Longitudinal Relations between Child Vagal Tone and Parenting Behavior: 2 to 4 Years

ABSTRACT: The longitudinal relations between physiological markers of child emotion regulation and maternal parenting practices were examined from 2 to 4 years of age. At Time 1, cardiac vagal tone was assessed for one hundred four 2-year-olds (54 females); their mothers completed an assessment of parenting styles. Two years later, at Time 2, 84 of the original participants were reassessed on measures of cardiac vagal tone and parenting style. Results indicated both baseline cardiac vagal tone and maternal parenting practices to be stable from 2 to 4 years of age. Children’s cardiac vagal tone predicted specific parenting practices from the toddler to preschool years. Further, child cardiac vagal tone moderated maternal restrictive-parenting practices from 2 to 4 years of age; mothers of children who were highly or moderately physiologically dysregulated were more likely to report restrictive parenting practices at both 2 and 4 years of age.

Keywords: emotion regulation; parenting; vagal tone

In recent years, researchers have identified cardiac vagal tone as a marker of the functional status, or efficiency, of the parasympathetic nervous system (Calkins, 1997; Porges & Byrne, 1992; Porges & Doussard-Roosevelt, 1997), marking both general reactivity and the ability to regulate one’s level of arousal. Variations in cardiac interbeat intervals can occur due to a variety of influences including changes in parasympathetic influence, sympathetic influence, and circulating hormone levels. Cardiac vagal tone is a measure of heart period variability and is thought to be attributed to the influence of the vagus nerve—the 10th cranial nerve—on parasympathetic function (Porges, 1991, 1995; Porges & Doussard-Roosevelt, 1997).

According to polyvagal theory, the vagal system assists in the maintenance of homeostasis through negative feedback with the peripheral nervous system in response to sympathetic arousal (Porges, 1991, 1995). The vagus nerve acts as a “brake” in the autonomic nervous system via the inhibition of heart rate (Porges, 1995; Porges, Doussard-Roosevelt, Portales, & Greenspan, 1996). Under stressful conditions, the removal of this “vagal brake” increases cardiac function and induces activation of the sympathetic nervous system thereby arousing the body for action; on the other hand, the activation of the “vagal brake” inhibits sympathetic stimulation and allows an individual to regulate negative arousal (Porges et al., 1996). Thus, according to Porges (1991, 1995) and colleagues (Porges et al., 1996; Porter, Porges, & Marshall, 1988), cardiac vagal tone, because of its influences on parasympathetic functioning, is an assessment of physiological regulation of arousal.

Cardiac vagal tone is assessed via the measurement of respiratory sinus arrhythmia (RSA; Berntson et al., 1997). RSA refers to the changes in heart rate during respiration; this pattern of change is thought to originate in differences in activity of efferent nerves beginning in the vagal nerve complex projecting to the heart (Porges et al., 1996). Specifically, during exhalation, there is an increase of activity along these efferent pathways which results in a decrease in heart rate; during inhalation, there is a
decrease in vagal efferent activity which results in an increase in heart rate (Katona & Jih, 1975; Porges, 1995). It is these efferent pathways that are thought to act as the aforementioned “vagal brake,” regulating parasympathetic functioning via increases and decreases in heart rate.

Thus, baseline measures of RSA reflect the efferent vagal projections to the heart at rest—or an individual’s potential to engage the “vagal brake” and ability to return the body to homeostasis after sympathetic arousal. Indeed, researchers have demonstrated that baseline cardiac vagal tone, as measured by RSA, is associated with individual differences in such temperamental constructs as reactivity, regulation/soothability, and attention/persistence from infancy through childhood (Calkins, 1997; Calkins & Fox, 1992; Stifter & Fox, 1990; Stifter & Jain, 1996; & Suess, Porges, & Plude, 1994). Therefore, it seems reasonable to conclude that variation in resting RSA may reflect individual differences in the ability to regulate arousal. In recent years, researchers have begun to investigate relations between individual differences in cardiac vagal tone, as measured by RSA, and behaviors thought to be, in part, influenced by the ability to effectively regulate arousal. For instance, significant relations between low cardiac vagal tone and expressions of emotionally dysregulated behavioral inhibition in novel social situations (Fox & Field, 1989) and the maternal report of a greater sensitivity of the Behavioral Inhibition System (Blair, 2003) have been found in samples of preschool-aged children. Further evidence supporting the relations between low cardiac vagal tone and behavioral inhibition have been found in studies of the same sample of children described herein. Specifically, Rubin, Hastings, Stewart, Henderson, and Chen (1997) found that baseline cardiac vagal tone was negatively related to “traditional inhibition” in toddlers. Rubin and colleagues (1997) defined “traditional inhibition” as the amount of time a toddler spent in close proximity to his or her mother in an unfamiliar setting, the latency to approach an unfamiliar adult and toy, and the latency to complete an unfamiliar task (e.g., crawl through a tunnel). This assessment of inhibition is thought to capture inhibited behavior that is dispositionally based (Kagan, 1989), thus suggesting that the relations Rubin and colleagues (1997) found between baseline cardiac vagal tone and inhibition may mark a temperamental individual difference. Additionally, in a recent factor analysis, Hastings, Rubin, and Mielcarek (2004) reported that both observed inhibition and maternally reported temperamental shyness loaded significantly on the same factor as baseline cardiac vagal tone (with a negative loading of the latter) at both 2 and 4 years of age with this same sample of children.

Furthermore, these physiological patterns (low cardiac vagal tone) have been associated with the development of those types of maladjustment thought to be, in part, a result of dysregulated affect, in both children (El-Sheikh, Harger, & Whitson, 2001) and adults (Friedman & Thayer, 1998). Alternately, high cardiac vagal tone has been associated with the ability to self-soothe after displays of negative affect (Fox, 1989). Thus, it appears that resting cardiac vagal tone may be taken as a marker of dispositional ability to regulate affect, with low cardiac vagal tone marking emotion dysregulation.

While researchers have attempted to link cardiac vagal tone, emotion regulation, and varying expressions of behavior, there also is emerging a body of literature connecting emotion regulation and its concomitants to specific patterns of parenting behavior. For example, researchers have documented that certain child-temperament characteristics reflecting emotion regulation processes predict particular patterns of parenting behaviors and beliefs. Specifically, children who are dispositionally “easy” (e.g., highly soothable, not easily aroused, highly sociable) have parents who are warm and responsive whereas children who display “difficult” temperaments (e.g., easily upset and difficult to soothe, easily angered and uninhibited) have parents who are more rejecting and less warm and accepting (for a review, see Putnam, Sanson, & Rothbart, 2002). Similarly, Rubin, Nelson, Hastings, and Asendorpf (1999) reported that parents who viewed their toddlers as inhibited and fearful in unfamiliar social situations reported greater restriction over their children’s independence 2 years hence. Importantly, parenting at 2 years did not predict parent reports of inhibited, fearful behavior at age 4. Hastings and Rubin (1999) also found that mothers were more likely to suggest the use of physical affection and spending time together to comfort their socially withdrawn preschoolers when, 2 years earlier, they had described their toddlers as more socially fearful.

It is clear that child characteristics affect the manner in which parents respond to their children and plan their socialization practices; however, there also is a growing body of evidence that indicates that parenting may influence child behavior and emotion regulation. Specifically, it appears as if particular parenting patterns can ameliorate or exacerbate certain temperamental characteristics in children. For example, Crockenberg (1987) reported that irritable infants whose mothers were more punitive and hostile displayed greater anger and non-compliance 2 years later than their irritable counterparts whose mothers engaged in less harsh parenting practices. Similarly, Rubin, Burgess, Dwyer, and Hastings (2003) found that emotionally “difficult” temperament (an aggregate of observed undercontrol and mother-rated anger proneness and lack of avoidance) at 2 years predicted externalizing behaviors at 4 years; this was especially so for those toddlers whose mothers were highly negative.
and controlling. Further, infants who have low thresholds of negative reactivity and whose parents are overprotective and intrusive are likely to be behaviorally inhibited during the toddler years (Park, Belsky, Putnam, & Crnic, 1997). Moreover, temperamentally fearful toddlers whose mothers demonstrate relatively high frequencies of intrusive control and/or derisive comments are more likely to be socially reticent in the company of their preschool peers 2 years hence than their temperamentally fearful counterparts whose parents do not engage in such behavior (Rubin, Burgess, & Hastings, 2002). And some researchers have shown that more responsive and sensitive forms of caregiving can buffer children with a difficult temperamental profile from the development of maladaptive psychosocial behaviors, such as aggression (Calkins & Johnson, 1998). Thus, several researchers have demonstrated that parental behavior can moderate the contemporaneous and predictive relation between toddlers’ dispositionally based characteristics and their social behavior.

Although researchers have examined meaningful temperament–parenting relations, the majority of this literature has focused on parental reports of children’s dispositional characteristics. Rarely have researchers examined the links between parenting and emotion regulatory processes through the physiological assessment of dispositional characteristics. In one of the few relevant studies, Calkins, Smith, Gill, and Johnson (1998) found that maternal negative and controlling behavior during a positive emotion task was negatively associated with vagal suppression.

The largest body of relevant work connecting physiology to parenting, however, has focused on child–parent attachment quality. For example, Nachmias, Gunnar, Mangelsdorf, Hornick Parritz, and Buss (1996) reported that secure child–mother attachment moderated the relation between an inhibited temperamental disposition and activation of the hypothalamic–pituitary–adrenocortical system. Specifically, Nachmias et al. (1996) collected assays of cortisol (thought to be an index of stress reactivity) prior to and after two stress-inducing paradigms: (a) a coping session within which children were confronted with several novel, arousing stimuli and (b) the Strange Situation paradigm (Ainsworth, Blehar, Waters, & Wall, 1978). Nachmias et al. (1996) found that children with an inhibited temperamental profile, who were insecurely attached to their mothers, had higher posttest cortisol levels (in both sessions) than inhibited children who had secure attachment relationships. Similar patterns of results for the ameliorating effect of secure attachment quality have been reported by Spangler and Schieche (1998), who found that the Strange Situation activated the endocrine stress response in ambivalent infants, but not in securely attached or avoidantly attached infants.

Whereas the extant literature pertaining to the relations between quality of attachment and physiological correlates of stress reactivity has illuminated important links between these two constructs, there is a lack of longitudinal research examining the relations between child-rearing practices and physiological measures of emotion regulation processes. Thus, it seems timely to examine the associations between physiological characteristics of children’s temperamental reactivity and regulation and mothers’ parenting practices.

In summary, both cardiac vagal tone and child-rearing practices are associated with young children’s abilities to regulate the experience of emotion. Cardiac vagal tone is thought to be moderately stable, with individual differences remaining relatively similar from infancy to early childhood (Bornstein & Suess, 2000; Porges, Doussard-Roosevelt, Portales, & Suess, 1994). It also is the case that parenting styles are moderately stable in infancy and early childhood (e.g., Bornstein & Tamis-LeMonda, 1990; Feldman, Greenbaum, Mayes, & Erlich, 1997; Rubin et al., 1999); however, little is known about factors that influence change and stability in parenting. Furthermore, factors associated with individual changes in cardiac vagal tone also have not been examined.

As previously mentioned, past research has indicated that both parenting and physiology are thought to influence both adaptive and maladaptive development. Furthermore, as underscored by developmental systems theory, there is a dynamic, bidirectional relationship between developing individuals and the environments in which they grow (e.g., Lerner, 1998; Lerner, Rothbaum, Boulou, & Castellino, 2002). Indeed, one aspect of developmental systems theory, developmental contextualism, asserts that psychosocial functioning is the product of an individual’s actions on his or her environment (e.g., behaviors associated with particular temperamental profiles such as social withdrawal or aggression) and the actions of the environment on an individual (e.g., parenting practices) (Lerner et al., 2002). From this perspective, neglecting to examine both the environmental influences on a developing individual and the influences of the developing individual on the environment provides an incomplete picture of where behavior “comes from” since these systems work together in a transactional, reciprocal fashion to shape behavioral and psychological functioning (Lerner, 1998; Lerner et al., 2002). Thus, the aim of the present study was to examine the transaction between child cardiac vagal tone and maternal child-rearing practices both concurrently and longitudinally in the toddler and preschool years.

In the present study, the longitudinal relations between cardiac vagal tone and child-rearing practices were examined over a 2-year period for children aged 2 to 4 years. This particular age period was selected because of
its significance for the development of children’s social and emotional skills (for relevant reviews, see Denham, 1998; Rubin, Bukowski, & Parker, 1998). It is now known that the social and emotional behaviors of preschoolers (2- to 4-year-olds) predict subsequent adjustment (Denham et al., 2003; Rydell, Berlin, & Bohlin, 2003) and maladjustment (Rubin, Coplan, Fox, & Calkins, 1995; Rydell et al., 2003). Furthermore, parenting styles exhibited during this period are not only stable but also predictive of both positive (Rose-Krasnor, Rubin, Booth, & Coplan, 1996; Zahn-Waxler, Radke-Yarrow, Wagner, & Chapman, 1992) and negative (Park et al., 1997; Rubin, Hastings, Chen, Stewart, & McNichol, 1998; Rubin et al., 1997) child outcomes.

**DEFINING STABILITY AND PREDICTING CARDIAC VAGAL TONE**

When making predictions and drawing conclusions regarding the stability of measures, it is imperative to distinguish between different types of stability (e.g., mean-level stability vs. rank order stability). Bornstein and Suess (2000) recently noted that confusion may result if one synonymously uses the terms “continuity,” “stability,” and “consistency.” In keeping with this perspective, we refer to stability as “the consistency of relative ranks of individuals in a group with respect to a function or process through time” (Bornstein & Suess, 2000, p. 54). Thus, following the recent findings of Bornstein and Suess, we posited that cardiac vagal tone would remain stable from 2 to 4 years; however, because the stability of cardiac vagal tone is moderate, at best (Bornstein & Suess, 2000; Porges et al., 1994), and because parents may influence children’s dispositional characteristics over time (Crockenberg, 1987), it also was expected that parental behavior might influence physiological indices of emotion reactivity and regulation.

More specifically, it was expected that restrictive and controlling parenting at 2 years would be negatively predictive of cardiac vagal tone, a proxy measure of physiologically based dysregulation at 4 years. Furthermore, socialization strategies marked by warm and supportive parenting practices at 2 years of age were hypothesized to predict higher cardiac vagal tone (emotion regulation) at 4 years. Finally, considering the literature pertaining to the possible exacerbating effects of parental overprotection has on children’s social wariness and shyness (Rubin et al., 1997), it was posited that parents who were more protective and less encouraging of independence towards their toddlers would have children with lower cardiac vagal tone at 4 years of age.

It was expected, however, that parenting practices may moderate the stability of children’s physiological dysregulation from the toddler to the preschool years. As mentioned previously, certain patterns of parenting have been shown to have ameliorating (Fish & Crockenberg, 1981) and exacerbating (Park et al., 1997; Rubin et al., 2002) effects on children’s negative emotionality and reactivity. Thus, it was expected that similar patterns in parenting would affect children’s ability to physiologically regulate emotion. Consistent with findings by Fish and Crockenberg (1981) that supportive parenting has an ameliorating effect on temperament, we hypothesized that the relation between measures of low cardiac vagal tone (emotion dysregulation) at ages 2 and 4 years would be nonsignificant for children whose mothers reported more supportive parenting practices. On the other hand, we posited that low cardiac vagal tone (emotion dysregulation) would be stable from 2 to 4 years when mothers engaged in either (a) harsh/negative parenting or (b) overprotective parenting toward their toddlers.

**PREDICTION OF PARENTING PRACTICES**

Consistent with previous literature (Holden & Miller, 1999; Rubin et al., 1999), mothers’ parenting practices were expected to remain relatively stable over the 2-year period; however, as mentioned earlier, child dispositional characteristics affect the way parents behave towards their children (Gauvin & Fagot, 1995; Rubin, Hastings, et al., 1998; van den Boom & Hoeksma, 1994). Thus, the data were examined to explore whether physiological characteristics of children affected parenting longitudinally. It was predicted that 2-year cardiac vagal tone would be positively predictive of supportive parenting at 4 years and that it would be negatively associated with both harsh/restrictive and overprotective parenting at 4 years. These predictions were drawn from earlier research in which maternal interactive style was shown to be influenced by children’s temperamental characteristics (Calkins et al., 1998; Hastings & Rubin, 1999; Rubin et al., 1997; Rubin et al., 1999; van den Boom & Hoeksma, 1994).

In addition, it was predicted that cardiac vagal tone, as a marker of emotion regulation, would moderate the 2- to 4-year relations between parenting styles. That is, it was expected that parents who were restrictive when their children were 2 years of age and whose toddlers were physiologically dysregulated (low cardiac vagal tone) would be more likely to continue to report restrictive parenting 2 years later than those mothers whose toddlers were not physiologically dysregulated. Similar patterns were expected to emerge for parents who reported overprotective parenting at 2 years of age. Parents who reported overprotection and whose toddlers were physiologically dysregulated were expected to continue to report overprotective parenting patterns when their children
were 4 years of age; this pattern was not expected for those overprotective parents whose toddlers were able to effectively regulate their emotions. The foundation for these predictions is rooted in the literature pertaining to children’s pervasive influence on parental behavior. Several researchers have found that “child effects” contribute to the manner in which parents socialize their children (Bell, 1971; Bell & Chapman, 1986; Lytton, 1991); specifically, it has been demonstrated that particular parenting behaviors (e.g., the display of negative affect) appear to be more susceptible to the influence of children’s dispositional traits than other parenting styles (Deater-Deckard, 1996; Lytton, 1991).

METHOD

Participants

The participants for this study were drawn from a sample of 104 children (54 females) from families who lived in and around the Canadian cities of Kitchener and Waterloo, Ontario (approximate population = 250,000). The children and parents were first involved in the study at toddler age 2 years. The present report represents a follow-up of those parents who agreed to complete a set of questionnaires at child age 4 years, with children who had their cardiac vagal tone measured at 4 years, and for whom a complete dataset was available at 2 years (N = 84). Participants were identified by birth announcements in the local newspaper and recruited by telephone solicitation. Participants were restricted to two-parent families. Of all families recruited, 75% consented. Ninety-seven percent of the participants were Caucasian. The average age of the mothers, at child age 2 years, was 31.05 years (SD = 4.12, range = 23–41); the average age of the fathers was 32.49 years (SD = 3.91, range = 24–43). On average, both mothers and fathers had some college education. The families had a mean score of 46.46 (SD = 10.80, range = 24–43) on the Hollingshead Social Status Index (Hollingshead & Redlich, 1958).

Procedure

Mothers and children visited the laboratory twice at age 2 years. The first visit was within 3 months of the child's second birthday; the second visit followed by approximately 12 weeks. Two years later, children returned to the laboratory. Eighty-eight children (42 females) from the original sample participated at age 4 (M = 51 months, SD = 1.33). Although 20 children were not available for the 4-year visit, attrition appeared to be non-selective. Nonsignificant differences were found for both demographic (parental education, familial SES) and behavioral variables.

Measures

Cardiac Vagal Tone ($V_{NA}$). Porges’ (1985) algorithm for computing $V_{NA}$ was used to quantify RSA using a UFI iso/fetode signal amplifier connected to a Delta-Biometrics Vagal Tone Monitor-II (VTM). The VTM found the peak of the R-wave to the nearest ms and timed the interval between successive R-waves, or heart periods, to the nearest ms. Sequential heart period data were stored in a computer file for each child. Mexedit software (Delta-Biometrics, 1989) was used to manipulate heart period data. The software visually displayed patterns of heart period and allowed the manual modification of outliers caused by movement. The Mexedit software uses a moving polynomial algorithm with age-specific frequency bandpass parameters to quantify RSA, which is Porges’ index of $V_{NA}$. The frequency band for RSA computation ranged from 0.24 to 1.04 Hz. This method reports $V_{NA}$ in units of ln (ms)$^2$. The mean of the sequential 20-s intervals for each child was used as an estimate of baseline $V_{NA}$ in this analysis. The data array used in the Mexedit software varied by participant depending on each child’s heart period; the average data array was 110 points.

Participants and their mothers came to the laboratory, where $V_{NA}$ was assessed after the necessary informed consent was obtained. At 2 years of age, toddlers sat on their mother’s lap and were “introduced” to an Ernie (Sesame Street) puppet. The Ernie puppet was used to demonstrate to the children how the electrodes would be placed on their chest. Children were allowed to play with Ernie while three electrodes were attached to their chest in a triangular pattern. After the leads were attached to the monitor, children were given 1 to 2 min to adjust to the setting and the procedure. If the child became upset, he or she was given time to calm down before collecting leads and starting the procedures.

The children’s cardiac cycles were recorded for 1 min. A baseline reading was gathered while the children sat quietly looking at a blue video monitor screen. No $V_{NA}$ data were collected for 3 children who became too upset to complete this procedure.

At 4 years of age, children and their mothers returned to the laboratory for a multisegment visit. The visit began with the $V_{NA}$ assessment. The $V_{NA}$ data were measured in the same fashion and with the same apparatus used during the 2-year visit. Children sat beside their mother while three disposable electrodes were attached to each child’s chest in a triangular pattern. After children were comfortable in the testing room, children sat and looked at a blank blue screen for 1 min to assess baseline heart rate variability.

Maternal Parenting Practices. Parenting style was assessed at child age 2 and 4 years by the Child-Rearing Practices Report (CRPR; Block, 1981; Block, Block, & Morrison, 1981). This 91-item Q-sort was obtained from mothers when their children were both 2 and 4 years of age. The CRPR assesses child-rearing attitudes, beliefs, and behaviors. Three measures of parenting style were drawn from the Q-sort, two of which were originally described by Block (1981): supportive parenting (“I talk or reason with child when she/he is misbehaving.” “I respect and encourage my child’s opinions.”) and restrictive/overcontrolling parenting style (“My child is not allowed to question my decisions.” “Scolding and criticism makes my child improve.”) The third parenting style, overprotective parenting, was characterized by items describing discouragement of independence and...
high protectiveness. This latter aggregate was formed by multiplying the standard scores of two Q-sort dimensions: the inverse score of Encouragement of Independence ("I let my child make decisions for him/herself." "I encourage my child be curious, to explore, and question things.") and the score of Protection/Concern ("I stop my child from playing rough games." "I do not go out if my child must stay with a stranger.")

RESULTS

Means and SDs for child VNA and parenting dimensions at 2 and 4 years are reported in Table 1. Two-tailed correlations between all variables are presented in Table 2. Sample size differed for each variable because 4 children refused to participate in VNA assessment at 2 years of age; in addition, there was the aforementioned nonselective attrition.

The first set of analyses examined the associations between the different parenting dimensions and VNA, as assessed by RSA, over time via a path analytic approach consistent with those described by Rogosa (1980) and used by Rubin et al. (1999). This procedure uses the standardized betas as path coefficients from a regression procedure where the 4-year assessment of one variable (either child VNA or the parenting variable) was regressed on both the 2-year assessment of the parenting variables and child baseline VNA. Parenting behaviors (supportive, restrictive/overcontrolling, and overprotective parenting) and baseline VNA assessed at 2 years of age were used as predictors of age 4 parenting behaviors and age 4 baseline VNA. The path coefficients presented in Figures 1–3 indicate that 2-year baseline VNA directly influenced both maternal ratings of restrictive and supportive parenting practices.

Regression analyses were conducted to examine the possible moderating effects of (a) child VNA on the parenting dimensions over time and (b) the parenting dimensions on child VNA over time (see Tables 3 and 4). Two-year baseline VNA and age 2 maternal Q-sort factors were used as predictors of age 4 maternal parenting behaviors and age 4 baseline VNA. Specifically, variables were entered on the following steps: (1) child VNA, (2) dimensions of parenting (e.g., supportive; restrictive; or overprotective), and (3) the interaction between baseline VNA and corresponding parenting dimension.

### Predicting Baseline VNA Tone at 4 Years

A significant main effect was found for 2-year baseline VNA in the prediction of 4-year baseline VNA ($R^2$ $\delta = .23, F$ change $= 19.53, p < .001$). The presence of a positive beta weight ($\beta = .48$) indicated that those children who exhibited higher baseline VNA at 2 years of age had higher baseline VNA at 4 years. None of the parenting indices assessed at 2 years predicted VNA at 4 years.

### Predicting Restrictive/Overcontrolling Parenting at 4 Years

A significant main effect was found for the prediction of maternally reported restrictive/overcontrolling parenting practices at 4 years of age from 2-year baseline VNA ($R^2$ $\delta = .09, F$ change $= 6.08, p < .05$). The presence of a negative beta weight ($\beta = -.31$) indicated that children who had lower baseline VNA at 2 years of age had mothers...
who reported higher restrictive/overcontrolling parenting practices at 4 years.

Additionally, maternal report of restrictive/overcontrolling parenting at 2 years of age was a significant predictor of maternal restrictive/overcontrolling parenting practices at 4 years ($R^2 = .26$, $F$ change $= 23.51$, $p < .001$). The presence of a positive beta weight ($\beta = .52$) indicated that mothers who reported higher restrictive/overcontrolling parenting practices at 2 years of age also reported greater levels of restrictive/overcontrolling parenting practices at 4 years.

It was found that 2-year $V_{NA}$ moderated the relation between maternal report of restrictive/overcontrolling parenting practices at 2 and 4 years of age ($R^2 = .05$, $F$ change $= 4.44$, $p < .05$). This interaction was further examined by comparing the correlation coefficients independently for 2-year-old children with high, medium, and low $V_{NA}$ (tertile splits). The correlation between maternal restrictive/overcontrolling parenting practices at 2 and 4 years of age was significant only for those participants who exhibited low or medium $V_{NA}$ at 2 years of age (low $V_{NA} r = .72$, $p < .001$, $n = 35$; medium $V_{NA}$ $r = .49$, $p < .05$, $n = 35$; high $V_{NA} r = .35$, n.s., $n = 34$). A series of $r$ to $z$ transformations (Ferguson, 1966) were computed, and the difference in the magnitude of correlations for low $V_{NA}$ and medium $V_{NA}$ was nonsignificant ($z = 1.07$, n.s.), the difference in the magnitude of correlations for low $V_{NA}$ and high $V_{NA}$ was significant ($z = 6.899$, $p < .001$), and the difference in the magnitude of correlations for medium $V_{NA}$ and high $V_{NA}$ was nonsignificant ($z = 1.79$, n.s.).

The interaction was also probed following Cohen, Cohen, West, & Aiken (2003). The regression equation was restructured to express the regression of age 4 restrictive/overcontrolling parenting on age 2 restrictive/overcontrolling parenting at levels of child cardiac vagal tone. These equations are plotted in Figure 4 to display the interaction.

Predicting Supportive Parenting at 4 Years

Two-year baseline $V_{NA}$ predicted maternal ratings of supportive parenting at 4 years of age ($R^2 = .07$, $F$ change $= 4.41$, $p < .05$). The presence of a positive

![Figure 1](image-url)  
**FIGURE 1** Transaction between maternal restrictive parenting and children’s baseline cardiac vagal tone. *$p < .05$; **$p < .001$.

### Table 2. Correlations between 2-Year Measures and 4-Year Measures

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<td>1. Baseline Vagal Tone</td>
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<td>3. Supportive Parenting</td>
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$^a p < .05$.  
$^{*a} p < .01$ (two-tailed).
beta weight ($\beta = .26$) indicated that children who exhibited higher levels of baseline VNA at 2 years of age had mothers who were more supportive in their espoused parenting practices.

Maternal supportive parenting practices at 2 years predicted maternal supportiveness parenting at 4 years ($R^2 = .44, F$ change $= 52.60, p < .001$). The presence of a positive beta weight ($\beta = .68$) indicated that mothers who reported higher levels of supportive parenting practices at 2 years of age also reported high levels of supportive parenting when their children were 4 years old.

**DISCUSSION**

The primary purpose of this study was to examine the longitudinal association between cardiac vagal tone and parenting behaviors from 2 to 4 years of age. As hypothesized and consistent with previous research (e.g., Bornstein & Suess, 2000; Marshall & Stevenson-Hinde, 1998), cardiac vagal tone was stable from the toddler to the preschool years. Furthermore, as reported in studies in infancy and early childhood (Bornstein & Tamis-LeMonda, 1990; Rubin et al., 1999), mothers’ parenting practices were consistent over time from the toddler to the preschool years. However, despite the stability of both child cardiac vagal tone and parenting, some evidence emerged that these constructs influence each other longitudinally.

The findings indicated that, in general, children’s early biological dispositions influenced parenting practices. Thus, baseline cardiac vagal tone at 2 years predicted both maternal restrictive/overcontrolling parenting and sup-
portive parenting at 4 years. Lower cardiac vagal tone, an index of emotion dysregulation and a correlate of social wariness and behavioral inhibition (Hastings et al., 2004; Rubin et al., 1997), predicted maternal engagement of harsh parenting practices; conversely, higher cardiac vagal tone, an index of emotion regulation, predicted more supportive parenting by mothers. This pattern of results supports the existing literature that temperament is an elicitor of parenting behaviors and beliefs (Bell, 1971; Bell & Chapman, 1986; for a relevant review, see Putnam et al., 2002). However, unlike previous research on this topic in which markers of temperament, or emotional reactivity and regulation, were drawn from parent ratings (e.g., Rubin et al., 1997), observed behavior (e.g., Crockenberg & McCluskey, 1986; Crockenberg & Smith, 1982), or an aggregate of both parental report and observed temperament (e.g., Park et al., 1997; Rubin, Hastings, Chen, Stewart, & McNichol, 1998), the study reported herein assessed regulatory processes physiologically. Thus, these early physiological processes may be internal reflections of externally evidenced child behaviors that may subsequently influence parental response. Not only did cardiac vagal tone predict parental behavior, it also served to moderate the relation between parenting styles at child ages 2 and 4 years. Thus, restrictive parenting was stable in very early childhood, but only for those children who were highly or modestly emotionally dysregulated. These findings prove significant when considering the literature pertaining to the differential susceptibility in the development of maladaptive behaviors (Belsky, 1997a, 1997b). Belsky (1997a, 1997b) argued that some children may develop symptoms of psychopathology because they are temperamentally predisposed to behave in a dysregulated and negatively reactive manner. To Belsky (1997a, 1997b), these children may be more likely to elicit hostile parental behavior because of their negative dispositions; thus, these children are likely to be more susceptible to the

![Figure 4](image-url)  
**FIGURE 4**  Age 4 maternal restrictive parenting as a function of age 2 maternal restrictive parenting at three levels of child cardiac vagal tone.

| Table 3. Regression Analyses Predicting Vagal Tone from 2 to 4 Years of Age |
|----------------------|---|---------|---|---|
| **Predictors at 2 years** | **R** | **ΔR²** | **β** |
| Vagal Tone            | 0.48 | 0.23* | 0.48 |
| Restrictive Parenting | 0.49 | 0.02  | 0.13 |
| Vagal Tone × Restrictive Parenting | 0.51 | 0.01  | 0.12 |
| Vagal Tone            | 0.48 | 0.23* | 0.48 |
| Supportive Parenting  | 0.51 | 0.04  | −0.19 |
| Vagal Tone × Supportive Parenting | 0.52 | .002  | −0.04 |
| Vagal Tone            | 0.48 | 0.23* | 0.48 |
| Overprotective Parenting | 0.50 | 0.02  | 0.14 |
| Vagal Tone × Overprotective Parenting | 0.51 | .009  | 0.10 |

* p < .001.
development of externalizing difficulties when faced with negative, hostile environments while the presence of a nurturing rearing environment may prove to inhibit the development of behavioral problems commonly associated with difficult temperament (Belsky, 1997a, 1997b).

Thus, it appears that the developmental trajectory for children who are physiologically dysregulated and whose mothers consistently engage in restrictive parenting may be marked by problematic social and emotional functioning. Indeed, the cumulative effects of restrictive parenting and temperamental difficultness in early childhood have been associated with and predictive of maladaptive behavior (e.g., externalizing difficulties) not only in early childhood (Belsky, Hsieh, & Crnic, 1998; Rubin, Hastings, Chen, Stewart, & McNichol, 1998) but also in the mid to late years of childhood (Sheffield Morris et al., 2002).

In summary, the predictive relations between cardiac vagal tone and parenting make sense given that parents might choose to be restrictive if they believe their emotionally fearful and dysregulated children are at psychological or physical risk should they be left to make decisions on their own. Thus, to the extent that the children with low vagal tone are actually behaviorally inhibited (Hastings et al., 2004; Rubin et al., 1997), the constraints imposed by restrictive parents may deny these children the necessary challenging experiences to develop their self-regulatory abilities. Parents’ child-rearing orientations may serve to maintain or exacerbate the nascent wariness and emotional dysregulation in their children.

Finally, in the present study we explored directional effects in the relations between children’s cardiac vagal tone and parenting at ages 2 and 4. Two major findings emerged: (a) Both physiological markers of emotion regulation as well as parent reports of socialization preferences were stable from 2 to 4 years of age, and (b) dispositional, physiological markers of emotion regulation predicted restrictive parenting while the reverse was not the case.

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