Children's Emotional Reactions to Stressful Parent-Child Interactions: The Link Between Emotion Regulation and Vagal Tone

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SUMMARY. This paper examines children's physiological reactions to stressful parent-child interactions and tests the notion that vagal tone is a physiological index of the ability to regulate emotion. Basal vagal tone and the suppression of vagal tone at age 4-5 were examined as predictors of mother ratings of child's emotion regulation ability at age 8. Two hypotheses about the mechanism by which vagal tone predicts emotion regulation were examined: a stress inoculation hypothesis and a recovery from arousal hypothesis. Path analyses showed that age 4-5 regulatory physiology predicted child emotion regulation scores at age 8, and that this was partially mediated by the 4- to 5-year-old child's ability to maintain a low heart rate during stressful parent-child interactions. Interrupted time-series analyses of these events as a function of the child's basal vagal tone showed that children with higher basal vagal tone have both a larger heart rate increase to these events as well as faster recovery than children with lower vagal tone. *[Article copies available for a fee from The Haworth Document Delivery Service: 1-800-HAWORTH. E-mail address:*

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There has been a great deal of interest in the developing child's ability to regulate emotion (e.g., Fox, 1994; Garber & Dodge, 1991). It has been suggested that the ability to regulate emotion underlies the development of other competencies, such as children's peer social skills (Gottman & Katz, 1989; Katz & Gottman, 1991) and cognitive performance in tasks involving delay or inhibition (e.g., Mischel & Mischel, 1983). Central peer social competencies include the ability to resolve conflict, to find a sustained common ground play activity, and to empathize with a peer in distress (e.g., see Asher & Coie, 1990; Gottman, 1983; Gottman & Parker, 1986).

Despite widespread differences in the definition of emotion regulation, most researchers agree that parents play a powerful role in the socialization of emotion and in the development of emotion regulation abilities (Denham, 1998; Eisenberg, Cumberland & Spinrad, 1998; Parke & McDowell, 1998). Most theorists have suggested that it is through parent-child interaction that children learn how to modulate emotional expression. Thus, it appears that parental direction and coaching function to promote the development of emotion regulation skills. It is also the case that the family is a prime context for children to exercise their emerging regulatory abilities. Family interactions are replete with both positive and negative emotion, and the ability to regulate emotion, particularly during conflictual moments, is necessary for the successful navigation of many familial relationships, including the sibling relationship (Stocker & Youngblade, 1999), the parent-child relationship (Gottman, Katz & Hooven, 1997; Katz & Gottman, 1996), and the marital relationship (Gottman, 1994). In this paper, we focus particularly on how children regulate emotion within the context of stressful parent-child interactions.

Another area of agreement among researchers interested in emotion regulation is the idea that what is regulated involves physiological arousal, cognitive processes (e.g., attentional processes, interpretation of events, expectations), and behavioral tendencies (Calkins, 1994). Attention to individual differences in the ability to regulate emotion has been important in efforts to distinguish factors that predict adaptive and maladaptive child outcomes. One fruitful approach has been in the examination of individual differences in children's physiological reactivity to emotional events. Individual differences in the reactivity of particular physiological systems have been linked to differences in children's behavioral reactivity to specific emotion-eliciting events (Fox, 1989b; Kagan, Reznick & Snidman, 1989). For example, Kagan and colleagues (e.g., Kagan et al., 1989) have found that children with high and stable heart rates are more inhibited in the face of novelty than children with low and more variable heart rates.

Porges (1984) suggested that the physiological basis for the ability to regulate emotion lies in the functioning of the vagus nerve, the main nerve of the parasympathetic nervous system (PNS). The tonic firing of the vagus nerve slows many physiological processes down, such as heart rate. Research by Porges and his colleagues on the PNS indicates a strong association between high vagal tone and good attentional abilities, and he has speculated that these processes are also related to emotion regulation abilities. Porges (1984) reviewed evidence that suggests that a child's *baseline vagal tone* is related to the child's capacity to react to environmental stimuli. There is a substantial body of literature that shows that basal vagal tone is related to greater behavioral reactivity, but also to greater soothability, greater ability to focus attention, and greater ability to self-soothe and explore novel stimuli (DiPietro & Porges, 1991; Fox, 1989a; Hofheimer & Lawson, 1988; Linnemeyer & Porges, 1986; Porter, Porges, & Marshall, 1988; Richards, 1987; Stifter & Fox, 1990; Stifter, Fox & Porges, 1989). There is also preliminary evidence that vagal tone is related to the regulation of emotion in social situations. Fox (1989a) found that 14-month-old infants with high vagal tone showed a shorter latency to approach a stranger and less proximity to mother while the stranger was present than infants with low vagal tone. Fox and Field (1989) found children with that high vagal tone, high activity level and low distractibility exhibited a faster shift from solitary to group play during the transition to a new preschool environment. Thus, there is preliminary evidence that individual differences in vagal tone predict reliable differences in behavioral reactivity and regulation to emotion-eliciting situations.

There is another dimension of vagal tone that needs to be considered, namely, the ability to suppress vagal tone. In general, vagal tone is suppressed during states that require focused or sustained attention, mental effort, focusing on relevant information, emotional interaction, and organized responses to stress. Thus, the child's ability to perform a transitory suppression of vagal tone in response to environmental, and particularly emotional demands, is another index that needs to be added to the child regulatory physiology construct.[1] It relates to the likelihood of approach rather than withdrawal; some infants with a high vagal tone who were unable to suppress vagal tone in attention-demanding tasks exhibited other regulatory disorders (e.g., sleep disorders) (Huffman, Bryan, Pederson, & Porges, 1992). Porges, Doussard-Roosevelt, Portales- Lourdes and Suess (1994) found that 9-month-old infants who had lower baseline vagal tone and less vagal tone suppression during the Bailey examination had the greatest behavioral problems at 3 years of age, as measured by the Child Behavior Checklist (Achenbach & Edelbrock, 1986). Measures of infant temperament derived from maternal reports (Bates, 1980) were not related to the 3-year outcome measures.

In this paper, we further explore Porges' suggestions that basal vagal tone and the ability to suppress vagal tone may be related to children's emotion regulation ability within the context of stressful parent-child interactions. To date, studies of individual differences in children's physiological reactivity have largely examined emotion regulation in infants and toddlers. Furthermore, we know little about the degree to which variation in physiological reactivity is useful in predicting long-term behavioral adjustment (i.e., Fox, 1989a; Porges et al., 1994). In our research, we examine whether individual differences in vagal tone at the preschool-age predicts children's emotion regulation abilities during middle childhood. The child's emotion regulation ability was measured with the Katz-Gottman Emotion Regulation Questionnaire that asked parents to report how much they have to "down-regulate" their 8-year-old child's negative emotions; that is, how much they think that their child is emotionally out of control.

A second goal of this research was to understand *how* the vagal tone variables might work to predict emotion regulation. How does the child with higher vagal tone and greater ability to suppress vagal tone manage to regulate emotions? We suggest two possible hypotheses of how a higher vagal tone might function. One is a "stress inoculation" hypothesis and the second is a "recovery hypothesis." According to a "stress inoculation" hypothesis, having high vagal tone protects the child from having a strong physiological reaction to stressful life events. If the stress inoculation hypothesis were true, the child should maintain a high vagal tone and lowered heart rate during normally stressful interactions. However, according to a "recovery" hypothesis, having high vagal tone would enable a child to recover quickly from strong physiological arousal during stress. If the recovery hypothesis were true, then a child with high vagal tone might be quite physiologically reactive during stressful interactions but should still recover more quickly. In this paper we explore these two hypotheses.

Children's physiological reactivity is examined in response to what was hypothesized to be a particularly potent interpersonal stressor, that of parental rejection. Parental rejection has been associated with depression, alcohol use, delinquency, truancy and runaway behavior, disruptive classroom behavior, and physical aggression in children (Gray & Ray, 1990; Peretti, Clark & Johnson, 1984; Simons, Robertson & Downs, 1989; Williams, 1989). Parental rejection during childhood has also been found to predict a variety of adjustment problems in adulthood, including poor relationships between adult children and their parents, alcohol abuse, depression, the intergenerational transmission of depressed mood, and Type A behavior (Whitbeck, Hoyt, & Huck, 1994; Whitbeck, Hoyt, Simons, & Conger, 1992; Wright, 1983). We indexed parental rejection by assessing three types of negative parenting behaviors during a parent-child teaching interaction: mockery, criticism and intrusiveness. Children's physiological reactivity to these stressful negative parenting events which may tax children's emotion regulation abilities was hypothesized to be a good context in which to explore how vagal tone is related to emotion regulation.

METHODS

Participants

Fifty-six families were recruited from a small Midwestern university town for this study; 32 families had a male and 24 had a female child. The average age of the children was 67.45 months (SD = 6.3 months). Ninety-six percent of the parents were Caucasian. The mean age of husbands and wives were 33.5 and 32.9, respectively. Number of years of education for husbands and wives averaged 14.1 and 13.7, respectively. Approximately two-thirds of the families were classified as white-collar workers and the remaining families were classified as blue-collar workers (see Krokoff, 1984, for classification criteria). Three years later 53 of the 56 families were recontacted (94.6% of the original sample).

Procedures

Procedures consisted of laboratory sessions and home interviews for both parents and children. A combination of naturalistic interaction, highly structured tasks, and semi-structured interviews were used. Home and laboratory visits consisted of two home visits, one with the marital couple and one with the child, and three laboratory visits, one with the couple only, one with the couple and their 4-5-year-old child, and one with the child alone. Only procedures directly relevant to the conceptual question addressed in this paper will be described.

Time-1 Assessments

Parent-child interaction. The parent-child interaction session consisted of a modification of two procedures used by Cowan and Cowan (1987). In the first task parents were asked to obtain information from their 4-5-year-old child. The parents were informed that the child had heard a story and they were to find out what the story was. The story that the children heard did not follow normal story grammar and was read in a monotone voice, and so the story was only mildly interesting for the children and hard for most children to recall. This made the parents' inquiry potentially stressful. The second task involved teaching the child how to play an Atari game that the parents had learned to play while the child was hearing the story. The interaction lasted 10 minutes. Videotaped data was collected from all three family members but physiological data was obtained only from the child.

Children's film viewing. To obtain an assessment of child's baseline vagal tone and ability to suppress vagal tone outside of the parent-child interaction context, children were shown segments of a neutral and an emotion-eliciting film. The neutral film was an instructional film about fly-fishing. The emotion-eliciting film was a clip from the flying monkey scene in *The Wizard of Oz* in which the monkeys take Dorothy to the witch's castle. This film clip was preceded by a neutral story and an emotion induction film clip of an actress who acted out the emotions of the protagonist in the upcoming story. The function of the emotion induction was to direct the child to identify with the protagonist and to experience the specific emotion in question.

Child's physiological functioning. The child's cardiac interbeat interval (IBI) was assessed continuously by measuring the time between successive R-waves of the electrocardiogram (EKG). Miniature Beckman silver-silver chloride electrodes were applied to either side of the child's chest after lightly abrading the area with Omni-prep solution. Bechman's electrolyte was used to facilitate conductivity of electrical signals. IBI was averaged into 1-second intervals and synchronized in time with observational data.

Time-1 Measures/Coding

Observational coding of parent-child interaction. Parental rejection was coded using the Kahen Engagement Coding System (KECS) and the Kahen Affect Coding Systems (KACS) (Kahen, 1995). The KECS consists of seven parental engagement codes: Engaged, Positive Directiveness, Responds to Child's Needs, Disengaged, Negative Directiveness, Intrusiveness, and neutral. The KACS also consists of seven parental affect codes: Affection, Enthusiasm, Humor, Criticism, Anger, Mockery, and Neutral. Given our interest in parental rejection, only the Criticism, Intrusiveness and Mockery codes were examined in the analyses. Intrusiveness involved physical interference with the child's actions (e.g., grabbing the joy stick). Criticism involved direct disparaging comments or put-downs of the child's behavior or performance. Mockery occurred when parents used humor in a derisive way, at the child's expense (e.g., through sarcasm or by making fun of the child).

Parent-child interactions were coded continuously in real-time with coding synchronized to the original parent-child interaction. The total number of times each variable occurred in the 10-minute parent-child interaction session was recorded and totals across time were calculated for each of the 14 parent-child interaction variables. This index represents an estimate of the frequency of the parenting behavior within a 10-minute period. Mothers and fathers were coded by independent observers. Engagement and affect dimensions were also coded by independent observers. Reliability was calculated across coders using a correlation coefficient. Because total number of seconds within each parent code was the variable computed and used in all data analyses, the appropriate reliability statistic is a correlation coefficient rather than Cohen's kappa or percent agreement. For the KECS, the mean inter-coder correlation was .96, with a range of .86 to .99, and for the KACS the mean correlation was .93, with a range of .84 to .97.

Child regulatory physiology. For our physiological variables we selected as an estimate of the child's baseline vagal tone the vagal tone when the child was listening to a neutral story about fly fishing, a variable we will call "BASAL VAGAL." This story was presented before any of the emotion-eliciting films were shown. The child's ability to withdraw vagal tone was estimated as a difference between this estimate of basal vagal tone and the child's vagal tone during the flying monkeys scene in *The Wizard of Oz*, a clip designed to elicit a strong emotional response. We expect vagal tone to be withdrawn and heart rate to increase when the child is emotionally engaged with the fearful stimuli in this second film clip. We call this second variable "DELTA VAGAL." This second variable indexes the child's ability to suppress vagal tone when engaging with a strong emotional stimulus which includes an environmental demand for changing attentional focus, or regulating emotion; in our case the engagement with the environment involves the demands for an emotional response being elicited by the emotional film, as well as the demands to focus attention on the Atari video game the child played immediately after each film clip standing for a difference in vagal tone from the baseline film to the exciting film conditions. However, the order of the films was randomized; hence DELTA VAGAL represents the difference between two vagal tones, the child's vagal tone while viewing the neutral story about fly fishing minus the child's vagal tone while viewing the emotion-eliciting film from *The Wizard of Oz*. We computed our index of "vagal tone" as the amount of variance in the interbeat interval (related to the heart rate: Heart rate = 60000/interbeat-interval) spectrum that was within the child's respiratory range using spectral time-series analysis. This measures respiratory sinus arrhythmia, a measure of parasympathetic nervous system tonus, which has been found to index attentional processes and emotion regulation abilities (Porges, 1984). For our computations, we used the program SPEC from the Gottman-Williams computer program time-series package (Williams & Gottman, 1981). We also computed mean levels of interbeat interval during parent-child interaction to examine the stress inoculation and reactivity hypotheses.

Time-2 Assessments

Families were re-contacted 3 years later for follow-up assessments of child outcomes. Children were on average 8 years old (M = 96.9 months; Range = 82-110). Ninety-five percent (53 out of 56) of the families in the initial sample agreed to participate in the Time-2 assessments.

Mothers filled out a 45-item questionnaire about the degree to which their child requires external regulation of emotion (Katz & Gottman, 1986). This questionnaire includes items that reflect instances within the past week when the parent needed to "down regulate" the child. Sample items include: "How often did you tell your child to simmer down? How often did you tell your child to get to bed when he/she was too excited to go to sleep? How often did you tell your child to stop interrupting?" The alpha coefficient for the scale was .74.

RESULTS

Table 1 summarizes the means and standard deviations for the major variables used in our analyses. We now turn to the questions explored in this study.

Does Vagal Tone at Age 4-5 Predict Emotion Regulation at Age 8?

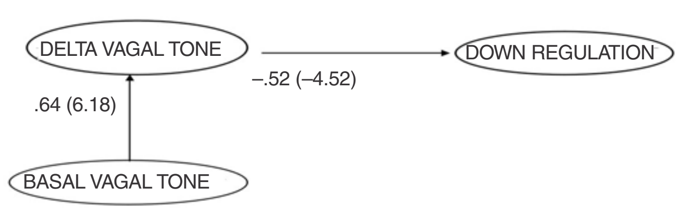
The program EQS was used for the path analyses (Bentler, 1992). A *non-significant* chi-square is sought as evidence that the model fits the data. Figure 1 is a summary of a path analytic model from the vagal tone variables at age 4-5 and emotion regulation at age 8. The model fit the data well, with a non-significant χ^2 (1) = .007, p = .935, Bentler-Bonett Normed Index of fit (BBN) = 1.00, with multiple correlation coefficient R^2 = .52 for emotion regulation at age 8. The path coefficient from basal vagal tone to the suppression of vagal tone at age 4-5 was statistically

TABLE 1. Means and Standard Deviations for Key Variables in the Analyses

Variable	Mean	Standard Deviation
Basal Vagal Tone	15.57	1.66
Delta Vagal Tone	.98	2.73
Down Regulation	1.91	.47
Child IBI* during paternal criticism	340.28	293.97
Child IBI during paternal mockery	222.57	241.80
Child IBI during paternal intrusiveness	450.81	343.04

* IBIs are in milliseconds

FIGURE 1. Vagal Tone Variables at Age 4-5 Predict Emotion Regulation at Age 8



significant (.64, $z = 6.18$), and the path coefficient from the suppression of vagal tone variable at age 4-5 to the down regulation variable at age 8 was significant ($-.52$, $z = -4.52$).

How Might Vagal Tone Variables Work to Predict Emotion Regulation at Age 8?

The relational data base. To begin examining a stress inoculation and a recovery hypothesis, we first asked whether it was the case that to the extent that the child's vagal tone was being used to keep heart rate low during stressful parent-child moments at age 5, the child would be higher in emotion regulation ability at age 8. To find a mechanism that might provide an answer to this question, we constructed a relational data base that time-locked the parent's most negative and potentially stressful behaviors (Intrusiveness, Mockery, and Criticism) to the child's physiology during the parent-child interaction in our laboratory. We then correlated the child's cardiac interbeat interval during these specific moments with our emotion regulation variable and with our two vagal tone variables, the child's basal vagal tone and the child's ability to suppress vagal tone.

Stress Inoculation Hypothesis

Table 2 provides support for the stress inoculation hypothesis that the child's vagal tone was being used to keep heart rate low during stressful parent-child moments with the father. For example, for father mockery, those children higher in basal vagal tone and higher in the ability to suppress vagal tone were able to keep their heart rates low (i.e., had longer IBIs). The children lower in heart rate during moments of father mockery also required less down regulation at age 8. The child who maintained a lower heart rate during moments of mockery by the mother also required less down regulation at age 8. However, judging by the pattern of correlations, the effect was not mediated by the vagal tone variables since IBI during mother mockery was not related to basal vagal tone or vagal suppression. A stronger statement of this first hypothesis is the following: If a child has higher vagal tone and greater ability to suppress vagal tone, then, to the extent that this child can maintain a lower heart rate (i.e., longer IBI) during these stressful negative parenting behaviors, the child should be able to regulate emotion at age 8. This statement of the hypothesis suggests that it is precisely by being able to

TABLE 2. Relationship Between the Child's Cardiac Interbeat Interval and Basal Vagal Tone, the Suppression of Vagal Tone at Age 5, and Emotion Regulation Ability at Age 8

Variable IBI During	Basal Vagal Tone	Suppression of Vagal Tone	Parents need to down regulate Child at age 8
Father Mockery	.46*	.70**	−.46*
Mother Mockery	.05	−.02	−.69*
Father Criticism	.31*	.38*	−.32*
Mother Criticism	.19	.10	−.19
Father Intrusiv.	.23	.35[a]	−.59**
Mother Intrusiv.	.43[a]	.47[a]	−.40

[a] $p < .10$; * $p < .05$; ** $p < .01$; *** $p < .001$; Intrusiv. = Intrusiveness

maintain a lowered heart rate during stressful moments that a high vagal tone child is able to regulate negative affect.

To test this strong form of the first hypothesis, we took the father's mockery, which seemed to best fit the weak form of the hypothesis in terms of its pattern of correlations, and we then fit a path analytic model, attempting to place the child's interbeat interval during the father's mockery between DELTA VAGAL and DOWN REGULATION in the model in Figure 1.

Figure 2a shows that the new model fit the data well ($\chi^2\,(3) = 4.92$, $p =$ .178, BBN = .992), and the path coefficients significant between the DELTA VAGAL and the child's interbeat interval when the father used mockery, and between the child's interbeat interval when the father used mockery and DOWN REGULATION. Hence, the old path between DELTA VAGAL and DOWN REGULATION was successfully replaced with an intervening variable, making the direct pathway an indirect pathway through our theoretical variable. Figure 2b adds a path to this model suggested by Baron and Kenny (1986). This model fit the data, with $\chi^2\,(2) = .03$, $p = .986$, BBN = .999. Consistent with the Baron and Kenny's suggested analysis, one compares the path coefficient of Figure 1 of −.52 with the same path coefficient in Figure 2b of −.35 between DELTA VAGAL tone and DOWN REGULATION. Since the path coefficient of −.35 is significant, but smaller in absolute value than the path coefficient of −.52, we have the conditions for partial mediation.

FIGURE 2a. Child's IBI During Father Mockery as a Mediating Variable Between Vagal Tone at Age 5 and Down Regulation at Age 8

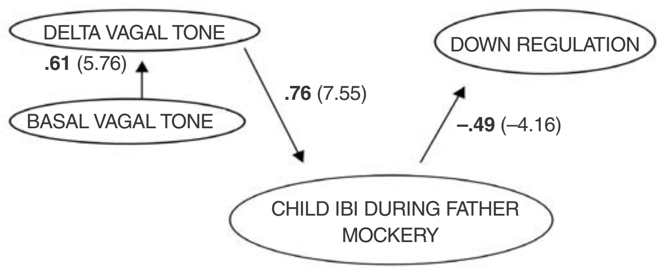
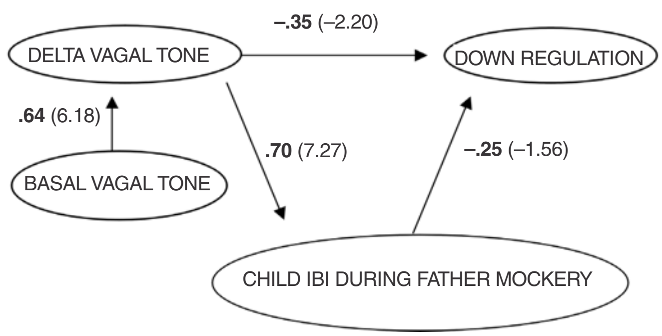


FIGURE 2b. Model Demonstrating Partial Mediation



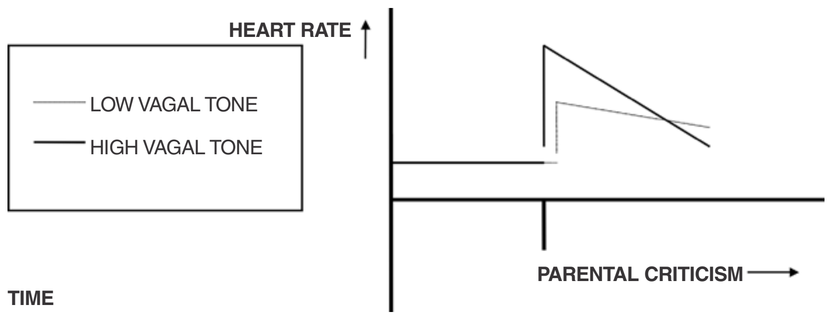
We also fit identical models as in Figure 2a (new model) for father criticism and father intrusiveness. For father criticism, the model did not fit, with $\chi^2(3) = 9.84$, $p = .020$, BBN = .975. However, the path coefficient from the child's interbeat interval when the father used criticism to DOWN REGULATION was $-.33$, $z = -2.54$, $p < .05$, and the path coefficient from DELTA VAGAL to the child's interbeat interval when the father used criticism was .54, $z = 3.30$, $p < .01$. For father intrusiveness, the model also did not fit, with χ^2 (3) = 8.07, p = .045, BBN = .983. However, the path coefficient from the child's interbeat interval when the father used criticism to DOWN REGULATION was −.59, z = −5.41, p < .001, and the path coefficient from DELTA VAGAL to the child's interbeat interval when the father used criticism was .47, z = 2.88, p < .05. Hence, in these two cases, although the overall model did not fit the data, the relevant paths for judging whether the variable of the child being able to keep his or her heart rate down mediated significantly between DELTA VAGAL and DOWN REGULATION in both instances.

The Recovery Hypothesis: Interrupted Time-Series Analyses

A problem with the path modeling analyses is that, although they support the inoculation hypothesis, they do not rule out the recovery hypothesis because they do not tell us how the child maintains a lowered heart rate. The child could maintain a lowered heart rate by reacting more but still recovering more quickly. This would be an unusual state of affairs in physiology in which greater reactivity is typically associated with slower recovery (Martin & Venables, 1980). However, Porges has noted that children higher in vagal tone are more emotionally responsive, and this observation was supported by Fox (1989a).

Therefore, we used interrupted time-series analysis to continue testing the recovery hypothesis by studying the immediate effects on the child's heart rate of parental mockery, criticism, or intrusiveness, as well as the amount of the child's recovery from heart rate increases within a 5-second window (i.e., 5 seconds before and 5 seconds after the parental stressor). For our analyses we used the Crosbie (1993) interrupted time-series analysis computer program (see Figure 3; see also Crosbie & Sharpley, 1989). In this analysis, straight lines (each with an intercept and a slope) are fit to the pre-moment and post-moment IBI data (the moments are parental mockery, intrusiveness, or criticism), after controlling for autocorrelation in the data. The change in the intercept (post minus pre) is an index of the size of the heart rate response, whereas the change in the slope (post minus pre) is an index of the amount of heart rate recovery. To study physiological recovery, we selected all moments in which the child's interbeat interval intercept (IBI) decreased (i.e., the level of the child's heart rate increased) after the parental behavior, and then computed the change in slope from pre-moment to post-moment. We split the children at the median on their baseline vagal tone and conducted the time-series analyses.

FIGURE 3. Interrupted Time-Series Analyses Effects of Parental Criticism on Children's Heart Rate as a Function of Whether the Children Were High or Low on Basal Vagal Tone, Showing a Greater Response and a Greater Recovery of Children High in Basal Vagal Tone



Amount of heart rate increase. Because there were many more moments of criticism than either mockery or intrusiveness, we compared the extent of the child's heart rate increase in response to parental criticism as a function of whether the children were high or low in basal vagal tone. For mother criticism, children with high vagal tone showed larger decrease in IBI (i.e., greater increase in heart rate) than children with low vagal tone, $F(1,85) = 6.25$, $p = .014$; the low vagal tone group decreased 42.43 msec and the high basal vagal tone group decreased 73.35 msec. Results for father criticism showed a similar pattern but did not approach significance $F(1,68) = 0.20$, ns; the low basal vagal tone group decreased 46.63 msec and the high basal vagal tone group decreased 51.24 msec. Thus, children high in basal vagal tone whose heart rate increased in response to parental criticism had a greater heart rate increase in response to maternal criticism increase and a faster recovery than children low in basal vagal tone.

Recovery from heart rate increase. In examining the slope change, for mockery and intrusiveness there were no significant differences between groups $F(1, 23) = 0.04$, and $F(1,35) = 1.25$, respectively, but for criticism there was a significant effect, $F(1,155) = 8.58$, $p < .01$ (low basal vagal tone group: slope change = 8.45, high group: slope change = 15.94); hence, the high basal vagal tone group recovered significantly more quickly than the low basal vagal tone group. The basal vagal heart rate recovery effect for criticism did vary depending on whether the mother or father did the criticizing, for mother, $F(1,85) = 5.88$, $p = .017$; for father, $F(1,68) = 2.69$, ns. Splitting children on the suppression of vagal tone variable yielded no significant effects.

Thus, children high in basal vagal tone had a *greater heart rate increase in response to maternal criticism and a faster recovery* (for both paternal and maternal criticism) than children low in basal vagal tone. These results support the recovery hypothesis rather than the stress inoculation hypothesis. Thus, the path modeling data supported a stress inoculation hypothesis for children's response to the father's stress-inducing behavior, while the interrupted time series analyses supported a recovery hypothesis, for mother's stress-inducing behavior.

DISCUSSION

This paper provides further support for Porges' (1984) suggestion that children's vagal tone is related to their emotion regulation abilities. We found that children's vagal tone at age 4-5 predicted mother ratings of emotion down-regulation ability at age 8. This provides an extension of studies with infants and toddlers, indicating that basal vagal tone is related to greater ability to self-soothe.

The mechanism by which vagal tone works to predict emotion regulation was also investigated in this paper. The hypothesis that the child's maintaining a relatively lowered heart rate during stressful parent-child interaction could be a mediating variable that could explain this prediction was supported. However, this path model did not specify the process by which this effect occurred, via an inoculation against stress model (in which children high in vagal tone do not react very much physiologically to parental negativity), or a recovery model (in which children high in vagal tone do react, but recover quickly). From the interrupted time-series analyses we learned that the basal vagal tone variable was related to a recovery model and not to an inoculation against stress model. Children with high vagal tone are not avoiding situations that lead to stress, nor are they non-reactive. Instead we found that they are both more highly reactive and able to recover more quickly than children low in basal vagal tone. This combination is quite unusual physiologically.

It is interesting that children's physiological reactions vary with fathers and mothers. With fathers, the patterns in the data supported a stress inoculation hypothesis. When fathers were mocking, those children with high vagal tone and greater ability to suppress vagal tone were better able to maintain a lower heart rate and were better able to regulate emotion at age 8. This may partly reflect the father's role in the development of emotion regulation skills. Consistent with evidence of gender differences in overt expression of emotion between men and women (see, for example, Hall, 1984), fathers may discourage the expression of strong negative emotion in their children, and may instead encourage children to take a more "level-headed" approach to negative events. This may be reflected in children exhibiting less autonomic reactivity to stress when with their fathers. In response to mother's negativity, children with high basal vagal tone had a greater heart rate increase and faster recovery than children low in vagal tone. The greater heart rate increase to mother's criticism may reflect children's greater emotional reaction to mother's negativity. An examination of children's behavioral reactions to fathers' and mothers' negativity would be useful in addressing these possibilities.

NOTE

1. Porges points out that we must be cautious about expecting the suppression of vagal tone to always be the appropriate vagal response to external demands. In the neonatal intensive care unit the appropriate response to gavage feeding turned out to be increases in vagal tone, consistent with the support of digestive processes (DiPietro & Porges, 1991). Premature infants who increased vagal tone during gavage feeding had significantly shorter hospitalizations.

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