Psychophysiological Correlates of Infant Temperament:
Stability of Behavior and Autonomic Patterning
From Five to Eighteen Months

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Abstract

The stability of infant temperament and autonomic patterning (heart period and cardiac vagal tone) was examined longitudinally when infants were 5, 10, and 18 months of age. Behavioral measures of reactivity and regulation to frustration tasks, and maternal perceptions of infant temperament were obtained at each age along with baseline measures of cardiac activity. No stability was found from 5 to 10 months while some stability of behavior and autonomic patterning was identified from 10 to 18 months with the exception of negative reactivity. High levels of cardiac vagal tone ($V$) were associated with negative reactivity at 18 months. When examining groups based on degrees of reactivity and regulation we found infants who responded negatively to frustration but who also displayed more regulatory behavior to have higher $\hat{V}$. 
Psychophysiologial Correlates of Infant Temperament:

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Theories of temperament exist which propose that individual differences are constitutionally based and relatively stable over time. The study of temperament in infancy has been exceptionally important toward identifying these characteristics as infants' responses to stimuli are believed to be primarily biologically driven. But such studies are not without their difficulties. Establishing the stability of behaviors across the first year of life as well as identifying their constitutional basis is often hampered by the rapid growth and development that typifies the infancy period. Moreover, behavior becomes more complex over time. For example, the stability of a crying response may be obscured by developmental changes in crying behavior which occur through maturation of the nervous system (Emde, Gaensbauer, & Harmon, 1976) and the responsivity of the environment (Bell & Ainsworth, 1972; Fish, Stifter, & Belsky, 1991). Rapid physiological changes also make it difficult to detect the relationship between behavior and biology. Research has documented developmental change in heart rate and heart rate variability during the first 6 months of life (Harper, Hoppenbrouwers, Sterman, McGinty, & Hodgman, 1976) but little individual stability over this same age period has been reported (Stifter & Fox, 1990; c.f. Izard et al, 1991).

While theories of temperament have provided conceptual frameworks which guide empirical study, Rothbart and Derryberry’s (1981) theory of infant temperament is particularly useful because it is primarily biological and provides two constructs which can be readily applied to several physiological indices. They define temperament as "constitutional differences in reactivity and self-regulation" and propose that reactivity reflects the individual’s behavioral and biological reaction to changes in the environment while regulation is reflected by the processes used to modulate this response.

Identifying the physiological bases of individual differences in behavior has been a goal
of recent research in developmental psychophysiology. Perhaps because of the ease of recording heart rate in infants, the relationship between autonomic nervous system (ANS) activity and infant behavior has been of particular interest. While the sympathetic branch of the ANS has been the focus of research examining normative changes in response to emotional stimuli (see Berg & Berg, 1988), the parasympathetic branch, as measured by the vagal control of the heart, has been the primary focus of individual differences research. The function of the parasympathetic branch, to modulate changes in sympathetic activity, has made it especially interesting with regard to individual differences in behavior or temperament. Indeed, based on a review of the literature, Porges (1992) has suggested that cardiac vagal tone may be an autonomic mediator of the infants' ability to react and self-regulate.

Early research on the relation between cardiac vagal tone and reactivity examined infants' physiological responsivity (i.e., heart rate change) to visual or auditory stimuli. In sum, these studies have shown that infants with high resting levels of cardiac vagal tone are more reactive physiologically, exhibiting large heart rate decelerations to stimuli (Porges, 1974; Porges, Arnold, & Forbes, 1973). More recently, studies have examined the association between emotional reactivity and a digitally-filtered measure of cardiac vagal tone, $\tilde{V}$ (Porges, 1985). In a study of newborns' physiological and behavioral responses to circumcision, Porter, Porges, and Marshall (1988) found infants with high $\tilde{V}$ to show greater cardiac reactivity to stress as well as higher cry pitch during stress. Using a frustration task, Stifter & Fox (1990) found that 5 month old infants with high $\tilde{V}$ responded with more frequent and intense anger responses than infants with low $\tilde{V}$. In another study (Stifter, Fox, & Porges, 1989) of 5-month- and 10-month-olds' responses to an approaching mother and stranger, a link was found between high cardiac vagal tone and expressions of interest and joy but only for the 5 month old infants.

In contrast to what would be considered appropriate responsivity to eliciting events (e.g., cry to painful stimulus, anger to frustration), Porges (Porges, Doussard-Roosevelt,
Infant Psychophysiology

5

Portales, & Suess, 1994) found that infants with high $\hat{V}$ were rated as more difficult by their mothers at 9 months of age. Likewise, DiGangi and colleagues (DiGangi, DiPetro, Greenspan, & Porges, 1991) found infants presenting with sleep and/or feeding disorders, and difficulty self-soothing ("regulatory-disordered") also exhibited with high baseline levels of $\hat{V}$. Interestingly, the regulatory-disordered infants also exhibited disorganized patterns of physiological response to cognitively-challenging tasks. Whereas these data appear to conflict with the data on emotional reactivity it is important to note that infants from both of these studies were older and were categorized as difficult using maternal reports of infant behavior. Nevertheless, it may be that early measures of cardiac vagal tone may be indicative of more organized responses to emotion-eliciting stimuli but that as the infant matures high levels of $\hat{V}$ and the lack of vagal suppression are indicators of extremes in reactivity (Porges, Doussard-Roosevelt, & Maiti, 1994). The development of self-regulatory skills during this period may also explain this change in the cardiac vagal tone/reactivity relationship (Fox, 1989). Indeed, more recent studies with preschool children suggest that cardiac vagal tone may be related to controlled expressivity (Fabes, Eisenberg, & Eisenbud, 1993; Wilson & Gottman, 1993). For example, in 10-13 year-olds high heart rate variability, another index of vagal control of the heart, was related to greater sympathetic reactions while low heart rate variability was related to personal distress (Fabes, et al., 1993).

The ability to regulate internal and external responses is an important developmental task of infancy. While the caretaker has primary responsibility for regulating infant state in the early months of life (Kopp, 1989), infants are not without the ability to self-regulate as well. Attentional strategies such as gaze aversion or re-orientation, for example, can serve to temporarily remove the infant from the source of stimulation. Several studies have been conducted which have examined the relationship between measures of heart rate variability and behaviors which can be thought of as regulatory. Using heart rate change in response to a visual stimulus as an index of attention, Richards (1987) showed that greater respiratory sinus
arrhythmia, an index of parasympathetic tone, was related to the ability to physiologically attend even in the face of a distracting stimulus. Behavioral measures of attention such as looking and looking away have also linked to high levels of parasympathetic tone (Stifter et al., 1989). Finally, there is evidence that infants with high levels of cardiac vagal tone are more approaching and sociable with strangers (Fox, 1989; Richards & Cameron, 1989), behaviors hypothesized to require the regulation of both internal and external states.

Together, the data on the physiological bases of temperament, specifically reactivity and regulation, suggest that the parasympathetic nervous system may mediate individual differences in reactivity and regulation. However, developmental changes in reactivity, perhaps by virtue of development of more regulatory skills, appear to alter this relationship. The present challenge, therefore, is to identify individual stability in the relationship between behavior and biology within the development of more complex, integrated behaviors.

Porges (1992) has recently proposed that measuring cardiac vagal tone may act as a non-invasive indicator of stress vulnerability. With his colleagues, he has shown that high risk infants (premature and/or medically compromised) presented with low levels of $V$ (Porges, 1983; Fox & Porges, 1985). Porges (1992) has also suggested the inverse - that high vagal tone is an indicator of stress resiliency. That is, individuals with high $V$ may be more behaviorally competent. This conclusion is supported by the data cited above -- infants with high cardiac vagal tone are more responsive, physiologically and behaviorally, and have better regulatory skills. While these findings are indicative of some link, they are based on correlations that are weak to moderate at best. Given that there is little or no stability in either measures of cardiac vagal tone or behavior across this period, these data are not surprising. Controlling for change across the first year, however, may increase our ability to identify the physiological correlates of infant behavior.

In the present study we attempted to address this issue by examining longitudinally the behavior and cardiac vagal tone ($V$) of infants at 5 months, 10 months, and 18 months of age.
Our hypothesis was that infants who present with high $V$ across this period may be predisposed toward adapting to the rapid changes that characterize the infancy period. We also examined the predictive and concurrent relationships between $V$ and behavioral measures of reactivity and regulation measured at 5 months, 10 months, and 18 months of age.

Method

Subjects

One hundred subjects were recruited at a local community hospital and tested within 8 to 72 hours after birth. Criteria for selection were that they be healthy, term (>37 wks) infants with APGARS of at least 7 at one and 5 minutes. Pregnancies and labor were also free of complications. Subjects were from predominantly white, middle class families (2 African American, 1 Asian American, 1 Hispanic). Of the 100 subjects, 90 returned at 5 months, 84 were present for the 10 month follow-up visit, and 74 were tested at 18 months of age. All subjects were tested within two weeks of their 5, 10 and 18 month birthdays.

Procedures

Infants participated in age-appropriate tasks designed to elicit differing levels of negative reactivity at 5, 10 and 18 months. Baseline EKG was recorded prior to the start of the procedures. Temperament questionnaires were mailed and completed just prior to their visits. All procedures were videotaped for later coding.

5, 10 and 18 month procedures/measures

Negative reactivity task. At 5, 10 and 18 months of age infants and mothers participated in laboratory procedures designed to elicit negative reactivity and self-regulation. At 5 months, the arm restraint procedure was used (Stifter & Fox, 1990). The infant was placed in an infant seat situated at eye level and across from mother. Mother was instructed to gently restrain her infant by holding his/her arms down to the infant’s sides. Mother was also
instructed to maintain a neutral facial expression and to refrain from verbally interacting with her infant. After two minutes of arm restraint or 20 seconds of hard crying, mother was cued to release her infant’s arms but to continue her neutral, noninteractive posture for one minute. Mother was then told that she could soothe her child if necessary using whatever method she deemed appropriate. The mean length of arm restraint was 103 seconds (SD = 23.9).

At 10 months of age, the infant was placed in an infant high chair and mother was seated toward the side but in front of the infant. For 90 seconds mother and infant played with an attractive Busy Box toy that consisted of several moving and noise-making parts. Upon a cue from the experimenter, mother removed the toy from her infant and held it out of reach but within the infant’s sight. Mother was also instructed to assume a neutral expression during this time. Toy removal lasted for two minutes or 20 seconds of hard crying. Mother was then cued to return the toy to the infant but to remain noninteractive. After one minute mother resumed interacting with her infant. The mean length of toy removal was 115 seconds (SD = 13.0).

Like the 10 month negative reactivity procedure, the 18 month task involved toy removal. While seated across from each other, mother and infant played together with a "Slinky" for two minutes after which mother was cued to place the toy in a jar and place the lid on without tightening. Mother was also instructed to assume a neutral posture and not interact with her child. One minute later, mother was asked to remove the toy from her infant, place it in the jar and screw the lid on tightly. Again, mothers maintained a noninteractive posture. The jar lid was unscrewed after two minutes or 20 seconds of hard crying. Mother could also soothe her child during this period if needed. The mean length of time the lid was screwed on tightly was 117.6 seconds (SD = 4.3).

Parent-rated temperament. Parents completed the Infant Behavior Questionnaire (IBQ; Rothbart, 1981) when their infants were 5 and 10 months of age. The IBQ is a 94-item questionnaire which asks respondents to rate the observed frequency with which their child
infant exhibited certain behaviors within the last two weeks. The IBQ consists of 6 subscales: 1) activity level; 2) distress to limitations; 3) distress and latency to approach novel persons and objects; 4) smiling/lactation; 5) duration of orientation; and 6) soothability. Mothers completed the Toddler Behavioral Assessment Questionnaire (TBAQ, Goldsmith et al., 1986), a 147-item instrument, on their 18 month old infants. Based on the IBQ, the TBAQ assesses 5 dimensions of temperament: 1) activity level; 2) anger; 3) social fear; 4) happiness; and 5) interest. Because the present study focused on negative responses to frustration and the regulation of those responses only the distress to limitations/anger dimensions which we will call frustration, and the distress to novelty/social fear dimensions, referred to as fear, were examined.

**Behavioral data quantification**

**Negative reactivity.** Negative vocalizations to the 5 month arm restraint procedure, and the 10 and 18 month toy removal tasks were coded every 10 seconds on a 5-point scale of 0 (no negative vocalization, 1 (whimper or fuss), 2 (escalated fussing with a least one sob), 3 (cry), and 4 (shrieking, hysterical crying) (Fish, Stifter, & Belsky, 1991). Negative vocalizations were only coded for the most frustrating period of the task. Thus, negative vocalizations were coded during arm restraint at 5 months, toy removal at 10 months, and the period during which the jar's lid was tightened at 18 months. The ratings were summed and divided by the length of the frustration period to yield a negative reactivity score for each age. Inter-rater reliability for the 5 month, 10 month and 18 month negative reactivity measures resulted in a mean Cohen's kappa of .70, .82 and .82, respectively.

**Regulatory behaviors.** Regulatory behaviors were coded from the videotapes of the 5 month arm restraint procedure and the 10 and 18 month toy removal tasks. A laptop computer was used to code the behaviors continuously and was programmed to calculate the presence and duration of each regulatory behavior. Based on previous research (Braungart & Stifter, 1991; Giannino & Tronick, 1985), behaviors which reflect the infant's attentional strategies,
avoidance, self-comforting, and communication attempts were selected for coding. At 5 months of age, orienting toward objects, orienting toward mother, scanning, escape behaviors, and nonnegative vocalizations were coded from the arm restraint procedure. Because it was not possible to code self-comforting during arm restraint, self-comforting was coded when the arms were released. These same behaviors were coded from the 10 and 18 month procedures with three additions -- orienting toward the toy/jar, nonnegative vocalizations or verbalizations (18 month only) and communicative gestures. The total time each behavior was exhibited was divided by the length of the arm restraint/toy removal periods for each subject. This proportion was the variable used in the statistical analyses. Interrater reliabilities for 10% of the sample resulted in an average of .85 by Cohen's kappa for the 5 month behaviors, .81 for the 10 month behaviors and .83 for the 18 month regulatory behaviors.

Heart rate recording and quantification

Baseline heart rate was recorded at the beginning of the 5, 10, and 18 month laboratory visits. Infant EKG was recorded by placing three disposable electrodes on the infants' chest in a triangular pattern. During the visits, 10 minutes of resting EKG was recorded while the infant sat quietly in his/her mother's lap or a high chair.

Infant EKG was collected off-line using a Grass pre-amplifier (Model P15) and Vetter FM instrumentation recorder. To quantify the data the EKG pulses were passed through an A/D converter programmed to display the raw EKG signal. The data were viewed and a threshold set to trigger at each R spike. The square wave impulses produced by the trigger were then timed in msec and organized into a heart period file. An analytic method developed by Porges (1985) was then applied to these data and the $V^2$ statistic, an index of vagal tone, computed. This method detrends the heart period data to remove influences due to non-stationarities, and using time series analysis extracts the components of heart period within the respiratory frequency band for newborns (0.3 to 1.3 Hz) and older infants (0.24 to 1.04 Hz). The natural logarithm of this variance produces the $V^2$ statistic. $V^2$ was calculated on sequential
30s epochs of the baseline recordings. The program also calculates the mean heart period (in msec) and heart period variance.\(^3\)

In cases of excessive movement that disrupts the EKG signal, the MXEDIT software program (Delta Biometrics) has the capacity to exhibit the heart period data in graphic and numerical form allowing for the visual identification of artifact. These periods of data are then edited manually using the absolute values within the range of the artifactual data. Due to difficulties in recording EKG (equipment failure, infant fussiness, etc.) only 47 subjects had sufficient, and relatively artifact-free EKG data at all three age points.

Results

**Preliminary Analysis and Data Reduction**

Due to the large number of regulatory variables we sought to reduce them to a composite regulatory factor. Exploratory factor analyses were performed and the resulting standardized scoring coefficients applied as weights.\(^4\) The sum of the weighted variables resulted in new factors for which high scores represented more advanced, cognitively-based behaviors (orienting, communicative behaviors). The resulting means for the three new factors were -.06 (SD = .20) for 5 months, .13 (SD = .16) for 10 months, and -.02 (SD = .14) for 18 months.

All behavioral and heart rate variables were tested for sex differences and no significant differences were found.

**Interrelations Among Behavioral Variables**

Pearson correlations were performed to test for associations between negative reactivity, regulation, and parent-rated temperament. As can be seen in Table 1 few significant correlations emerged. Perhaps the most striking finding is the pattern of the relationships between reactivity and regulation at 5, 10, and 18 months. At 5 months of age, there was a trend for infants who were highly reactive to exhibit less regulatory behavior. This relationship disappeared at 10 months but by 18 months it had reemerged to reveal a strong,
significant association. Reactivity and regulatory behavior showed no stability across the three ages although there was a trend for 10 months olds to show similar levels of regulation at 18 months.

Finally, while parent perception of temperament was stable, parental ratings of temperament were also significantly related to laboratory measures of reactivity and regulation. For example, infants who were rated as more easily frustrated exhibited more regulatory behaviors at 10 and 18 months. A similar finding was revealed for maternal ratings of frustration at 10 months; those rated high in frustration displayed more regulatory behavior at 10 and 18 months.

Heart Period and Vagal Tone Analyses

Repeated measures analysis of variance with 5 month, 10 month, and 18 month heart period and V̇ as the repeated factors were significant, HP - F (2,92) = 80.02, p < .0001, V̇ - F (2,92) = 35.11, p < .0001. As can been seen in Table 2 heart period and vagal tone increased significantly from 5 months to 18 months of age.

While the correlations between heart period and V̇ within the three age periods were highly significant (all r's > .58), there was no stability from 5 months to 10 months, HP- r =
.07, $\hat{V} - r = .17$, and from 5 months to 18 months, $HP - r = .04$, $\hat{V} - r = .15$. The stability of $HP$ and $\hat{V}$ from 10 to 18 months, however, improved to near significant ($HP - r = .26$) and significant ($\hat{V} - r = .30$) levels.

**Relations with Behavior.** Pearson correlations were computed to test for the concurrent and predictive relations between the two measures of autonomic activity, $HP$ and $\hat{V}$, and the behaviors measured at 5 months, 10 months, and 18 months of age. Only 6 of a possible 72 correlations were significant, and 3 were near significant ($p < .1$) therefore, the significant relations should be interpreted with caution. No concurrent relations were revealed for the 10 months autonomic measures. At 5 months of age only $HP$ was significantly related to negative reactivity, $r = .22$. The more striking finding to emerge was the relationship between the 18 month heart rate measures and 18 month behavior. $\hat{V}$ and $HP$ at 18 months were significantly correlated to negative reactivity, $\hat{V} - r = .34$, $p < .01$; $HP - r = .30$, $p < .05$, and parent ratings of social fear, $\hat{V} - r = -.24$, $p < .05$; $HP - r = -.25$, $p < .05$. At 18 months of age, infants who had high levels of $\hat{V}$ were more reactive to toy removal, and were rated as less fearful by their parents. The only other significant correlation was that between parent ratings of frustration at 5 months and 10 month $\hat{V}$.

**Longitudinal Analyses.** One of our research hypotheses was concerned with the long term stability of autonomic activity such that stable high $\hat{V}$ would be indicative of a more organized system. We addressed this question in two ways: 1) by creating a mean score which averaged each subjects' $\hat{V}$ across the three ages, and 2) by forming groups based on the median split of $\hat{V}$ at each age and placing subjects who were high on vagal tone at each age into the high group, subjects who exhibited low $\hat{V}$ at the three ages into the low group, and comparing them to the rest of the sample who displayed instability of $\hat{V}$ across this period.

The mean score was correlated with the 5, 10, and 18 month behaviors and only three relationships emerged. Greater mean $\hat{V}$ was related to lower levels of parent-rated frustration at 18 months, $r = -.29$, $p < .05$. There was also a tendency for infants with high mean $\hat{V}$ to
be more negatively reactive at 18 months, $r = .26$, $p < .08$. Mean HP was positively related to 5 month negative reactivity and negative related to 5 month regulation. That is, infants who displayed high levels of HP across the first 18 months of life were more reactive and less regulatory at 5 months. These same infants were also rated as low on fear at 18 months, $r = -.29$, $p < .05$.

Creating stable $\hat{V}$ groups across the three ages resulted in N's of 9, 5, and 33 for the stable low, stable high, and unstable groups, respectively. Repeated measures ANOVAs on the reactivity, regulation, and temperament variables revealed several significant relations. As can be see in Table 3, all but one of the behavioral variables were found to have interaction effects. Follow-up univariate ANOVAs were performed some group differences emerged.

Negative reactivity at 5 months of age, $F(2,41) = 4.18$, $p < .02$, differed for the stable low $\hat{V}$ group. Infants who displayed low vagal tone across the first 18 months of life were less negatively reactive to arm restraint than the stable high $\hat{V}$ and unstable $\hat{V}$ groups. While there was a significant interaction effect for parent-rated temperament, follow-up analyses only revealed trends. Infants with low stable $\hat{V}$ were rated as more fearful at 10 months and more frustrated at 18 months than infants who exhibited high $\hat{V}$ across the first 18 months.

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**Reactivity/Regulation Groups**

Conceptually, reactivity and regulation are believed to be interdependent and our data support this. Because individuals may vary on the degree to which they react and regulate that reaction, we created groups based on whether infants were high or low in reactivity as well as high or low in regulation, and tested whether they exhibited differences in vagal tone (see Fox, 1989). Four groups - low react/low regulation (LL), low react/high regulation (LH), high...
react/low regulation (HL), and high react/high regulation (HH) were formed by aggregating the subjects' scores across the three age periods and using median splits on the aggregated reactivity and regulation scores. Repeated measures analysis of variance was performed with \( \bar{V} \) measured at 5, 10, and 18 months as the repeated factor and reactivity/regulation as the grouping variable. A significant interaction effect was found, \( F(8, 86) = 9.43, p < .0001. \) Follow-up univariate ANOVAs revealed a significant group effect for 5 month \( \bar{V}, F(4, 43) = 4.76, p < .01. \) Planned contrasts revealed that infants in the HH group exhibited higher \( \bar{V} \) at 5 months, \( M = 3.55, \) than the HL, LH, and LL groups, \( M's = 3.02, 2.55, 2.81, \) respectively. The HL group was also significantly higher in \( \bar{V} \) than the LH group. Thus, infants who reacted negatively to a frustrating stimulus but also exhibited high levels of regulatory behaviors were more likely to have high \( \bar{V} \) at 5 months.

Univariate analysis of variance was also used to test whether the reactivity/regulation groups were different on mean \( \bar{V}. \) A significant result was found, \( F(3, 43) = 2.78, p < .05. \) Follow-up contrasts revealed that the LH group was significantly lower in mean \( \bar{V}, M = 3.31, \) than the HL, \( M = 3.82, \) and HH, \( M = 3.88, \) groups.

Discussion

The results of our analyses on the stability of behavior and autonomic activity across the first 18 months of life were mixed, although a pattern did emerge for both behavior and physiology after 5 months of age. As expected, maternal perceptions of temperament were stable across all ages which is consistent with previous research. The lack of concurrent relations between maternal ratings and observed behavior in the present study reinforce the conclusion that these data reflect stability of maternal perceptions and not necessarily that of infant behavior. Performance on the Bayley exam was also stable from 5 to 18 months and from 10 to 18 months despite a significant decrease in scores at 10 months.

The pattern that did emerge from these data was stability from 10 to 18 month. In addition to stability of mental performance and maternal ratings of temperament across this
period, there was a trend for regulatory behavior such that infants who exhibited high (or low) levels of regulation during a frustration task at 10 months were more likely to do the same 8 months later. What is most interesting is that this pattern of behavioral stability was mirrored by the stability of heart period and vagal tone from 10 to 18 months. Research has shown autonomic activity to be discontinuous from early infancy but that toward the end of the first year of life stability improves (Fox, 1989; Fracasso, Porges, Lamb, & Rosenberg, 1994). Likewise, studies of behavior have shown improved stability after the first 6 months of life (Rothbart, 1986). Taken together, these data suggest that behaviors and physiology become more consolidated toward the end of the first year. Differing rates of maturation may contribute to the instability often seen in early infancy. However, it may be that once having progressed through the biobehavioral shifts in development during which the organism is believed to reorganize behaviorally and physiologically (Emde, Gaensbauer, & Harmon, 1976), infant behavior and physiology become more stable and predictable.

In contrast to the stability data, the relationship between behavior and autonomic patterning was not as demonstrable as few associations were found. The relations that did emerge, however, support earlier studies. For example, the finding that 5 month old infants with high vagal tone performed better on the Bayley exam than infants with low vagal tone confirms previous research which has consistently described a relationship between $V^V$ and cognitive performance (Fox & Porges, 1985; Richards & Cameron, 1989). The present data strengthen the argument that $V^V$ is a marker of developmental status.

At 18 months high levels of $V^V$ were related to greater negative reactivity. This result is similar to a study of Porges (Porges et al., 1994) which found high levels of $V^V$ to be related to ratings of difficultness thus providing what might be observable evidence that these infants are more negatively reactive. However, it is important to note that the infants in our study were older and were observed in a frustration task rather than across a variety of situations. Moreover, we found that 18 month olds with high vagal tone were rated as more positive and
less negative by their mothers. Thus it appears that whereas infants with high vagal tone may continue to respond more negatively when they are 18 months of age they do so under specific circumstances. Clearly, more observational research is needed to fully understand the role of vagal tone in behavioral development.

The only behavior to show discontinuity in our study was negative reactivity. Indeed, our data revealed an inverse relationship between negative reactivity at 5 and 18 months. Infants who were highly reactive to arm restraint at 5 months were less likely to respond negatively to toy removal at 18 months. Fox (1989) found a similar reversal in which infants who were more reactive to arm restraint at 5 months were more sociable and approaching at 14 months. It may be that the development of regulatory strategies, of which one function is to reduce/attenuate negative arousal, is more rapid and effective for the highly reactive infant.

Consider for a moment that an infant who exhibits high levels of negative reactivity might elicit more attention from the environment. Responses such as soothing or attempts to change the infant’s state to a more positive one, in turn, would provide important opportunities for learning regulatory strategies (Kopp, 1989). Interestingly, our finding that the highly reactive 5-month-olds also showed more regulatory behaviors at 18 months suggests this possibility.

In Fox’s 1989 study he also found that the highly reactive infants who became more sociable had high levels of V. In the present study, the relationship between V and behavior is not as clear because we did not use extreme groups for comparison. On the other hand, when we examined what might be considered a more organized response to frustration we found a link to vagal tone. By crossing reactivity with regulation, we found that infants who reacted strongly to frustration but who also exhibited more regulatory behaviors had high V at 5 months of age. Responding to a frustrating task with negative reactivity is both appropriate and adaptive. It motivates the infant to remove the aversive stimuli and elicits responses from the environment. Regulating these responses with self-comforting behavior or reorientation is also adaptive particularly if the obstacle that is causing the frustration cannot be removed. This
finding further supports Porges' (1992) contention that high vagal tone underlies flexible responses to environmental demands.

Controlling for maturational changes by examining infants who maintained high or low levels of vagal tone across the three ages did not result in any new findings. Rather, the results were similar to those found for concurrent links between autonomic patterning and behavior (e.g., Bayley). Our data did reveal one interesting finding; infants with low mean $\tilde{V}$ were more likely to be low in reactivity but high in regulation. Fox (1989) hypothesized that this group, the LH group, might be inhibited. Our findings confirm this hypothesis and support the work of Kagan (Kagan, Reznick, & Snidman, 1987) that behaviorally inhibited infants have low parasympathetic tone.

The study of infant behavior and physiology is complicated by the confluence of several areas of development and their differential rates of maturation. In the present study we examined stability in infant temperament and autonomic patterning and their interrelationships with mixed results. The findings that did emerge, however, suggest that behavior becomes more organized toward the end of the first year of life and that it is related in a limited way to vagal tone.
Footnotes

1 Support for this paper was provided by a grant from the National Institute of Mental Health (#MH 44324) and a grant from the Pennsylvania State University Biomedical Research Support Program to the first author. We would like to thank all the mothers and infants who participated in the study. We would also like to gratefully acknowledge Julia Braungart and Margaret Fish for their assistance.

2 Refer to Stifter & Braungart (in press) for a more detailed description of the individual behaviors.

3 The heart period variance measure was highly correlated with the $\hat{V}$ measure at all ages, $r$'s > .9, therefore, it was dropped from further analyses.

4 Only 47 subjects with artifact free data at all three ages were available for analyses. These 47 subjects were compared to those with missing values on all the behavioral measures using analysis of variance and no significant differences were found.
References


Table 1  
Intercorrelations among the behavioral variables

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<td>4. Parent-rated fear&lt;sup&gt;2&lt;/sup&gt;</td>
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<td>.22+</td>
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<td>.26*</td>
<td>.37**</td>
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Ten Months

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<td>5. Negative reactivity</td>
<td>.20+</td>
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<td>6. Regulation</td>
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<td>.23*</td>
<td>.22*</td>
<td>.20+</td>
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<td>7. Parent-rated frustration&lt;sup&gt;1&lt;/sup&gt;</td>
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<td>.35**</td>
<td>.29*</td>
<td>.38**</td>
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<tr>
<td>8. Parent-rated fear&lt;sup&gt;2&lt;/sup&gt;</td>
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<td>.21+</td>
<td>.36**</td>
<td>.48***</td>
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Eighteen Months

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<tr>
<td>9. Negative reactivity</td>
<td>-.41**</td>
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<td>10. Regulation</td>
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<td>11. Parent-rated anger&lt;sup&gt;3&lt;/sup&gt;</td>
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<td>12. Parent-rated fear&lt;sup&gt;4&lt;/sup&gt;</td>
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Note: + - p < .1, * - p < .05, ** - p < .01, *** - p < .001; ¹ - IBQ distress to limitations dimension; ² - IBQ distress to novel objects and persons dimension; ³ - TBAQ anger dimension; ⁴ - TBAQ social fear dimension.
Table 2
Means and standard deviations for heart period and vagal tone at 5, 10, and 18 months

<table>
<thead>
<tr>
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<th>18 Months</th>
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<tr>
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<td>SD</td>
<td>Mean</td>
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<td>Heart Period (msecs)</td>
<td>414.99</td>
<td>27.2</td>
<td>457.52</td>
<td>29.1</td>
<td>494.85</td>
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<tr>
<td>Vagal Tone (log)</td>
<td>2.98</td>
<td>.7</td>
<td>3.64</td>
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<td>1.0</td>
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Table 3
Means, Standard Deviations, and Significance Tests for the 5, 10, and 18 Month Vagal Tone Groups

<table>
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<tr>
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<th>Effects</th>
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<tr>
<td><strong>Negative Reactivity</strong></td>
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<tr>
<td>Low V</td>
<td>.92 (.2)</td>
<td>1.70 (.1)</td>
<td>1.17 (.8)</td>
<td>F (df)</td>
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<tr>
<td>High V</td>
<td>2.62 (.9)</td>
<td>1.63 (.9)</td>
<td>1.80 (.5)</td>
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<tr>
<td>Unstable V</td>
<td>2.12 (1.1)</td>
<td>1.74 (.9)</td>
<td>1.50 (.9)</td>
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<td><strong>Regulation</strong></td>
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<td>Interaction</td>
</tr>
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<td>Low V</td>
<td>-.26 (.2)</td>
<td>.20 (.1)</td>
<td>.04 (.2)</td>
<td>5.81 (6,80)***</td>
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<tr>
<td>High V</td>
<td>-.11 (.2)</td>
<td>.12 (.1)</td>
<td>-.02 (.1)</td>
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<tr>
<td>Unstable V</td>
<td>.02 (.3)</td>
<td>.12 (.2)</td>
<td>-.02 (.2)</td>
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<td><strong>Parent-rated frustration</strong></td>
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<td>Interaction</td>
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<tr>
<td>Low V</td>
<td>3.60 (1.1)</td>
<td>3.44 (.4)</td>
<td>4.46 (.8)</td>
<td>11.25 (6,74)**</td>
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<tr>
<td>High V</td>
<td>3.36 (.6)</td>
<td>3.40 (.7)</td>
<td>3.59 (.4)</td>
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<td>Unstable V</td>
<td>2.98 (1.0)</td>
<td>3.58 (.8)</td>
<td>4.12 (.8)</td>
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<td><strong>Parent-rated fear</strong></td>
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<td>Interaction</td>
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<tr>
<td>Low V</td>
<td>2.19 (.7)</td>
<td>3.48 (.8)</td>
<td>4.37 (1.2)</td>
<td>35.03 (6,74)***</td>
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<td>1.77 (.5)</td>
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<td>Unstable V</td>
<td>2.31 (.8)</td>
<td>2.92 (.7)</td>
<td>4.09 (.8)</td>
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Note: * - p < .05  
** - p < .01  
*** - p < .001