Vagal Tone and Temperament as Predictors of Emotion Regulation Strategies in Young Children

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Abstract

This study examines vagal tone and two dimensions of temperament as predictors of emotion regulation (ER) strategy use among children ($n = 54$, ages 4-7) of mothers varying in risk for depression. In one protocol, ER strategies were coded by trained raters during a delay of gratification task. Physiological and psychometric data were collected in an independent and separate protocol: vagal tone during rest (baseline), during the emotional challenge and following the challenge (recovery), and maternal reports of effortful control and negative affectivity. Children with lower vagal recovery and higher negative affectivity tended to focus on the desirable object or toy. Effortful control and negative affectivity were not associated with the ER strategies of positive reward anticipation or behavioral distraction. These findings are consistent with models of vagal tone and temperament as markers of individual differences in ER.
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An important developmental accomplishment of childhood is the establishment of effective emotion regulation skills. Thompson (1994, pp. 27-28) defines emotion regulation as “the extrinsic and intrinsic processes responsible for monitoring, evaluating, and modifying emotional reactions, especially their intensive and temporal features, to accomplish one’s goals.”

Across infancy and childhood, children gradually develop the capacity to self-regulate their emotions, particularly negative emotion (Kopp, 1989). There are developmental changes from reflexive attempts to regulate (e.g., self-soothing) in infancy to more volitional attempts at behavioral control in toddlerhood and the preschool period. Emotion regulation skills are critical for the development of appropriate and adaptive social behavior during preschool and school years (Calkins, 1994; Thompson, 1994). Individual differences in the capacity for regulation are a function of both the relationship the child has with the primary caregiver and variability in individual characteristics, such as temperament.

Two temperamental characteristics relevant to children’s emotion regulation are negative affectivity and effortful control. Negative affectivity is a child’s tendency to react to stimuli with discomfort, fear, anger/frustration, and/or sadness (Rothbart, Ahadi, & Hershey, 1994; Rothbart, Ahadi, Hershey, & Fisher, 2001). Effortful control is the utilization of attentional resources to regulate behavior and emotions. It is positively related to empathy, conscience, and lower levels of psychopathology and maladjustment (Eisenberg, 2000; Kochanska et al., 2000; Rothbart & Bates, 1998).

Theories that focus on the underlying physiological components of emotion regulation propose that maturation of central and autonomic nervous systems provide the foundation for
emotional and behavioral regulation. Research has indicated that measures of cardiac control may index individual differences in emotional and behavioral regulation. Porges (1991, 1995) has proposed a model in which maturation of the parasympathetic nervous system plays an important role in the development complex regulatory behaviors, including the regulation of state, motor activity, and emotion. In this study, we examined the relations among vagal tone and two dimensions of temperament (effortful control and negative affectivity), and emotion regulation strategies used by 4-, 5-, and 7-year-old children during a delay of gratification task.

**Vagal Tone and Emotion Regulation**

Cardiac vagal tone, an index of the functional status of the parasympathetic nervous system, has been viewed as a psychophysiological marker of emotion regulation and arousal (Porges, 1991, 1995). Parasympathetic nervous system functioning, measured by high frequency variability in heart period, is related to the control of attention, emotion, and behavior. The high frequency power in heart period is mainly a result of respiratory influences (respiratory sinus arrhythmia). Porges (1992a) has developed methods for the quantification of power in this frequency band and has called his estimate of this power vagal tone.

Baseline cardiac vagal tone has been associated with individual differences in reactivity and regulation/soothability (e.g., Calkins, 1997; Calkins & Fox, 1992; Stifter & Fox, 1990). Measures of negative affectivity are generally inversely related to resting vagal tone, although this relationship changes with age (see Beauchaine, 2001, for a review). High vagal tone in toddlers is associated with approach to strangers, high activity level, regulated distress in frustrating situations, and lower levels of aggression (Calkins & Dedmon, 2000; Porges, Doussard-Roosevelt, Portales, & Greenspan, 1996; Stifter & Fox, 1990; Stifter, Fox, & Porges, 1989; Stifter & Jain, 1996). In young boys, high vagal tone has been found to be associated with
greater empathy, social competence, subjective feelings of sympathy, and teacher and parent reports of sociability and emotion regulation (Eisenberg et al., 1995; Fabes, Eisenberg, & Eisenbud, 1993; Fabes et al., 1994).

Studies of vagal tone in children have primarily examined baseline vagal tone as a predictor of behavior or as an outcome or predictor of emotional health (e.g., Calkins & Fox, 1992; Fox, 1989; Gunnar et al., 1995). However, the degree to which an individual suppresses vagal tone during a challenging task may also be related to the regulation of attention and behavior (Calkins, 1997; Porges, Doussard-Roosevelt, & Maiti, 1994). This suppression may act to increase orientation to stimuli. While these mechanisms are both part of the self-regulatory system, an additional factor, physiological effort to recover from a stimulus, is rarely addressed in child psychophysiology studies. Physiological recovery from a stimulus is adaptive as such a reaction conserves energy when not engaging in an active response to the stimulus. Measuring the ability to regulate emotions in the physiological systems should take into account the baseline pattern, the reactive response, and the attempt to return to baseline (Fox, 1998). This approach can provide a more complete picture of the temporal course of emotion reactivity and regulation. In the current study, we addressed this issue by including (1) baseline vagal tone, (2) vagal reactivity, the change in vagal tone from baseline to stressor (the stressor being an “M&M” delay of gratification task), and (3) vagal recovery, defined as a vagal tone during a baseline period following the M&M task.

**Temperament and Emotion Regulation**

Rothbart defines temperament as “constitutionally-based individual differences in emotional, motor, and attentional reactivity and self-regulation” (Rothbart & Bates, 1998, p. 109). Reactive aspects of temperament include onset, and intensity of affective reaction (both
negative and positive). Regulatory processes such as effortful control serve to modulate reactivity.

Although temperament may be moderated or mediated by environmental influences, such as parenting behavior or the development of attention, a number of studies have demonstrated that temperament may be directly related to the development and display of specific emotion regulation strategies (Calkins, 2004). For example, Stifter and Braungart (1995) examined the relationship between changes in regulatory behaviors used by infants and how these behaviors were adjusted with changes in negative affect. Infants were found to more likely to use avoidance and communicative behaviors during situations of increasing distress (i.e., in response to arm restraint or toy removal). Calkins and Johnson (1998) demonstrated relations between regulatory behaviors in toddlers and their tendency to become distressed in frustrating situations. Regulation was assessed by examining child aggression, distraction, mother-orientation, and constructive coping during tasks that were designed to elicit frustration. Children who tended to become distressed in the frustrating situations were more likely to use aggressive behaviors (i.e., children who reacted negatively were less likely to show adaptive behaviors).

The self-regulatory aspect of temperament may also underlie the internalization of conduct standards (Kochanska, 1993). Kochanska proposed that inhibitory control, a regulatory aspect of temperament and a dimension of effortful control, was important in the organization of behaviors that reflect an emerging sense of conscience (Kochanska, DeVet, Goldman, Murray, & Putnam, 1994). In a study of young children’s conscience and temperament, children whose parents reported them high on inhibitory control were more likely to demonstrate active moral regulation and vigilance behaviors while in the presence of forbidden toys. These findings
suggest that inhibitory or effortful control may be an important underpinning of behavioral regulation in toddlers and young children (Kochanska, Murray, & Coy, 1997).

Other studies have found more distal relationships between temperament and emotion regulation. For example, negative affectivity, the tendency to react with high emotionality, has been consistently associated with problem behavior associated with emotion regulation (e.g., externalizing and internalizing symptoms; Bates, Maslin, & Frankel, 1985; Campbell, Shaw, & Gilliom, 2000; Keenan, Shaw, Walsh, Delliquadri, & Giovannelli, 1997; Shaw, Vondra, Dowdell Hommerding, Keenan, & Dunn, 1994). In the current study, we examined the association of two temperament factors, negative affectivity and effortful control, with behavioral and emotional strategies used by children during a delay of gratification task.

Aims and Hypotheses

This study examined vagal tone at different time points (at rest/baseline, during an M & M delay-of-gratification task, and during post-task recovery), and two aspects of temperament (negative affectivity and effortful control), as predictors of observed emotion regulation strategies utilized by children during a delay of gratification task. In response to an emotion challenge, children’s emotion regulation strategies (i.e., negative focus on delay, positive reward anticipation, and behavioral distraction; Silk, Shaw, Forbes, et al., 2006) were measured in one laboratory on a given day, while psychophysiological and psychometric assessments were obtained independently in a different laboratory and on a separate day. The sample in the current study includes children of mothers with (COD) or without a history of childhood-onset depression (nonCOD). Because children of COD mothers may be considered at risk for difficulties in regulating emotions (Silk et al., 2006), we chose children of both COD and nonCOD mothers to have sufficient variability in emotion regulation behaviors.
We hypothesized that lower resting and recovery vagal tone and greater dispositional negative affectivity would be associated with negative emotion and behavior (negative focus on delay) during the delay task. Conversely, we hypothesized that high resting and recovery vagal tone and dispositional effortful control would be associated with positive affect and good attentional control (positive reward anticipation, behavioral distraction) during the delay task. Based on the findings of Kochanska et al. (1994), we also explored whether the inhibitory control component of the effortful control temperament factor would predict child ER behavior during the delay task.

Method

Participants

Fifty-four children (24 females, 30 males) and their mothers participated in the study. Children ranged in age from four to seven (M = 5.09, SD = 1.194) and mothers ranged in age from 21 to 39 (M = 28.78, SD = 4.567). The cutoffs for each age group (4, 5, and 7) were: Age 4 (3.5 to 4.5 years), Age 5 (4.5 to 5.5 years) and Age 7 (Age 6.5 to 7.5 years). The three age groups (4, 5, and 7) had the following number of children: Age 4 (8 girls, 13 boys), Age 5 (11 girls, 9 boys) and Age 7 (5 girls, 8 boys).

Twenty-nine children were offspring of mothers with childhood-onset depression (COD) and 25 were offspring of children of never-depressed mothers (NCOD). Mothers and children were participants in a larger program project on risk factors for childhood-onset mood disorder. All mothers with history of COD met DSM criteria (DSM-III, DSM-IV; American Psychiatric Association, 1980, 1994) for major depressive and/or dysthymic disorder (n = 21) by age 14, or bipolar spectrum disorder (Bipolar I, Bipolar II, or Cyclothymic Disorder) by age 17 (n = 8). All NCOD mothers reported a lifetime history free of major psychiatric disorders. All participants
were free of pre-existing major systemic medical disorders and were without evidence of mental retardation.

As shown in Table 1, COD and NCOD groups did not differ in race, marital status, mother’s education, family income, or child gender. Although COD mothers were significantly younger than NCOD mothers, mother’s age was not a significant predictor of child ER strategies and was thus not included as a covariate in subsequent analyses.

Recruitment and Diagnoses

COD mothers were recruited via accessing individuals who had participated in a follow-up study of childhood depression (Kovacs, Obrosky, Gatsonis, & Richards, 1997; N = 11), and by advertising in the general community (N = 18). Diagnostic status was confirmed via administration of standardized, semistructured psychiatric interviews. NCOD participants were recruited by a) using the Cole Directory, which provides phone numbers for families meeting specific sociodemographic criteria (N = 4), b) advertising for volunteers in the general community (N = 14), or c) advertising through local Women, Infants, and Children (WIC) Nutritional Supplement Centers, a program that provides nutritional services for income-eligible families with young children (N = 7).

Procedures

Procedures used in the collection, processing, and analysis of behavioral data from the Parent-Child Interaction Lab have been described in Silk, Shaw, Forbes, et al. (2006). Participants visited two different laboratories on separate days, spaced on average 126.59 days apart. In the Parent-Child Interaction laboratory, participants completed a 2.5-hour visit that was video-recorded through a one-way mirror. The current report focuses on observational data from two similar delay-of-gratification tasks completed at ages 4 (i.e., Cookie Task) and 5 and 7 (i.e.,
Waiting Task). As previously reported (Silk, Shaw, Forbes et al., 2006; Silk, Shaw, Skuban et al., 2006), both the Cookie Task (Martin, 1981) and the Waiting Task (Gilliom et al., 2002) tap children’s skills for regulating affect when forced to wait for a desired outcome with little to interest them in the immediate environment. In the Cookie Task, children were required to wait for a cookie, while during the Waiting Task (age 5 and 7), children waited for a toy that would be given to them after a longer waiting period. During both tasks, the laboratory was cleared of all toys and mothers were asked to sit at a table and complete questionnaires. At age 4 task, the mother was given a clear bag with a cookie inside of it and asked to keep it within the child’s view but out of his or her reach. At the age 5 and 7 task, the mother was given similar instructions, but this time the child was asked to wait for a wrapped present for 7 minutes. At the end of the task, the examiner signaled the mother to give the cookie or toy to the child.

Electrocardiogram (ECG) data were recorded in a psychophysiology laboratory on a separate day from the behavioral data in the Parent-Child Interaction Lab. ECG data included in the current study are from a subset of tasks completed by each participant.

Measures

Maternal depression. The Psychiatric Evaluation Core of the Program Project, staffed by professional-level clinical evaluators and independent psychiatrists, conducted all psychiatric assessments. Two senior psychiatrists independently reviewed the assessment results and supporting records and arrived at a final DSM-based consensus diagnoses. Interviews were conducted with the mother and a second informant (e.g. a parent or sibling), if available. In addition, childhood psychiatric records were required to verify the pediatric onset of relevant symptomatology. Two senior psychiatrists independently reviewed the assessment results and supporting records and arrived at a final DSM-based consensus diagnoses.
Follow-Up Interview Schedule for Adults. COD probands recruited from the follow-up study of childhood depression (Kovacs et al., 1997) were assessed via the Follow-Up Interview Schedule for Adults (FISA), a semi-structured diagnostic interview adapted from the Interview Schedule for Children and Adolescents (Sherrill & Kovacs, 2000). Diagnoses were derived based on symptom ratings and assigned by consensus among the interviewers according to DSM-III criteria. Inter-rater reliabilities are satisfactory, with a mean intra-class correlation of .89 for psychiatric symptoms.

Structured Clinical Interview for DSM-IV Patient Version (SCID). The Structured Clinical Interview for DSM-IV Axis I Disorders, Patient Edition (SCID, First et al., 1995) was used to assess lifetime psychiatric disorders among most COD probands and NCOD cases. The SCID is a semi-structured, clinician-administered diagnostic interview that includes modules corresponding to major DSM psychiatric classes. The SCID was expanded to include criteria for selected childhood diagnoses and DSM-III (APA, 1980) current and lifetime criteria for affective disorders. Raters showed high agreement on DSM-IV/DSM-III diagnoses of major depressive and bipolar episodes (kappas: .91-1.00), and good agreement on episodes of dysthymia (kappas: .63 -.78).

Child Behavior Questionnaire (CBQ). The CBQ (short version; Putnam & Rothbart, 2005) is a 99-item assessment of temperament in early to middle childhood. Each item was rated on a seven-point scale, ranging from ‘1,’ indicating that the item was “extremely untrue of my child,” to ‘7’, which indicated that the item was “extremely true of my child”. Based on previous factor analyses (Ahadi et al., 1993), the following scales were averaged to yield measures of effortful control (attention focusing, inhibitory control) and negative affectivity (anger, fear and
sadness). Crohbach’s alpha for the subscales in the current sample are as follows: anger (.798),
fear (.774), sadness (.624), attentional focusing (.756), and inhibitory control (.778).

*Child Emotion Regulation.* Children’s displayed affect and ER strategies were coded
using a system adapted by Gilliom et al. (2002) from the work of Grolnick, Kurowski,
McMenamy, Rivkin, and Bridges (1998). Children’s displays of joy, anger, and sadness were
coded in 10-s intervals using facial and verbal cues of affect. Codes were assigned on a scale of
“0” to “3” with a “0” for “none” a “1” for “low,” a “2” for “moderate,” and a “3” for “high.”
Additionally, the presence or absence of each of five mutually exclusive ER strategies was coded
during each 10-s interval. Strategies were: (1) *active distraction* (i.e., purposeful behaviors in
which the focus of attention is shifted away from the delay object or the task of waiting,
including fantasy play, exploration of the room, talking with the mother, singing or dancing); (2)
*focus on delay object or task* (i.e., speaking about, looking at, or trying to retrieve the cookie or
toy, or speaking about or trying to end the waiting period); (3) *passive waiting* (i.e., standing or
sitting quietly without engaging in any overt activity); (4) *information gathering* (i.e., asking
questions aimed at learning more about the waiting situation, but not aimed at changing the
situation); and (5) *physical comfort seeking* (i.e., touching the mother, requesting to be held).
Based on previous data indicating a low base-rate of physical comfort seeking on this task for 4-
7 year olds, we excluded this strategy from analyses. For each strategy, a ratio was computed
reflecting the number of intervals in which the child used the strategy out of the total number of
completed intervals. All tapes were coded by graduate-level coders who were blind to mothers’
diagnostic status. Initially, coders viewed tapes together and assigned codes by consensus. After
establishing reliability, coders viewed tapes independently (kappas ranged from .61-.97).
Three emotion regulation strategy factors were derived from the emotion and behavioral responses during the tasks (Silk et al., 2006). The first factor, labeled *Negative Focus on Delay*, includes children’s displays of sadness and anger, and the strategy of focusing on the delay task or object. The second factor, labeled *Behavioral Distraction*, includes children’s use of active distraction and the converse strategy of passive waiting (reverse coded). The third factor, labeled *Positive Reward Anticipation*, includes children’s displays of joy and children’s use of information gathering while waiting for the cookie/story. As in Silk, Shaw, Forbes, et al. (2006), Log 10 transformations were performed on the Negative Focus on Delay and Positive Reward Anticipation factors to reduce positive skew and a cube transformation was performed on the Active Distraction factor to reduce negative skew. Correlations between the three factors ranged from $r = -0.054$ to $r = 0.098$ and were not significant.

*Electrocardiogram (ECG).* Baseline ECG (3 min), emotional stressor (M&M task) ECG (2 min), and recovery ECG (2 min) were collected as part of a larger electrophysiological and behavioral assessment of emotion regulation. Resting baseline was recorded prior to any task conditions. Standard guidelines were used in the ECG data acquisition (Berntson et al., 1997). All ECG data were recorded and reduced using software and equipment from the James Long Company (Caroga Lake, NY). Ag/AgCl ECG electrodes were placed axially on the left and right rib cage, approximately level with the heart. The bioamplifier was set for bandpass filtering with frequencies of 0.01 and 1000 Hz. The ECG signal was amplified with a gain of 500 and data were digitized with a sampling rate of 512 Hz (Berntson et al., 1997) and resampled off-line at 1000 Hz to increase the precision of R-wave detection. A linear interpolation was applied to the digitized signal. A sampling rate of 250 Hz is the minimum sampling rate required to HF
rhythms (Berntson et al., 1997; Task Force, 1996), although recent studies have used 1000 Hz (e.g., Thayer et al., 2003).

For the duration of the experimental session, participants were seated upright in a large comfortable chair facing a computer monitor. R-waves in the ECG signal were automatically identified using a multi-pass algorithm. This automated R-wave identification was manually checked using an interactive program for missed or mislabeled R-waves. Ectopic beats were deleted and replaced with a marker interpolated from the mean of the previous and subsequent sinus R-waves. Interbeat intervals (IBI) were calculated from the R-wave time series and prorated into equal time intervals of 125 ms.

Spectral analysis of beat-to-beat alterations in heart rate can be applied as a useful non-invasive tool to describe sympathetic and parasympathetic processes within short-term cardiovascular neural control mechanisms (Akselrod et al., 1985; Malliani, Pagani, Lombardi, & Cerutti, 1991). The steps in processing the ECG data (IBI interval data) include detrending the IBI time series using a high-pass filter with a period of 30-s. Fast Fourier transform analysis was then applied to calculate the amount of variability within the 0.20-1.00 Hz range for 4 and 5 year olds, and .15-.50 Hz for 7 year olds, which represents the variability due to respiration (Bar Haim et al., 2000). High frequency power values were log-transformed to normalize the distribution yielding units of log[ms²].

Statistical Analyses

A series of one-way Analyses of Variance were used to examine maternal COD status, child gender, child race, age, and task differences in relation to ER factors. There were no significant between-group differences on maternal COD status, gender, child age, or child race; therefore, these variables were removed from subsequent analyses. Multiple linear regression
models were used to examine the effects of task, vagal tone, and temperament on child ER factors. Colinearity among predictor variables was inspected with tolerance values. Four pairs of siblings and one group of three siblings from the COD group and two pairs of siblings from the NCOD group participated in the study together. Although seven sets of siblings participated (six pairs and one set of three siblings), there were an insufficient number of family groups to apply a random effects modeling procedure to control for the use of multiple siblings for these seven families. Thus, regression analyses did not include the family variable.

Results

Preliminary Analyses

A one-way Analysis of Variance was used to examine task differences in relation to ER factors. The Cookie Task at age 4 elicited higher levels of negative focus on delay ($F(1, 52) = 6.154, p < .05$) and lower rates of active distraction ($F(1, 52) = 5.714, p < .05$) than during the Waiting Task at ages 5 and 7. There were no significant task differences for positive reward anticipation. To account for these task differences, we included task (Cookie vs. Waiting) as a covariate in all subsequent analyses. Older children (5 and 7 year-olds) had higher M&M task vagal tone ($F(1, 52) = 5.990, p < .05$) and a trend for higher baseline vagal tone than younger children ($F(1, 52) = 3.961, p = .052$), but did not differ on recovery vagal tone, negative affectivity, or effortful control.

Correlations Among Predictor Variables: Vagal Tone and Temperament

Means, standard deviations, and minimum and maximum values for all predictor and outcome variables are listed in Table 2. To examine the relation among predictor variables, correlation analyses were conducted. Examination of bivariate relations among the temperament
and vagal variables indicated negative associations between effortful control and child negative affectivity \( (r = -0.424, p < .01) \) and a positive relation between baseline vagal tone and vagal recovery \( (r = 0.604, p < .001) \) and baseline vagal and vagal reactivity \( (r = 0.268, p = .05) \). All bivariate relations among predictors are in Table 3.

**Regressions for ER factors**

Separate multivariate regressions were applied for each of three ER factor outcomes: (1) negative focus on delay, (2) positive reward anticipation, and (3) behavioral distraction. We used the following sets of predictors in each regression model: (1) two temperament variables (negative affectivity and effortful control), (2) three assessments of vagal tone (baseline, during task, and post-task recovery), and (3) a covariate for type of task/challenge (cookie: age-4 protocol vs. toy: age-5 or age-7 protocol). Task was entered first in each regression equation and all other variables were entered in a second step.

Results for regression analyses are summarized in Table 4. The model for negative focus on delay was significant, \( F(6, 47) = 4.540, p < .01, R^2 = .367 \) Negative affectivity and effortful control were positively associated with negative focus on delay, and vagal recovery was negatively related to negative focus on delay. The model for positive reward anticipation was not significant, \( F(6, 47) = 1.340, p > .05, R^2 = .146 \). For behavioral distraction, only the first block entered with task age as a positive predictor was significant, \( F(1, 52) = 5.375, p < .05, R^2 = .094 \). However, the full model was not significant, \( F(6, 47) = 1.355, p > .05, R^2 = .148 \).¹

Our vagal tone predictor variables were highly correlated, particularly baseline and recovery vagal tone \( (r = 0.68) \). Colinearity indices did suggest that there was overlap between the

¹ We also conducted analyses for the three ER factors utilizing vagal recovery as a change score (task vagal – post task vagal) (e.g., Cole et al., 1999). Subject with negative vagal change from task to recovery (i.e., vagal tone increased following the task) showed less negative focus on delay whereas subjects with little change in vagal tone, or whose vagal tone decreased following the task, showed greater negative focus on delay during the task. These results are consistent with our findings in Table 3.
two variables (Tolerance values were .81 and .82 in the model for negative focus on delay).
However, we believe that despite this limitation it is important to retain baseline vagal tone in the
model due to the law of initial value (Wilder, 1967). This law states that the magnitude of phasic
change in a response system is dependent on the pre-stimulus base level. Thus in any model
utilizing either vagal reactivity or vagal recovery, the variance due to baseline vagal tone must be
accounted for.

Because both negative affectivity and vagal recovery were significant predictors of
negative focus on delay, we next investigated whether these variables were significant predictors
of the emotional (anger, sadness) or attentional (focus on delay task) components of negative
focus on delay. The same regression model for predicting the emotion regulation factors (Table 4)
was utilized to predict the negative focus on delay components: anger, sadness, and focus on
delay. Younger children showed more sadness during the delay task (Table 5). Temperamental
negative affectivity and effortful control were predictors of anger during the delay task, \( B = .089, \)
\( SE = .030, t = 2.956, p = .005 \) and \( B = .057, SE = .026, t = 2.187, p = .034 \); negative affectivity
also predicted sadness during the delay task, \( B = .109, SE = .054, t = 2.016, p = .05 \). The full
model for predicting focus on delay was significant, \( F(6, 47) = 2.876, p = .018 \). Vagal recovery
negatively predicted focus on delay (\( B = -.064, SE = .025, t = -2.525, p = .015 \)). Younger
children used more focus on delay during the delay task (\( B = -.086, SE = .041, t = -2.099, p =
.041 \)). This finding suggests that vagal recovery predicted attention, and not negative emotion,
during the delay of gratification tasks.

Because effortful control was a positive predictor of negative focus on delay, we used
linear regression to explore whether inhibitory control and attentional focusing, the CBQ factors
that comprise effortful control, predicted emotion and behavior during the delay task. We found
that attentional focusing was predictive of negative focus on delay during the task (B = .570, SE = .184, t = 3.093, p = .003); negative affectivity and vagal recovery also remained as significant predictors of this factor. When this relationship was explored further, we found that attentional focusing was predictive of more sadness and anger, both components of negative focus on delay, during the delay task (B = .152, SE = .043, t = 3.489, p = .001 and B = .056, SE = .026, t = 2.147, p = .037) (Table 6). We also found opposite effects on active distraction for the scales that comprise effortful control: inhibitory control positively predicted active distraction (B = .098, SE = .049, t = 2.006, p = .05) and attentional focusing negatively predicted active distraction (B = -.086, SE = .042, t = -2.043, p = .046).

Discussion

The results of this study in part support our hypotheses that child characteristics, such as vagal tone and negative affectivity, are associated with behavioral strategies during a delay of gratification task. Specifically, children who demonstrated lower vagal recovery and higher emotional reactivity were more likely to show sustained focus on the delayed cookie or toy. The dimensions of temperament we examined were not related to positive reward anticipation or behavioral distraction.

Vagal Tone

A surprising finding was that vagal recovery and not baseline vagal tone was associated with greater focus on delay. We found that those children with lower vagal tone following the M&M task engaged in more focus on delay during the cookie or toy delay task. This finding was especially intriguing because there are no child studies where vagal tone following a stressor is examined in relation to emotion regulation.
Specifically, we found that lower vagal tone following a laboratory task that included a delay of gratification paradigm predicted children’s behaviors during that paradigm. Behaviors that we labeled “focus on delay” object during this experimental task included speaking about, looking at, or trying to retrieve the cookie or toy, or speaking about or trying to end the waiting period and displays of negative affect. However, vagal recovery did not predict negative emotion displays during this task. Previous studies have suggested baseline vagal tone is inversely related to externalizing behaviors (Achenbach, 1991; Eisenberg et al., 1995); however, these studies examined baseline vagal tone, and not vagal recovery, as a predictor of maladaptive behaviors. In our study, children with low vagal recovery utilized more focus on delay behaviors. This suggests that children who lack the physiological flexibility to change vagal tone with task requirements may also lack the emotional and attentional flexibility required for successful task management. These children directed their attention to negative aspects of the task, whether it was the denied cookie, toy, or waiting period.

Our hypotheses that baseline vagal tone and vagal reactivity would predict emotion regulation strategies were not supported. Regarding baseline vagal tone, past studies have found high resting vagal tone to be a predictor of positive affective expression in infants (e.g., Stifter et al., 1989) and social competence in school-age children (Fabes, Eisenberg, & Eisenbud, 1993; Fabes et al., 1994). Nevertheless, in the current study baseline vagal tone was negatively related to negative focus on delay, which is consistent with previous findings that low baseline vagal tone is a predictor of negative emotion and behavior.

In comparison to the findings in Bazhenova, Plonakaia, and Porges (2001), we found that vagal reactivity was not associated with emotion regulation strategies. According to Porges et al. (1996) vagal suppression, the ability to suppress vagal tone during an attention-demanding or
cognitively challenging task, is a regulatory strategy that underlies complex behaviors that allow for a young child to utilize behavior management in the absence of parental or other caregiver support. Thus, children who are physiologically unable to suppress vagal tone during a challenge task appear to be less capable of generating adaptive regulatory strategies. However, several studies have not supported the link between vagal suppression and emotion or behavior (e.g., Marshall & Stevenson-Hinde, 1998; Quas, Hong, Alkon, & Boyce, 2000). The emotional stressor task utilized in the current study may not have been sufficiently challenging to invoke a strong autonomic response. Small changes in heart rate from baseline to task support this assertion. The mean change in heart rate from baseline to task was -1.092, which means that, on average, the children’s heart rate increased during the task by approximately one beat per minute. Vagal tone values, which are distributed on a log10 scale, decreased on average by .21. This suggests that, on average, there was little autonomic change in response to the delay of gratification task.

Temperament: Negative Affectivity and Effortful Control

As predicted, higher negative affectivity on the CBQ was associated with children’s greater use of negative focus on delay. This finding is consistent with literature documenting linkages between individual differences in negative emotionality and later ER skills and problem behavior (Bates et al., 1985; Campbell et al., 2000; Keenan et al., 1997). Negative affectivity has been associated with problem behavior, particularly in relation to problems behaviors associated with emotion regulation (e.g., externalizing and internalizing symptoms; Bates, Maslin, & Frankel, 1985; Campbell, Shaw, & Gilliom, 2000; Keenan, Shaw, Walsh, Delliquadri, & Giovannelli, 1997; Shaw, Vondra, Dowdell Hommerding, Keenan, & Dunn, 1994). Further analyses showed that negative affectivity predicted anger and sadness during the delay task but
not attention (focus on delay). This finding is in keeping with the definition of negative affectivity, a child’s tendency to react to stimuli with high degrees of emotionality, which encompasses negative emotion of varying degrees of arousal or intensity. Because negative affectivity did not predict focus on delay during the task (speaking about, looking at, or trying to retrieve the cookie or toy, or speaking about or trying to end the waiting period), this suggests that children with high negative affectivity were not necessarily perseverating on the delay object and instead were demonstrating negative aspect to nonspecific aspects of the task.

Effortful control predicted negative focus on delay during the delay of gratification task (Table 4). Effortful control indexes the ability to effectively inhibit behavioral responses and mobilize attentional resources to regulate behavior and emotions (Rothbart, Ahadi, & Hershey, 1994). One emotion regulation factor in this study, behavioral distraction, contains aspects of utilizing attention resources to shift from the delay object. These characteristics are especially apparent in the active distraction component of the behavioral distraction factor. Examples of active distraction in the present study include purposeful behaviors in which the focus of attention is shifted away from the delay object or the task of waiting, including fantasy play, exploration of the room, talking with the mother, singing, or dancing. Although effortful control was not associated with active distraction component of the behavioral distraction factor, the individual variables of which effortful control is comprised (attentional focusing and inhibitory control) were in themselves significant predictors of active distraction. Specifically, we found that inhibitory control, the capacity to plan and to suppress inappropriate approach responses under instructions (Rothbart, Ahadi, Hershey, & Fisher, 2001), predicted a child’s ability to utilize active distraction during the delay task. Thus children who were reported by their parents to have good self-control skills demonstrated these behaviors during the delay task.
A surprising finding was that effortful control was a positive predictor of negative focus on delay during the delay of gratification task. When we examined the scales that comprise effortful control, attentional focusing and inhibitory control, separately as predictors of negative focus on delay, we found that attentional focusing predicted more negative focus on delay during the task, and that this variable specifically predicted more sadness and anger (Table 6). Attentional focus is the tendency to maintain attentional focus upon task-related channels. Attentional processes and emotion are mutually influential, and one can serve to modulate the other. Attention can be influenced by a child’s current emotional state, such as sadness related to denial of a desired object, and may also be used to maintain control over that emotional state (Greenberg & Snell, 1997). Thus, a reasonable explanation for this finding is that if children are being denied a desirable object, their attentional focus is more likely to be on either that object or the denial of that object, rather than other topics or tasks.

We found that the relations between temperament/vagal tone and ER strategies did not differ based on maternal COD status. However, because we did not measure maternal behavior during this task, we were unable to examine how maternal depression status may have impacted parenting behavior and parental response to child behavior during the delay task. Calkins (2004) proposed that temperament may be moderated by extrinsic factors such as parenting behavior. These ideas are consistent with Goodman and Gotlib’s (1999) model that maternal depression may play a role in children’s ability to regulate emotion by influencing temperamental and physiological characteristics, as well as learned behavioral responses and strategies for regulating emotion (Goodman & Gotlib, 1999). Measuring parent behavior, or how history of depression impacts a mother’s ability to interact with her child, will be an important step for future studies.
Our findings were consistent with developmental theories of the emergence of regulatory skills. During infancy, primitive mechanisms of self-soothing (sucking, motor movements) are utilized to decrease discomfort, and by the end of the first year of life, infants become more purposeful in their attempts to regulate arousal. By the end of the second year of life, children have transitioned from passive to active methods of emotional regulation (Rothbart et al., 1992). Although emotional regulation skills are not complete and the caregiver plays an important role, this stage ushers in emerging skills in compliance and behavioral self-control (Kopp, 1989). This suggests that intrinsic factors play an important role in emotion regulation skills during childhood. However, individual differences in regulatory skills are still evident during childhood, and negative affectivity plays an important role in the display or emotion regulation skills. The children in our study with high arousal (negative affectivity) were unable to utilize compliance and self-control during the delay task, resulting in attention to the delay task or object.

Limitations and Conclusions

The present study has several limitations. First, the assessment of emotion regulation was on a small sample and limited to only five strategies. Although we were able to code children’s overt behaviors and vocalizations, we know little about potentially co-occurring cognitive processes. An additional limitation is the relatively wide age range of the children, and that the task varied slightly across age groups. Because this was a cross sectional study, we were unable to determine the relationship between physiological and behavioral indices of regulation over time and how these variables predicted long-term outcomes.

Despite these caveats, this study also has a number of important strengths. First, it provides support for the confluence of physiological, behavioral, and self-report variables in examining emotion regulation in children. Second, as the vagal tone and temperament data were
collected at a separate point in time than the behavioral data, it suggests relationships between regulatory control at both the behavioral and physiological levels. Third, the study utilized observational data collected during a laboratory mood-induction paradigm to assess ER strategies rather than relying on reports of parents or children. Overall, the findings are consistent with models of vagal tone as a marker of individual differences in ER and highlight the importance of studying multiple dimensions (negative and positive affect) and markers of emotion regulation.
Acknowledgements

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References


human and animal research (pp. 201-223). Hillsdale, NJ: Lawrence Earlbaum Associates.


Table 1

Demographic Characteristics of Participants

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<tr>
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<th>NCOD (n =25)</th>
<th>COD (n = 29)</th>
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*p < .01
Table 2
Means and Standard Deviations for Vagal Tone, Temperament, and Emotion Regulation Strategy Variables

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<th>M</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
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<tr>
<td>Baseline vagal (log[ms²])</td>
<td>6.64</td>
<td>1.32</td>
<td>4.07</td>
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<td>Vagal reactivity (log[ms²])</td>
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<td>0.61</td>
<td>-0.92</td>
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<td>Vagal recovery (log[ms²])</td>
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<td>1.18</td>
<td>4.67</td>
<td>9.55</td>
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<tr>
<td>Negative affectivity</td>
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<td>0.66</td>
<td>2.58</td>
<td>5.71</td>
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<tr>
<td>Effortful Control</td>
<td>4.61</td>
<td>0.76</td>
<td>3.05</td>
<td>6.12</td>
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<table>
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<th>Outcome Variables</th>
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<td>Negative focus on delay⁺</td>
<td>0.47</td>
<td>0.12</td>
<td>0.31</td>
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<tr>
<td>Positive Reward Anticipation⁺</td>
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<td>0.14</td>
<td>0.16</td>
<td>0.83</td>
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<tr>
<td>Behavioral Distraction @</td>
<td>2.49</td>
<td>3.23</td>
<td>-8.17</td>
<td>12.55</td>
</tr>
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⁺ log10 + 3 transformation
@ cube transformation
Table 3

Bivariate Relations Among Predictor Variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>negative affectivity</th>
<th>effortful control</th>
<th>baseline vagal tone</th>
<th>vagal reactivity</th>
<th>vagal recovery</th>
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<td>–</td>
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<td>effortful control</td>
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<td>1.00</td>
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<td>.268*</td>
<td>.604**</td>
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<tr>
<td>vagal reactivity</td>
<td>–</td>
<td>–</td>
<td>–</td>
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<tr>
<td>vagal recovery</td>
<td>–</td>
<td>–</td>
<td>–</td>
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<td>1.00</td>
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*p < .05, **p < .001
Table 4
Regression Analyses for Child Emotion Regulation Strategies

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<tr>
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<th>Negative Focus on Delay</th>
<th>Positive Reward Anticipation</th>
<th>Behavioral Distraction</th>
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<tr>
<td></td>
<td>B (SE)</td>
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<td>B (SE)</td>
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<tr>
<td><strong>Step 1</strong></td>
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</tr>
<tr>
<td>Task</td>
<td>-.067 (.031)</td>
<td>-2.164*</td>
<td>.004 (.040)</td>
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<td><strong>Step 2</strong></td>
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<td>-.057 (.029)</td>
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<td>-.013 (.041)</td>
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<tr>
<td>Baseline vagal</td>
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<td>.025 (.030)</td>
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<td>-.044 (.024)</td>
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<td>.028 (.034)</td>
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<tr>
<td>^ (Baseline vagal – task vagal)</td>
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<tr>
<td>Vagal recovery</td>
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<td>-.005 (.025)</td>
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<td>Negative affectivity</td>
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<td>3.369**</td>
<td>-.046 (.033)</td>
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<tr>
<td>Effortful control</td>
<td>.047 (.020)</td>
<td>2.356*</td>
<td>.027 (.028)</td>
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* p < .05; **p < .01
Table 5
Regression Analyses for Components of Negative Focus on Delay

<table>
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<tr>
<th></th>
<th>Anger</th>
<th>Sadness</th>
<th>Focus on Delay</th>
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<tr>
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<tr>
<td><strong>Step 1</strong></td>
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<tr>
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<td>-.155 (.066)</td>
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<td><strong>Step 2</strong></td>
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<td>Vagal reactivity</td>
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<td>.084 (.046)</td>
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*< .05; **< .01
Table 6
Regression Analyses for Components of Negative Focus on Delay with Effortful Control Subscales as Predictors

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<th>Focus on Delay</th>
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</thead>
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<tr>
<td><strong>Step 1</strong></td>
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<tr>
<td>Task</td>
<td>-.056 (.039)</td>
<td>-1.461*</td>
<td>-.155 (.066)</td>
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<tr>
<td><strong>Step 2</strong></td>
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<td></td>
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<tr>
<td>Task</td>
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<td>-.800</td>
<td>-.078 (.066)</td>
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*p < .05; **p < .01