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

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ABSTRACT: *We examined indices of vagal tone and two dimensions of temperament as predictors of emotion regulation (ER) strategies among children (n = 54, ages 4–7) of mothers with a history of depression and control mothers. Children's (adaptive and maladaptive) ER strategies were observed during a delay of gratification (frustration) task in one protocol. In a separate and independent protocol, vagal tone was assessed during rest (baseline), during emotional challenge (reactivity) and post-challenge (recovery) and mothers rated their children's temperament (effortful control, negative affectivity). Lower vagal recovery and higher negative affectivity were associated with maladaptive ER responses to frustration. However, vagal tone and temperament were not associated with adaptive ER responses and maternal depression status did not affect the results. Overall, the findings are consistent with models of vagal tone and temperament as markers of individual differences in ER. © 2008 Wiley Periodicals, Inc.* Dev Psychobiol 50: 205–216, 2008.

Keywords: *vagal tone; temperament; emotion regulation; child*

INTRODUCTION

An important early developmental accomplishment 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.'' Starting in late infancy, children gradually develop the capacity to self-regulate their emotions, particularly their negative emotions (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 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 child's context, particularly the relationship with primary caregivers, and personal characteristics, such as temperament.

Two aspects of temperament, relevant to children's emotion regulation, are negative affectivity and effortful control. Negative affectivity is the tendency to react to

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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 highlight 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 of complex regulatory behaviors, including the regulation of state, motor activity, and emotion. In the present 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, 1992a, 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 it 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 & Jain, 1996; Stifter, Fox, & Porges, 1989). In young boys, high vagal tone has been found to be associated with greater empathy, social competence, and 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 and Fox, 1992; Fox, 1989; Gunnar, Porter, Wolf, Rigatuso, & Larson, 1995). However, the degree to which an individual suppresses vagal tone during a challenging task (*vagal reactivity*) may also be related to the regulation of attention and behavior and may facilitate orientation to stimuli (Calkins, 1997; Porges, Doussard-Roosevelt, & Maiti, 1994). An additional factor, the physiological effort to recover after exposure to a stimulus (*vagal recovery*), 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 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 therefore examined various phases of our physiological target, namely (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.

Psychosocial Variables and Emotion Regulation

The development and unfolding of emotion regulation skills are influenced by a variety of intrinsic and extrinsic factors. Intrinsic factors, such as temperament, have been much studied because they are believed to index individual differences in emotion experiences (Gilissen, Koolstra, van Ijzendoorn, Bakermans-Kranenburg, & van der Veer, 2007; Tamas et al., 2007). Extrinsic factors, such as parents' adjustment and mental health, have been of interest because ER skills develop in a social context (Thompson, 1994) and thus parental history is likely to contribute to individual differences in offspring's ER competence.

Temperament. 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. They reported that infants were more likely to use avoidance and communicative behaviors during situations of increasing distress. Calkins and Johnson (1998) demonstrated relations between regulatory behaviors (e.g., aggression, distraction, mother-orientation, and constructive coping) 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 evidenced distress in the frustrating situations were more likely to use aggressive behaviors (i.e., children who reacted negatively were less likely to show adaptive behaviors). And it has been proposed that inhibitory control, a regulatory aspect of temperament and a dimension of effortful control, is important in the organization of behaviors that reflect the emergence of conscience (Kochanska, 1993; Kochanska, DeVet, Goldman, Murray, & Putnam, 1994).

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 behaviors which are often characterized by impaired 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, and behavioral and emotional ER strategies used by children during a delay of gratification task.

Parental Mood Disorder. There is considerable agreement that parental mood disorder may adversely affect offspring's development, including emotion regulatory skills and abilities (Goodman & Gotlib, 1999). For example, depressed mothers interacting with their young offspring tend not to respond appropriately to their children's affective displays (Shaw et al., 2006) and may reinforce inappropriate ways of regulating emotions (Gross, Conrad, Fogg, Willis, & Garvey, 1995).

Silk, Shaw, Skuban, Oland, and Kovacs (2006) found that when children were required to wait for a desirable object or toy, a task which presumably is somewhat frustrating and should mobilize various of the processes of interest, children of mothers with childhood-onset depression (COD) displayed behaviors typically associated with nonoptimal ways of managing emotions under challenge: they were more likely to focus on the desirable object than offspring of mothers without childhood-onset depression (NCOD). Daughters of COD mothers were also more likely to wait passively and less likely to engage in self-distraction than daughters of NCOD mothers. Given the evidence that children of parents with mood disorder are at risk for various psychosocial problems and, by implication, are also likely to evidence some problems in ER, research using such samples may help to characterize aspects of "at-risk" status. In the present study, we further explore the effect of maternal depression on children's ER by examining its role in children's use of behavioral strategies for regulating emotion.

Aims and Hypotheses

We examined whether 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) predict observed emotion regulation strategies of children during a delay of gratification task. Children participated in 2 separate studies (Psychophysiology and Parent-Child Interaction) in 2 different laboratories. Children's emotion regulation strategies (i.e., negative focus on delay, positive reward anticipation, and behavioral distraction; Silk, Shaw, Forbes, Lane, & Kovacs, 2006) in response to an emotion challenge were observed in one laboratory on a given day; psychophysiological and psychometric assessments were conducted independently in a different laboratory on a separate day. The sample includes children of mothers with or without a history of childhood-onset depression (COD and NCOD, respectively).

We hypothesized that lower vagal tone during both rest and recovery, and greater dispositional negative affectivity, would be associated with maladaptive ER as evidenced in negative emotion and behavior (negative focus on delay) during the delay-of-gratification task. Conversely, we hypothesized that high resting and recovery vagal tone, and dispositional effortful control, would be associated with adaptive ER, as evidenced in positive affect and good attentional control (positive reward anticipation, behavioral distraction) during the delay task. In addition, we sought to explore whether vagal reactivity explains some of the variance in children's ER behavior. We also expected that lower vagal tone, in general, would be more characteristic of offspring of COD mothers. Finally, based on the findings of Kochanska et al. (1994), we 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 (3.5–4.5 years), Age 5 (4.5–5.5 years) and Age 7 (Age 6.5–7.5 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 (control) mothers (NCOD). Mothers and children were participants in a larger Program Project on risk factors for childhood-onset mood disorder. All mothers with a history of COD met DSM criteria (DSM-III, DSM-IV; American Psychiatric Association, 1980, 1994) for major depressive and/or dysthymic disorder ($n = 21$) or bipolar spectrum disorder (Bipolar I, Bipolar II, or Cyclothymic Disorder). Childhood-onset was operationally defined as first depressive episode by age 14, or first manic/hypomanic episode by age 17 ($n = 8$). NCOD mothers had no lifetime history of major psychiatric disorders. All participants were free of pre-existing major systemic medical disorders and were without evidence of mental retardation.

Table 1. Demographic Characteristics of Participants

	NCOD ($n = 25$)	COD ($n = 29$)	F/χ^2
Mother's age			11.71*
M	30..72	26.90	
SD	5.04	3.06	
Mother's marital status			8.45
Married, common-law	4	10	
Married: legal	17	11	
Divorced/separated	3	4	
Single	5	13	
Widowed	0	1	
Mother's race			4.32
European American	16	23	
African American	7	5	
Asian/biracial/other	2	1	
Mother's education			5.08
Grade 7–9	1	2	
Grade 10–11	2	1	
High school graduate/GED	8	14	
Some college	12	11	
Graduated college	2	0	
Graduate/professional degree	0	1	
Child's age (in years)			1.69
M	5.28	4.93	
SD	1.17	1.16	
Child's sex			.625
Female	12	12	
Male	13	17	

*$p < .01$.

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 previously participated in a follow-up study of childhood depression (Kovacs, Obrosky, Gatsonis, & Richards, 1997; $N = 11$), by advertising in the general or mental health community ($N = 13$), through a research registry ($N = 1$), and by referral from another research study ($N = 1$). Diagnostic status was confirmed via administration of standardized, semi-structured psychiatric interviews. NCOD participants were recruited by advertising for volunteers in the general community ($N = 13$), advertising through local Women, Infants, and Children (WIC) Nutritional Supplement Centers ($N = 8$), and by referral from another research study ($N = 4$).

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., parent or sibling) who provided information about her as well. 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.

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. These cases also were then assessed via the Structured Clinical Interview for DSM-IV Axis I Disorders, Patient Edition (SCID, First, Spitzer, Gibbon, & Williams, 1995), which served to establish lifetime psychiatric disorders in the rest of the study participants. The SCID is a clinician-administered diagnostic interview, which was expanded to include selected childhood diagnoses and affective symptoms. Raters showed high agreement on DSM-IV/DSM-III diagnoses of major depressive and bipolar episodes (kappas: .92–1.00), and good agreement on episodes of dysthymia (kappas: .63–.78).

Procedures

Subjects participated in two separate studies (Psychophysiology; Parent-Child Interaction) which entailed visits to two different laboratories on separate days, spaced on average 126.59 days apart. Procedures used in the collection, processing, and analysis of behavioral data from the Parent-Child Interaction Study have been described in Silk, Shaw, Forbes et al. (2006); it involved a 2.5-hr 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, Shaw, Beck, Schonberg, & Lukon, 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. At the age 4 task (Cookie), mother was given a clear bag with a cookie inside and asked to keep it within the child's view but out of his or her reach. At the age 5 and 7 tasks (Waiting), the mother was given similar instructions, but this time the child was asked to wait for a wrapped present for 7 min. During both tasks, the laboratory was cleared of all toys and mothers were asked to sit at a table and complete questionnaires. At the end of the task, the examiner signaled the mother to give the cookie or toy to the child.

As part of the separate Psychophysiology study, electrocardiograms (ECG) were recorded in a different laboratory during a resting baseline, an M&M task, and during a post-task baseline period. For the M&M task, one candy, five candies, and a bell were placed in front of the child. The child was told that if she rang the bell, she would receive one candy, but if she waited until the experimenter rang the bell, she would receive all the candy. ECG data included in the current study are from a subset of tasks completed by each participant.

Measures

Child Behavior Questionnaire (CBQ). The CBQ (short version; Putnam & Rothbart, 2006) is a 99-item inventory 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', indicating that the item was "extremely true of my child". Based on previous factor analyses (Ahadi, Rothbart, & Ye, 1993), two scales (attention focusing, inhibitory control) were averaged to yield a measure of effortful control, and three scales (anger, fear, and sadness) were averaged to yield a measure of negative affectivity. 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). Displays of *joy*, *anger*, and *sadness* were coded in 10-s intervals, using facial and verbal cues, on a scale of "0"–"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 .64 to .97).

Three emotion regulation strategy factors were derived from the emotion and behavioral responses during the tasks (Silk, Shaw, Skuban 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. Negative focus on delay is an index of maladaptive responding whereas the latter two are believed to index responses that are adaptive and likely to downregulate distress. 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 Behavioral Distraction factor to reduce negative skew. Correlations between the three factors ranged from $r = -.054$ to $r = .098$ 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 more extensive 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 1,000 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 1,000 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 1,000 Hz (e.g., Thayer et al., 2003). A sampling rate lower than 250 Hz may result in inadequate estimation of the R-wave fiducial point. Because the heart rate variability spectrum is calculated from the R-R interval, it is essential that the R-wave be appropriately identified in each waveform (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996).

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, Marshall, & Fox, 2000). High frequency power values were log-transformed to normalize the distribution yielding units of log[ms^2].

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. 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

Based on a series of one-way Analysis of Variance, we found that the Cookie Task at age 4 elicited higher rates 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 the Waiting Task at ages 5 and 7. There were no significant task differences in 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. There were no significant between-group differences on maternal COD status, gender, child age, or child race; therefore, these variables were not included in subsequent analyses.

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. Examination of bivariate relations among the temperament and vagal variables indicated negative associations between effortful control and child negative affectivity ($r = -.424$, $p < .01$) and a positive relation between baseline vagal tone and vagal recovery ($r = .604$, $p < .001$) and baseline vagal and vagal reactivity ($r = .268$, $p = .05$). All bivariate relations among predictors are in Table 3.

Modeling ER Factors

We used separate multivariate regressions to model each of three ER outcomes, namely: negative focus on delay, positive reward anticipation, and behavioral distraction. In each regression model, we used the following sets of predictors: (a) two temperament variables (negative affectivity and effortful control), (b) three indices of vagal tone (baseline, during task, and post-task recovery),

Table 2. Means and Standard Deviations for Vagal Tone, Temperament, and Emotion Regulation Strategy Variables

	M	*SD*	Min	Max.
Predictors				
Baseline vagal tone (log[ms^2])	6.64	1.32	4.07	9.87
Vagal recovery (log[ms^2])	6.82	1.18	4.67	9.55
Negative affectivity[a]	4.12	0.66	2.58	5.71
Effortful control[a]	4.61	0.76	3.05	6.12
Outcome variables[b]				
Negative focus on delay[c]	0.47	0.12	0.31	0.91
Positive reward anticipation[c]	0.48	0.14	0.16	0.83
Behavioral distraction[d]	2.49	3.23	−8.17	12.55

[a]Variables by maternal report.
[b]Variables by behavioral observation.
[c]log10 + 3 transformation.
[d]Cube transformation.

Table 3. Bivariate Relations Among Predictor Variables

	Variables				
	Negative affectivity	Effortful control	Baseline vagal tone	Vagal reactivity	Vagal recovery
Negative affectivity	1.00	−.424*	.051	.192	.73
Effortful control	—	1.00	.092	.139	.090
Baseline vagal tone	—	—	1.00	.268*	.604**
Vagal reactivity	—	—	—	1.00	.139
Vagal recovery	—	—	—	—	1.00

*$p < .05$.
**$p < .001$.

and (c) 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 second.

As 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 step 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 ($r = .68$). Colinearity indices did suggest that there was overlap between the 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 (Tab. 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 (Tab. 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 ER responding 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 $B = .056$, $SE = .026$, $t = 2.147$, $p = .037$) (Tab. 6). We also found that 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 partly support our hypotheses that child characteristics, such as vagal tone and negative

[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, Blackstone, Pashkow, Snader, & Lauer, 1999). Subjects 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.

Table 4. Modeling Child Emotion Regulation Strategies

	Negative focus on delay		Positive reward anticipation		Behavioral distraction	
	B (*SE*)	*t*	*B* (*SE*)	*t*	*B* (*SE*)	*t*
Step 1						
Task[a]	−.067 (.031)	−2.164*	.004 (.040)	.110	2.013 (.868)	2.318*
Step 2						
Task	−.057 (.029)	−1.979	−.013 (.041)	−.325	2.404 (.945)	2.545*
Baseline vagal tone	.024 (.021)	1.134	.025 (.030)	.849	838–.(.686)	−1.222
Vagal reactivity (baseline vagal—task vagal)	−.044 (.024)	−1.868	.028 (.034)	.824	.084 (.769)	.109
Vagal recovery	−.038 (.018)	−2.103*	−.005 (.025)	−.213	.432 (.584)	.741
Negative affectivity	.078 (.023)	3.369**	−.046 (.033)	−1.387	.800 (.754)	1.060
Effortful control	.047 (.020)	2.356*	.027 (.028)	.947	.749 (.645)	1.161

[a]Cookie versus waiting tasks.
*$p < .05$.
**$p < .01$.

affectivity, are associated with observable ER strategies during experimentally induced frustration (delay of gratification). Therefore, the indications are that both physiology and temperamental dispositions are likely to contribute to emotion regulatory competence. Our overall findings also suggest that alternate indices of vagal tone vary in explanatory power with regard to ER. Finally, whereas we were moderately successful in modeling our index of maladaptive ER (negative focus on delay), we failed to model the two indexes of adaptive ER (positive reward anticipation, behavioral distraction); thus, adaptive and maladaptive regulatory processes may involve different pathways.

Vagal Tone

We found that lower vagal tone following an "M & M task" predicted children's maladaptive ER behaviors during a similar frustration paradigm in a different setting at a different point in time. This finding is especially noteworthy because there are no child studies of vagal tone following a stressor and its relations to ER. In our study, children with low vagal recovery were likely to remain focused on the desired object, rather than engage in other, more adaptive or distracting ER behaviors. This finding implies that children who lack the physiological flexibility to modify vagal tone in response to task demands also appear to lack the flexibility required for successful self-management of emotions.

Because it is possible that children's manner of coping with the M & M task (e.g., behavioral and affective responses) influenced their post-task vagal tone, we examined the videotapes of a randomly selected set of $n = 13$ (25%) subjects. However, we found little heterogeneity in observable behavioral responding or affective displays. Possibly, subtle differences in attentional

Table 5. Modeling Components of Negative Focus on Delay

	Anger		Sadness		Focus on delay	
	B (*SE*)	*t*	*B* (*SE*)	*t*	*B* (*SE*)	*t*
Step 1						
Task[a]	−.056 (.039)	−1.461*	−.155 (.066)	−2.348*	−.094 (.040)	−2.317*
Step 2						
Task	−.048 (.038)	−1.257	−.141 (.067)	−2.085*	−.086 (.041)	−2.099*
Baseline vagal tone	.020 (.028)	.710	.049 (.049)	.997	.045 (.030)	1.502
Vagal reactivity (baseline vagal—task vagal)	−.052 (.031)	−1.700	−.053 (.055)	−.958	−.039 (.033)	−1.163
Vagal recovery	−.030 (.023)	−1.285	−.070 (.042)	−1.680	−.064 (.025)	−2.525*
Negative affectivity	.089 (.030)	2.956**	.109 (.054)	2.016*	.048 (.033)	1.466
Effortful control	.057 (.026)	2.187*	.084 (.046)	1.823	.031 (.028)	1.129

[a]Cookie versus waiting tasks.
*$p < .05$.
**$p < .01$.

Table 6. Modeling Components of Negative Focus on Delay With Effortful Control Subscales as Predictors

	Anger		Sadness		Focus on delay	
	B (*SE*)	*t*	*B* (*SE*)	*t*	*B* (*SE*)	*t*
Step 1						
Task[a]	−.056 (.039)	−1.461*	−.155 (.066)	−2.348*	−.094 (.040)	−2.317*
Step 2						
Task	−.032 (.040)	−.800	−.078 (.066)	−1.184	−.069 (.043)	−1.599
Baseline vagal	.024 (.028)	.879	.068 (.046)	1.471	.050 (.030)	1.669
Vagal reactivity (baseline vagal—task vagal)	−.041 (.032)	−1.280	−.008 (.053)	−.144	−.026 (.035)	−.761
Vagal recovery	−.037 (.024)	−1.548	−.098 (.040)	−2.451*	−.071 (.026)	−2.761**
Negative affectivity	.075 (.0302)	2.340*	.053 (.054)	.993	.033 (.035)	.938
Inhibitory control	−.012 (.035)	.343	−.118 (.059)	−1.991*	−.028 (.038)	−.736
Attentional focusing	.056 (.026)	2.147*	.152 (.043)	3.489*	.046 (.028)	1.631

[a]Cookie versus waiting tasks.
*$p < .05$.
**$p < .01$.

response to the delay object may have determined vagal tone, since attention is known to influence heart rate parameters (e.g., see Thayer & Brosschot, 2005, for a review). This possibility should be examined in future studies. As well, it may be of interest to assess if children ruminate in response to experimental stress, which can result in decreased vagal tone (Brosschot, Gerin, & Thayer, 2006). These ideas are consistent with our findings that vagal recovery predicted attention, and not negative emotion, during the Cookie and Waiting tasks.

We failed to support our hypotheses that baseline vagal tone and vagal reactivity would predict observable emotion regulation strategies. 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 et al., 1993, 1994). Previous studies also have suggested that baseline vagal tone is inversely related to externalizing behaviors (Achenbach, 1991; Eisenberg et al., 1995). However, with the exception of studies of infants, none of the relevant investigations has focused specifically on emotion regulatory responses to distress. Therefore, our null finding regarding the relations of *baseline* vagal tone and ER needs to be confirmed in future research.

In contrast to the findings of Bazhenova, Plonakaia, and Porges (2001), vagal reactivity (vagal suppression) in our sample was not associated with emotion regulation strategies. According to Porges et al. (1996) the ability to suppress vagal tone during an attention-demanding or cognitively challenging task is a regulatory strategy that underlies complex behaviors allowing a young child to utilize adaptive self-management in the absence of caregiver support. However, several studies have not found the hypothesized links between vagal suppression and emotion or behavior (e.g., Marshall & Stevenson-Hinde, 1998; Quas, Hong, Alkon, & Boyce, 2000). Assuming that such a link does exist, our failure to detect it could reflect that the emotional stressor task 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 possibility. 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. And 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.

Psychosocial Variables and Emotion Regulation

As predicted, higher negative affectivity on the CBQ (as rated by mothers) was associated with children's greater use of a maladaptive ER response, namely, negative focus on delay. This finding is consistent with the literature on individual differences in negative emotionality as a putative trait characteristic and later ER skills and problem behavior (Bates et al., 1985; Campbell et al., 2000; Keenan et al., 1997) as well as concurrent externalizing and internalizing symptoms (Bates et al., 1985; Campbell et al., 2000; Keenan et al., 1997; Shaw et al., 1994). Additionally, in keeping with the definition of negative affective temperament, post-hoc analyses showed that it predicted anger and sadness during the delay task. Effortful control (an adaptive trait) also predicted maladaptive ER (negative focus on delay) during the frustration task (Tab. 4) but the direction of the association was unexpected. Effortful control indexes the ability to effectively inhibit behavioral responses and mobilize attentional resources to regulate behavior and emotions (Rothbart et al., 1994). When we separately examined the scales that comprise effortful control (attentional focusing and inhibitory control) as predictors of negative focus on delay, we found that attentional focusing predicted maladaptive ER and more sadness and anger (Tab. 6).

The critical importance of attention deployment in adaptive ER has been widely discussed (e.g. Kopp, 2002; Hill, Degnan, Calkins, & Keane, 2006) and thus our finding is counter to common beliefs. The fact that attention is comprised of various facets (Posner & Rothbart, 1998; Posner & Rothbart, 2007) may partly explain our results. Namely, adaptive ER is believed to require the *ability to switch attention* from the source of distress and re-deploy it in ways that can reduce distress. Thus the attentional focusing scale on the CBQ, which indexes absorption, concentration and distraction, may not be the best indicator of the attentional skills that underlie adaptive ER behavior.

We found that the relations between children's temperament/vagal tone and their ER strategies did not differ based on maternal COD status, which contrasts with a previous report on a partially overlapping sample of cases (Silk, Shaw, Skuban et al., 2006). Because the current sample size was substantially smaller than the one previously studied, it is likely that we lacked sufficient statistical power to detect moderate or weaker effects of maternal psychopathological history. As well, studying the consequences of maternal depression history on children's emotion regulation may require more fine grained characterization of maternal disorder.

Finally, it is of interest that, while we had some success in modeling our maladaptive ER factor (negative focus on delay), nothing of note emerged when we sought to model two separate indexes of adaptive ER (behavioral distraction, positive reward anticipation). Overall, these results suggest that adaptive and maladaptive ER responding represent separable and at least partly independent dimensions, rather than opposite poles of a continuum, and may also be associated with different pathways or mechanisms.

Limitations and Conclusions

The present study has several limitations. First, our assessment of emotion regulation was limited to only five strategies and our sample was rather small. Although we were able to code children's overt behaviors and vocalizations, we know little about potentially co-occurring cognitive operations. Additional limitations include the relatively wide age range of the children, and that the frustration task varied slightly across age groups. Also, because we examined physiology and ER behavior at single time points, we do not know whether our findings would remain stable across development.

Despite these caveats, our study also has important strengths. First, it provides support for the confluence of physiological, behavioral, and psychological variables as contributing to emotion regulation in children. Second, our ability to model maladaptive ER responses is particularly notable as the collection of vagal tone and temperament data were temporally separated from the collection of the behavioral data and in different laboratories. Third, we used a multi-method, multi-trait approach to study children's ER. Overall, the findings are consistent with models of vagal tone as a marker of individual differences in ER and highlight the importance of studying both adaptive and maladaptive dimensions of emotion regulation.

NOTES

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