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Parent and Child Vagal Tone: Examining Parenting Behaviors as Moderators of the Association

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ABSTRACT

Research indicates that learning how to regulate one's emotions is critical to successful child development and is associated with adaptive social functioning and psychological adjustment (Dunn & Brown, 1994; Eisenberg, Fabes, Guthrie, & Reiser, 2000; Eisenberg, Fabes, & Murphy, 1996). Children's emotion regulation abilities are thought to be influenced by both child (e.g., age, temperament) and parent characteristics (e.g., parenting behaviors, parental regulation; Eisenberg, Cumberland, & Spinrad, 1998). Resting heart rate variability (HRV) has emerged as a potentially important biomarker associated with emotion regulation (Porges, 2007; Thayer & Lane, 2000); however, there are still significant gaps in research. In particular, research indicates genetic correlates associated with HRV as well as an important role of parents in children's emotion socialization, but research has yet to establish a strong link between parent and child HRV. Theoretically, parent and child HRV may be linked but only in specific contexts. For example, parent and child resting HRV may become more or less strongly related in the context of specific parenting behaviors, but research has yet to test this hypothesis. The present study examined the association between parenting behaviors and child resting HF-HRV (i.e., high frequency HRV), the links between parent and child resting HF-HRV, and potential moderating effects of parenting behaviors on the association in youth. Additional analyses examined associations between parent and child vagal regulation.

Ninety-seven youth (11-17 years) and their caregivers (n = 81) participated in a physiological assessment and completed questionnaires assessing parenting behaviors. Results indicated that parent's inconsistent discipline and corporal punishment were negatively associated with their child's resting HF-HRV while positive parenting and parental involvement were positively associated. Furthermore, parent's inconsistent discipline and parent's involvement moderated the relationship between parent and child resting HF-HRV, such that in the context of high inconsistent discipline and high parental involvement, high parent resting HF-HRV was associated with low child resting HF-HRV. Findings add to the literature by providing evidence for the role of parenting behaviors in shaping the development of children's HF-HRV and indicating that inconsistent discipline and parental involvement may affect the entrainment of HF-HRV in parents and their adolescent children.

Keywords: heart rate variability, vagal tone, parenting

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Introduction

Emotions and individual differences in the ways that we interpret, process, and regulate our emotional experiences are central to child development. Emotions reflect the status of one's ongoing adjustment to changing environmental demands by facilitating communication between the individual and their environment (Frijda, 1986; Schwarz & Clore, 1983; Thayer & Lane, 2009). Emotions enable individuals to achieve their goals through fostering decision making and promoting adaptive behavioral responses (Gross & Thompson, 2007; Oatley & Johnson-Laird, 1987). The ability to respond flexibly to changes in environmental demands is crucial for survival, and thus a variable range of emotions and the ability to recover after exposure to environmental stressors are related to positive health outcomes (Appelhans & Luecken, 2006; Thayer & Lane, 2009).

Research indicates that learning how to regulate one's emotions in adaptive ways is critical to successful child development and is associated with adaptive social functioning and psychological adjustment (Eisenberg et al., 2000; Izard et al., 2001; McDowell et al., 2002). Alternatively, emotional dysregulation occurs when one's response is a poor match to the environmental requirements, and dysregulation has been shown to be associated with maladaptive outcomes in youth, including greater risk of developing internalizing and externalizing disorders (Southam-Gerow & Kendall, 2002; Weems et al., 2005; Yap, Allen, & Sheeber, 2007). Research implicates both biological and environmental factors in the development of children's emotion regulation (Calkins, 1994; Eisenberg & Fabes, 1994; Kupper et al., 2004; Morris et al., 2007). However, research is less clear on ways in which a child's environment and biology may reciprocally affect one another to promote the development of emotion regulation.

Cardiac activity, specifically parasympathetic-mediated activity (i.e., vagal tone), has received recent attention as a physiological biomarker associated with self-regulation (Appelhans & Luecken, 2006). Research to date implicates resting heart rate variability (HRV; i.e., the naturally occurring variation in heart rate that accompanies respiration) and vagal regulation (i.e., the change in HRV in response to a stressful event) as biomarkers associated with emotion regulation (Appelhans & Luecken, 2006; Beauchaine, 2001; Porges, 2007; Thayer & Lane, 2000). The purpose of the present study is to examine the association between parenting behaviors and child resting HF-HRV (i.e., high frequency heart rate variability), the links between parent and child HF-HRV, and potential moderating effects of specific parenting behaviors on the association in youth. The following sections set up the theoretical and empirical foundation for the study. The first section, **Emotion Regulation,** defines emotion regulation, reviews the theory behind emotion regulation, and introduces the potential importance of resting HRV in emotion regulation. The second section, **Biological Mechanisms of Influence,** reviews the biological underpinnings of the development of emotion regulation and introduces a method for quantifying resting HF-HRV as a biomarker of one's ability to regulate their emotional states. The third section, **The Association between Parent and Child Vagal Tone,** discusses processes by which parent and child vagal tone may become entrained and reviews the extant literature investigating the association of parent and child vagal tone (i.e., HF-HRV). The fourth section, **Parenting Effects on Child Emotion Expression and Regulation,** reviews the role of parenting in the development of child emotional expression and regulation and briefly reviews theorized mechanisms through which this effect may occur. The fifth section, **Parenting as a**

Moderator of the Association between Parent and Child Resting HRV, introduces the theory that parenting behaviors may help entrain parent resting HRV to child resting HRV tone. The sixth section, **Parent and Child Vagal Regulation**, introduces the concept of vagal regulation and reviews theoretical and empirical research regarding a potential association between parenting and vagal regulation as an alternative to assessing resting HRV. The final section, **The Present Study,** delineates the hypotheses for this study.

1. Emotion Regulation

Emotions are multifaceted states which arise from interactions between the cognitive, behavioral, neurological, and physiological systems in response to a situational demand (Gross, 1998; Gross & Thompson, 2007). The way in which we experience, express, and respond to emotional states is best conceptualized as a multi-dimensional construct dependent on multiple interrelated processes (Thompson, 1994). The ability of an individual to modulate (i.e., automatically or voluntarily) the occurrence, intensity, and expression of their emotions, both positive and negative, to achieve a personal goal is referred to as emotion regulation (Gross, 1998; Thompson, 1994). Emotion regulation involves individual variations in the intensity, persistence, latency, magnitude, and recovery from emotional responses and thus is conceptualized as a dynamic process involving behavioral, experiential, and physiological domain changes (Gross, 1998; Thompson, 1994). Regulating one's emotions is a critical component of interpersonal and intrapersonal functioning (Southam-Gerow & Kendall, 2002) and has the potential to either enhance or diminish one's developmental outcomes.

According to Gross's (1998) process model of emotion regulation, there are two time-dependent categories of emotion regulation: antecedent-focused and response-focused emotion regulation. Antecedent-focused emotion regulation strategies refer to strategies implemented prior to the generation of the emotional response, including situation selection, situation modification, attentional deployment, and cognitive change. For example, an individual may choose not to attend a funeral because they know it will be emotion-provoking for them and wish to avoid the negative feelings they may experience (i.e., situation selection). Alternatively, response-focused emotion regulation strategies refer to the use of modifications in one's emotional response which occurs after the emotional response is fully generated. For example, a child afraid of dogs may modify their cognitions about the feared situation (e.g., "The dog is behind a fence and can't hurt me") in order to calm themselves down.

Modulating one's physiological response to an emotional experience is another response-focused emotion regulation strategy (Gross, 1998). The emotions that an individual experiences are associated with varying degrees of physiological arousal (Levenson, 2003), and, thus, emotion regulation depends on one's ability to adjust their physiological arousal in accordance with environmental demands (Gross, 1998; Thompson, 1994). For example, an individual scared of dogs may experience physiological changes such as increased heart rate after encountering a dog (i.e., the feared stimulus). In response, the individual might use deep breathing techniques to slow their rapid heart rate and return to a feeling of calm. The assessment of physiological measurements such as heart rate and heart rate variability is becoming more common in research as these measurements are posited to provide a direct, objective method for quantifying emotion regulation (Appelhans & Luecken, 2006). For example, research has provided empirical support of an association between resting HF-HRV and one's ability to regulate their emotions (Butler, Wilhem, & Gross, 2006; Gottman & Katz, 2002; Scott & Weems, 2014; Vasilev, Crowell, Beauchaine, Mead, & Gatzke-Kopp, 2009). In order to best understand the implications of physiological biomarkers associated with emotion regulation in both research and applied settings, one must first understand the neurophysiological underpinnings. Thus, the next section reviews the literature on neurological and physiological mechanisms theorized to play a role in shaping the development of emotion regulation.

2. Biological Mechanisms of Influence

French physiologist Claude Bernard was a pioneer in the study of the sympathetic nervous system and one of the first to systematically investigate the connection between the heart and the brain (see Bard, 1929). Other prominent researchers (e.g., Gaskell, 1920; Langley, 1921) continued to advance the literature, building a strong basis of evidence supporting the effect of the central nervous system on the physiological activity of the peripheral organs, specifically the heart. Decades later, the field of emotion regulation emerged, characterizing emotions in terms of response tendencies and examining bodily systems which collectively modulate emotional arousal and facilitate a response to environmental demands (Gross, 1998; Thompson, 1994). Thayer and Lane (2000) proposed that the autonomic, attentional, and affective systems are integrated into a collective network responsible for facilitating self-regulation and adaptation to changing contextual demands (i.e., neurovisceral integration model). More generally, research indicates that there are direct and indirect connections between the brain and the heart, and that the capacity to regulate emotional arousal depends upon the interrelated interactions between neurological and physiological substrates related to physiological reactivity, self-regulation, and autonomic regulation (Thayer & Lane, 2000; 2009; Zeman, Cassano, Perry-Parrish, & Stegall, 2006).

Several neurological constituents crucial in emotion regulation have been identified in research, including the amygdala, prefrontal cortex, and hypothalamic-pituitary-adrenocortical (HPA) system (e.g., Cannon, 1929; Ledoux & Phelps, 2000; Thompson, 1994; Zeman et al., 2006). The amygdala is an almond-shaped structure within the limbic system that is important in processing emotional experiences, specifically playing a critical role in many of the fear responses (e.g., freezing, heart rate changes, and potentiated startle; Cummins & Ninan, 2002; Rosen & Schulkin, 1998). Labeled as the "emotional computer" by Ledoux and Phelps (2000), the amygdala plays a central role in emotional arousal through its effect on the physiological components of emotion (Zeman et al., 2006). The amygdala is credited as determining the emotional significance of a given stimuli and then relaying that information to lower brain structures responsible for initiating response (e.g., motor movement). Highly processed sensory information from areas of the cortex is integrated in the amygdala through its lateral and basolateral nuclei (Amaral, 1987; Burwell, Witter, & Amaral, 1995). The basolateral nuclei then project to the central nucleus of the amygdala (Aggleton, 1985; Amaral, 1987; Pitkänen et al., 1995; Savander, Go, Ledoux, & Pitkänen, 1995). The central nucleus receives autonomic information from the brain stem nuclei that controls heart rate, blood pressure, and respiration (Rosen & Schulkin, 1998; Veening, 1978). Research has also implicated the amygdala in the recall of emotional or arousing memories (Cahill, Babinsky, Markowitsch, & McGaugh, 1995).

There are dense connections between the frontal cortex and the amygdala involved in the regulation of autonomic output (Schulkin et al., 1994; Schmidt, Fox, Schulkin, & Gold, 1999) and the modulation of a range of social and cognitive functions (Young, Scannell, Burns, & Blakemore, 1994). As reviewed by Fox (1994), the frontal cortex plays an important role in many aspects of emotion including the expression and regulation of emotion as well as the organization and integration of cognitive processes underlying emotion. The frontal lobes are hypothesized to be differentially involved in positive versus negative emotional states, with left frontal areas involved with positive emotions (e.g., joy) and the right frontal areas involved with negative emotions (e.g., fear) and withdrawal behaviors (Davidson, 2000; Fox, 1991). The amygdala and prefrontal cortex work seamlessly in coordinating the body's response to stress. The amygdala has outputs to the autonomic, endocrine, and other physiological regulation systems and is under tonic inhibitory control by the prefrontal cortex (PFC; Davidson, 2000; Thayer & Lane, 2009). In situations of threat or uncertainty, the PFC becomes hypoactive while the amygdala is activated and the body prepares to engage the threat. This preparation for "fight or flight" is the body's healthy physiological response to stress and is essential for survival (Cannon, 1929).

The physiological response to stress is facilitated by the autonomic nervous system (ANS) through fluctuating degrees of physiological arousal in response to emotions experienced while interacting with the environment (Levenson, 2003; Porges, Doussard-Roosevelt, & Maiti, 1994; Thayer & Lane 2000). The heart is innervated by the two branches of the ANS: the excitatory sympathetic nervous system (SNS) and the inhibitory parasympathetic nervous system (PNS), which interact antagonistically to regulate cardiac activity by influencing the sinoatrial node (i.e., primary pacemaker of the heart). At rest, the PNS inhibits the firing rate of the sinoatrial node, maintaining resting heart rate below the firing rate of the sinoatrial node, resulting in low physiological arousal (Appelhans & Luecken, 2006; Bernston et al., 1997). Alternatively, the SNS becomes predominant during exposure to stress, exerting an excitatory influence on the sinoatrial node, resulting in increased heart rate and physiological arousal to prepare the body to respond to the challenge. Porges (1995) referred to this influence on the heart by the vagus nerve as vagal tone. According to Porges' polyvagal theory (Porges et al., 1996), there are two functions of vagal tone: (1) during periods of low environmental stress, vagal tone promotes homeostasis and (2) while in situations of high stress, vagal tone works to regulate metabolic output to meet external demands with the former functioning as a baseline measure of reactivity and the latter as a "vagal brake" or an indicator of one's ability to flexibly respond to stressful tasks and control their emotional responses (Beauchaine, 2001; Porges, 2007).

Theoretical and empirical research indicates that PNS-mediated cardiac activity is more closely related to emotional and behavioral processes than SNS-mediated cardiac activity (see Appelhans & Luecken, 2006), and thus physiological biomarkers associated with PNS-mediated cardiac activity (i.e., HF-HRV) are emerging as focal points in emotion regulation research. One way to assess vagal tone is through monitoring the rhythmic increase and decrease in normal beat-to-beat heart intervals associated with respiratory inhalation and exhalation, termed respiratory sinus arrhythmia (RSA; Beauchaine, 2001; Bernston et al., 1997; Porges et al., 1994a). Inhalation of air into the lungs temporarily inhibits the parasympathetic influence on heart rate (i.e., decreased heart rate), and exhaling air out of the lungs reinstates the parasympathetic influence on heart rate (i.e., increased heart rate; Bernston, Cacioppo, & Quigley, 1993). A common statistical technique used to assess vagal tone is the power spectral analysis of the artifact-free inter-beat intervals as recorded using an electrocardiogram (EKG; Appelhans & Luecken, 2006; Bernston et al., 1997; Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). Power spectral analysis allows researchers to distinguish SNS and PNS effects of one's heart rate by separating the quantity of HRV occurring at different frequencies (as expressed in hertz, calculated as cycles per second; Appelhans & Luecken, 2006). This frequency-based technique produces two major components: a high-frequency (HF) and low-frequency (LF) component reflecting cardiac vagal tone (Appelhans & Luecken, 2006; Thayer, Åhs, Fredrikson, Sollers, &

Wager, 2012). Controversy exists in the literature concerning the use of LF-HRV versus HF-HRV (Appelhans & Luecken, 2006; Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996) components in power spectrum analyses. However, results from of a pharmacological blockade study by Cacioppo and colleagues (Cacioppo et al., 1994) suggest that the high-frequency component of HRV is a better estimate of PNS-mediated heart rate control and the low-frequency component provides a mixed assessment of both SNS- and PNS-mediated control. Therefore, the high frequency component of HRV (RSA frequency band) is emerging as the most commonly used index in research regarding emotion and heart rate variability (Elliot, Payen, Brisswalter, Cury, & Thayer, 2011; Lane et al., 2009; Scott & Weems, 2014).

There are large individual differences in HRV, and behavioral and molecular genetic studies attribute a significant part of these differences to underlying genetic factors (Kupper et al., 2004; Snieder, Boomsma, van Doornen, & Gues, 1997; Thayer & Lane, 2009; Thayer et al., 2003; Wang et al., 2009). Twin studies (Boomsma, van Baal, & Orlebeke, 1990; Kupper et al., 2004) and family studies (Singh et al., 1999; 2001) report that up to 65% of the variance of HRV at rest can be explained by genetic influences. In one study assessing HRV in 160 adolescent twin pairs at rest and during a stressful laboratory task, Boomsma and colleagues (Boomsma et al., 1990) found that 25% of variance in HRV was accounted for by genetic influences at rest, and the genetic contribution increased up to 51% during a stress task. Singh et al. (2001) compared correlations of frequency-domain measures of HRV between siblings and spouses to compare genetic versus shared environmental effects on HRV. Results indicated consistently higher correlations among siblings (r = 0.21-0.26) compared to spouses (r = 0.01-0.19) after adjusting for gender and age. Furthermore, molecular genetic studies have reported significant associations with the angiotensin converting insertion/deletion gene (Busjahn et al., 1998; Thayer et al, 2003), indicating that a specific gene or additive effects of multiple genes may contribute to individual differences in HRV. While advances in behavioral and genetic studies have begun to explain pathways by which genetic influences may shape HRV, there is a paucity of research examining parent and child HF-HRV and how HRV may be affected by parenting factors across development~~.~~

3. The Association between Parent and Child Vagal Tone

Changes in the brain critical to the development of parasympathetic control over heart rhythms begin in utero (Groome et al., 1999). Specifically, the third trimester of pregnancy is a developmental period marked by a rapid increase in synapses, dendritic growth, myelination, and synaptic remodeling (Levitt, 2003), and these changes in the brain are thought to be critical in supporting the development of emotional signaling and affect sharing between the caregiver and infant within the first few months of life (Levitt, 2003; Porges, 2003; Schore, 1996). Research shows that premature infants born prior to the third trimester of pregnancy display disorganized biological rhythms, limited arousal modulation, and lower thresholds of negative emotionality (Feldman, 2006). The third semester in utero is also critical for the formation of mother-infant synchrony, a process that coordinates the exchanges of hormonal, behavioral, and physiological stimuli between the mother and infant (Rosenblatt, 1965; Schneirla, 1946).

Research indicates that children's biological and environmental context reciprocally interact and shape each other throughout infancy (Sameroff, 2000). After birth, parent-infant synchrony continues to develop through social contact, and parent-infant face-to-face interactions represent the infant's first experiences with regulation (Feldman, 2006; Tronick, 1989). In the first few months of life, parents and infants engage in face-to-face interactions marked with synchrony of non-verbal cues, including mutual gazing, co-vocalizations, and the matching of affective expression (Tronick, 1989). These non-verbal cues facilitate biological synchrony between the mother and infant which in turn supports the development of infant physiological regulation through the entrainment of biological rhythms (Hofer, 1971; Feldman, 2006). Research indicates links between interaction synchrony and maternal-infant cardiac vagal tone (i.e., the respiratory component in heart rate variability, RSA). Following synchronous play with caregivers in research studies, infants have shown greater vagal-tone suppression to a normally distressing still-face paradigm, indicating that caregiver-infant synchrony facilitates an adaptive autonomic response to stress in infants (Moore & Calkins, 2004), and similar findings have been reported for mothers (Moore et al., 2009) as well.

Theoretically, given the above mentioned research findings which indicate mother-infant synchrony of vagal tone beginning in utero and continuing through infancy, one may expect to see a continued association between parent and child vagal tone across the child's development. However, only two studies to date have examined concordance in vagal tone between parents and children, and both have failed to find a significant relationship between parent and child resting vagal tone (Bornstein & Suess, 2000; Perlman, Carmras, & Pelphrey, 2008). In a study of 81 mothers and their children (aged 2 months to 5 years), Bornstein and Suess (2000) found nonsignificant correlations between mother and child resting vagal tone when the child was assessed at 2 months of age ($r = .01$, $p > .05$) and again at 5 years of age ($r = .004$, $p > .05$), though results did indicate concordance between parent and child vagal regulation (i.e., change in vagal tone from baseline to attentional task) when children were 5 years of age ($r = .42$, $p < .01$). Perlman and colleagues also found no significant relation ($r = .04$, $p > .05$) between caregiver and child resting vagal tone in a sample of parents and children between the ages of 4 and 5 years (n = 42). While the results of these two studies do not suggest concordance between parent and child resting vagal tone, the young age of the children in the samples (aged 2 months to 5 years, Bornstein & Suess, 2000; aged 4 to 5 years, Perlman et al., 2008) prevents generalization of these findings to older children.

Research indicates that the vagal system continues maturing from birth through middle childhood such that mean levels of baseline RSA were reported to be 3.7 for 13-month olds, 4.3 for 18-months olds, 5.7 for 3-year olds, and 7.5 for school-age children aged 7-12 years (Hickey, Suess, Newlin, Spurgeon, & Porges, 1995; Porges, Doussard-Roosevelt, Portales, & Suess, 1994b; Stifter & Jain, 1996; Suess, Newlin, & Porges, 1997; Suess, Porges, & Plaude, 1994). As children age, their vagal fibers undergo myelination, their physiological systems improve organizationally, and their abilities to regulate their emotions and behaviors improve. Thus, the lack of concordance in parent-child dyads' resting vagal tone found by Bornstein and Suess (2000) and Perlman et al. (2008) may be in part due to the age of the samples. It may be that there is synchrony very early on (as reviewed above) but as children age, parent HRV is entrained (or decoupled) with child HRV over time, such that the relationship does not become evident until the child reaches late childhood or adolescence or is only evident under certain contexts that help entrain parent and child HRV. That is, a number of factors may help to entrain or decouple parent and child HRV, and parenting factors may be particularly important.

4. Parenting Effects on Child Emotion Expression and Regulation

Parents are important socializing influences on the emotional development of children (Eisenberg et al., 1998; Morris et al., 2007; Shipman & Zeman, 2001; Thompson, 1994) through both direct and indirect means. As reviewed by Eisenberg and colleagues (Eisenberg et al., 1998), the family context may affect the development of child emotion regulation in a variety of ways. For instance, attachment theorists have argued that the quality of parent-infant attachment influences children's emotion regulation (Cassidy, 1994). Secure caregiver-infant attachment is theorized to develop in relationships in which caregivers are sensitive and responsive to the infant's needs. As a result, securely attached infants are thought to feel more comfortable expressing a range of emotions and develop expectations that their needs will consistently be met by their caregiver (Bridges & Grolnick, 1995; Cassidy, 1994). Alternatively, inconsistent parenting is thought to promote insecure caregiver-infant attachment in which infants may display high levels of negative arousal in response to distress. Rejecting or unresponsive caregiving may also lead to another form of insecure attachment in which infants may develop alternative, maladaptive strategies for regulating their arousal (e.g., self-regulation through sucking on their thumb; Braungart & Stifter, 1991). Thus, research suggests that the responsivity and sensitivity of caregivers in the first few months of life affects the caregiver-infant attachment and has long-term implications on children's emotional development.

Children also develop emotionally by observing their parent's emotional expression and emotional regulation and through social referencing (Eisenberg et al., 1998; Thompson, 1994; Zeman et al., 2006). Social referencing allows children to navigate novel situations by looking to their parents for information on how to feel and appropriately respond in a specific situation (Feinman & Lewis, 1983). Through observational learning and modeling of their parents' emotion regulation techniques, children learn to identify, understand, and respond to the emotional information in their environment (Denham & Grout, 1993; Morris et al., 2007; Parke, 1994). A child's ability to regulate their emotional state is thought to emerge through continuous interactions with their environment, specifically with caregivers (Denham et al., 1997), and thus parents may positively or negatively affect the development of their child's emotion regulation.

Research suggests that parents who express a limited range of emotions (e.g., depressed mothers) may hinder their child's emotional development. For example, Denham (1989) found that children of depressed mothers who exhibited high amounts of anger were more likely to display negative emotions and less likely to display positive emotions. Furthermore, research suggests that parents' emotion expression and regulation affects their child's social skills (Denham & Grout, 1993; Denham, Renwick, & Holt, 1991). For instance, children may transfer negative affect and poor regulation strategies (e.g., physical or verbal aggression) they have learned through parent-child interactions into their peer relationships, leading to deficits in social functioning and an array of social problems in school (Fabes, Eisenberg, & Miller, 1990).

Alternatively, parents who display a wide range of emotions of moderate intensity provide children exposure to a range of emotional expression as well as providing information about the types of situations that may elicit specific emotions and ways to modulate one's arousal as needed to adjust to changing environmental demands (Denham et al., 1997). Previous research indicates that children show a better understanding of emotion when parents foster an atmosphere of positive emotion within the home (Denham & Kochanoff, 2002). Parents may also positively affect their child by modeling adaptive regulation strategies (e.g., deep breathing, walking away from a confrontation) to modulate their emotional arousal in stressful situations (Morris et al., 2007). In a study assessing parents' vagal tone specifically, Perlman et al. (2008) found that parents with higher resting vagal tone reported practicing more adaptive emotion regulation behaviors (i.e., expressive encouragement, problem-focused coping, and emotion-focused coping) and were more likely to have children who were more knowledgeable about emotional situations. Moreover, Daly and colleagues (Daly, Abramovitch, & Pliner, 1980) found a positive relationship between mothers' ability to clearly and accurately express their emotions and children's depth of emotional knowledge indicating the importance of providing clear, consistent emotional information to children.

Parents also affect children's emotion regulatory abilities by their reactions to their child's emotional expression (Eisenberg et al., 1998). For example, punitive parental reactions to children's emotions have been associated with lower socio-emotional competence in children (Jones, Eisenberg, Fabes, & MacKinnon, 2002). Parental reactions that minimize children's expressions of emotion have been associated in research with a wealth of negative developmental outcomes in youth including low coping skills, avoidant coping, and socially inappropriate behavior (Eisenberg et al., 1996; Jones et al., 2002). Alternatively, supportive parental reactions including comforting and encouraging problem-focused responses (e.g., teaching adaptive coping strategies) may enhance children's understanding of their emotions and improve their abilities to regulate their physiological arousal in emotionally-salient situations (Eisenberg et al., 1998; Eisenberg & Fabes, 1994). A study by Gottman and colleagues (Gottman, Katz, & Hooven, 1996) found that parents' emotion-coaching behaviors were positively linked to children's emotion regulation as well as to their levels of vagal tone. Thus, it appears that parents who validate and accept their child's expressions of emotion, both negative and positive, provide an opportunity for children to explore their emotions in a predictable, safe environment and promote the development of problems solving skills (Gottman et al., 1996). Moreover, positive parents may bolster their child's abilities to express, label, and regulate their emotional arousal, while harsh parents who react negatively to their children's displays of emotion may thwart their child's development of healthy emotion regulation.

The emotional climate of the family also impacts the development of emotion regulation in children. The emotional climate of the family is reflected through the quality of relationships between family members, including the marital relationship and parent-child relationship (Morris et al., 2007). The quality of the parent-child relationship is thought to be impacted by the predictability of the emotional environment, parental expectations, and the amount of positive and negative emotionality expressed in the home (Darling & Steinberg, 1993). Theoretically, in a highly negative environment in which a child is exposed to inconsistent discipline or coercive parenting techniques, children may feel emotionally vulnerable and develop emotional dysregulation due to exposure of frequent, unexpected displays of emotion by their parents (Cummings & Davies, 1996; Morris et al., 2007). Alternatively, parents who are comforting and supportive of their children may foster adaptive emotion regulation because predictable, responsive parents create an emotionally secure environment for their children in which children feel safe expressing their emotions (Eisenberg et al., 1998). However, research has yet to empirically test these theorized associations using a direct biomarker associated with youths' regulatory abilities. The Alabama Parenting Questionnaire (APQ; Shelton, Frick, & Wootton, 1996) is an ideal measure to test for potential effects of positive and negative parenting behaviors on youths' resting HRV as it assesses positive parenting, parental involvement, poor monitoring, inconsistent discipline, and corporal punishment as reported by both the parent and child. Higher levels of positive parenting behaviors (i.e., warmth) and parental involvement may foster a supportive, responsive emotional climate in which children may develop higher resting HF-HRV. On the other hand, poor monitoring, inconsistent discipline, and corporal punishment may create a negative, threatening, and unpredictable emotional climate for children which may undermine children's emotion regulation and result in lower resting HF-HRV. In addition to these direct links, parenting behaviors may also affect emotion regulation by moderating the association between parent and child resting HF-HRV. In other words, it may be that parent and child HF-HRV are associated only in specific contexts, such that parent and child resting HF-HRV may become more or less strongly related in the context of specific parenting behaviors.

5. Parenting as a Moderator of the Association between Parent and Child Resting HRV

While research has begun to look at associations between parenting and child emotion regulation and psychopathology, it is likely that parent and child's emotion regulation may become further entrained or decoupled depending on the context of parenting behaviors. For example, in children of parents with low HRV, exposure to harsh parenting behaviors may exacerbate the child's underlying biological risk for dysregulation and further entrain parent and child HRV. Alternatively, if parents are able to recognize their poor emotion regulatory abilities and compensate with parenting behaviors that foster adaptive emotion regulation in their children, these children may be buffered from developing poor emotion regulation themselves due to a decoupling effect of parent and child HRV. No study to date has tested parenting behaviors as moderators of the link between parent and youth resting HRV.

The APQ may be a useful tool for examining this theory as the APQ measures positive and negative parenting constructs which may serve to help entrain or decouple parent and child resting HF-HRV. Positive parenting behaviors (i.e., warmth) and parental involvement are generally conceded to be important components of secure parent-child attachment (DeKylen, Speltz, & Greenberg, 1998) and have been shown to serve as important protective factors against psychological risk (Brookmeyer, Henrich, & Schwab-Stone, 2005). Previous research has found higher resting HF-HRV in mothers who display greater sensitivity when interacting with their infants (Musser, Ablow, & Measelle, 2012). Higher resting HF-HRV has also been found in mothers who show greater emotional flexibility and positivity during mother-adolescent laboratory interactions (Connell, Hughes-Scalise, Kostermann, & Azem, 2011). Theoretically, families characterized by high levels of parental involvement may provide more opportunities for youth to talk with their parents about their experiences and for parents to teach children healthy strategies for coping with distressing feelings and heightened physiological arousal (Bacchini, Miranda, & Affuso, 2011). This may be particularly beneficial for children of parents with low resting HRV as it may decouple the entrainment of their HRV with their parent's HRV and thus buffer the child from the negative effects of their parents' autonomic inflexibility (i.e., emotion dysregulation).

The APQ provides the opportunity to examine the effect of three potentially detrimental parenting behaviors (poor monitoring, inconsistent discipline, and corporal punishment) as moderators of parent-child resting HF-HRV. Research has begun investigating the effect of a few negative parenting behaviors (e.g., neglectful, controlling parenting) in relation to parent HRV (Skowron, Cipriano-Essel, Benjamin, Pincus, & Ryzin, 2013), but the effect of negative, harsh parenting practices on child HF-HRV has received less attention. Emotionally dysregulated have been found to display harsh and punitive parenting behaviors, and research shows that these negative parenting behaviors affect their children's ability to regulate their emotions as well (Eisenberg et al., 1999). For example, Calkins and colleagues (Calkins et al., 1998) found that mothers who used more negative and controlling behavior had toddlers who exhibited poorer physiological regulation. Furthermore, Chang, Schwartz, Dodge, and McBride-Chang (2009) also found that harsh parenting had an indirect effect on child aggression in school through the mediating process of child emotion regulation. Theoretically, this may be especially problematic for children of parents with low vagal tone as the negative parenting behaviors may exacerbate the child's difficulty regulating their physiological arousal in response to changes in the environment and in turn further entrain their emotional dysregulation with their parents' dysregulation. However, parent-child HRV may be decoupled if a caregiver with poor emotion regulation learns to control their emotional reactions when interacting with their child, and the child may be more likely to develop healthy emotion regulation strategies. For example, a parent with low resting HF-HRV is more likely to model maladaptive emotion regulation strategies for their child, such as lashing out or hitting the child when they are angry. Due to genetic influences on the development of HF-HRV, this child is already at-risk for developing similar inflexible autonomic responses to emotional arousal, and exposure to their parent's maladaptive regulation strategies may put this vulnerable child at an even greater risk for emotion dysregulation. Thus, parent-child resting HF-HRV may be less strongly related in the context of negative parenting behaviors, and this association may become more evident later in children's development as older youth have theoretically experienced prolonged exposure to the negative parenting behaviors.

6. Parent and Child Vagal Regulation

In addition to resting HF-HRV, vagal regulation (i.e., changes in HF-HRV in response to a challenging or stressful event compared to baseline) is emerging as another physiological index associated with emotion regulation. As previously described, Porges' polyvagal theory (Porges, 2007; Porges et al., 1996) postulates that there are two functions of the parasympathetic nervous system: promoting homeostasis and regulating metabolic output in times of high stress to meet external demands. Porges termed the later of these two functions the "vagal brake" or an indicator of one's ability to flexibly respond to stressful tasks and control their emotional responses (Beauchaine, 2001; Porges, 2007). During times of stress, vagal input to the heart is withdrawn in order to free up physiological resources required to permit the individual to respond to the challenge presented (Porges, 2003; 2007), and this resulting decrease in RSA is referred to as vagal regulation (also referred to as vagal withdrawal or the change in RSA). Porges postulates that greater vagal regulation is an indicator of autonomic flexibility and an adaptive physiological response to a stressful situation (Porges, 2007) and low vagal regulation (i.e., decreased withdrawal or absence of vagal withdrawal in response to a stressor) is an indicator of autonomic inflexibility and a dysregulated or maladaptive response to stress. In a previous study conducted with the same sample of parent-child dyads as focused on in the present study, Scott and Weems (2014) found an increase in vagal tone from a video baseline to a mild cognitive stressor task in youth with elevated anxiety symptoms and a decrease in vagal tone in youth reporting low levels of anxiety symptoms.

Research investigating the association between parent and child vagal regulation is in its infancy. While Bornstein and Suess (2000) did not find a significant association between parent and child resting vagal tone in their previously mentioned study of 81 mothers and their children (aged 2 months to 5 years), results did indicate concordance between parent and child vagal regulation (i.e., change in vagal tone from baseline to attentional task) when children were 5 years of age ($r = .42$, $p < .01$). Furthermore, several studies to date have indicated a relation between the quality of parent-child relationships and physiological regulation in children. For example, Calkins, Graziano, Berdan, Keane, and Degnan (2008) found that maternal-child relationship quality predicted vagal regulation in children at age 5, such that children with poorer quality parent-child relationships displayed significantly poorer vagal regulation and lower heart rate acceleration. El Sheikh and colleagues (El-Sheikh, Harger, & Whitson, 2001; El-Sheikh & Whitson, 2006) reported that poor vagal regulation in response to an emotional stressor moderated associations between parental difficulties and internalizing problems in children. In addition, Hastings et al. (2008) found that vagal regulation mediated the association between maternal negative control and children's adjustment, indicating that children's vagal regulation is partly shaped by their experiences of parental socialization. Furthermore, Perry and colleagues (Perry, Mackler, Calkins, & Keane, 2014) examined the association between maternal sensitivity and child vagal withdrawal in a longitudinal study (assessed at 2.5, 4.5, and 5.5 years) of mother-child dyads. Results of the study indicated that maternal sensitivity was positively associated with vagal withdrawal in children (from age 2.5 years to age 4.5 years), and in turn, vagal withdrawal at 4.5 years was positively associated with maternal sensitivity at 5.5 years.

Theoretically, as resting HF-HRV is an indicator of one's ability to maintain physiological homeostasis, parent's resting HF-HRV may be associated with their child's vagal regulation, such that a parent's ability to self-regulate may affect their child's ability to physiologically respond to stress. For example, a parent with a high resting HF-HRV may be better able to maintain their composure in stressful situations and thus focus on using the opportunity to teach their child coping strategies to modulate their emotional arousal. On the other hand, a parent with low resting HF-HRV may be so preoccupied with their own reaction to stressful situations that they are unable to teach or reinforce the use of adaptive emotion regulation strategies in their children. Thus, it may be that parent's emotion regulation abilities affect their child's emotion regulation abilities but that research to date has not uncovered this finding because past studies have not examined multiple physiological indices associated with emotion regulation (e.g., resting vagal tone and vagal regulation). Alternatively, it may be that the influence of parent emotion regulation on their child's emotion regulation becomes apparent only by examining both parent and child's vagal regulation. In other words, resting baseline HRV may not be the mechanism responsible for the entrainment of parent and child HRV; instead the association may be exemplified through the flexibility and functionality of individuals' ability to regulate their emotional arousal in response to stress.

7. The Present Study

The ability to regulate one's emotional responses is associated with adaptive social functioning and psychological adjustment, and emotion regulation has become a focal point for researchers in the study of child development (Eisenberg & Fabes, 1992; Han & Schaffer, 2013; Hubbard & Coie, 1994; Southam-Gerow & Kendall, 2002). Furthermore, heart rate variability has emerged as a potentially important biomarker associated with emotion regulation as it is a direct, objective measure of one's ability to successfully regulate their emotional arousal (Appelhans & Luecken, 2006). Despite empirical evidence that parent and child HRV become entrained beginning in utero and continuing outside of the womb through social interactions, no research to date has found an association between parent and child resting HF-HRV. Research indicates the role of parenting in helping to shape children's emotion regulation abilities, but previous studies have mainly focused on parent socialization of emotions and have looked at samples of younger children. Parenting behaviors may affect the emotional climate of the family, and this may in turn affect children's resting HF-HRV by facilitating or impeding the development of emotion regulation strategies. In addition to this direct link, parenting behaviors may also affect children's emotion regulation by moderating the association between parent and child resting HF-HRV, such that parent and child resting HF-HRV may become more or less strongly related in the context of specific parenting behaviors.

The present study first aims to investigate the relation between parent and child resting HF-HRV in a sample of adolescents. Secondly, the study aims to test for possible effects of positive and negative parenting behaviors (positive parenting, parental involvement, poor monitoring, inconsistent discipline, and corporal punishment) on child resting HF-HRV. The third aim is to examine these positive and negative behaviors as moderators of the association between parent and child HF-HRV to test the theory that parent and child HF-HRV may become entrained or decoupled in the context of specific parenting behaviors. Finally, the study aims to expand the literature by conducting exploratory analyses to examine vagal regulation as an alternative physiological index of emotion regulation and explore the theory that the concordance between parent and child emotion regulation may become more apparent through the analysis of vagal regulation versus resting HF-HRV.

7.1 Hypotheses

7.1.1 Hypothesis 1: Positive parenting, parental involvement, poor monitoring, inconsistent discipline, and corporal punishment were hypothesized to be associated with youth resting HF-HRV. Specifically:

a. Positive parenting and parental involvement were hypothesized to be positively associated with youth resting HF-HRV. Children exposed to positive parenting behaviors (e.g., warmth, acceptance) and high levels of parental involvement may feel more comfortable exploring their emotions in front of their parents without fear of their parents' reactions to their emotional expression. These children may thus have more opportunities to practice self-regulation and as a result feel more confident in their ability to control their physiological arousal in distressing situations. Involved parents may also invest more time in scaffolding their child's self-regulation by teaching and reinforcing their child's use of adaptive emotion regulation strategies. Thus, children with positive, involved parents may be more likely to develop a flexible range of emotion regulation strategies evidenced through higher resting HF-HRV.

b. Poor monitoring, inconsistent discipline, and corporal punishment were hypothesized to be negatively associated with youth resting HF-HRV. Children of parents who do not monitor them closely may feel as if their parents are less invested in their lives and may in turn be less likely to seek assistance regulating their emotional states. Parents who do not monitor their child closely may also be less likely to notice signs of poor emotion regulation abilities in their child and may fail to intervene on the child's behalf resulting in emotional dysregulation as evidenced by low resting HF-HRV. Inconsistent discipline may also undermine a child's emotion regulation as reflected by low resting HF-HRV because a lack of predictable, clear boundaries may decrease the likelihood that children internalize parents' rules, expectations, and guidance in emotion socialization and self-regulation abilities, thus hindering children's development of appropriate emotional responses to distressing situations. Finally, research indicates corporal punishment is associated with emotional and behavioral maladjustment in children as parents' use of corporal punishment models unhealthy emotion regulation. Furthermore, the frequent use of corporal punishment may lead a child to perceive their home environment as threatening and decrease their sense of control over their environment, leading to emotional dysregulation as evidenced by low resting HF-HRV.

7.1.2 Hypothesis 2: Parenting behaviors were hypothesized to moderate the association between parent resting HF-HRV and youth resting HF-HRV. Specifically:

a. Among youth exposed to negative parenting behaviors (i.e., poor monitoring, inconsistent discipline, corporal punishment), parent resting HF-HRV was hypothesized to be positively associated with child resting HF-HRV. Emotionally dysregulated parents may be more likely to display uninvolved, harsh, and inconsistent parenting behaviors. These parenting behaviors may be especially detrimental for children of parents with low HF-HRV as the negative parenting behaviors may exacerbate the child's underlying predisposition for inflexible autonomic regulation and thus further entrain their emotional dysregulation with their parents' dysregulation.

b. Among youth exposed to greater positive parenting behaviors (i.e., positive parenting, parental involvement), parent resting HF-HRV was not hypothesized to be associated with youth resting HF-HRV because exposure to positive parenting behaviors was expected to provide a buffering effect for these youth. Families characterized by high levels of positive emotion and high levels of parental involvement provides children with greater exposure to expressions of positive emotion and emotion regulation. This may be particularly beneficial for children of parents with low resting HF-HRV as it may decouple the entrainment of their HRV with their parent's HRV and thus buffer the child from the negative effects of their parents' autonomic inflexibility (i.e., emotion dysregulation).

In addition to the two previously stated study hypotheses, the present study also aimed to conduct exploratory analyses to examine if high parent resting HF-HRV would be associated with increased child vagal regulation in response to a mental arithmetic stressor task. Additionally, the present study aimed to examine if vagal regulation in parents would be positively associated with vagal regulation in children in an exploratory analysis.

8. Method

8.1 Participants

Ninety-seven caregiver-youth dyads (81 caregivers and 97 youth) were recruited from New Orleans and the surrounding area by the Youth and Family Anxiety, Stress, and Phobia Lab of the University of New Orleans (UNO) from August 2011 to March 2013. Recruitment procedures entailed distributing flyers in local intermediate and secondary schools, recruiting undergraduate students enrolled in psychology courses at the University of New Orleans to refer caregiver-adolescent dyads, and posting advertisements via the internet (i.e., Craigslist and Facebook). The flyers and advertisements specifically asked for help from caregiver-youth dyads in conducting a project on the emotional reactivity of both caregivers and teenagers (see Scott & Weems, 2014). Families received a small cash compensation for their participation.

Five parents in the sample were missing physiological data. Additionally, two parents reported that their children had a history of a pervasive developmental disorder (i.e., Asperger's and Autism) and thus were excluded from study analyses as research indicates that HRV in children with Autism may differ relative to control children (Bal et al., 2010; Graveling & Brooke, 1978). The final sample consisted of 95 socioeconomic and ethnically diverse group of youth (79 child-caregiver dyads) aged 11 to 17 years ($Mean_{age}$ = 13.84, SD_{age} = 1.95; 49.5% female). Caregivers reported youth's ethnicities as 34.7% African American (n = 33), 36.8% Euro-American (n = 35), 22.1% other/mixed ethnic background (n = 21) and 6.3% Hispanic (n = 6). The median family income (n_{family} = 79) was between \$20,000 and \$49,999 a year.

8.2 Measures

8.2.1 Heart Rate Variability

The first physiological index was the *High Frequency – Heart Rate Variability (HF-HRV; Involuntary Parasympathetic-mediated Regulation of Heart Rate)* which drawing from numerous past studies (Appelhans & Luecken, 2006; Berntson et al., 1997; Butler et al., 2006; Vasilev et al., 2009; Wetzel et al., 2006) was calculated using "normal" IBIs extracted from the EKG signal (more specific details on this process is described in the Procedures section). The HF-HRV for the Resting Baseline is explained in detail below.

The second physiological index was *Vagal Regulation* or change in HF-HRV from the Resting Baseline condition to the Mental Arithmetic Task. The HF-HRV from the first three minutes of the Resting Baseline and Mental Arithmetic Task were used in multilevel modeling to derive a repeated measures index of Vagal Regulation in youth (this method of analysis is described in the Results section). This method allowed for testing specific hypotheses related to vagal regulation and youths' emotional and behavioral problems.

8.2.2 Parenting Behaviors. Parenting behaviors were assessed using the parent and child versions of the Alabama Parenting Questionnaire (APQ-P and APQ-C; Frick, 1991; Shelton et al., 1996). The APQ (both parent and child measures) is a 42-item self-report measure that assesses parenting practices across five domains: positive parenting, parental involvement, poor monitoring, inconsistent discipline, and corporal punishment. Directions tell the parent/child to circle the number that best describes how often each item typically occurs in their home on a 5-point scale where 1 = *never* and 5 = *always*. For 9 of the 10 items included on the parental involvement scale on the APQ-Child report, the questions are asked about the child's mother and father separately (e.g., "your mom helps you with your homework"). As done previously in

Shelton et al. (1996), analyses conducted in the present study with the parental involvement subscale tested mother parental involvement and father parental involvement separately. A number of previous studies have found the APQ-P and APQ-C to demonstrate good reliability and validity estimates. For example, Shelton et al. (1996) reported that scales from the APQ were generally uncorrelated with measures of a socially desirable response set for both the child report and parent report forms (r's ranging from −0.01 to 0.23 across APQ dimensions). Dadds, Maujean, and Fraser (2003) found good levels of test-retest reliability in an Australian community sample of 4 to 9 year old children using the parent report form of the APQ across a 2-week period (n = 19, involvement: r = .87, monitoring/supervision: r = .84, positive techniques: r = .85, inconsistent discipline: r = .88, corporal punishment: r = .90). In a large community sample of children aged 10 to 14 years, Essau, Sasagawa, and Frick (2006) found acceptable levels of internal consistency (above .70), with the exception of the inconsistent discipline scale (.54 and .62 for father and mother data, respectively). The current sample showed good internal consistency on both the child and parent report [i.e., child report: Cronbach's α = .86 (positive parenting), .83 (mother parental involvement), .76 (father parental involvement), .77 (poor monitoring), .61 (inconsistent discipline), .69 (corporal punishment); parent report: Cronbach's α =.82 (positive parenting), .78 (parental involvement), .74 (poor monitoring), .71 (inconsistent discipline), and .82 (corporal punishment)].

8.2.3 Demographic Information. Caregivers were asked to provide personal information for themselves and their children, including age, gender, ethnicity, and family income. In addition, they were asked to provide information regarding any medication they or their child was currently taking (i.e., what type of medication and last time of administration).

8.3 Procedure

Caregiver-youth dyads interested in participating in the study contacted the research lab via the phone number printed on a flyer and/or advertisement. A member of the research staff provided the caregiver with an overview of the project and gathered further contact (e.g., name, phone number, etc.) and screening information. For those caregiver-youth dyads who were still interested in participating in the study, the research staff scheduled an appointment for them to come into the lab at a time of their convenience. Each dyad was instructed not to eat, drink (water was acceptable), or smoke cigarettes one hour before coming to the research lab.

Upon arrival, a trained graduate assistant (GA) explained to both the parent and child the purpose of the study and had them sign written informed consent and youth assent forms, respectively. In addition, the GA gave both the caregiver and child an opportunity to ask further questions and answered such questions before proceeding with the study. Once informed consent and assent was obtained, both the GA and a trained research assistant (RA) escorted the dyad to the control room, and the GA explained that he/she would be sitting in this room during the physiological assessment period and providing instructions through a microphone. This was intended to ease the novelty of the situation and attempt to lessen any apprehension the child or caregiver might have about the location of the GA and RA. Then the RA escorted the caregiver and child to the physiological assessment room and placed the physiological sensors on the child (the caregiver was present for this procedure).

Physiological measurements (i.e., heart rate, respiration, skin conductance, and temperature) were collected and stored on a Dell Studio XPS, Intel ® Core™, 2.67GHz, 3GB RAM using Biograph Infiniti software and the accompanying hardware competent, ProComp Infiniti encoder (Meyers, 2010). The Biograph Infiniti software was run using a Microsoft

Windows 7, 32-bit operating system and output was automatically stored within a designated file (using only the participant's unique id number) on the computer. Sensors connected to both the ProComp Infiniti encoder were attached to youth via specially designed cables and fiber optic wiring, respectively. Electrocardiogram (EKG) sensors were attached using UniGel electrodes (pre-gelled) and were placed on the right and left abdomens (below the rib cage) and at the top of the sternum. Respiration, blood volume pulse (BVP), galvanic skin response (GSR), and temperature were also assessed, but these data were not analyzed in the present study. After attaching the sensors, the RA (RA1) instructed the child to sit in a comfortable chair and face the computer monitor, while the caregiver was taken to another quiet room to complete the parent-report measures with an additional RA (RA2) present to answer questions or clarify items if needed.

The RA (RA1) next shut the door to the physiological room and entered the control room (adjacent to the physiological room) where the GA began running a scripted physiological protocol using the Biograph Infiniti software. The GA checked the physiological signals for poor connections and other possible artifacts before proceeding with the physiological assessment. If a problem was discovered before (or during) the assessment, the RA was asked to adjust the sensor(s) per the GA's instructions. The physiological assessment protocol lasted approximately 60 minutes and was video and audio recorded (and monitored live) via a webcam attached to the ceiling behind the child.

The first phase of the physiological assessment (i.e., Video Baseline) consisted of the experimenter asking the participant to relax and watch a short film clip (i.e., *Coral Sea Dreaming Film Clip*). This five-minute film clip displayed coral reef and undersea fish and was extrapolated from the DVD version of *Coral Sea Dreaming*. The purpose of this relaxationbased film clip was to help the participant acclimate to the testing environment, while keeping their attention focused on the monitor and recording Video Baseline physiological data. If problems with the signal were detected, the experimenter asked a research assistant (RA) to readjust sensor placement on the participant immediately following this phase. The second phase consisted of the experimenter asking the participant to relax and breathe normally for five minutes (i.e., Resting Baseline) while physiological data was recorded. The third phase consisted of two blocks on one-minute trials (3 trials per block) in which the experimenter instructed the participant to increase (speed up) or decrease (slow down) his heart rate. The overall purpose of this phase was to measure participants' ability to control their heart rate.

The fourth phase consisted of a modified non-vocal and developmentally appropriate version of the serial 7's task (i.e., Mental Arithmetic Task; Stroud et al., 2009). This phase consisted of the participant being asked to subtract a specific number (13 if child's age was 11-14 years; 17 if child's age was 15-17 years and for adult participants) from 500 and continue to subtract that number from each subsequent answer. The task lasted exactly three minutes and five seconds (only the first three minutes of data were extracted and analyzed) and participants were asked to type their answers into a keypad placed directly in front of them on the desk. The purpose of this nonverbal procedure was to minimize fluctuations in EKG and respiration signals due to speaking that may influence the HF-HRV index.

Only youth completed the final phase of the physiological assessment; parents' participation in the physiological assessment ended after completion of the mental arithmetic task. Youth watched 10 video vignettes (10-20 seconds in length) depicting ambiguous situations youth may have with their peers in between a 10 second resting baseline before the vignette began and a 30 seconds recovery period after the vignette ended. The youth then were asked to orally answer six questions after each video vignette that assessed their level of hostile attribution in response to each video vignette. The physiological measurements obtained during the first (video baseline), third (heart rate control) and final phase (vignettes) of the physiological assessment were not used in this study.

After the child completed the physiological assessment component of the study, the RA (RA1) led the child to the quiet room and administered the youth questionnaire packet while the other RA (RA2) led the caregiver to the physiological room. The caregiver completed the same physiological assessment while the youth completed the questionnaire packet. Upon completion of the parent's physiological assessment and child's completion of the questionnaires, the caregiver-youth dyad were provided with a debriefing form and asked if they had questions or concerns. The GA then thanked for their time and provided $50 for their participation.

8.3.1 Data Analytic Strategy

Fourteen families in the sample participated with more than one child (families with two children, n = 12; families with three children n = 2). In cases when multiple children participated from a family, parents completed parenting measures (APQ-P) about each child. Thus, children were nested within families, introducing the possibility of effects due to shared family variance into the model. This dependency in the data was handled by testing hypotheses with hierarchical linear modeling (HLM) which accommodates the nested nature of the dataset and does not assume that individual observations are independent or that error terms are uncorrelated (Bryk & Raudenbush, 1992). In the HLM models tested, the identifying variable across Level 1 and 2 was the family number (i.e., the parent and all children of that parent received a single unique family identification number). In predicting child vagal tone, child's age, child's gender, and report of parenting behaviors specific to that child were Level 1 predictors and parent vagal tone was tested on Level 2; moderation was tested by the significance of the effects of parents' vagal tone on the Level 1 associations.

8.3.2 Physiological Data Extraction. EKG data from the resting baseline and mental arithmetic task were analyzed using the Kubios HRV 2.1 software (Tarvainen, Niskanen, Lipponen, Ranta-aho, & Karjalainen, 2009). The data were first manually and visually inspected for artifacts (e.g., misidentified, missed, or extra heart beats). Next, an automatic artifact detection algorithm (medium correction setting) was used to detect interbeat-intervals that were .25 seconds above or below the mean inter-beat intervals for the entire time series. If the automatic detection results were consistent with manual inspection findings, automatic correction of inter-beat intervals artifacts was then applied to the data (manual correction was implemented for discrepancies). This method of artifact correction allowed for a standardized procedure of normalizing the inter-beat intervals data (i.e., without under- or over-correction). The artifact-free inter-beat intervals were then resampled at .025 Hz and the entire time series was detrended using a second-order polynomial (Porges, Doussard-Roosevelt, & Maiti, 1994a) in an effort to remove non-stationary data. The inter-beat intervals were then finally subjected to a power spectral analysis using a Fast Fourier Transform algorithm for the resting baseline and mental arithmetic task conditions, which produced absolute power (or variance) distributions for low frequency HRV (.04 to .15 Hz) and high frequency HRV (.15 to .40 Hz) consistent with reported standards for spectral analysis (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996).

Vagal regulation was calculated as the difference between physiological recordings of the mental arithmetic (i.e., stressor task) and resting baseline physiological conditions (HF-HRV during the resting baseline condition subtracted from the HF-HRV during the mental arithmetic task). Positive change scores represented an increase in vagal withdrawal from the baseline to stressor task while negative change scores represented a decrease in vagal withdrawal when exposed to the stressor task. In an effort to construct reliable and valid intercepts and slopes from the resting baseline to the mental arithmetic task, only the first three minutes of the resting baseline recording were used to directly correspond with the three-minute HF-HRV from the mental arithmetic task. To maintain consistency, all study analyses were conducted using the first three minutes of the resting baseline physiological recording.

9. Results

9.1 Preliminary Data Analyses

Preliminary examination of the distributions and scatter plots between the main study variables identified 12 univariate outliers for the APQ parental (father) involvement (child report $n = 1$), APQ poor monitoring scale (child report $n = 1$), APQ inconsistent discipline scale (child report $n = 1$), APQ corporal punishment scale (child report $n = 1$), parent HF-HRV (resting baseline condition, $n = 2$; mental arithmetic condition, $n = 2$), and child HF-HRV (resting baseline condition, $n = 2$; mental arithmetic condition, $n = 2$). Pairwise deletion of cases was used to handle univariate outliers given that different variables were used in each analysis and each case had usable data for other analyses. The means, standard deviations, range, and skewness of the study variables after the exclusion of outliers are summarized in Table 1.

Table 1. *Means, Standard Deviations, Ranges, and Skew for Measures*

	n	*M*	*SD*	Min-Max	Skew(*St.E*)
Child HF-HRV					
Resting Baseline	93	1110.86	1011.68	69.75-5975.44	2.08(.25)
Mental Arithmetic Task	93	1091.10	990.26	83.83-4555.74	1.68(.25)
Parent HF-HRV					
Resting Baseline	74	537.19	586.17	29.29-3277.09	2.39(.28)
Mental Arithmetic Task	73	350.54	372.09	0.86-2017.41	2.29(.28)
APQ-Child Report					
Positive parenting	93	21.54	5.20	6-30	-0.51(.25)
M Parental Involvement	95	33.83	7.83	10-49	-0.29(.25)
F Parental Involvement	86	24.44	9.50	10-42	0.15(.26)
Poor Monitoring	93	20.88	6.19	10-38	.43(.25)
Inconsistent Discipline	94	14.39	3.71	6-24	0.04(.25)
Corporal Punishment	94	4.23	1.73	3-10	1.26(.25)
APQ-Parent Report					
Positive Parenting	85	25.21	3.88	16-30	-0.63(.26)
Parental Involvement	85	38.88	6.14	21-49	-0.56(.26)
Poor Monitoring	85	16.39	5.25	10-32	1.21(.26)
Inconsistent Discipline	85	14.51	4.14	6-23	0.01(.26)
Corporal Punishment	85	4.28	1.79	3-9	1.48(.26)

Note: APQ-C = Alabama Parenting Questionnaire - Child Report, subscales: M Parental Involvement = Mother's Involvement, F Parental Involvement = Father's Involvement; APQ-P = Alabama Parenting Questionnaire - Parent Report; HF-HRV, High Frequency Heart Rate Variability.

As shown in Table 1, the APQ corporal punishment scales (parent and child report) were slightly positively skewed. However, this skewness is consistent with past research using this measure and thus the variables were not transformed. HF-HRV indices for the resting baseline (parent and child) and mental arithmetic task (parent and child) were severely positively skewed and were log-transformed using base 10 [log(10)] to produce a more normal distribution as is common practice with HF-HRV indices in the literature (see e.g., Monk et al., 2001). The skewness of the HF-HRV indices was significantly improved as a result of the log-transformation. Pearson's correlations were conducted to examine relations across the study variables and are summarized in Tables 2 and 3.

Table 2. *Pearson's Correlations for Self-Report Measures*

	1	2	3	4	5	6	7	8	9	10
Child										
1. APQ-C Positive Parenting										
2. APQ-C Mother Involvement	.76**									
3. APQ-C Father Involvement	.50**	.45**								
4. APQ-C Inconsistent Discipline	.14	.22*	-.06							
5. APQ-C Poor Monitoring	-.07	<.01	-.09	.56**						
6. APQ-C Corporal Punishment	<.01	-.05	.03	.10	.12					
Parent										
7. APQ-P Positive Parenting	.55**	.44**	.13	.14	.01	.01				
8. APQ-P Parental Involvement	.42**	.45**	.17	.19	-.11	.12	.65**			
9. APQ-P Inconsistent Discipline	-.09	.08	.08	.15	.15	.09	.01	-.06		
10. APQ-P Poor Monitoring	-.23*	-.24*	-.16	-.09	.23*	-.21	-.12	-.36**	.33**	
11. APQ-P Corporal Punishment	.24*	.22*	.20	.02	-.02	.37**	.10	.16	.05	-.06

Note: ** $p < .01$; * $p < .05$. APQ-C = Alabama Parenting Questionnaire –Child Report; APQ-P = Alabama Parenting Questionnaire – Parent Report.

Table 3. *Pearson's Correlations for Physiological Indices and Demographics*

	1	2	3	4	5	6	7	8
Child								
1. Gender								
2. Age	-.02							
3. HF-HRV Resting Baseline	-.10	<.01						
4. HF-HRV Arithmetic Task	-.11	<-.01	.68**					
5. HF-HRV Vagal Regulation	-.01	-.01	-.45**	.35**				
Parent								
6. Gender	-.04	.23*	.03	.14	.13			
7. HF-HRV Resting Baseline	.17	-.11	.11	.17	.04	.06		
8. HF-HRV Arithmetic Task	.11	-.04	.01	.09	.08	.31**	.65**	
9. HF-HRV Vagal Regulation	-.07	.07	-.08	-.03	-.06	.33*	-.20	.62**

Note: ** $p < .01$; * $p < .05$. HF-HRV, Log transformed High Frequency Heart Rate Variability.

Multilevel modeling was conducted using the software program HLM 7.0 (Raudenbush, Bryk, Cheong, Fai, Congdon, & du Toit, 2011) in order to examine the association between parent and child resting baseline HF-HRV. The outcome variable was child HF-HRV for the resting baseline condition. The parent HF-HRV for the resting baseline condition was entered as a level 2 predictor and grand-mean centered to reduce multicollinearity (Tabachnick & Fidell, 2007). Results indicated that there was no significant effect of parent resting baseline HF-HRV on child resting baseline HF-HRV [coefficient = 0.15, $t(70) = 1.44$, $p > .05$].

A model was also tested with child age and child gender as moderators of the association. Age and gender (coded 0 = boy and 1 = girl) were entered as level 1 predictors, parent resting HF-HRV score (grand-mean centered) was entered as a continuous level 2 predictor, and child resting baseline HF-HRV was the outcome variable. Results indicated no significant age [coefficient = -0.01, $t(70) = -0.05$, $p > .05$] or gender [coefficient = -0.16, $t(70) = -0.89$, $p > .05$] effect on the association between parent and child resting HF-HRV.

9.2 Testing for Possible Medication Effects

Given past research suggesting that the use of psychotropic drugs may affect HF-HRV indices (e.g., Blom et al., 2010), two additional HLM analyses were conducted with current medication use (by the parent and child, analyzed separately) as a covariant. First, a potential effect of parent medication use was investigated in a HLM analysis. Parent medication use (coded 0 = no current medication use, 1 = current medication use) was entered as a level 2 predictor along with parent resting baseline HF-HRV and an interaction term (medication use * parent resting baseline HF-HRV, centered). Results of the analysis indicated that parent medication use did not affect the association between parent and child resting baseline HF-HRV [coefficient = 0.16, $t(68) = 0.81$, $p > .05$]. To examine a potential effect of child medication use, a second HLM analysis was conducted with a child medication usage variable (coded 0 = no current medication use, 1 = current medication use) entered as a level 1 predictor, parent resting baseline HF-HRV entered as the level 2 predictor, and child resting baseline HF-HRV as the outcome variable. Results indicated a non-significant finding. Child medication use did not moderate the association between parent and child resting baseline HF-HRV [coefficient = 0.27, $t(70) = 0.99$, $p > .05$].

9.3 Parent Gender Effects

Although most parents in the sample were mothers, there were 6 fathers in the sample and so gender of the parent was analyzed to test if parent gender affected the association between parent and child resting baseline HF-HRV. An HLM analysis was conducted with parent gender (coded 1 = Father, 2 = Mother), parent resting baseline HF-HRV (grand-mean centered to reduce multicollinearity), and an interaction term (parent gender, centered * parent resting baseline HF-HRV, centered) as level 2 predictors and child resting baseline HF-HRV as the outcome variable. Results provided no indication that parent gender affected the association between parent and child resting baseline HF-HRV [coefficient = -0.18, $t(68) = -0.28$, $p > .05$].

9.4 Hypothesis 1: Positive parenting, parental involvement, poor monitoring, inconsistent discipline, and corporal punishment were hypothesized to be associated with child resting baseline HF-HRV.

Multilevel modeling was conducted using HLM 7 to account for the nested nature of the study design. Specifically, the HLM analyses nested children (level 1) as a function of their HF-HRV within their family (level 2; i.e., their parent's HF-HRV). Child resting baseline HF-HRV was the outcome variable in the model, parent resting baseline HF-HRV (grand-mean centered to reduce multicollinearity; Tabachnick & Fidell, 2007) was the level 2 variable, and each of the five parenting behaviors (positive parenting, parental involvement, poor monitoring, inconsistent discipline, and corporal punishment) was tested in a separate model as a level 1 predictor (grand-mean centered). Analyses were run with both parent and child report of the parenting behavior, such that ten analyses were run in total.

Results indicated a significant association between positive parenting as reported by the parent [coefficient = 0.04, $t(70) = 3.33$, $p < .01$] and child resting HF-HRV, such that higher levels of positive parenting were associated with higher levels of resting HF-HRV in children. Parental involvement as reported by the parent [coefficient = 0.02, $t(70) = 2.53$, $p < .05$] was also positively associated with child resting HF-HRV, such that higher levels of parental involvement were associated with higher levels of child resting HF-HRV. Results indicated a significant negative association between inconsistent discipline as reported by the parent [coefficient = -

0.02, $t(70) = -2.25$, $p < .05$] and child resting HF-HRV, such that higher levels of inconsistent discipline were associated with lower levels of child resting HF-HRV. Finally, the child's report of their parent's use of corporal punishment was associated with child resting HF-HRV [i.e., significant main effect; coefficient = -0.06, $t(69) = -2.43$, $p < .05$]; however, this association was only significant when the child's gender was simultaneously entered as a level 1 predictor (see Table 4). In other words, parent's use of corporal punishment was negatively associated with child resting HF-HRV but only after controlling for gender effects. This finding indicates the presence of a statistical suppressor effect. Given the significant negative correlation between child gender and corporal punishment (child-report, $r = -.21$, $p < .05$; see Appendix A), it is likely that variation common to both gender and corporal punishment suppressed the error term (i.e., error variance) for corporal punishment, causing corporal punishment to become significantly associated with child resting baseline HF-HRV.

Table 4. *Hierarchical Linear Modeling of Corporal Punishment Main Effect (Including Gender)*

Fixed Effect	Coefficient	*SE*	*t*-ratio	*df*	*p*-value
Intercept, β_0					
Intercept, γ_{00}	3.09	0.12	26.46	69	<0.001**
PRBHRV, γ_{01}	0.55	0.25	2.25	69	0.027*
Gender slope, β_1					
Intercept, γ_{10}	-0.13	0.08	-1.79	84	0.077
PRBHRV, γ_{11}	-0.27	0.18	-1.51	84	0.136
CORPPUNC slope, β_2					
Intercept, γ_{20}	-0.06	0.03	-2.43	69	0.018*
PRBHRV, γ_{21}	-0.03	0.07	-0.48	69	0.635

Note: ** $p < .001$; * $p < .05$. PRBHRV, Parent Resting Baseline Log Transformed High Frequency Heart Rate Variability; CORPPUNC, Alabama Parenting Questionnaire - Child Report Corporal Punishment subscale.

Results indicated no evidence of an association between positive parenting as reported by the child [coefficient = 0.02, $t(70) = 2.07$, $p > .05$], parental involvement as reported by the child [mother's involvement, coefficient = 0.01, $t(70) = 1.75$, $p > .05$; father's involvement, coefficient = -0.01, $t(65) = -0.23$, $p > .05$], poor monitoring as reported by the parent [coefficient = 0.01, $t(70) = 0.69$, $p > .05$] or by the child [coefficient = -0.01, $t(69) = -1.31$, $p > .05$], inconsistent discipline as reported by the child [coefficient = 0.01, $t(69) = 0.12$, $p > .05$], or corporal punishment as reported by the parent [coefficient = -0.01, $t(70) = -0.47$, $p > .05$] and child resting baseline HF-HRV.

9.5 Hypothesis 2: Negative and positive parenting behaviors would moderate the relationship between parent and child resting HF-HRV.

Hypothesis 2 states that specific negative and positive parenting behaviors would moderate the relationship between parent and child resting baseline HF-HRV, such that in the context of negative parenting behaviors (poor monitoring, inconsistent discipline, and corporal punishment), parent and child resting HF-HRV would become more entrained, and in the context of positive parenting behaviors (positive parenting, parental involvement), parent and child resting HF-HRV would be decoupled providing a buffering effect for children pre-disposed to developing low resting HF-HRV. Parenting behaviors were examined as potential moderators with multilevel modeling using HLM 7 to account for the nesting of child variables within the parent HF-HRV. Specifically, the HLM analyses nested children (level 1) as a function of their HF-HRV within their family (level 2; i.e., their parent's HF-HRV). Each APQ subscale (positive parenting, parental involvement, poor monitoring, inconsistent discipline, and corporal punishment from both the parent and child report) was tested in a separate model as a level 1 predictor (grand-mean centered to reduce multicollinearity; Tabachnick & Fidell, 2007). All

HLM analyses were conducted with parent resting baseline HF-HRV (grand-mean centered) as the level 2 variable and the child resting baseline HF-HRV as the outcome variable.

As summarized in Table 5, results of the analysis indicated that inconsistent discipline (parent report) significantly moderated the association between parent HF-HRV and child resting HF-HRV [coefficient = -0.06, $t(70) = -3.49$, $p < .001$]. More specifically, in the context of high inconsistent discipline, parent resting HF-HRV was negatively associated with child resting HF-HRV and in the context of low inconsistent discipline (i.e., consistent discipline), high parent resting HF-HRV was positively associated with high child resting HF-HRV (see Figure 1).

Table 5. *Hierarchical Linear Modeling of Inconsistent Discipline Moderation Effect*

Fixed Effect	Coefficient	*SE*	*t*-ratio	*df*	*p*-value
Intercept, β_0					
Intercept, γ_{00}	2.86	0.04	64.34	70	<0.001**
PRBHRV, γ_{01}	0.01	0.11	0.06	70	0.951
INCONDISP slope, β_1					
Intercept, γ_{10}	-0.02	0.01	-2.25	70	0.028*
PRBHRV, γ_{11}	-0.06	0.02	-3.49	70	<0.001**

Note: ** $p < .001$; * $p < .05$. PRBHRV, Parent Resting Baseline Log transformed High Frequency Heart Rate Variability; INCONDISP, Alabama Parenting Questionnaire - Parent Report Inconsistent Discipline subscale.

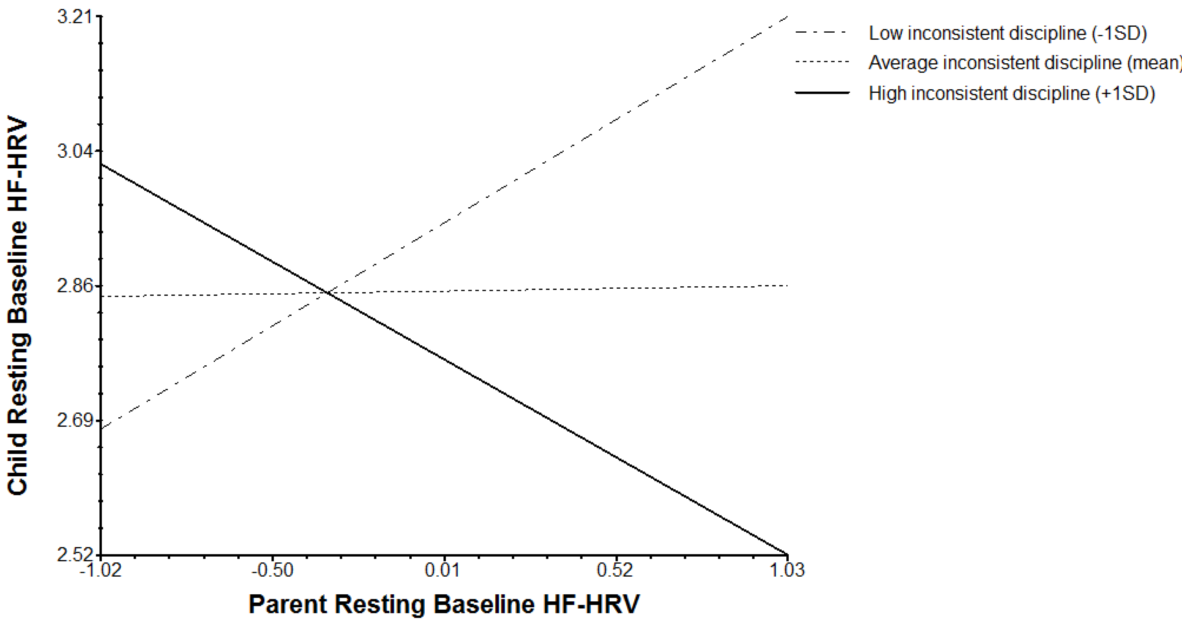

Figure 1: Inconsistent Discipline Moderates the Association between Parent and Child Resting Baseline High Frequency Heart Rate Variability (HF-HRV)

Additionally, as summarized in Tables 6 and 7, results indicated that mother's [coefficient = -0.03, $t(70) = -2.07$, $p < .05$] and father's [coefficient = -0.02, $t(64) = -2.10$, $p < .05$] involvement (child report) significantly moderated the association between parent resting HF-HRV and child resting HF-HRV, such that in the context of high parental involvement (mother and father), high parent resting HF-HRV was associated with low child HF-HRV and in the context of low parental involvement, parent and child resting HF-HRV were positively associated (see Figures 2 and 3).[1]

Table 6. *Hierarchical Linear Modeling of Mother's Involvement Moderation Effect*

[1] Inconsistent discipline (parent report) and parental involvement (child report of mother and father's involvement) were still found to significantly affect the relation between parent and child resting baseline HF-HRV after statistically controlling for possible confounding effects of parent gender, parent medication use, and child medication use on the association.

Fixed Effect	Coefficient	*SE*	*t*-ratio	*df*	*p*-value
Intercept, β_0					
Intercept, γ_{00}	2.89	0.04	76.27	70	<0.001**
PRBHRV, γ_{01}	0.16	0.09	1.72	70	0.090
INVOLVEM slope, β_1					
Intercept, γ_{10}	0.01	0.01	1.75	70	0.085
PRBHRV, γ_{11}	-0.03	0.01	-2.07	70	0.042*

Note: ** $p < .001$; * $p < .05$. PRBHRV, Parent Resting Baseline Log transformed High Frequency Heart Rate Variability; INVOLVEM, Alabama Parenting Questionnaire - Child Report Mother's Involvement subscale.

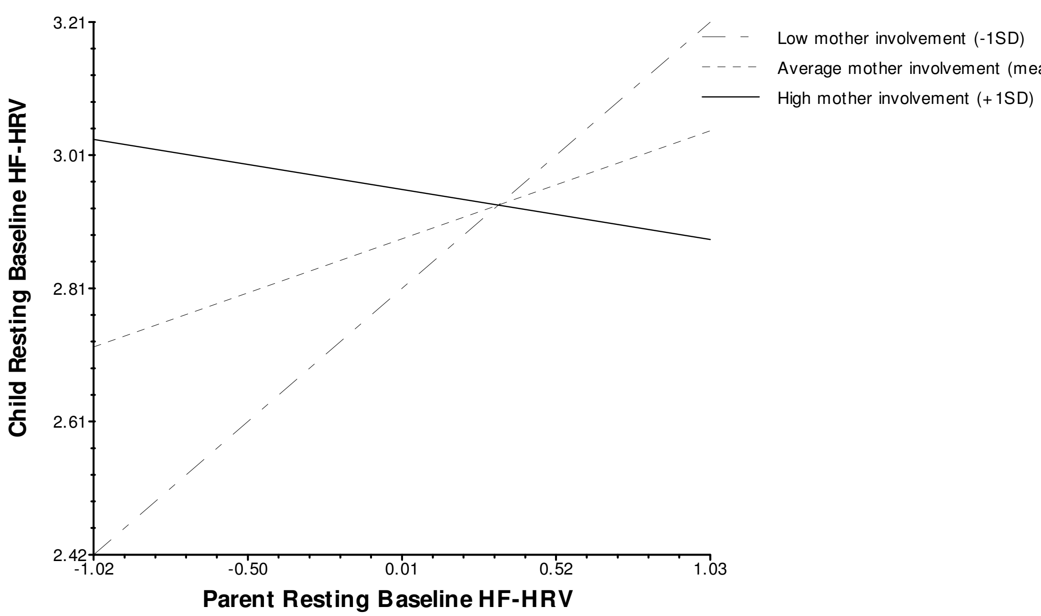

Figure 2: Mother's Involvement Moderates the Association between Parent and Child Resting Baseline High Frequency Heart Rate Variability (HF-HRV)

Table 7. *Hierarchical Linear Modeling of Father's Involvement Moderation Effect*

Fixed Effect	Coefficient	*SE*	*t*-ratio	*df*	*p*-value
Intercept, β_0					
Intercept, γ_{00}	2.84	0.04	63.33	64	<0.001**
PRBHRV, γ_{01}	0.21	0.10	2.08	64	0.041*
INVOLVEF slope, β_1					
Intercept, γ_{10}	-0.01	0.01	-0.34	64	0.733
PRBHRV, γ_{11}	-0.02	0.01	-2.10	64	0.040*

Note: ** $p < .001$; * $p < .05$. PRBHRV, Parent Resting Baseline Log transformed High Frequency Heart Rate Variability; INVOLVEF, Alabama Parenting Questionnaire - Child Report Father's Involvement subscale.

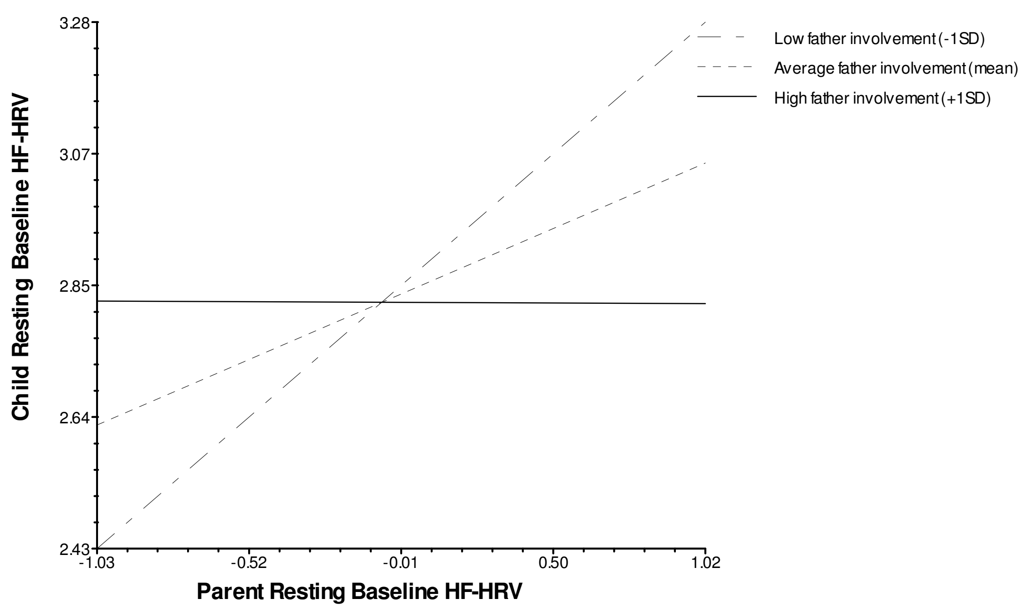

Figure 3: Father's Involvement Moderates the Association between Parent and Child Resting Baseline High Frequency Heart Rate Variability (HF-HRV)

Identical HLM models were run with each of the parenting variables (as reported by both parent and child, analyzed separately) as moderators. Results indicated no significant effect of positive parenting as reported by the child [coefficient = -0.04, $t(70) = -1.23$, $p > .05$] or parent [coefficient = -0.02, $t(70) = -0.83$, $p > .05$], parental involvement as reported by the parent [coefficient = -0.01, $t(70) = -0.88$, $p > .05$], poor monitoring as reported by the child [coefficient = -0.01, $t(69) = -0.51$, $p > .05$] or parent [coefficient = -0.02, $t(70) = -0.91$, $p > .05$], inconsistent discipline as reported by the child [coefficient = -0.02, $t(69) = -0.53$, $p > .05$], or corporal punishment as reported by the child [coefficient = -0.01, $t(69) = -0.07$, $p > .05$] or parent report [coefficient = -0.04, $t(70) = -0.57$, $p > .05$] as a moderator of parent and child resting baseline HF-HRV.

9.6 Exploratory Analyses

Multilevel modeling was conducted to examine individual differences in child HF-HRV change (random effects at level-1; repeated observations within the individual) from the resting baseline physiological recording to the mental arithmetic task to determine if parent resting baseline HF-HRV predicted this change. The outcome variable was the child HF-HRV score for the resting baseline and mental arithmetic conditions. Time (coded 0 = resting baseline, 1 = mental arithmetic task) was entered as the level 1 predictor and parent resting baseline HF-HRV (grand-mean centered) was entered as the level 2 predictor. Results indicated no significant effect of parent resting baseline HF-HRV on child HF-HRV change from the resting baseline to mental arithmetic task [coefficient = 0.03, $t(71) = 0.41$, $p > .05$].

Multilevel modeling was also used to examine if parent vagal regulation [i.e., the change in child HF-HRV from the baseline to stressor (mental arithmetic) task] predicted child vagal regulation. Parent vagal regulation (i.e., the parent HF-HRV change score) was entered as the level 2 predictor and the child vagal regulation score was entered as the outcome variable. Results indicated that parent vagal regulation was not associated with child vagal regulation [coefficient = 0.03, $t(68) = 0.35$, $p > .05$]. Next the child's gender was entered into the model as a covariate (coded 0 = boy, 1 = girl) on level 1 to examine if child's gender affected the relationship between parent and child vagal regulation. As summarized in Table 8 and depicted in Figure 4, results indicated that the child's gender was a moderator of the relationship between parent and child vagal regulation [coefficient = 0.35, $t(68) = 2.22$, $p < .05$], such that there was a positive association between parent and daughter's vagal regulation and a negative association between parent and son's vagal regulation.[2]

Table 8. *Child Gender Moderation Effect between Parent and Child Vagal Regulation*

Fixed Effect	Coefficient	*SE*	*t*-ratio	*df*	*p*-value
Intercept, β_0					
Intercept, γ_{00}	0.02	0.10	0.15	68	0.882
Parent Vagal Reg, γ_{01}	-0.55	0.29	-1.92	68	0.060
Child Gender slope, β_1					
Intercept, γ_{10}	-0.01	0.06	-0.17	68	0.869
Parent Vagal Reg, γ_{11}	0.35	0.16	2.22	68	0.030*

Note: * $p < .05$. Parent Vagal Reg, Parent Vagal Regulation.

[2] An additional HLM analysis was conducted to examine if the child's gender remained a significant moderator o the relationship between parent and child vagal regulation when adding parent gender as a covariate in the analysis. Results of the analysis indicated that parent gender moderated the association between parent and child vagal regulation [coefficient = .94, $t(66) = 2.47$, $p < .05$] and child gender was no longer a significant moderator.

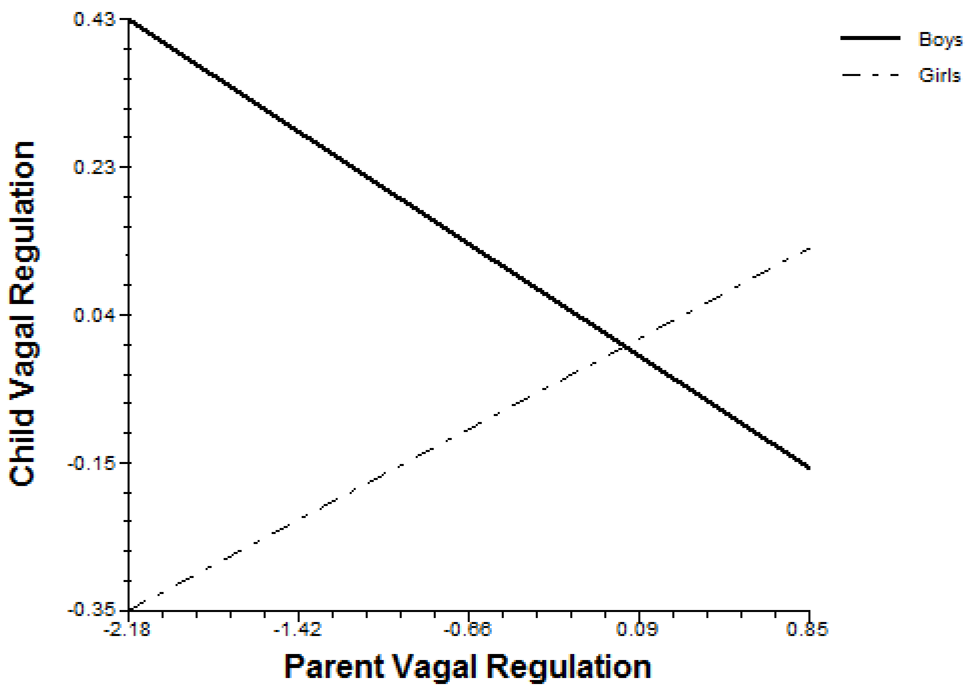

Figure 4. Child Gender Moderates the Association between Parent and Child Vagal Regulation

Again, given past research suggesting that some medications may affect cardiac vagal indices, two additional HLM analyses were conducted to test for any potential confounding effects of parent or child medication use. In the first analysis, parent medication use (coded 0 = no current medication use, 1 = current medication use), parent vagal regulation (grand-mean centered), and an interaction term (medication use * parent vagal regulation, centered) were entered as level 2 predictors. Child gender remained on level 1 and child vagal regulation was the outcome variable. Results of the analysis indicated that parent medication use did not affect the gender moderation effect [coefficient = 0.39, $t(66) = 1.22$, $p > .05$]. To examine a potential effect of child medication use, a second HLM analysis was conducted with a child medication usage variable (coded 0 = no current medication use, 1 = current medication use) entered as a level 1 predictor, parent vagal regulation (grand-mean centered) entered as the level 2 predictor, and child vagal regulation entered as the outcome variable. Results indicated a non-significant finding. Child medication use did not affect the relationship between parent and child vagal regulation [coefficient = -0.40, $t(68) = -0.73$, $p > .05$].

10. Discussion

The present study makes a number of contributions to knowledge about parents' role on their child's HRV. The present study was the first to specifically examine the effect of parents' positive parenting behaviors, as reported by the parent and child, on their child's resting baseline HF-HRV in an adolescent sample of youth. As hypothesized, positive parenting was positively associated with child resting HF-HRV, such that more positive parenting was associated with higher resting HF-HRV in youth. This is consistent with previous research indicating a link between supportive, warm parenting and parents' reports of their child's ability to regulate emotion (Davidov & Grusec, 2006; Shaffer, Suveg, Thomassin, & Bradbury, 2012). Theoretically, warm, positive parents are likely to model displays of positive emotion and positive emotion regulation for their children. Children exposed to warm, positive parenting may feel more comfortable talking to their parents about their emotions and seeking help in controlling their emotional arousal. Furthermore, positive parenting behaviors may signal to children that their emotions, both positive and negative, are normative and healthy and encourage children to express their emotions instead of repressing or avoiding them. Positive parenting may foster confidence in children in their abilities to independently cope with stressful situations and control their emotional arousal. As research provides evidence of an association between high vagal tone and healthy developmental outcomes, higher social competence, and a decreased likelihood of youth developing internalizing and externalizing disorders, the present finding of a positive association between positive parenting behaviors and resting HF-HRV further supports the role of parenting as an external contributor to youth's emotion regulation abilities.

Additionally, parent's report of their involvement in their child's life was positively associated with child resting HF-HRV as hypothesized. While this was the first study to examine the effect of parental involvement on a sample of adolescents' resting HF-HRV, this finding is consistent with the infant literature which suggests that children of mothers who provide greater emotional support and positive touch have been found to be better emotionally regulated and less physiologically reactive to stress (Feldman et al., 2010). The child's report of their parents' involvement was also found to moderate the association between parent and child resting HF-HRV; however, the nature of the moderation effect was not in the hypothesized direction. Results indicated that youths' reports of both mother's and father's involvement significantly moderated the association, such that in the context of high parental involvement, there was a negative association between parent and child resting HF-HRV. This finding suggests that high levels of mother and father involvement may interfere with the entrainment of parent and child HF-HRV while low levels of involvement may facilitate entrainment of parent and child HF-HRV.

Contrary to previous research that has found parental involvement to be protective against psychological risk in youth (Brookmeyer et al., 2005), the current findings did not provide evidence for parental involvement as measured in this study as a protective factor for youths' emotion regulation development. It may be that parents that are overinvolved in their child's daily activities and decision making may adversely affect youth by not allowing the child the opportunity to practice regulating their emotions on their own. Similar to parental control, which has been found to negatively affect youths' social and emotional well-being in prior research, it may be that youth, especially in the adolescent age group, require autonomy and self-direction in order to develop adaptive self-regulation abilities. The present study provides an interesting view of parental involvement as it assesses youths' report of their mother and father's involvement and adds to the literature by indicating that parental involvement may be a mechanism by which children may become emotionally dysregulated. Additional research collecting physiological data from an equal sample of mothers and fathers is needed to further examine parent gender effects across parental involvement and effects of involvement on emotion regulation specifically.

Although initial results did not provide support for an effect of corporal punishment on child resting HF-HRV, corporal punishment did become a predictor of child resting HF-HRV when child gender was entered into the model as a predictor, such that there was a negative association between corporal punishment and child's resting HF-HRV. This finding indicates the presence of statistical suppression. Suppression is said to occur when the simultaneous analysis of two or more variables (e.g., corporal punishment and gender) improves or strengthens the association with one or all of the other variables (Gaylord-Harden, Cunningham, Holmbeck, & Grant, 2010). In other words, youths' gender in the analysis was suppressing the error variance in the statistical model, and thus allowing the association between corporal punishment and child resting HF-HRV to become significant. This negative association between corporal punishment and child resting HF-HRV is consistent with a previous research study that found negative, controlling parenting behaviors to be associated with poor physiological regulation in toddlers (Calkins et al., 1998). More specifically, the current finding provides further support for the literature indicating that children exposed to corporal punishment are more likely to have problems with emotional and behavioral adjustment (Aucoin, Frick, & Bodin, 2006; Bradley et al., 2001; Eamon, 2001).

There are several theoretical explanations that may explain why corporal punishment was associated with low HF-HRV. For example, parents who exhibit hostile, negative harsh parenting techniques model dysregulated behavior for their children (Eisenberg et al., 2001) which may in turn foster emotion dysregulation in their children. Children exposed to corporal punishment may learn it is acceptable to lash out at others and disregard others' feelings when they are upset or angry and thus may be more likely to engage in similar maladaptive emotion regulation strategies. Furthermore, the extended use of corporal punishment as a disciplinary technique may be especially harmful for youth with low HF-HRV because it may cause youth to view their home environment as threatening and decrease their sense of control over their environment, which may exacerbate existing emotion dysregulation and maintain low HF-HRV levels.

The current study also adds to the literature by suggesting that parenting behaviors may serve as moderators of the association between parent and child resting HF-HRV. Consistent with the hypothesis that negative parenting behaviors would moderate the association between parent and child HF-HRV, findings indicated that inconsistent discipline was a significant moderator of the association, such that in the context of high inconsistent discipline, there was a negative association between parent and child resting HF-HRV. On the other hand, in the context of low inconsistent discipline (i.e., consistent discipline), there was a positive association between parent and child resting HF-HRV. This finding suggests that inconsistent discipline may interfere with the entrainment of parent and child HF-HRV while consistent discipline may entrain parent and child HF-HRV (i.e., make parent and child resting HF-HRV more similar).

Theoretically, there are several reasons why inconsistent discipline may moderate the association between parent and child resting HF-HRV. It may be that inconsistent discipline prohibits the entrainment of HRV because in the absence of predictable, clear boundaries, children are less likely to internalize adaptive emotion regulation tendencies. The unpredictability of inconsistent adherence to rules and consequences may undermine a child's sense of control (Laskey & Cartwright-Hatton, 2009) and cause youth to feel uneasy or emotionally insecure (Cummings & Davies, 1996). Children frequently exposed to inconsistent discipline may also feel less comfortable expressing their negative emotions because they are unsure of how their parent will react or fear negative responses from their parent. Alternatively, predictable consequences may enable youth to feel more secure thus providing a safe zone for youth to explore a range of emotions and provide opportunities for youth to practice self-regulation techniques. Because parents play a critical role in the socialization of children's emotion, it may be that children whose parents practice inconsistent discipline are less likely to be exposed to displays of positive emotion and receive less emotion coaching from their parents. Inconsistent discipline may cause children to feel their parents are not invested in their emotional development or that their home is not a safe place to express their emotions because of fear of consequences and thus lead to unhealthy emotion regulation strategies such as avoidance, suppression, or explosive outbursts of negative emotion. These children may develop an inflexible autonomic response to stressful situations because they were not taught adaptive ways to calm themselves down and diminish their emotional arousal. Furthermore, in a child with low vagal tone, inconsistent parenting may be especially problematic in that parents may further exacerbate their child's difficulty regulating their emotional arousal in response to changes in the environment.

Alternatively, results did not provide evidence of poor monitoring as a predictor of child resting HF-HRV or a moderator of the relation between parent and child resting baseline HF-

HRV. This finding is interesting in light of the study findings previously mentioned which indicate parental involvement may both negatively and positively affect a child's resting HF-HRV. This may suggest that it is parents' involvement in their child's everyday activities versus the act of monitoring the child's activities that is more influential on youths' capacity to regulate their emotions. Additionally, neither positive parenting nor corporal punishment was indicated as a moderator of the association between parent and child resting HF-HRV. Given the findings that positive parenting and corporal punishment did significantly influence child's resting HF-HRV, it may be that parenting behaviors affect youths' heart rate variability directly, and thus parents' heart rate variability is not the mechanism of influence. Alternatively, it may be that parenting behaviors do interact with parents' emotion regulation abilities to predict their child's emotion regulation abilities but that this association is not reflected through the physiological assessment of heart rate variability. Thus, behavioral observations or questionnaire measures assessing parents' emotion regulation capacities may serve as a more ideal assessment technique to test this theory.

Consistent with findings from previous studies (Bornstein & Suess, 2000; Perlman et al., 2008), results indicated that parent resting HF-HRV was not associated with child resting HF-HRV. The present study adds to the literature by examining an older sample of youth (aged 11-17 years) than examined in the two previous studies by Bornstein and Suess (2000; aged 2 months to 5 years) and Perlman and colleagues (Perlman et al., 2008; aged 4 to 5 years). While research does suggest that the vagal system continues to mature from birth to middle childhood and that mean levels of baseline RSA rise over development (Porges et al., 1994b; Stifter & Jain, 1996; Hickey et al., 1995; Suess et al., 1997), results of the present study did not provide any evidence supporting the hypothesis that parent resting HRV may become entrained with youth

HRV as a function of development. In fact, the present study found a large difference between the HF-HRV scores of the parents and youth in the sample. This may be due to the fact that although the sample of the present study was between the ages of 11 and 17 years, the mean age of youth in the sample was just under 14 years of age (13.8 years). Thus, older samples of adolescents and their parents should be examined in future longitudinal research to aid in our understanding of the nature of the relationship between parent and child vagal tone and how it changes across development.

The present study also increments the literature by testing for potential effects of medication on the concordance between parent and child resting HF-HRV. Results of the present study did not support previous research findings that suggest that the use of SSRI medications affect HF-HRV indices (Blom et al., 2010) in youth. However, the present study examined a community sample of youth (49.5% female), while Blom and colleagues (Blom et al., 2010) examined a clinical sample of exclusively female adolescents with anxiety disorders and/or major depressive disorders compared to healthy controls. More specifically, Blom and colleagues examined the effects of SSRI use on HRV. Only one child in the present study was taking an SSRI and thus does not provide the present study with enough statistical power to adequately test for differences in HRV due to the sole use of SSRIs. The most common medication taken in the present sample was stimulant medication (n = 25; e.g., Vyvanse, Adderall, Concerta). The present study also did not support previous research findings that indicate decreased vagal tone with significantly diminished HRV in unmedicated children with attention-deficit hyperactivity disorder compared to children with ADHD medicated with methylphenidate (Buchhorn et al., 2012). As previously mentioned, the present study examined a community sample of children and did not assess for psychopathology. In addition, parents reported that less than half of the children (n = 10) who reportedly took stimulant medication had taken their medication the day of their participation in the study. Thus, the present finding that child medication use did not affect the interaction between parent and child vagal tone is not surprising.

Results did not indicate a significant effect of parent medication use (n = 43) on the association between parent and child HF-HRV. It is important to note that previous literature regarding medication use and HRV in adult samples is mixed and that many adults in the study reported taking more than one type of medication (e.g., a stimulant and SSRI) which further complicates the examination of medication effects as different classes of medications may each affect HRV in a different manner, obscuring effects of individual medications. For example, previous research indicates that antidepressants are associated with increased HRV (Licht, Geus, van Dyck, & Penninx, 2010) while beta blockers targeting hypertension improve HRV and vagal regulation (Curtis & O'Keefe, 2002). Thus, while a methodological strength of the present study is the increased power of the analyses due to the inclusion of all study participants in the analyses, the lack of a significant effect of adult medication use on the association between parent and child resting HF-HRV should be interpreted with caution.

In regards to the first exploratory analysis, results indicated that parent resting HF-HRV was not associated with child vagal regulation. It may be that parent emotion socialization or supportive parent practices better account for the effect of parenting on children's emotion regulation abilities. For example, Perry et al. (2014) found that maternal sensitivity was positively associated with vagal regulation in young children. Alternatively, it may that emotion regulation in infancy and early childhood mainly stems from biological regulation based off of parent-infant coregulation while emotion regulation in middle childhood and adolescence is affected by a host of other factors including pubertal brain development and peer friendships. As older youth usually spend more time with their friends instead of with their parents, it may be that the peer group is a stronger mechanism of emotion socialization in adolescence. It is also possible that the mental arithmetic task was not stressful enough to elicit a stress response. Future research studies comparing vagal regulation as assessed from baseline to stressor task would benefit from testing more than one stressor task (e.g., cognitive stressor, social stressor) as some individuals may find a certain type of task (e.g., social stressor) more stressful than a mild cognitive stressor task.

The present study further expands the literature by examining the association between parent and child vagal regulation in a sample of youth aged 11 to 17 years. Contrary to the previous study (Bornstein & Suess, 2000) finding that reported an association between parent and child vagal regulation in a sample of 5-year-old children, the present study indicated no significant association between parent and youth vagal regulation. Results did indicate that the child's gender affected the association between parent and child vagal regulation, such that there was a positive association between parent and daughter's vagal regulation and a negative association between parent and son's vagal regulation. This finding suggests that there may be differences in the way that parent and adolescent emotion regulation abilities are associated based on the gender of the parent and child assessed.

10.1 Limitations

Although this study adds to the existing literature, several limitations must be considered. First and most importantly, the cross-sectional design of this study prohibits causal inferences. Second, the sample was composed of community recruited youth and thus findings may not be generalizable to clinical populations. Lastly, because the sample consisted mainly of mothers, there were insufficient numbers of fathers to conduct separate analyses by parent gender. Given the finding that parent gender moderated the relationship between parent and child vagal regulation, it is important that future research includes an adequate sample of both mothers and fathers to further investigate the robustness of this finding.

10.2 Conclusions

This study provides important information about the association between parent and child physiological measures of emotion regulation and suggests that specific parenting behaviors may be associated with individual differences in youths' emotion regulation. The present study advances the literature on parent and child emotion regulation in several ways. First, the finding that inconsistent discipline moderated the association between parent and child HF-HRV indicates that inconsistent discipline may interact with the parent's biological predisposition for emotion regulation (i.e., HF-HRV) to affect the development of child HF-HRV. This suggests that parents may affect their child's development of emotion regulation through both genetic and environmental contributions and suggests that consistent discipline may be a crucial parenting behavior to target in parent-child interventions with poorly regulated youth. Secondly, by collecting both the child and parent's report of parenting behaviors, this study allowed for a more robust and reliable view of parenting behaviors from both the parent and child perspective. In addition, because the study was not retrospective in nature as were most previous studies in the literature, it is less likely that the informants' memories of the behaviors have been changed or distorted over time. Lastly, the use of HLM accommodated the nested study design (i.e., dependency in the dataset; non-independent observations) by accounting for variance shared between multiple children from one family whereas the use of traditional linear regression would have only allowed for one child per family to be analyzed, thus decreasing the sample size and power of the analyses.

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Appendix A. Pearson's Correlations Between Age, Gender, Self-Report, and Physiological Measures

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Child Gender													
2. Child Age	-.02												
3. Parent Gender	-.04	.23*											
Child Report													
4. APQ-C Positive Parenting	.08	-.18	-.03										
5. APQ-C Parent Involvement M	.09	-.12	.03	.76**									
6. APQ-C Parent Involvement F	-.03	-.13	-.21	.50**	.45**								
7. APQ-C Poor Monitoring	-.27**	.45**	.19	-.07	<.01	-.09							
8. APQ-C Inconsistent Discipline	-.03	.21*	.18	.14	.22*	-.06	.56**						
9. APQ-C Corporal Punishment	-.21*	-.07	.04	<.01	-.05	.03	.12	.10					
Parent Report													
10. APQ-P Positive Parenting	-.07	-.11	.01	.55**	.44**	.13	.01	.14	.01				
11. APQ-P Parental Involvement	<.01	-.01	-.02	.42**	.45**	.17	-.11	.19	.12	.65**			
12. APQ-P Poor Monitoring	<-.01	.31**	-.04	-.23*	-.24*	-.16	.23*	-.10	-.21	-.12	-.36**		
13. APQ-P Inconsistent Discipline	.08	.05	-.06	-.09	.08	.08	.15	.15	.09	.01	-.06	.33**	
14. APQ-P Corporal Punishment	-.05	-.06	.10	.24*	.22*	.20	-.02	.02	.37**	.10	.16	-.06	.05

	1	2	3	4	5	6	7	8	9	10	11	12	13
HRV Measures													
15. Child Resting Baseline HF-HRV	-.10	<.01	.03	.15	.17	.10	-.12	-.03	-.20	.31**	.22*	<-.01	.06
16. Child Arithmetic Task HF-HRV	-.11	<-.01	.14	.07	.08	-.03	-.05	.04	-.13	.32**	.22*	-.03	-.22*
17. Child Vagal Regulation	-.01	-.01	.13	-.07	-.07	-.19	.08	.11	.08	-.05	-.05	-.03	.07
18. Parent Resting Baseline HF-HRV	.17	-.11	.06	-.08	-.04	-.19	-.07	-.11	.04	-.01	-.01	-.06	-.31**
19. Parent Arithmetic Task HF-HRV	.11	-.04	.31**	.04	-.01	-.22	-.02	-.16	.06	.10	.09	-.17	-.40**
20. Parent Vagal Regulation	-.07	.07	.33**	.13	.07	-.01	.09	-.08	.05	.10	.09	-.13	-.10

	14	15	16	17	18	19
15. Child Resting Baseline HF-HRV	-.02					
16. Child Arithmetic Task HF-HRV	-.12	.68**				
17. Child Vagal Regulation	-.09	-.45**	.35**			
18. Parent Resting Baseline HF-HRV	<.01	.11	.17	.04		
19. Parent Arithmetic Task HF-HRV	.10	.01	.09	.08	.65**	
20. Parent Vagal Regulation	.15	-.08	-.03	.06	-.20	.62**

Note: ** $p < .01$; * $p < .05$. APQ-C = Alabama Parenting Questionnaire - Child Report; APQ-P = Alabama Parenting Questionnaire - Parent Report, subscales: Parent Involvement M = Mother's Involvement; Parent Involvement F = Father's Involvement; HF-HRV = Log transformed High Frequency Heart Rate Variability.

Vita

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