Physiological and Behavioral Regulation in Two-Year-Old Children with Aggressive/Destructive Behavior Problems

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Calkins, S.D. & Dedmon, S.A. (2000). Physiological and behavioral regulation in two-year-old children with aggressive/destructive behavior problems. *Journal of Abnormal Child Psychology, 28, 103-118.*

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Abstract:

A sample of 99 two-year-old children was selected on the basis ofparents' responses to two administrations ofthe Child Behavior Checklist for two- to three-year-olds. Forty-nine ofthese children displayed symptoms of aggressive/destructive (externalizing) problems that were in the borderline clinical range (labelled "high risk") and 50 children displayed few such symptoms ("low risk"). The children were assessed in a series of laboratory procedures that were intended to be emotionally and behaviorally challenging, during which time heart rate was recorded and behavior was observed. To assess physiological regulation, resting measures of heart period and respiratory sinus arrythmia (RSA), and heart period change and RSA suppression were derived from these procedures. To assess emotional and behavioral regulation, children's affect and on-task versus types of off-task behaviors were measured. Results indicated that children in the high-risk group did not differ from children in the low-risk group on the resting measure of heart period. Boys displayed lower heart rate than did girls, regardless of risk group. However, boys in the low-risk group differed from boys in the high-risk group in terms of resting measures of RSA. Children in the high-risk group did display significantly and consistently lower RSA suppression (physiological regulation) during the challenging situations than did the children in the low-risk group. High-risk children displayed more negative affect and dysregulated emotion regulation behaviors than did the low risk children. These findings are discussed in terms of the development of behavioral and emotional regulation that underlie adaptive versus maladaptive behavior.

KEY WORDS: Behavior problems; aggression; regulation; heart rate.

Article:

The significance of the early display of externalizing- type problems for later behavior as been well-established. Preschoolers displaying aggressive, noncompliant, destructive, and impulsive behaviors are likely to display such behaviors during school-age (Cummings, Ianotti, & Zahn-Waxler, 1989; Rose, Rose, & Feldman, 1989) and are at risk for peer rejection and associated problems (i.e., dropping out of school; Parker & Asher, 1987). Aggressive behavior in childhood is predictive of aggression in early adulthood (Olweus, 1979). Recently, there has been a great deal of interest in the correlates and predictors of aggressive behavior that may be observed during early childhood and infancy (Bates, Bayles, Bennet, Ridge, & Brown 1991; Campbell, 1990,1991, 1995; Maziade et al., 1985). Identifying relevant and related child and environmental factors may assist researchers in understanding the precipitating factors in the early development of aggressive patterns of behavior.

In considering the dimensions of early behavior that may be relevant to aggression and its development, it is useful to consider how such behavior is often defined and explained in young children. For example, in characterizing the behavior of children with early externalizing behavior problems, there is often reference to a lack of control, undercontrol, or poor regulation (Campbell, 1995; Lewis & Miller, 1989). Clearly, the acquisition of regulatory skills is an important developmental achievement. By the time the child has reached the end of the toddler period, he or she is expected to be capable of emotional, behavioral, and physiological regulation that supports an emergent independent identity and self-sufficient behavior (Cicchetti, Ganiban, & Barnett, 1991; Kopp, 1982). However, although there is an identifiable developmental progression in the acquisition of self-regulatory skills and abilities within these domains, individual differences may effect how a child demonstrates competent regulation. These individual differences have been shown to have important implications for psychosocial adaptation and the acquisition of important developmental achievements (Sroufe,1996). Consequently, an examination of early correlates of externalizing difficulties should include a focus on regulatory functioning in the physiological, emotional, and behavioral domains.

Physiological Underpinnings of Externalizing Behavior

One category of correlates of aggressive behavior that has received attention recently is biological or psychophysiological functioning (Lahey, Hart, Pliszka, Applegate, & McBurnett, 1993; Mezzacappa, Kindlon & Earls, 1996; Raine, 1996). In the adult personality and psychopathology literature, a number of studies suggest links between aggressive and antisocial behavior and autonomic functioning using such indicators of autonomic functioning as heart rate and skin conductance (see Lahey et al., 1993 and Raine, 1996 for reviews). One conclusion to be drawn from this literature is that underarousal of the autonomic nervous system as reflected in low heart rate (HR) in particular is a core characteristic of aggressive behavior in adolescents and adults (Lahey et al., 1993; Raine, 1996; Raine, Venables, & Williams, 1990). The studies examining resting measures of heart rate and relations to aggression in children are few, however. Eisenberg and colleagues (Eisenberg et al., 1996) examined relations between resting HR in normal school age children and parent report of behavior problems and found modest relations between low resting HR and the incidence of problem behavior. Zahn-Waxler and colleagues found no association between problem behavior in preschoolers and heart rate (Zahn-Waxler, Cole, Welsh & Fox, 1995). Raine and colleagues linked low resting heart rate to behavior problems in late childhood (Raine & Jones, 1987; Raine, Venables, & Mednick, 1997) and found that low resting HR in adolescence is predictive of criminal behavior in adulthood. Raine suggested that low autonomic nervous system (ANS) arousal may be a genetic marker for aggressive behavior (Raine et al., 1990). If this hypothesis is valid, then one might expect to find a similar pattern of low resting HR in very young children who may be showing signs of early difficulties with aggressive behavior. To date, however, few studies have been conducted with very young children that examine concurrent relations between aggression and HR, and there has been little discussion of the developmental aspects of the phenomena. It is unclear, for example, whether low resting heart rate is a contributor to, or a consequence of, aggressive behavior, conduct problems, and criminal activity.

Other dimensions of cardiac activity, particularly those that reflect dimensions of physiological or behavioral regulation, have also been investigated in studies of early behavior problems in young children. One dimension of cardiac activity that has been linked to regulation in young children is heart rate variability. Although there are multiple ways to measure this variability, Porges (1985, 1991, 1996) and colleagues developed a method that measures the amplitude and period of the oscillations associated with inhalation and exhalation. Thus, this measure refers to the variability in heart rate that occurs at the frequency of breathing (respiratory sinus arrythmia, RSA) and is thought to reflect the parasympathetic influence on heart rate variability via the vagus nerve. Porges has termed this measure of heart rate variability vagal tone (Porges, 1996; Porges & Bryne, 1992). Although there are other components of HR variability, the RSA measure has been identified as suitable for the study of physiological links to multiple dimensions of behavioral functioning in young children (Huffman et al., 1998; Richards, 1985, 1987). For example, high resting RSA is one index of autonomic functioning that has been associated with appropriate emotional reactivity (Stifter & Fox, 1990) and good attentional ability (Richards, 1985, 1987; Suess, Porges, & Plude, 1994). Several studies have linked high RSA in newborns with good developmental outcomes, suggesting that it maybe an importantphysiological component of appropriate engagement with the environment (Hofheimer, Wood, Porges, Pearson, & Lawson, 1995; Richards & Cameron, 1989).

This research suggests that children with low RSA may be at risk because they may have difficulty attending and reacting to environmental stimulation (Porges, 1991; Wilson & Gottman, 1996). Again, however, there have been few studies examining the relations between RSA and aggressive behavior in young children. Pine and colleagues (Pine et al., 1998) recently reported that 11-yearold boys with externalizing symptoms had lower heart period variability. Mezzacappa and colleagues (Mezzacappa et al., 1997) report similar findings among adolescent males. Both researchers conclude that such relations may occur because of parasympathetic links to regulatory abilities involving attentional and behavioral control. Thus, it is of importance to explore this association in both male and female children displaying signs of regulatory difficulties.

A third dimension of cardiac activity that may be relevant to a study of the psychophysiological correlates of aggression refers to changes in cardiac activity in response to an external stress or challenge. Heart rate changes are thought to be a primary indicator of attention (see Ruff & Rothbart, 1996). Typically, deceleration of heart rate reflects attention directed outward (processing novel stimulation, for example), while acceleration reflects attention directed inward (during problem solving conditions; Ruff & Rothbart, 1996). Thus, it may be useful to examine whether individual differences in the ability to control attention, as indexed by heart rate changes, are related to early behavior problems. Eisenberg (Eisenberg et al., 1996) found that there was an association between boys' problem behavior and changes in HR during a distressing film, but argued this relation was due to the lower resting HR measure as opposed to any independent change in HR. Wilson and Gottman (1996) hypothesized that excessive heart rate reactivity may interfere with the effective allocation of attentional abilities to meet task demands. Given that resting measures of cardiac activity and response measures have been shown to be related in children (Calkins, 1997; Suess et al., 1994), it would be important to examine these effects independently.

Finally, a measure of cardiac change that may be more directly related to the kinds of problems displayed by aggressive children is a decrease (suppression) in RSA during situations where coping or emotional and behavioral regulation is required. Suppression of RSA during demanding tasks may reflect physiological processes that allow the child to shift focus from internal homeostatic demands to demands that require internal processing or the generation of coping strategies to control affective or behavioral arousal. Thus, suppression of RSA is thought to be a physiological strategy that permits sustained attention and behaviors indicative of active coping that are mediated by the parasympathetic nervous system (Porges, 1991, 1996; Wilson & Gottman, 1996). Recent research indicates that suppression of RSA during challenging situations is related to better state regulation, greater self- soothing and attentional control in infancy (DeGangi, DiPietro, Porges, & Greenspan, 1991; Huffman et al., 1998), fewer behavior problems and more appropriate emotion regulation in preschool (Calkins, 1997; Porges, Doussard-Roosevelt, Portales, & Greenspan, 1996), and sustained attention in school-age children (Suess et al., 1994). The extension of these research findings is that while the ability to suppress RSA may be related to complex responses involving the regulation of attention and behavior, a deficiency in this ability may be related to early behavior problems, particularly problems characterized by a lack of behavioral and emotional control (Porges, 1996; Wilson & Gottman, 1996). Moreover, in general, individuals with low resting RSA are less able to suppress RSA to meet environmental challenges. Thus, it would be useful to examine both dimensions of RSA (resting and response) and their relations to emotional and behavioral regulation. In fact, two recent studies with young children indicate that although resting and response measures of RSA are related to one another, they may be differentially related to temperamental reactivity and regulation (Calkins, 1997; Huffman et al., 1998).

Behavioral and Emotional Regulation and Their Relation to Externalizing Problems

Behavioral and emotional regulation refer to processes that serve to manage arousal and support adaptive social and nonsocial responses (Calkins, 1994; Thompson, 1994). Emotion regulation strategies such as self- comforting, help-seeking, and distraction may assist the child in managing early temperament-driven frustration and fear responses in situations where the control of negative emotions may be necessary (Stifter & Braungart, 1995). Moreover, emotion regulation skills may be useful in situations of positive affective arousal because they allow the child to keep arousal within a manageable and pleasurable range (Grolnick, Cosgrove, & Bridges, 1996; Stifter & Moyer, 1991).

Examples of behavioral management or control include compliance to maternal directives and the ability to control impulsive responses (Kopp, 1982; Kuczynski & Kochanska, 1995). Increasingly, these kinds of demands are placed on children during toddlerhood; the task for the toddler is to overcome impulsive reactions or to suspend desired activity to meet external demands. Self-control is demonstrated when a child is able to comply with demands, delay specific activities, and monitor his own behavior. As the balance of control shifts from external regulation to internal regulation, the different dimensions of self-control begin to be exhibited more frequently and in situations when caregivers are not present (Kopp, 1982).

One example of how problematic emotion regulation may lead to deficiencies in social competence is the possible relation between anger management and aggression. Eisenberg, Fabes & colleagues (Eisenberg et al., 1993, 1994; Fabes & Eisenberg, 1992) have studied the role that anger, and the regulation of anger reactions, may play in the development of social competence. They found that individuals who are highly emotional in response to anger- inducing events and low in regulation are likely to display aggression. Eisenberg hypothesizes that the intensity of anger is related to a loss of behavioral control. Strategies such as attentional control, avoidance, and instrumental coping may be useful in dealing with anger (Eisenberg et al., 1993, 1994). Children who fail to use such strategies tend to vent their emotions and may become aggressive. By the end of the second year of life, behavioral and emotional regulation patterns may be firmly established to the extent that they influence early personality and social interaction skills and contribute to problematic patterns of behavior (Calkins, 1994; Cicchetti et al., 1991; Cole, Michel, & O'Donnell, 1994; Stifter, Spinrad, & Braungart-Rieker, 1999).

The goal of the current study was to examine multiple measures of regulation in two-year-old children at risk for externalizing problems (those characterized by aggressive and destructive behavior) versus children at low risk for such problems. The first question addressed in the study was whether these groups would differ in terms of resting measures of cardiac activity. The adult literature would support the prediction that high-risk children would display higher resting heart period (lower resting HR); however, this literature focuses almost exclusively on older male subjects already exhibiting severe and chronic conduct problems (Raine, 1996). Therefore, we also examined whether male and female children in the two risk groups would differ on this measure. The second question addressed the possibility that group differences would exist between the risk groups on a measure of resting heart rate variability (RSA). Given the observation that children with high resting RSA are more responsive, attentive, and reactive to the environment, this analysis examined whether high-risk children who might have difficulties with attention, or relatively immature attention skills (Richards & Cameron, 1989) would display low resting RSA. The third question concerned response patterns of both heart period and RSA. It was hypothesized that, across all children, there would be a suppression in RSA during the challenging episodes because these situations would require a coping response supported by a decrease in heart rate variability. In addition, it was hypothesized that children at risk for externalizing problems would show less suppression of RSA (which may index the physiological regulation that underlies and supports coping) in situations requiring an active coping response. The final question addressed in this study was whether children at risk for externalizing problems would differ in terms of measures of affective and behavioral regulation. It was hypothesized, based on the traditional characterization of these children as undercontrolled, that they would display less adaptive regulation behaviors (e.g., more negative affect, venting, less attention to the task objects) than their low risk counterparts.

METHOD

Subjects

Four hundred and seventy-four 2-year-old children (X = 30 months-of-age, 248 boys and 226 girls) from a small southeastern city were recruited for aggressive behavior problem screening. Sixty-five percent of the families were European American, 30% were African American, and the remaining 5% were Asian, Hispanic, or mixed-race. The families were classified into SES groups on the basis of employment information provided by the parents on the screening questionnaire (Hollingshead, 1975). Based on Hollingshead scores, sixty-one percent of the families were classified as middle class, 25% as lower class, and 14% as upper class. The racial and SES characteristics are representative of the county where recruitment took place. The parents of the larger recruitment sample were contacted through local childcare centers, pediatricians' offices, and county health and human services facilities. Parents completed a behavior problem questionnaire, or were assisted in completing the form if they had reading difficulties, and a subset of the 474 children was selected for participation in the laboratory portion of the study. Procedures for selection of the target sample are described below.

Target Sample Selection

Of the larger screened sample a total of 121 children were initially selected for follow-up assessment on the basis of parents' responses to items on the Child Behavior Checklist (CBCL, 2-3 version, Achenbach, Edelbrock, & Howell, 1987). To identify a group of children at high risk for problems with aggressive behavior, the externalizing scale score (total score for aggressive and destructive subscales) for all 474 children was computed. Next, following Achenbach (1992), a t-score cut-off of 60 was established. This represented the borderline clinical range in Achenbach's (1992) study; children scoring in this range were 10 times more likely to have been referred for clinical services than children below this point. This cut-off represented the 80th percentile in the screened sample (the mean score for the entire screened sample was 52). As a contrast low-risk group, children whose t-score on the externalizing scale was 50 or below were selected. This represented the 50th percentile in the screened sample. Because not every child who was screened and met these criteria could be included in the study (e.g., the child was 3 years old by the time the questionnaire was scored, the family refused to participate or repeatedly missed appointments, or the family could not be contacted for an appointment), and because attempts were made to match the two risk groups in terms of race, SES, sex and age, the initial selected sample consisted of 121 children (70 high risk and 51 low risk).

The high-risk group was originally intended to have an n of approximately 50 children. However, given the possibility that the screening process identified children with only transient behavior problems, a second assessment of externalizing problems was conducted when the parent and child came to the laboratory for the physiological and behavioral assessment, approximately two months later. Analysis of the two scores over the 2-month period indicated they were highly correlated ($r = .78$, $p < .0001$). However, there was a significant decrease in the level of problem behavior among the high-risk group, but not among the low risk group, $F(1) = 22.01$, $p < .001$ (for the interaction term of group x time). For this reason, the selected sample of children was adjusted by using the mean of the two CBCL scores. Thus, the final sample consisted only of children whose mean score across the 2-month period was 60 or above ($n = 49$, 24 males) or 50 or below ($n = 50$, 25 males).

The two risk groups were matched on age, SES ($M = 37$ for high risk and $M = 38$ for low risk), race (34 caucasians in the high-risk group, 32 caucasians in the low- risk group) and marital status (34 married in the high-risk group, 39 married in the low-risk group). There were differences between the groups on both measures (recruitment and assessment) of externalizing problem behavior, $p < .001$ for both comparisons, $M = 64.47$ and 62.57 for the high-risk group, and $M = 45.74$ and 44.32 for the low- risk group. However, there was no longer an interaction of time of assessment and group in terms of externalizing. In addition, there were no other differences between the two groups in terms of other sample characteristics. There were no differences between children who met the behavior problem criteria for the study but did not participate and those who met the criteria and did participate on any relevant measure (race, sex, age, SES, marital status, or problem score). Finally, there were no differences on these measures between the children who were dropped from the final sample because they did not have the appropriate mean CBCL score and those who were retained in the sample.

Procedures

After subjects were selected for inclusion in the study, parents were contacted to schedule a laboratory assessment. This assessment took place within two to three months of completion of the original CBCL. Mothers were asked to accompany their children to the laboratory where the children were assessed using several procedures in a laboratory playroom. First, the experimenter, who was blind to the child's risk group status, placed three disposable pediatric electrodes in an inverted triangle pattern on the child's chest while the child was seated at a table next to the mother. The electrodes were connected to a preamplifier, the output of which was transmitted to a vagal tone monitor (VTM-I, Delta Biometrics, Inc, Bethesda, MD) for R-wave detection. The vagal tone monitor displayed ongoing HR and computed and displayed RSA (vagal tone) every 30 seconds. A data file containing the interbeat intervals (IBIs) for the entire period of collection was transferred to a laptop computer for later artifact editing (resulting from child movement) and analysis.

While connected to the heart rate collection equipment, the child was observed during a 6-episode sequence. The baseline episode consisted of a 5-minute segment of the videotape "Spot," a short story about a puppy that explores its neighborhood. While this episode was not a true baseline given that the child's attention was engaged in an external stimuli, it was sufficient to keep the child sitting quietly and showing little affect. Given the ages of the subjects in this study, such a stimulus was necessary in order to keep the child seated at the table and to limit movement artifact in the HR data. Following the baseline episode, the child was observed in several situations designed to elicit physiological stress and coping. The onset of each challenge episode was marked on the computer file of the IBI data through the use of an electronic signal controlled by the experimenter. First, one experimenter engaged the child in a 2-minute positive episode—a game of peek-a-boo with a puppet named Spot during which the experimenter's goal was to elicit smiling and laughter in the child. Next was an episode designed to elicit fear, in which a second experimenter presented the child with a large, realistic, and moving spider. The experimenter encouraged the child to touch the spider during the 2-minute presentation. In the next episode, problem solving, the child was presented with a difficult puzzle to solve, and the mother was asked to help the child piece the puzzle together during the four-minute period. The fifth episode was an empathy situation, during which the child looked at books for two minutes while the audiotape of a crying toddler was played just outside the playroom door. Finally, during the frustration episode, the experimenter asked the child whether he or she would like a snack. The experimenter placed a clear plastic container of cookies on the table, which the child was unable to open, and left the room. This episode lasted for two minutes. These types of tasks are considered appropriate for use with young children, and are typically employed to elicit measures of emotional and behavioral regulation in response to challenge or stress (c.f. Calkins, 1997; LAB-TAB, Goldsmith & Rothbart, 1993; Grolnick, Bridges, & Connel 1996). For each of the challenge episodes, the mother sat nearby and was asked to respond normally to the child but not to initiate interaction (except in the case of the problem-solving episode where she was explicitly instructed to assist her child).

Each challenge episode was separated from the subsequent episode by a very brief (2 to 3 minute) period during which the child was free to interact with the mother while the experimenter gathered materials for the next episode. This period was necessary, because the children's tolerance for the HR collection (and in particular, remaining seated for collection) was often quite low. In addition, this break was not considered an additional resting measure of cardiac activity with which to contrast the subsequent challenge episode because the child was almost always engaged with the mother or moving around (or both). Moreover, there was concern about carry-over effects from the episode to the break that would call into question the validity of using the break to derive resting measures. For these reasons, the initial baseline measure only was considered for analyses involving contrasts with the challenge episodes.

Assessment of Child Defiance

Two additional episodes were used to generate a measure of defiant behavior in the laboratory, which served as a validity check on the children's problem group assignment. This assessment followed the episodes during which heart rate was collected and the electrodes removed from the child's chest. For the first episode, the experimenter asked the mothers and children to sit beside each other on the floor and gave them a Sesame Street toy farm set. The experimenter asked the mothers to play with their children just as they would if they had a few minutes at home to play with their children. The experimenter left the room and allowed the mothers and children to play for 4 minutes. During the second episode, the experimenter presented the children with a set of three different puzzles with increasing levels of difficulty. The experimenter unobtrusively monitored the amount of time given to the children for each puzzle and gave the children the next puzzle when the mothers and children were done with the puzzle or when the maximum time limit was reached. A maximum of 2 minutes was given for the first puzzle; 3 minutes was given for the second puzzle; and 4 minutes was given for the last, most difficult puzzle. Mothers were told to help their children when they thought that their children needed help. It should be noted that, although compliance episodes (clean-up tasks or stop play tasks) are often used to derive measures of defiance, with children of this age, other tasks have been used to elicit compliance and are appropriate for examining defiance as well (Stifter et al., 1999).

Measures

Three types of measures were derived from the laboratory assessments: physiological measures (RSA and HP, and RSA suppression and HP change), emotional and behavioral regulation measures, and a measure of defiance.

Physiological Measures

To generate measures of cardiac activity from which to derive measures of resting heart period and RSA and heart period and RSA in response to challenge, the IBI files were edited and analyzed using MXEDIT software (Delta Biometrics, Bethesda, MD). Editing the files consisted of scanning the data for outlier points relative to adjacent data, and replacing those points by dividing them or summing them so that they would be consistent with the surrounding data. Data files that required editing of more than 2% of the data (12 data points in a 5-minute period, for example) were not included in the analyses.

Analysis of the IBI data consisted of applying the Porges (1985) method of calculating RSA. This method applies an algorithm to the sequential heart period data. The algorithm uses a moving 21-point polynomial to de- trend periodicities in HP slower than RSA. Then, a band-pass filter extracts the variance of HP within the frequency band of spontaneous respiration in young children, 0.24– 1.04 Hz. Although lower frequency bands maybe studied, research with young children has consistently examined this band and identified associations to child function-ing (Huffman et al., 1998; Porges et al., 1996; Stifter & Fox, 1990). The estimate of RSA is derived by calculating the natural log of this variance and is reported in units of $\ln(\text{msec})^2$. Heart period and RSA were calculated every 30 seconds for the 5-minute baseline period and the 4-minute problem-solving episode, and every 15 seconds for the 2-minute challenge episodes. These epoch durations are typical for studies of short duration tasks (Huffman et al., 1998). The mean RSA of the 15 and 30 sec epochs within each episode was used in subsequent analyses. If the standard deviation across the epochs was greater than 1.00 for RSA (indicating a high degree of variability over the course of the episode and calling into question the validity of the mean RSA value), that episode was excluded from subsequent analyses. Descriptive statistics for heart period and RSA for the baseline and challenge episodes are reported in Table I. As the table in-dicates, the data files of 16 children were not included in some of the analyses. A few children would not allow the experimenter to apply the HR electrodes (n = 3). In addition, the HR data collection equipment failed on several occasions (n = 4). However, the most common explanation for missing data was that the child pulled on the HR leads, which resulted in movement artifact affecting greater than 2% of the data in the HR file (n = 9).

Table I. Descriptive Statistics for Heart Period and RSA for Resting Epsiode and Five Challenge Episodes

		M	*SD*	Min	Max	*N*
Resting	Heart period	548.84	51.17	426.90	680.74	88
	RSA	5.75	11.41	1.10	8.58	
Positive	Heart period	524.81	43.32	433.86	641.50	85
	RSA	5.17	1.24	2.15	8.93	
Fear	Heart period	513.61	47.34	365.61	627.44	83
	RSA	4.94	1.15	2.04	8.18	
Problem-solving	Heart period	518.75	41.48	425.74	614.10	86
	RSA	4.74	1.13	2.18	7.29	
Empathy	Heart period	530.27	45.07	422.93	660.82	87
	RSA	5.25	1.28	2.14	8.15	
Frustration	Heart period	517.44	44.91	415.84	646.15	86
	RSA	5.00	1.25	2.47	8.57	

There was no relation between risk group membership and data loss.

Emotional and Behavioral Regulation Measures

In order to derive measures of emotional and behavioral regulation, the videotaped recordings were coded for verbal and facial affect and behavior using a computer based real-time coding system (OCS, Research Triangle Research Corporation, RTP, NC). Using this continuous time coding system, the coder was able to mark the exact onset and offset times of specific behaviors by striking preassigned keys. The resulting record of behaviors, throughout each task, allowed for a measure of duration of particular behaviors. Because an episode was occasionally shortened for various reasons (i.e., the child was very upset during novel toy), the measures of duration were then transformed into proportions of total time of episode.

Given that a number of studies have demonstrated associations between emotion regulation and emotional reactivity (Buss & Goldsmith, 1998; Calkins & Johnson, 1998, Stifter & Braungart, 1995), the affect episodes were scored for both kinds of behaviors. The taped affect episodes (positive, fear, empathy and frustration) were coded for instances of positive and negative affect using an age-appropriate coding scheme based on the work of Cole, Barret, & Zahn-Waxler (1992). Positive affect was defined as instances where the corners of lips were pulled up, cheeks were raised, and eyes were slightly squinted but the forehead was smooth. Negative affect included instances of sadness, anger, tension, worry, and vocal expression of fussing (negative verbalization associated with the emotions of anger, sadness, tension, and worry). Sadness was defined as instances where lip corners were turned down, the lower lip was depressed, inner brows were raised or lowered, and/or eyes appeared dropped. Anger was characterized by eyelids tightening and narrowing, or eyelids beings raised, lips pressed tightly together or if the mouth is opened, it should make a rectangular shape, and teeth clenched. Tension/Worry was characterized by tightened facial muscles, lowered brow, quick shifting of eyes, and/or repetitive twitching of the mouth. Reliability was computed using pearson correlations for duration of time and was 0.84 for positive affect and 0.90 for negative affect.

In addition to the emotion measures, each emotion episode was coded for behaviors commonly considered indicators of emotion regulation. These regulation strategies were chosen based on previous research measuring regulation in young children (Calkins, 1997; Calkins & Johnson, 1998; Stifter & Braungart, 1995). The videotaped episodes were coded using the same computer-based coding system employed to obtain measures of affect. For the emotion episodes (positive, fear, frustration, and empathy), these behaviors were construed as emotion regulation behaviors. For the mother-child problem-solving episode, the behaviors were construed as behavioral regulation measures. These behaviors, for both types of episodes, included: (a) self-comforting—thumbsucking, hair twirling, or other automanipulative behavior; (b) mother orientation—looking to mom, talking to or playing with mother, touching or pulling on mom; (c) distraction—attending to or manipulating an object other than the task object; (d) aggression/venting—banging, kicking, throwing, hitting the task object, or aggression directed toward mother or experimenter; (e) orienting to task object— looking at, touching, or manipulating task object. Other behaviors (orienting toward experimenter, scanning, unscorable behaviors) were coded also, but were not included in subsequent analyses because the overall occurrence was low.

The problem-solving episode was coded for behavioral regulation using similar measures. Given that the mother was instructed to assist her child with the puzzle, these measures were coded in terms of the child's response to the mother's verbal and physical attempts to help the child. On task behavior was defined as responses that involved orienting toward and touching, or manipulating the puzzle. Off task behavior was orienting away from the puzzle and mother. Venting/defiance was defined as tantrumming, physical aggression toward puzzle or mother, and hitting table or other objects. Facial affect was difficult to score during the episode, given the positioning of the child, the mother, and the puzzle. However, a measure of negative vocalizations was scored as child verbally refusing and/or fussing. The frequency of the behaviors was converted to a proportion by dividing frequency by total episode time.

The tapes were coded for both affect and regulation behavior by two research assistants who were blind to the children's risk group status, who coded 10% of the tapes together for training purposes and an additional 10% independently for reliability. Reliability correlations for the amount of time spent displaying certain affects ranged from 0.90 for unscorable affect to 0.99 for negative affect. For regulation behaviors the reliability correlations ranged from 0.80 for automanipulative behavior to 0.97 for orienting toward the focal object. Venting was a low occurring behavior with a reliability of 0.69. Finally, because the distribution of scores for both negative affect and venting were skewed toward 0, a log transformation was computed on these variables and used in all subsequent analyses.

Defiant Behavior

The videotaped mother-child interactions (farm toy and puzzle task) were scored for instances of child defiant behavior. Defiant behavior was defined as instances of child anger in response to a maternal request or directive, and defiance or tantrumming during the episode. Simple refusal was not included in this measure as this behavior is thought to be developmentally appropriate and not indicative of behavior problems (Crockenberg & Litman, 1987). The frequency of these behaviors was scored separately for both episodes. Reliability for these measures was 0.93 and 0.97 using Pearson correlations, with a kappa of 0.56 across both episodes. The mean proportion of defiant responses (out of total child responses) across the entire sample was 0.02 and 0.04 for the farm play and puzzle episode, separately.

RESULTS

Data Reduction

Given the large number of measures from the assessments, factor analysis was used to reduce the affect and behavioral data from the challenge episodes. The aim in using this approach was to reduce the data to generate a single measure of regulation from each episode. Analyses of the seven measures from each episode failed to yield single or even two-factor solutions for the five episodes. For this reason, these analyses were done using four of the measures about which specific hypotheses were made—negative affect, venting, distraction, and focal-object focus. Similar single factor solutions were generated for each of the five challenge episodes. For the Positive episode, this factor had an eigenvalue of 2.08, accounted for 52% of the variance, loaded (0.50 or greater) on negative affect, venting, distraction, and negatively (—0.50 or less) on focal object focus. For the Fear episode, this factor had an eigenvalue of 1.6, accounted for 54% of the variance, loaded on negative affect and distraction, and negatively loaded on focal object focus. For the Problem-Solving episode, this factor had an eigenvalue of 2.84, accounted for 71 % of the variance, loaded on negative affect, venting, off-task behavior, and negatively on on-task behavior. For the Empathy episode, this factor had an eigenvalue of 1.9, accounted for 50% of the variance, loaded on distraction and negative affect, and negatively on focal object focus. For the Frustration episode, this factor had an eigenvalue of 1.5, accounted for 53% of the variance, loaded on negative affect and venting. Because of the consistency of the factor load-ings, these five measures were labelled "dysregulation."

Risk Group Differences in Defiant Behavior in the Laboratory

To examine whether group differences in behavior as reported by parents would be observable in the laboratory, the child behaviors scored during the two mother- child freeplay interaction tasks were examined. A t-test comparing the low risk group to the high risk group revealed that the high risk children (M = .06 and .03) displayed significantly more defiance than did the low risk group (M = .01 and .00), $t(93) = —2.27$, $p < .02$ and $t(93) = —2.22$, $p < .03$ for the puzzle and farm play episodes, respectively. A second analysis compared the two groups of children in terms of whether any defiant behavior was displayed during the two episodes. This analysis revealed that the high-risk children were significantly more likely to engage in at least one defiant act (20 out of 48) than the low risk children (11 out of 48), $X^2 = 3.86$, $p = .05$. These data provide support for the risk group classification using the technique of multiple parental assessment of problem behavior, and suggest that the high-risk children's behavior was problematic across home and laboratory contexts. A comparison of boys versus girls in terms of defiant behavior revealed no significant differences.

Risk Group Differences on Physiological Measures

To examine the relations between risk group status and the measures of cardiac activity, several analyses were conducted. To examine whether there were gender differences or interactions of gender and risk group, gender was included as a grouping factor in all analyses. These analyses were conducted separately for the four types of physiological measures of interest.

Risk Group and Sex Differences in RSA

To examine whether there would be differences between the risk groups in terms of resting RSA, and to explore whether gender would be a factor in such differences, a two-way ANOVA was conducted, with risk group and gender as between-subjects factors and RSA from the baseline condition as the outcome measure. This analysis revealed no main effects for risk group or gender and an interaction of risk group and gender, $F(1, 87) = 4.62$, $p < .05$. This interaction is depicted in Fig. 1. As the figure indicates, boys in the low-risk group displayed significantly higher resting RSA than did boys in the high risk group. There was no baseline RSA difference between the low- versus high-risk girls.

Risk Group and Sex Differences in Resting Heart Period

To examine whether there would be differences between the risk groups in terms of resting heart period, and to explore again whether gender would be a factor in such differences, a two-way ANOVA was conducted with risk group and gender as between-subjects factors and heart period from the baseline condition as the outcome measure. This analysis revealed no main effect for risk group, a main effect for sex, $F(1, 87) = 56.42$, $p < .01$, and no interaction of risk group and gender. This analysis is depicted in Fig. 2. This analysis indicated that boys displayed significantly higher heart period (lower HR) during the baseline condition than did girls. The mean resting RSA for the high-risk group was 544.77

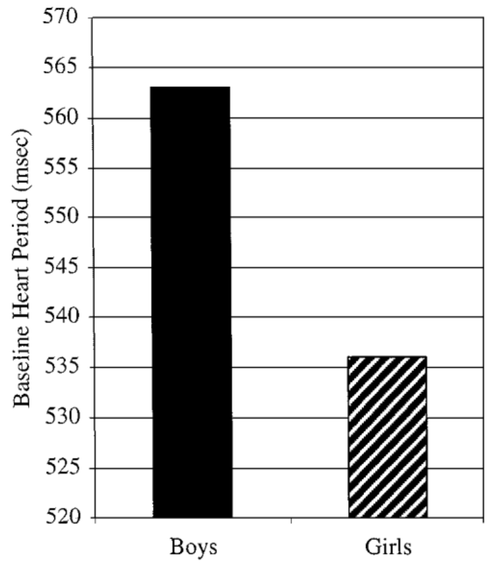

Fig. 2. Baseline heart period for boys versus girls.

(s.d. = 56.92) versus 553 (s.d. = 48.74) for the low-risk group.

Risk Group and Sex Differences in Suppression of RSA During Challenge

To address the question of whether there would be differences between risk groups in terms of RSA suppression, the data were first examined to determine whether a significant suppression effect was present from the

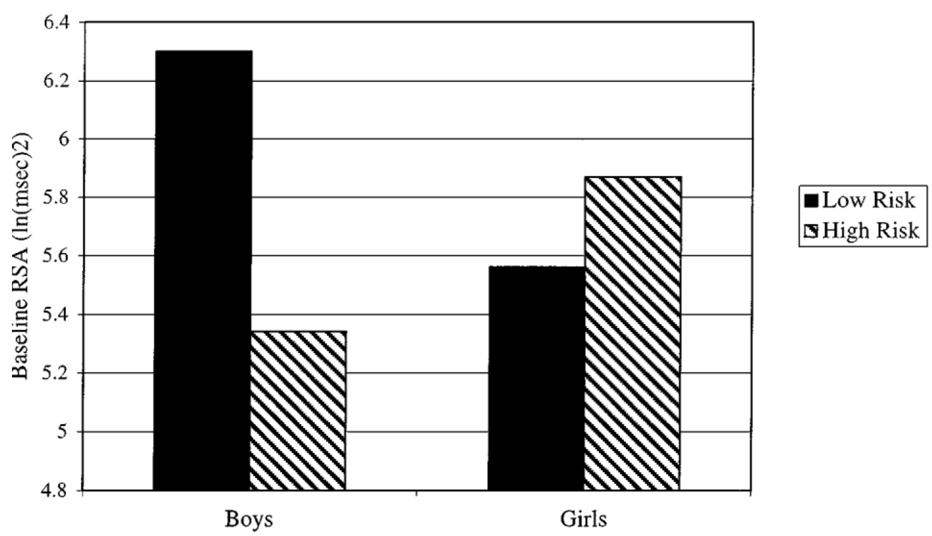

Fig. 1. Baseline RSA by gender and risk group (low versus high).

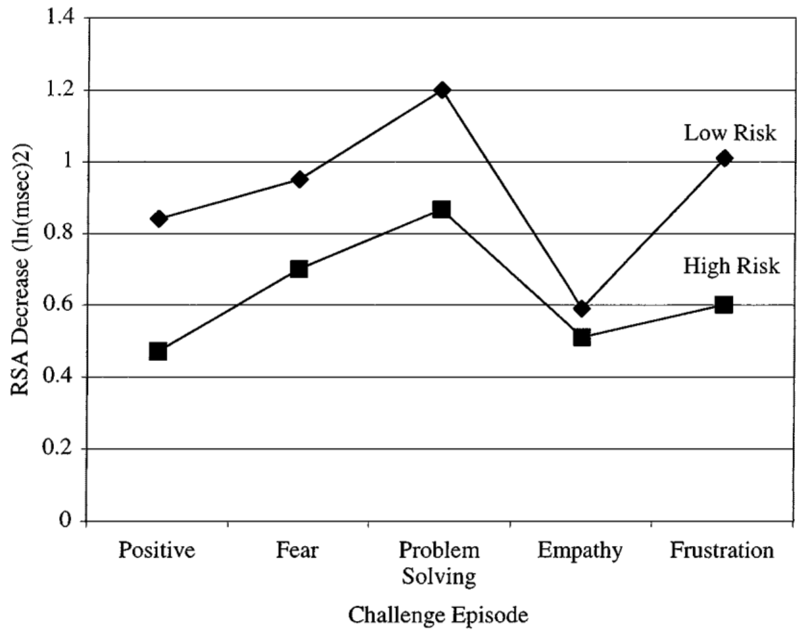

Fig. 3. RSA suppression (higher score = greater suppression) across five challenge episodes by risk group (low versus high).

baseline condition to the five challenging episodes. The RSA measures from the six episodes (baseline, positive, fear, problem, empathy, frustration) were analyzed using a repeated measures ANOVA with episode as a within- subjects measure and group and gender as between- subjects factors. This analysis revealed a significant episode effect, $F(5, 380) = 32.56$, $p < .001$, but no effect for gender or risk group. An examination of Table I and post-hoc t-tests comparing baseline to each episode indicated that, across both groups of children and both sexes, there was a significant suppression effect (RSA decreased) from baseline to each of the five challenge episodes, $p < .001$ for all five contrasts. On the basis of the analysis demonstrating a suppression effect across the five challenge episodes, RSA suppression scores were computed by subtracting the RSA for each challenge episode from the RSA from the baseline condition to yield five suppression scores.

To examine whether the magnitude of suppression differed by risk group, with gender as a possible interacting factor, a second repeated measures ANOVA was conducted using the RSA suppression scores computed for each of the five episodes with risk group and gender as between-subjects factors. Because the risk groups differed by gender on the measure of resting RSA, it was used as a covariate in this analysis. The analysis revealed a significant within-subjects episode effect $F(4,288) = 8.96$, $p < .001$. There was greater suppression during the fear, frustration, and problem-solving episodes than the positive and empathy episodes across all subjects (p's < .05 for significant contrasts). As expected, there was an effect of the covariate, $B = .61$, $t = 6.72$, $p < .001$. The analysis also revealed a main effect for risk group $F(1, 72) = 4.83$, $p = .03$, but no effect for gender, or interactions of gender and risk group. This analysis indicates that across all episodes and across both high and low baseline groups, the high-risk group displayed significantly less suppression than the low-risk group. These findings are depicted in Fig. 3.

Risk Group Differences in Heart Period During Challenge

To address the question of whether there would be differences between risk groups in terms of acceleration or deceleration of HR (change that is characterized by a decrease versus an increase in heart period), the data were examined to determine whether a significant change in heart period occurred from the baseline condition to the five challenging conditions. The heart period measures from the six episodes (baseline, pleasure, fear, problem, empathy, frustration) were analyzed using a repeated measures ANOVA with episode as a within-subjects measure and risk group and gender as between-subjects factors. This analysis revealed a significant episode effect, $F(5,380) = 32.07, p < .001$, but no effect for risk group, sex, or an interaction of sex and risk group. An examination of Table I and post-hoc t-tests comparing baseline to each episode indicated that, across both risk groups of children, there was a significant decrease in heart period (HR acceleration) from baseline to each of the five challenge episodes, $p < .001$ for all five contrasts.

On the basis of the analysis demonstrating a significant change in heart period from the baseline to the five challenge episodes, heart period change scores were computed by subtracting the heart period for each challenge episode from the baseline episode to yield five change scores. High or positive change scores indicated that there was a decrease in heart period from baseline to challenge episode (HR acceleration). To examine whether the magnitude of heart period change differed by risk group, with sex as an interacting factor, a repeated measures ANOVA was conducted using the heart period change scores computed for each of the five episodes. Because of the difference between boys and girls on the measure of resting HP, this measure was included as a co- variate to determine whether, above and beyond the effects of baseline heart period, there would be an effect of group or sex and to determine the nature of such an effect. This analysis revealed a significant episode effect, $F(4) = 6.79, p < .001$. Examination of the heart period data indicates that across all subjects there was a greater decrease in heart period (higher HR acceleration) during the fear, frustration, and problem-solving episodes than during the pleasure and empathy episodes. There was greater change during the pleasure episode than during the empathy episode. The analysis also revealed, as expected, an effect for the covariate of baseline heart period, $B = .65, t = 7.58, p < .001$. There was no effect for risk group or gender nor any interactions involving risk group and gender or episode. Thus, although boys differed from girls in terms of baseline HP, there was no gender difference in terms of HP response, after acounting for the resting difference.

Emotional and Behavioral Responses to Challenge

Emotional Reactivity During Challenge

To examine whether there were group and gender differences in terms of emotional and behavioral regulation, several analyses were conducted. First, a repeated measures MANOVA was conducted on the two affect measures (positive and negative). This analysis revealed, as expected, a significant episode effect, $p < .001$. These episode effects were examined, using paired t-tests, in order to test whether the episodes were eliciting the appropriate affect. For positive affect, these analyses revealed that the positive affect episode elicited the most positive affect ($p < .001$ for all contrasts), followed by the fear episode ($p < .05$ for all contrasts), followed by both the empathy and frustration episodes, which did not differ from one another. For negative affect, the analyses revealed that the fear episode generated the most negative affect ($p < .001$ for all contrasts), followed by the frustration episode ($p < .05$ for all episodes), followed by the problem solving episode ($p < .05$ for all episodes), followed by the empathy and positive episodes, which did not differ from one another. Thus, although, in the case of the fear episode, a moderate degree of both positive and negative affect was present, the episodes did appear to elicit the appropriate affective responses. This finding likely represents approach versus withdrawal differences during exposure to novel stimuli that are readily apparent in children of this age (Calkins & Fox, 1992). Alternatively, the smiling may have been an effort on the part of the children to disguise fear.

Group Differences in Emotional and Behavioral Regulation During Challenge

To examine risk group differences in emotional and behavioral regulation, a repeated measures MANOVA was conducted for the dysregulation measures from the five challenge episodes using risk group, and gender as between-subject factors. This analysis revealed a significant group effect, $F(1, 94) = 11.02$, $p < .001$, but no effect for gender and no significant group x gender interaction. The group means for the five dysregulation measures appear in Table II. Across all five challenge episodes, high-risk children displayed significantly more dysregulated behavior, characterized by negative affect, venting, low attention to the task, and greater distraction, than did low-risk children.

Table II. Group Means for Dysregulation Summary Score for Selected Sample by Episode[a]

	Low risk		High risk	
	M	*SD*	*M*	*SD*
Positive	−.16	.61	.26	1.39
Fear	−.16	.88	.08	1.13
Problem solving	−.17	.53	.16	1.27
Empathy	−.19	.97	.20	.99
Frustration	−.14	.99	.14	.99

[a]Positive scores = high negative affect, venting, and distraction, and low task object focus.

Relations Between Physiological Regulation (as Indexed by RSA Suppression) and Emotion and Behavioral Regulation

To examine whether physiological regulation was a direct reflection of the behaviors the children were engaged in during the challenge episodes, correlations were examined for these two measures from each episode. Only one correlation of the five was significant. RSA suppression during the problem solving episode was negatively correlated with dysregulation, $r = - = -.28$, $p < .01$.

DISCUSSION

There have been relatively few studies of very early emerging behavior problems (Shaw, Keenan, & Vondra, 1994; Shaw, Owens, Vondra, Keenan, & Winslow, 1996), and none examining the possible physiological correlates of such problems. In this investigation, 2 year-old children who may be at risk for externalizing-type behavior problems were identified on the basis of multiple measures of such problems. Three correlates of such behavior, physiological, emotional, and behavioral regulation, were examined by measuring heart period and heart rate variability (RSA) and behavior under resting conditions and during situations designed to challenge the child. In addition, the question of whether these relations would differ depending on gender was also addressed. Several important findings emerged from this study suggesting that physiological measures may provide insight into the functioning of children with early appearing problems, and that girls and boys differ in terms of this functioning. Moreover, important emotional and behavioral control differences clearly underlie the adjustment problems these children are experiencing.

The first question addressed in this study was whether there would be a difference between the high- and low- risk children in terms of resting HR, as researchers working with adults and older children have found. In this literature, this finding has been explained as reflecting low arousal, which may predispose the person to novelty seeking, impulsivity, and aggression (Raine, 1996). In comparing the risk groups on the resting measure of heart period (the inverse of HR), no significant difference was found. This resting measure was derived from a 5-minute period and the group sizes, even taking into account gender as a second grouping factor, were sufficient to detect such differences. Thus, this finding is in direct contrast to the findings with older children and adults. Importantly, though, there are no data with young children that contradict this finding.

There are two possible explanations for the null finding in this study. First, it may be the case that early in development, the underlying explanation for aggressive problematic behavior may not be underarousal. If this is the case, then resting measures of HR may not be a very sensitive index of problem behavior. It may be that the relation between ANS functioning, as indexed by heart rate measures, and aggressive behavior changes with development (Mezzacappa et al., 1996). For example, autonomic underarousal as reflected in low heart rate may develop as a function of early problematic behavior rather than being a cause of such behavior. A second explanation for this null finding is that, although the children in the study are considered “at risk” for later, more serious problems, there is no evidence that they will all develop severe conduct problems of the type that characterized the male children in Raine’s work, for example (Raine & Jones, 1987). Further, it would be of interest to know whether the high-risk children with low heart rate develop more serious problems than those with low heart rate but not at high risk. It should be noted that there was a sex difference in terms of resting HR, with boys displaying higher heart period (lower HR) than girls. Thus, another explanation for the null finding between problem groups may be that boys are more vulnerable to emerging problematic behavior than girls given this difference in characteristic arousal level. No risk group by gender interaction was found for resting heart period, however, a finding would have strengthened such an hypothesis.

In a second analysis, group differences in terms of resting RSA were examined. This measure of HR variability is thought to reflect developmental status and characteristic reactivity to the environment. Again, however, in comparing the risk groups, no differences were observed. There was, however, an interaction of gender and risk group: boys who were low risk displayed higher RSA than did boys in the high-risk group. This finding extends downward developmentally the recent findings of Pine (Pine et al., 1998) and Mezzacappa (Mezzacappa et al., 1997) relating externalizing problems in older males to lower heart rate variability. Resting RSA has been found to be related to greater emotional reactivity early in development (Stifter and Fox, 1990) and thus may be indexing the unregulated fussy temperament component of childhood externalizing behaviors. Stifter and Fox (1990) found that higher RSA was correlated with greater negative emotion in infants—an appropriate emotional response to a stressor at this age. With development, there is the expectation that children develop regulatory strategies that help them to cope with emotional arousal. It may be that children with low RSA have difficulty developing regulatory abilities (Porges, 1996) and, thus, are more negatively expressive and perhaps undercontrolled as well. Moreover, modest associations have been found between early temperament and later aggressive behavior problems (Bates et al.,1991). However, it maybe the case that poorly regulated negative temperament, rather than just early negative temperament, is at the core of aggressive behavior problems (Calkins, 1994). That the RSA- aggression relation in this study was found only among boys again suggests a possible reason for boys' greater vulnerabilities to these types of problems. Clearly socialization differences between boys and girls will likely also play a role, at the level of behavior, and perhaps, at the level of physiology as well.

The third analysis addressed the question of group differences in response measures of RSA and HP. It was hypothesized, based on prior work looking at suppression and attention and suppression and behavior problems, that the high risk group would show less RSA suppression in response to the challenging situations. This analysis revealed a significant difference between the high and low risk groups in terms of the degree of RSA suppression that was displayed across all the challenging episodes, but no gender difference, or interactions of gender and risk group. The data from the current study support the hypothesis that children who are having difficulties with behavioral control may also have difficulties with physiological regulation. Early problems characterized by aggression and destructive behavior may, in fact, reflect problems with physiological underregulation, in particular sympathetic controls that play a role in attention and behavioral regulation. One caveat regarding the RSA differences found is that no attempt was made to score motor activity during the episodes. Given that the high-risk children may be more active than the low-risk, it is possible that more movement affected their RSA activity. No HR differences between the two groups, however, undermines this explanation of risk group differences.

The question of whether there would be differences between risk groups in heart period change in response to challenge was also addressed in this study. The initial analysis examined the pattern of change across group and revealed that there was a decrease in heart period (HR acceleration) across both groups of children. An analysis of risk group and sex differences with respect to this change revealed that there were no such differences, once initial baseline values were covaried. Boys showed a greater decrease (higher acceleration) to some of the episodes than others, a difference that was accounted for by the difference in their resting heart period.

The physiological data from this study suggest that there may be important differences between children who are displaying early signs of problematic behavior char acterized by aggression, impulsivity, noncompliance, and destructive behavior and those who are not experiencing such difficulties. However, these differences may be more complex than previously thought and may reflect different underlying processes than those believed responsible for antisocial behavior in older children and adults. First, there was no evidence in this study that low resting heart rate is linked to aggressive behavior in 2-year-old children. Further, there is strong evidence that physiological regulation in the form of RSA and RSA suppression is linked to problematic behavior. This finding was reported by Porges (Porges et al., 1996) using a relatively small sample of low-risk children. The current data extend this finding to a high-risk sample. Second, it is clear when examining the literature focusing on early problem behavior that an important feature of these difficulties is control or regulation, not necessarily underarousal. This difference may be a part of what Hinshaw refers to as "heterotypic continuity" of early behavior problems—with development, the display of symptoms may change, perhaps even at the level of physiology, although the symptoms remain problematic and may reflect some stable underlying difficulties (Hinshaw, Lahey & Hart, 1993). Finally, it is becoming increasingly apparent that behavior problems among older children may be of various types and may reflect different developmental pathways and processes (Cicchetti & Rogosch, 1996; Moffitt, 1993). It may be that there are dimensions of ANS functioning that change or develop, perhaps partially, as a function of early environmental experiences (Raine, 1996), and that place some children on a more maladjusted trajectory. Perhaps, among those 2-year-olds at early risk, the severity of later problems will be dictated by ANS functioning such that children with low resting HR and hypothesized underarousal are at greater risk than those children with higher resting HR. Indeed, as Campbell (1995) has noted, as many as half of preschoolers displaying problems will not continue to show difficulties through early childhood. Clearly, the issue of physiological markers and their hypothesized genetic basis is in need of further exploration and, in particular, would benefit from longitudinal research with very young children that examines the course of both behavior and physiology over time.

A final question addressed in this study concerned the behavior that children engaged in during the challenging situations—behavior that is typically referred to as emotional or behavioral regulation. Both affect and regulatory behaviors were examined in this study. First, there were clear differences across episodes in terms of the affect displayed, differences that suggest that the episodes were differentially challenging for all the children. Second, there were differences between the two groups in terms of measures of negative affect and the behaviors that may co-occur with negative affect—venting, distraction, and focal-object focus. There has been some debate in the literature regarding the role of negative temperament in the emergence of early-appearing behavior problems (Campbell, 1995). That these children display more negative affect may not be surprising, given their tendency toward aggression and defiant behavior. However, the question of whether these affect differences are a cause of more pervasive problematic behavior, or simply a by-product of it, is left unanswered.

The finding that these problem toddlers do display consistently more negative affect in challenging situations than their low-risk counterparts suggests two possible roles of temperament. First, these children may be dispositionally more negative (a strong temperament view), or they may have failed to develop more appropriate ways of managing or regulating naturally occurring emotional experiences. Thus, temperament may exert a stronger effect on early emerging problem behavior when internal or external (parental) sources of regulation are not functioning or are unavailable (Calkins, 1994). Control of attention is likely to be one important component of affect regulation (Eisenberg et al., 1995; Ruff& Rothbart, 1996, Wilson & Gottman, 1996). The ability to stay focused on a given activity, such as book reading, may reflect attentional control that is used in the service of managing affect. Similarly, diverting attention away from a frustrating situation (cookies sealed in a container) may help to minimize the distress associated with being denied the desired object. Across all episodes, the children with early- appearing externalizing problems appear to have some difficulty managing affect and are more likely to resort to venting or tantrums than their nonaggressive counterparts. The observations from the present investigation suggests that children with early externalizing difficulties may not have a repertoire of more adaptive regulatory behaviors, which supports their characterization as “underregulated” or “dysregulated.” If these early individual differences in regulation are at the core of early externalizing difficulties, and these difficulties persist, later psychosocial adaptation and the acquisition of other important developmental achievements will almost certainly be affected.

Interestingly, only one correlation was observed between physiological regulation and emotional and behavioral regulation. The notion that self-regulation may occur on several levels, or within domains such as emotion, behavior, and physiology, has been discussed by various theorists (Cicchetti & Rogosch, 1996; Porges, 1996). These domains are likely to be interdependent components of a larger self-regulatory system. Basic regulatory processes, such as those that control physiological responding, are likely acquired early in development, and support later-developing regulatory processes, such as those involved in the regulation of affect, behavior, and even social interaction (Calkins, Smith, Gill & Johnson, 1998; Porges, 1996). The data from the present study suggest that there are important differences between high-risk toddlers and low-risk toddlers in terms of physiological regulation. Also, there were clear differences between these groups in some types of challenging situations in terms of the more complex emotional and behavioral regulatory processes. Clearly, there is not a one-to-one mapping of these physiological and behavioral processes, a finding that other researchers have noted (Calkins et al., 1998; Porges, 1996). In all likelihood, caregiving history likely plays a role in how or whether early physiological regulatory abilities develop into more complex behavioral repertoires that support more adaptive functioning. Children with early externalizing difficulties may have fundamental difficulties at the level of physiological regulation. They also appear to engage in different and less adaptive behavioral strategies that may either be a cause or consequence of more distress and negative affect when challenged.

The study is limited in that it is not longitudinal and therefore cannot inform us of the mechanism(s) through which physiological regulation affects behavior over time. Nor can it help us to understand the possible implications for later development of an early pattern of aggressive/destructive behavior, or poor physiological and behavioral regulation. However, the study provides important data relative to our understanding of the possible source of the difficulties of young children with aggressive/destructive tendencies, as well as insight into possible links between physiological functioning and emerging regulatory behaviors and behavior problems in young children. The study also suggests one hypothesis about the origins of emerging gender differences in rates of problematic behavior that begin to appear in early childhood. Longitudinal studies of the trajectories of early problem behavior would further our understanding of early correlates of such problems and factors that differentially affect boys versus girls.

ACKNOWLEDGMENTS
This research was supported by a National Institute of Mental Health B/START Award and a Research Council Grant and Summer Excellence Award from the University of North Carolina at Greensboro to Susan D. Calkins. The authors would like to thank Amy Clark, Kathryn Gill, Mary Johnson, Laura Lomax, and Cynthia Smith for their help in subject recruitment and data collection and coding.

The authors also thank the families who generously gave their time to participate in the study.

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