as follows: (2 year) positive $\alpha = .90$, responsiveness $\alpha = .82$, directiveness $\alpha = .81$, hostility $\alpha = .66$; (4 year) positive $\alpha = .88$, responsiveness $\alpha = .68$, directiveness $\alpha = .75$, hostility $\alpha = .66$; (5 year) positive $\alpha = .88$, responsiveness $\alpha = .68$, directiveness $\alpha = .77$, hostility $\alpha = .33$. Warmth/positive affect and sensitivity/responsiveness were positively correlated at each assessment year (2 year: $r = .81$; 4 year: $r = .74$, 5 year: $r = .76$). The mean warmth/positive affect scores and mean sensitivity/responsiveness scores were summed to create a positive parenting composite for each assessment year. Although the 5 year hostility alpha was low, we included hostility in the negative parenting composite for conceptual reasons and to maintain consistency across assessment years. Strictness/punitiveness and hostility were positively correlated at each assessment year (2 year: $r = .25$; 4 year: $r = .31$, 5 year: $r = .29$). The mean strictness/punitiveness average score and hostility average score were summed to create a negative parenting composite for each assessment year.

Children's Physiological Regulation. At the beginning of each laboratory assessment, an experimenter placed 3 disposable pediatric electrodes in an inverted triangle pattern on the child's chest. The electrodes were connected to a preamplifier and the output from the preamplifier was transmitted to a vagal tone monitor (VTM-I Delta Biometrics, Bethesda, MD) for R-wave detection. A data file containing the inter-beat intervals (IBIs) for the entire period of heart rate collection was saved on a laptop computer for later artifact editing (e.g., resulting from child movement) and analysis. Measures of children's baseline respiratory sinus arrhythmia (RSA) and RSA during the challenge tasks were obtained by editing IBI files using MXEDIT software (Delta Biometrics, Bethesda, MD). To edit the files, the data were scanned for outlier points, relative to adjacent data, and the outliers were replaced by dividing or summing them so they would be consistent with the surrounding data. Only data files in which less than 10% of the data required editing were included in the current study. The Porges (1985) method of analyzing IBI data was used to calculate RSA. 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 that are slower than RSA. Next, a bandpass filter extracts variance in HP within the frequency band of spontaneous respiration in young children, 0.24 – 1.04 Hz. The natural log of this variance is taken and reported in units of ln $(msec)^2$. For each of the laboratory tasks at the 2-, 4-, and 5-year assessments, RSA was calculated every 30 seconds and the average across the 30-second epochs for each episode was used in subsequent analyses. Data were excluded if the standard deviation for an episode was over 1.0.

Baseline RSA**.** Baseline RSA was obtained at the beginning of the laboratory assessments. For the 2-, 4-, and 5-year assessments, the child watched one of two 5-minute segments of the videotape "Spot," a puppy who explores his neighborhood. The use of the video stimulus was necessary to limit movement artifact in the data, given that the children were young and unlikely to remain quietly seated for the duration needed. While this episode is not a true baseline, as the child's attention was engaged, it was sufficient to gain a measure of RSA while the child was sitting quietly and showing little affect.

Change in RSA (ΔRSA)**.** During each of the tasks (e.g., effortful control, frustration, fear, mother-child interaction), at each assessment year, children's ΔRSA was calculated by subtracting the average RSA during the specified task from the average RSA during the baseline episode. Negative change scores occurred when there was an increase in RSA from the baseline to the task. Positive change scores occurred when there was a decrease in RSA from baseline to the task, which reflected attempts at vagal regulation. Therefore, higher positive ΔRSA scores indicate the child had greater vagal regulation. For the current analyses, two composites of ΔRSA were created at each wave: (a) average ΔRSA across the mother-child tasks and (b) average ΔRSA across the tasks where the child worked independently (e.g., effortful control, fear, & frustration).

Data Analytic Strategy

Growth curve analyses were conducted to examine the developmental trajectories of broad temperament dimensions across early childhood using hierarchical linear modeling (HLM; Raudenbush & Byrk, 2002). HLM was used because it allows for unbalanced designs so that children with incomplete outcome data across the three waves could be included in the analyses. For the current study, temperament was assessed when children were 4, 5, and 7 years of age. Age was centered at 90 months (7.5 years) so that the intercept indicated the status at the end of the growth period examined allowing us to explore whether physiological regulation and maternal parenting behavior when children were 2 years of age predicted children's temperament at age 7. The coefficients indicated the change that occurred in 1-year increments starting at age

4. Linear growth trajectories were fit using full maximum likelihood estimation, and the results reported are based on the robust standard errors. Gender was coded (male = 0, female = 1), and all continuous level 2 predictors were grand mean centered.

Level 1 Model. To explore the correlates of within-child change, children's RSA and maternal parenting behavior, assessed when children were 2, 4, and 5 years of age, were included in the model as time-varying covariates predicting changes in children's temperament over time (assessed when children were 4, 5, and 7 years of age). Including time-varying covariates as predictors of temperament trajectories allows us to examine how the time-varying scores of RSA and maternal parenting are related to the time-varying scores of temperament while controlling for interindividual differences in intraindividual change (Grimm, 2007). By including the time-varying covariates that were measured at an earlier assessment, we were able to examine whether previous levels of physiological regulation and maternal behavior predicted changes in children's temperamental reactivity at the subsequent assessment. In all of the models, the time-varying covariates were entered as fixed effects (non-randomly varying) given the limitation of having only three time points (Singer & Willett, 2003).

Level 2 Model. To explore the factors that accounted for interindividual change in children's temperament trajectories, children's physiological regulation and maternal parenting behavior were included as Level 2 predictors in the model using a backward elimination method. Specifically, a model including all time-invariant covariates and the interactions terms between maternal parenting behavior and children's RSA was fit and then the non-significant predictors were removed one by one beginning with the least significant predictor. Determination of the best model fit was assessed by the significance of the fixed effect (Singer & Willett, 2003) and with the Bayesian Information Criterion (BIC), where smaller numbers indicate a better fit (Kass & Raferty, 1995).

RESULTS

Preliminary Analyses

Missing Data. Examination of missing data patterns revealed that missing data were predicted by the continuous variables included in the model, Little's MCAR test, χ^2 (1897) = 2171.74, p < .001, indicating that the data was MAR as opposed to missing completely at random (MCAR; Little & Rubin, 1987). Therefore, the missing data for all variables were imputed. Listwise deletion of cases without complete data would have resulted in a reduction in sample size which would have produced a significant loss in power and possible bias. The amount of missing data for any one variable at each assessment was relatively small: baseline RSA (21%), ΔRSA independent tasks (7% – 23%), ΔRSA mother-child tasks (21% – 23%), maternal positive and negative parenting (2% – 14%), and temperament dimensions (2% – 16%). Missing values were imputed through maximum likelihood estimation (*mle*) using the expectation maximization method (EM) algorithm in SPSS 16. The EM method is an iterative process that has been found to be superior to listwise deletion, mean substitution, and multiple regression (Garson, 2006). All the analyses reported are based on the imputed data.

Descriptive Statistics

Descriptive statistics for all study variables are presented in Table 1. The correlations between negative affectivity and surgency with children's RSA and ΔRSA and maternal parenting behavior (the time-varying covariates) are presented in Tables 2 and 3. In general, children's baseline RSA at the 2 year assessment is positively correlated with surgency and negative affectivity at the 4, 5 and 7 year assessments. Overall, RSA measures at the 4 year assessment were not correlated with temperament. For the 5 year assessment, ΔRSA was generally negatively correlated with children's surgency and negative affectivity.

Table 1: Descriptive Statistics for Predictor and Outcome Measures (n = 370)

Measure	*M*	*SD*	Range
2-year Measures			
Baseline RSA	5.38	1.18	1.10 – 8.58
ΔRSA Child Tasks	.53	.57	-1.19 – 2.55
ΔRSA Mother-Child Interaction tasks	.83	.67	-1.08 – 3.03
Positive Parenting Behavior	6.25	1.37	2.50 – 8.00
Negative Parenting Behavior	3.40	.66	2.00 – 5.83
4-year Measures			
Baseline RSA	5.86	1.16	1.05 – 10.00
ΔRSA Child Tasks	0.32	.48	-1.13 – 2.50
ΔRSA Mother-Child Interaction tasks	0.64	.63	-.89 – 3.16
Positive Parenting Behavior	5.60	1.27	2.17 – 8.00
Negative Parenting Behavior	3.25	.57	2.00 – 6.00
Negative Affectivity	4.26	.62	2.39 – 6.07
Surgency	4.97	.67	2.92 – 6.96
5-year Measures			
Baseline RSA	6.03	1.09	2.77 – 9.42
ΔRSA Child Tasks	.17	.52	-2.66 – 1.98
ΔRSA Mother-Child Interaction tasks	.54	.60	-2.85 – 2.94
Positive Parenting Behavior	5.60	1.24	2.17 – 8.00
Negative Parenting Behavior	3.08	.58	2.00 – 5.17
Negative Affectivity	4.14	.66	2.32 – 6.09
Surgency	5.01	.63	3.05 – 6.92
7-year Measures			
Negative Affectivity	4.02	.69	2.05 – 5.89
Surgency	4.76	.69	2.98 – 6.60

Note. Descriptive statistics are based on the imputed data. RSA = respiratory sinus arrhythmia.

Table 2: Intercorrelations Among Temperament Dimensions and Children's Physiological Regulation (n = 370)

	2-year			4-year			5-year		
Outcome Measure	Baseline RSA	ΔRSA child tasks	ΔRSA mother-child tasks	Baseline RSA	ΔRSA child tasks	ΔRSA mother-child tasks	Baseline RSA	ΔRSA child tasks	ΔRSA mother-child tasks
Surgency									
4 year	.12*	.06	.02	.08	-.04	-.01	.05	-.12*	-.15**
5 year	.20**	.04	.02	.10	.09	.07	.06	.01	-.02
7 year	.16**	.03	-.01	.12*	-.02	-.02	.08	-.10	.013*
Negative affectivity									
4 year	.14**	-.04	.-02	.04	.03	.02	.09	-.03	-.01
5 year	.10*	.12*	.09	.07	.01	.00	-.01	-.16**	-.19**
7 year	.11†	.05	.06	-.01	.01	-.04	.01	.01	-.02

Note. RSA = respiratory sinus arrhythmia
†$p < .10$; *$p < .05$; **$p < .01$

The negative affectivity (r's = .66 to .77) and surgency (r's = .67 to .80) scores from the 4, 5, and 7 year assessments were significantly correlated ($p < .001$) indicating high stability in rank order across early childhood. Maternal parenting behavior was also significantly correlated ($p < .001$) across the 2, 4, and 5 year assessments (positive parenting r's = .64 to .65; negative parenting r's = .50 to .55). Measures of children's RSA were generally correlated across the 2, 4, and 5 year assessments (baseline RSA r's = .46 to .52, $p < .001$; ΔRSA child independent tasks r's = .09, *ns* to .18, $p < .01$; ΔRSA mother-child tasks r's = .21 to .38, $p < .001$). There were only a few significant correlations between children's RSA and maternal parenting behavior. Greater maternal positive parenting during the 2nd year assessment was associated with lower baseline RSA at the 2 ($r = -.15$, $p < .01$), 4 ($r = -.17$, $p < .001$), and 5 ($r = -.20$, $p < .001$) year assessments. Children's ΔRSA during the 2nd year mother-child tasks were positively associated with maternal positive parenting behavior at the 2 ($r = .13$, $p < .05$), 4 ($r = .17$, $p < .01$), and 5 ($r = .22$, $p < .001$) year assessments and negatively associated with negative parenting behavior at the 2 ($r = .11$, $p < .05$), 4 ($r = .11$, $p < .05$) assessments. Children's ΔRSA assessed during the 5 year mother-child tasks was negatively associated with negative maternal parenting behavior ($r = -.10$, $p < .05$).

Table 3: Intercorrelations Among Temperament Dimensions and Maternal Parenting Behavior (*n*=370)

	2-year		4-year		5-year	
Outcome measure	Positive	Negative	Positive	Negative	Positive	Negative
Surgency						
4 year	-.12*	.13**	-.07	.12*	-.06	.16**
5 year	-.09	.14**	-.05	.12*	-.04	.14**
7 year	-.12*	.10†	-.06	.08	-.11*	.15**
Negative affectivity						
4 year	-.19**	.12***	-.13*	.19**	-.08	.14**
5 year	-.12*	.17**	-.06	.16**	-.06	.12*
7 year	-.10†	.14**	-.07	.12*	-.07	.13*

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

Developmental Trajectories of Temperamental Reactivity

Unconditional growth models were fit to explore the developmental trajectories of children's negative affectivity and surgency from 4 to 7 years of age (Tables 4 & 5). The fixed effects indicated that from 4 to 7 years of age, children's negative affectivity significantly decreased on average by .07 points each year with an average decrease from 4 to 7 years of .21 points (range: −.31 to .13). This change is approximately a third of a standard deviation on the negative affectivity scale. Children's average level of negative affectivity was 4.03 when they were 7 years of age. The correlation between the slope and children's level of negative affectivity at age 7 was .45, indicating that the change of negative affectivity over time was associated with children's scores at age 7. Surgency significantly decreased from 4 to 7 years of age at a rate of .07 points each year, with an average decrease from 4 to 7 years of .21 points (range: −.47 to .15). This change is approximately a third of a standard deviation on the surgency scale. Children's average surgency score was 4.80 when they were 7 years of age. The correlation between the slope and children's surgency at age 7 was .32. The parameter estimates had adequate reliability for both negative affectivity (intercept reliability = .85, slope reliability = .40) and surgency (intercept reliability = .83, slope reliability = .41).

The variances around the intercept and slope (random effects) indicate whether the parameter estimates varied across children and represent interindividual differences in the linear change that occurred from 4 to 7 years of age and overall levels of negative affectivity and surgency at age 7. For both negative affectivity and surgency, the random effects were significant. This indicates that there was substantial interindividual heterogeneity in the rate of change over time as well as the level of negative affectivity and surgency at age 7 that can be explained by including level 2 predictors in the model.

Predictors of Within-Child Changes in the Trajectories of Temperament Dimensions

The results examining predictors of within-child changes in children's negative affectivity (Table 4) and surgency (Table 5) are presented in the *Time-Varying Covariates* columns. We included children's physiological regulation and maternal parenting behavior from the 2, 4, and 5 year assessments as time-varying covariates to examine whether they predicted changes in children's negative affectivity and surgency (assessed at 4, 5, & 7 year assessments). Models testing the main effect of the time-varying covariates (i.e., baseline RSA, ΔRSA during independent tasks, ΔRSA during mother-child interaction tasks, mother positive parenting, and mother negative parenting), and the age × time-varying covariate interaction terms for each predictor were fit sequentially using a backward elimination method. Specifically, the initial model included all predictors and then the non-significant predictors (i.e., both the main effect and interaction term were not significant) were removed one by one beginning with the least significant predictor. Only significant effects were included in the final model.

Table 4: Results of Hierarchical Linear Models for Trajectories of Negative Affectivity Across Early Childhood (n = 370)

Fixed Effects	Unconditional Growth		Time-Varying Covariates		Level 2 Predictors	
	β (*SE*)	*t*(*df*)	β (*SE*)	*t*(*df*)	β (*SE*)	*t*(*df*)
Intercept (centered 7.5 years)	4.03 (.04)	115.08 (369)***	3.91 (.16)	24.56 (369)***	4.04 (.16)	24.59 (368)***
Maternal Negativity					.11 (.06)	2.03 (368)*
Slope (Age)	-.07 (.01)	-8.21 (369)***	.07 (.05)	1.34 (369)	.06 (.05)	1.21 (368)
Maternal Negativity					-.01 (.01)	-.96 (368)
Time Varying Covariates						
Baseline RSA			-.04 (.02)	-1.96 (1105)*	-.04 (.02)	-1.96 (1103)*
Maternal Negativity			.12 (.03)	4.37 (1105)***	.08 (.03)	2.43 (1103)*
Baseline RSA X Age			-.02 (.01)	-2.64 (1105)**	-.02 (.01)	-2.59 (1103)**
Random Effects	*Variance Component*	x^2 (*df*)	*Variance Component*	x^2 (*df*)	*Variance Component*	x^2 (*df*)
Intercept	.39	2513.85 (369)***	.38	2491.50 (369)***	.38	2483.94 (368)***
Slope	.01	619.05 (369)***	.01	602.65 (369)***	.01	304.73 (368)***
Baseline RSA X Age						
BIC (#Parameters)	1558.99 (6)		1538.36 (9)		1534.89 (11)	

Note. RSA = respiratory sinus arrhythmia; BIC = Bayesian information criterion.
*p < .05; **p < .01; ***p < .001

For negative affectivity, the results indicated that there were significant time-varying covariate main effects for baseline RSA and maternal negative parenting behavior (Table 4, *Time-Varying Covariates* columns). Thus, higher levels of baseline RSA and lower levels of maternal negative parenting at the previous assessment were associated with lower levels of negative affectivity at the later assessment. There was also a significant baseline RSA × age interaction effect. Specifically, this indicates that the rate of change in negative affectivity across early childhood differs based on the level of baseline RSA, with higher baseline RSA being associated with higher rates of change in negative affectivity. When the baseline RSA × age interaction was included in the model, the main effect of age (linear slope) was no longer significant, indicating that age was not a significant predictor of within-child changes in negative affectivity once changes in baseline RSA were taken into account. The linear age (slope) term was kept in the model because the BIC indicated that the overall model fit was better (as indicated by a lower BIC) for the model that included the linear age (slope) term (BIC = 1538.36) versus the model with the linear age term removed (BIC = 1564.99, Difference = 23.63). In addition, the random effect of linear age was still significant indicating that there was still substantial interindividual heterogeneity in the rate of change in negative affectivity over time that can be explained by including level 2 predictors of linear age in the model.

Table 5: Results of Hierarchical Linear Models for Trajectories of Surgency Across Early Childhood (n = 370)

Fixed Effects	Unconditional Growth		Time-Varying Covariates		Level 2 Predictors	
	β (*SE*)	*t*(*df*)	β (*SE*)	*t*(*df*)	β (*SE*)	*t*(*df*)
Intercept (centered 7.5 yrs)	4.80 (.03)	140.62 (369)***	5.14 (.09)	59.31 (369)***	5.13 (.11)	48.45 (365)***
Cohort 1					.19 (.08)	2.38 (365)*
Cohort 3					.13 (.08)	1.54 (365)
Gender (girl)					-.21 (.07)	-3.12 (365)**
Baseline RSA (2 yr)					.08 (.03)	2.89 (365)**
Slope (Age)	-.07 (.01)	-7.96 (369)**	-.08 (.01)	-8.75 (369)***	-.10 (.02)	-5.23 (365)***
Cohort 1					.03 (.02)	1.46 (365)
Cohort 3					.02 (.02)	1.20 (365)
Gender (girl)					.00 (.02)	.00 (365)
Baseline RSA (2 yr)					.00 (.01)	.05 (365)
Time Varying Covariate						
ΔRSA Mother-Child			-.06 (.02)	-2.67 (1106)***	-.06 (.02)	-2.65 (1098)**
Positive Parenting			-.06 (.01)	-4.03 (1106)***	-.05 (.01)	-3.78 (1098)***
Random Effects	*Variance Component*	x^2 (*df*)	*Variance Component*	x^2 (*df*)	*Variance Component*	x^2 (*df*)
Intercept	.36	2288.18 (369)***	.35	2286.18 (369)***	.32	2136.40 (365)***
Slope	.01	635.72 (369)***	.01	632.69 (369) ***	.01	627.51 (365)***
BIC (#Parameters)	1606.95 (6)		1588.52 (8)		1579.22 (16)	

Note. RSA = respiratory sinus arrhythmia; BIC = Bayesian information criterion.
*p < .05; **p < .01; ***p < .001

For surgency, the results indicated that the main effects for children's ΔRSA during mother-child tasks and maternal positive parenting significantly predicted changes in children's surgency across early childhood (Table 5, *Time-Varying Covariates* columns). Specifically, greater ΔRSA during mother-child tasks and greater maternal positive parenting at the previous assessment were associated with decreases in surgency at the later assessment. The age × ΔRSA during mother-child tasks and age × maternal positive parenting were not significant. In addition, the main effects of baseline RSA, ΔRSA during independent tasks and negative maternal parenting did not predict changes in children's level of surgency.

Predictors of Interindividual Differences in Trajectories of Temperament Dimensions

The results that examined interindividual differences are presented in the *Level 2 Predictors* columns in Table 4 for negative affectivity and Table 5 for surgency. To explore whether demographic or sample characteristics needed to be included as level 2 covariates of the intercept and slope in the model, the first Level 2 model fit for both negative affectivity and surgency included gender, minority status, socioeconomic status, and cohort. There were no significant demographic or cohort effects for the negative affectivity model so these variables were not included in subsequent models. Gender and cohort were significant predictors of the level of surgency at age 7 and were included in all the additional level 2 models predicting surgency. Specifically, girls had lower levels of surgency then boys, and children in cohort 1 had higher levels of surgency at 7 than children who were in cohort 2.

For the remaining models, the demographic covariates, as well as children's physiological regulation and maternal parenting behaviors from the 2-year laboratory assessment were included as time-invariant level 2 predictors to examine whether they accounted for the interindividual variation in children's temperament trajectories. All level 2 predictors were grand-mean centered. Models were fit using a backward elimination method. Specifically, a model including all time-invariant covariates and the interaction between maternal behavior and children's RSA was fit and then the non-significant predictors were removed one by one beginning with the interaction terms that were the least significant and then the direct effects (e.g., maternal positive parenting, maternal positive parenting × baseline RSA, maternal positive parenting × individual suppression, maternal positive parenting × suppression during mother-child task) and the same level 2 predictors were included for the intercept and slope. For children's negative affectivity, greater maternal negativity was associated with higher levels of negative affectivity at age 7 (Table 4, *Level 2 Predictors* columns). Children's physiological regulation, maternal positive behavior, and the interactions between maternal parenting behavior and children's RSA were not associated with interindividual differences in the linear change of children's negative affectivity over time.

The results for the *Level 2 predictors* model for children's trajectory of surgency are presented in Table 5. Girls had lower levels of surgency at age 7. In addition, greater baseline RSA was associated with higher levels of surgency at age 7. Children's physiological regulation, maternal parenting behavior and the interaction between children's RSA and maternal parenting behavior were not associated with interindividual differences in linear change in children's surgency over time.

Following the guidelines outlined by Singer & Willett (2003), we calculated a pseudo-R^2 statistic that reflects the proportion of total variation in the outcome explained by the specific set of predictors included in the model. The pseudo-R^2 for the final level 2 model was .90 and .89 respectively for negative affectivity and surgency, indicating the total outcome variation explained by the specific set of predictors in the model. The random effects from the models indicated that for both negative affectivity and surgency, there was still significant variation in the intercept and slope not accounted for by the level 2 predictors included in the model.

DISCUSSION

The current study investigated changes in two broad temperament dimensions reflecting different aspects of reactivity, negative affectivity and surgency during the transition from preschool to school age in a large community sample (that was oversampled for externalizing behavior problems at age 2). To date, little research has explored the parenting and child factors that are linked with children's surgency. In addition, the studies that have explored the link between maternal controlling behavior and negative affectivity have frequently relied solely on maternal reports (Paulussen-Hoogeboom et al., 2007). Given that higher levels of negative affectivity and surgency are often linked to maladaptive outcomes such as increased externalizing behavior problems and lower peer acceptance (Berdan et al., 2008), it is important to develop a more nuanced understanding of the child characteristics and parenting behaviors that may alter the developmental course of temperamental reactivity across early childhood.

The first aim of this study was to examine the developmental trajectories of negative affectivity and surgency from 4 to 7 years of age. Overall, as expected children exhibited decreased levels of negative affectivity (by .21 points) and surgency (by .21 points) across early childhood. This is consistent with research indicating that early childhood is a time characterized by gains in children's regulatory abilities (Blandon et al., 2008). During this period of time, children are undergoing maturational changes in the brain and changes in their daily contexts, such as entering school, that we would expect to have an impact on their positive and negative emotionality (Beauregard, Lévesque, & Paquette, 2004; Rimm-Kaufman et al., 2002). As children enter new developmental contexts and learn the rules for appropriate emotional behavior across different situations, they are more equipped to respond to challenging and exciting situations. Overall, this supports the notion that children's temperamental reactivity is dynamic and does change during early childhood.

The second aim of the study was to examine whether children's physiological reactivity and regulation and maternal parenting behavior were associated with within-child changes that occurred in children's negative affectivity and surgency across early childhood. Specifically, we included children's baseline RSA and RSA suppression and maternal parenting behaviors as time-varying predictors of children's later levels of negative affectivity and surgency (i.e., children's physiology and maternal behavior were assessed at the 2, 4, and 5 year laboratory assessments; temperamental reactivity was assessed at the 4, 5, and 7 year assessments). We found that children's baseline RSA was associated with lower levels of negative affectivity, and when mothers utilized more controlling parenting strategies, children displayed increased levels of negative affectivity at the later laboratory assessment. Restrictive parenting behaviors have frequently been cited as a factor in children's negative emotionality, though much of this research is based on parental reports of both parenting behavior and children's emotionality (Paulussen-Hoogeboom et al., 2007). The current study provides further support that parent-directed parent-child interactions, with little focus on the child's goals and behavior, may be linked with children's negative emotionality based on observed parenting behavior across several different types of tasks (e.g., freeplay, clean-up, & teaching). It should also be noted that it is likely the case that the link between negative aspects of maternal parenting behavior and children's negative affectivity is at least in part genetically mediated.

In addition, there was a significant baseline RSA × age interaction, which in conjunction with the linear effect of age becoming non-significant, indicates that the trajectory of children's negative affectivity is dependent upon their level of baseline RSA and not due to age related changes in negative affectivity. This builds on the previous research that has linked children's early physiological regulation with their observed emotional reactivity during challenging and frustrating tasks. For instance, in early infancy, baseline RSA has been linked with children's fear and frustration reactivity (Stifter & Fox, 1990). Overall, this supports the notion that there are specific physiological underpinnings of temperamental negative affectivity.

Although baseline RSA was an important factor in negative reactivity, children's vagal suppression (Δ RSA) was not. Other research indicates that for children who had stable patterns of high RSA withdrawal from 2 to 4 years of age, mothers reported that they had lower levels of negative affectivity (Calkins & Keane, 2004), although interestingly a mixed pattern of results were found for children whose RSA suppression changed during that period. It may be the case that vagal withdrawal is a better indicator of responses during specific regulatory challenges, rather than temperamental reactivity as assessed using the Child Behavior Questionnaire. Further research is needed to develop a more detailed understanding of the link between physiological regulation and negative affectivity across childhood.

The physiological and parenting characteristics that accounted for changes in children's trajectories of surgency across early childhood differed from the pattern we found for children's trajectories of negative affectivity. Overall, these results indicate that parenting may have an impact on children's temperamental reactivity at different levels. First, maternal sensitive parenting and controlling behavior were associated with changes in children's emotional reactivity. Although, children's negative affectivity increased when their mother engaged in more negative and directive parenting strategies, it was maternal warmth and responsiveness that was an important predictor for changes that occurred in children's surgency during early childhood. Indeed, when mothers engaged in high levels of warm and responsive behavior, children's surgency decreased across early childhood. Understanding the factors that are linked with decreasing surgency may be critical because children who are unable to control their exuberance and approach behavior may be at an increased risk for poor social outcomes and more behavior problems. What will be important for future research is to determine whether the specific characteristics that are subsumed within the surgency construct operate similarly or whether different combinations of these characteristics may be linked with differential outcomes. One example of a more nuanced approach to understanding the link between temperament and children's outcomes is Laptook et al. (2008) who found that low positive affect and high behavioral inhibition predicted lower levels of approach, but only in novel situations. In non-novel situations their link with approach behavior differed.

In contrast to the results for negative affectivity, the changes in children's trajectories of surgency were linked to children's earlier physiological regulation (as indexed by ΔRSA). This is consistent with the research which indicates that greater vagal withdrawal during challenging situations is related to better state regulation, greater self-soothing and more attentional control in infancy (DeGangi, et al., 1991; Huffman et al., 1998) and more appropriate emotion regulation in preschool children (Calkins, 1997; Calkins & Dedmon, 2000; Calkins & Keane, 2004). These results extend this area of research by differentiating between suppression during independent and mother-child interaction tasks. In fact, children who exhibited higher levels of vagal suppression during mother-child interaction tasks evidenced greater decreases in their levels of surgency over time. This was not the case for vagal suppression when the child was expected to manage their emotional reactivity independently during a challenging or distressing task. Recently research has highlighted the link between the caregiving environment and children's physiological regulation. It has been proposed that during infancy and toddlerhood, the development of characteristic patterns of physiological responding is dependent upon the dyadic interactions between the parent and toddler (Calkins & Hill, 2007; Moore & Calkins, 2004; Propper & Moore, 2006). Therefore, we might expect that even during early childhood, children may be more adept at controlling their physiological responses during a challenging task in which they are engaged with their mother because it is during such interactions where mothers are warm and responsive that adaptive behavior patterns are being learned that can then be applied in other situations over time.

Our final aim was to explore whether maternal parenting behavior and children's physiological regulation could account for interindividual differences in children's trajectories of negative affectivity and surgency. Again, maternal parenting behavior was an important predictor with respect to children's negative affectivity. Children whose mothers used more controlling parenting strategies when children were 2 years of age were more likely to exhibit greater negative affectivity when they were 7 years of age compared to children whose mothers did not use controlling parenting behaviors. For surgency, we found that at age 7, girls exhibited lower levels of surgency than boys. This is consistent with research showing that boys engage in more externalizing behaviors, given that high levels of surgency have been linked to more externalizing problems. Interestingly, early RSA was linked to children's later levels of surgency. Specifically, children who had higher levels of baseline RSA when they were 2 years of age were more likely to have higher levels of surgency when they were 7 years of age. This is consistent with the notion that high levels of baseline RSA reflect one's openness to the environment. The impact this openness to the environment has on children's social and emotional development may differ depending on the emotional tone of their environmental context (Boyce & Ellis, 2005; Ellis, Essex, & Boyce, 2005). Further research on the links between baseline RSA and surgency are warranted. It may be the case for both baseline RSA and surgency, that particularly high levels and low levels of each may be less adaptive (Berdan et al., 2008; Cole et al., 1996; Eisenberg et al., 1999). Overall, it is clear that maternal parenting behavior and certain aspects of children's physiology account for individual differences in children's temperamental reactivity in early childhood.

The study has some limitations that must be noted. First, the sample was overselected for externalizing behavior problems and thus, may not be representative of community samples, given that emotion dysregulation has been implicated in the stability of externalizing problems across childhood. It may also be the case that the attrition across the study could have influenced the results, though the use of full maximum likelihood estimation allowed us to utilize the full sample for the current analysis. Second, temperamental reactivity was assessed exclusively by maternal report. However, important elements of the study were not maternal report, specifically children's physiological regulation and observed maternal parenting behavior. There is some evidence that maternal reports of children's temperamental tendencies are consistent with observed reactivity during laboratory interactions (Calkins, Gill, Johnson, & Smith, 1999). In longitudinal studies across childhood, temperament is assessed using different types of tasks at different developmental stages (LAB-TAB, Goldsmith & Rothbart, 1993). Maternal report of children's temperament, therefore, is one of the best methods for examining trajectories from 4 to 7 years of age given the need to use the same measures across the different assessments (Singer & Willett, 2003). Finally, we were not able to explore non-linear patterns of change given we only had three waves of data available.

Overall, this study extends the literature on children's temperament by focusing on the physiological and parenting factors that are associated with changes in children's negative affectivity and surgency from 4 to 7 years of age. Although stability has often been considered a hallmark of temperamental traits, our data supports recent research that indicates there are individual differences in the change that occurs in children's negative affectivity and surgency across early childhood. Several interesting results emerged highlighting children's physiological indices of reactivity and regulation, maternal parenting behavior, as important factors in the changes that occur in children's temperamental reactivity across early childhood. The results of this study emphasize the importance of developing an understanding of the factors that may facilitate changes in children's temperamental reactivity.

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FOOTNOTES

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