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Research on the relation between children's physiological capacity to modulate arousal and social competence has been limited and has focused primarily on brain electrical activity or the sympathetic branch of the autonomic nervous system (ANS). Only recently have researchers begun to study the crucial role of the parasympathetic branch of the ANS in modulating metabolic output to foster engagement and disengagement strategies that are considered important for social development. This study examined the relation between vagal regulation, an index of the parasympathetic influence on the heart, and children's social competence and behavior problems in school. In this study, 335 kindergarteners participated in a laboratory assessment designed to examine physiological regulation and a sociometric assessment designed to examine peer status. In addition, teacher and parent reports of behavioral and social functioning were collected. Results indicated that girls with higher levels of vagal regulation had better peer status and better social skills, including greater ability to deal with problem situations with peers (as reported by teachers) than girls with lower levels of vagal regulation. No significant associations emerged for boys.

VAGAL REGULATION AND CHILDREN’S SOCIAL COMPETENCE

By

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Approved by

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Committee Chair

To my wonderful, loving, and understanding wife, Marianna, my parents, Thereza and Renato, and my brother, Arthur.

APPROVAL PAGE

This thesis has been approved by the following committee of the Faculty of The Graduate School at The University of North Carolina at Greensboro.

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CHAPTER I

INTRODUCTION

In recent years, there has been increasing interest in the role of emotion regulation in the development of children's social competence and behavior problems. The reason for such interest lies in the observation that children who do not properly control their emotions are at an increased risk for numerous negative outcomes such as later internalizing and externalizing problems (Bates, 2000). In addition, children who display poor regulation of negative emotion exhibit more intense and frequent expressions of anger, impulsivity, and are at risk for violence and aggression (Bohnhnert, Cmic, & Lim, 2003; Eisenberg et al., 2001; Davidson, Putnam, & Larson, 2000). Although research has linked ineffective emotion regulation with negative behavioral outcomes, considerably less research has examined the relation between emotion regulation and social competence. Given the detrimental outcomes associated with negative social relations such as early conduct problems, later adolescent disorders, school truancy, suspension, and leaving school early, understanding the role of emotion regulation in the development of social competence is crucial. Such an understanding would facilitate early identification of at risk children and initiate preventative efforts to avoid these negative outcomes (Coie, Lochman, Terry, & Hyman, 1992; Miller-Johnson, Coie, Maumary-Geremaud, Bierman, & Conduct Problems Research Group, 2002; Woodward & Fergusson, 2000).

Emotion regulation is a dynamic process that involves the interaction of both sympathetic and parasympathetic branches of the autonomic nervous system as well as behavioral and cognitive processes in response to changes in one's emotional state (Garber & Dodge, 1991). While researchers vary in their definition of emotion regulation, most agree that it involves successful management of emotional arousal in a way that facilitates adaptive social functioning (Calkins, 1997; Dodge & Garber, 1991; Eisenberg et al., 1996; Keenan & Shaw, 2000). Within the social functioning domain, the concept of social competence refers to an effectiveness in interaction, resulting from successful implementation of organized behaviors that meet short- and long-term developmental needs (Denham et al., 2003).

In early development, an infant's ability to regulate both positive and negative experiences is central to his or her socioemotional development (Kopp, 1989). Furthermore, as children develop, their capacity to regulate emotions becomes increasingly complex and organized as they learn how to apply their knowledge about emotions and expressions to interpersonal exchanges (Fox, 1994; Shields & Cicchetti, 1997; Denham et al., 2003). Entrance to school marks a developmentally important period as children experience increased interaction with unfamiliar people, such as peers and teachers, and begin to develop social relationships. These changes may arouse strong feelings for young children, who must regulate their feelings and express them in a way that facilitates adaptive social functioning (Miller & Olson, 2000). As such, entrance to school marks a significant and appropriate developmental period to study how emotion regulation relates to social competence and behavioral problems. Research on the physiological substrates of emotion regulation — children's physiological differences in the capacity to experience and modulate arousal — has primarily focused on behavior problems while ignoring how physiological regulation relates to the development of children's social competence. This study extended the current research by examining the relation between children's physiological ability to regulate arousal, social competence, and behavior problems in school.

Eisenberg & Fabes (1992) proposed a heuristic model in which individual differences in emotionality and regulation contribute to children's level of social competence, including popularity. They proposed that children who are prone to intense emotion, especially negative emotion, and are low in regulation are more likely to engage in externalizing behavior. On the other hand, children who are well regulated and experience moderate levels of intense emotion are socially more competent and popular. A series of studies by Eisenberg and colleagues provided evidence for this model. For instance, Fabes and colleagues (1999) found that highly regulated children were more likely to demonstrate socially competent responses during high intensity interactions that elicited emotional responses. Moreover, Eisenberg and colleagues (1993; 1996; 1997) found that children low in attention regulation have lower social skills and lower sociometric status, whereas children high in behavioral and attention regulation were more likely to be viewed by teachers as socially competent and tended to be high in prosocial reputations and social skills.

Other researchers have confirmed Eisenberg and colleagues' assertion and found that children who are unable to manage negative affect have difficulty managing peer conflict situations and are less popular with peers (Dunn & Brown, 1994; Stocker & Dunn, 1990). Others have also demonstrated a link between emotion regulation and behavioral problems in school. For example, Rydell, Berlin, and Bohlin (2003) found that high anger emotionality and low regulation of positive emotions predict children's externalizing problem behavior; high fear emotionality and low fear regulation predict internalizing problem behavior. Moreover, children who were poor regulators and low in social interactions had more internalizing problems than children that were good regulators and low in social interactions. On the other hand, the high social interaction children, who were also poor regulators, had more externalizing problems. Although both internalizing and externalizing cases were associated with poor regulation, the amount of social interactions moderated the type of behavior problem (Rubin, Coplan, Fox, & Calkins, 1995). Taken together, these findings support the view that regulatory skills, such as emotion regulation, play an important role in children's social functioning. No study, however, has addressed how individual differences in physiological regulation relate to social competence in school age children. Assessing this relation is critical to our understanding of the underlying mechanisms involved in individual differences in emotion regulation, as well as its impact on social relationships and behavior in school.

Findings from several longitudinal studies suggest links between early temperamental tendencies such as frustration tolerance and regulatory developments at the levels of physiological, attentional, and emotion regulation. Research on physiological differences underlying regulatory development has primarily focused on brain electrical activity and adrenocortical activity (Calkins & Fox, 2002). Several studies have related individual differences in social behavior in childhood to patterns of frontal brain electrical activity as indexed by electroencephalographic (EEG) techniques. Among these studies, a common finding has been the association of left frontal EEG asymmetry with preschooler's sociability during interactions with unfamiliar peers (Henderson, Marshall, Fox, & Rubin 2004; Fox et al. 1995). It has been speculated that a stable resting pattern of frontal EEG asymmetry reflect an underlying "trait" disposition for the motivational states of approach or withdrawal, which may facilitate adaptive regulatory behavior in social development (Fox 1994; Fox, Schmidt, Calkins, Rubin, & Coplan, 1996; Fox, Henderson, Rubin, Calkins, & Schmidt, 2001).

In order to examine the role of the autonomic nervous system (ANS) in the facilitation of adaptive social behavior, most research has concentrated on the sympathetic branch of the ANS by examining cortisol levels. Adrenocortical reactivity occurs when an individual confronts a challenging situation. Successful coping with the situation leads to decreased levels of reactivity in future challenges whereas unsuccessful coping or avoidance of the situation leads to increased levels of reactivity. By measuring cortical reactivity levels, one may be able to measure an individual's stress reactivity level, which is thought to be vital for appropriate social interactions (Gunnar, Tout, de Haan, Pierce, & Stansbury, 1997). In fact, previous studies have suggested that peer rejection may be related to cortisol activity in young children. For example, behavioral characteristics known to predict poor peer relations, such as aggression and low regulation, have been associated with higher levels of cortisol activity (Tout, de Haan, Kipp-Campbell, & Gunnar, 1998; Dettling, Gunnar, & Donzella, 1999).

Donzella, Gunnar, Krueger, & Alwin (2000) found that children who were described by teachers as more surgent and lower in effortful control and displayed higher levels of tense or angry affect had increased cortisol levels during a losing competition. Direct examinations between peer rejection and cortisol levels have revealed that rejected children tend to have higher levels of cortisol reactivity (Gunnar et al., 1997; Gunnar, Sebanc, Tout, & Donzella, 2003). Other studies, however, have failed to find a relation between cortisol reactivity and social competence (Schmidt et al., 1999; de Haan, Gunnar, Tout, Hart, & Stansbury, 1998). Conflicting findings may be due to problems related to how cortisol is colleted, such as time of the day, method of collection, and whether it is collected in a familiar or unfamiliar setting (Gunnar et al., 1997; Kirschbaum & Hellhammer, 1989; Schwartz, Granger, Susman, Gunnar, & Laird, 1998).

In summary, although there have been studies using physiological measures to examine the relation between individual differences in emotion regulation and social competence, most of these have concentrated only on the brain electrical activity (Schmid et al., 1999; Henderson et al., 2004; Fox, 1994; Fox et al., 1996; Fox et al., 2001), or the sympathetic branch of the ANS via cortisol levels (Gunnar et al., 2003; Donzella et al., 2000; Dettling, Gunnar, & Donzella, 1999; Hart, Gunnar, & Cicchetti, 1995). Only recently, have researchers begun to look at the influence of the parasympathetic branch of the ANS on adaptive social behavior. The importance of studying the influence of the parasympathetic branch on social behavior lies in its role in modulating metabolic output from internal homeostasis demands to environmental demands. These environmental demands require internal processing which create coping strategies aimed at controlling affective arousal. An individual's ability to shift this metabolic output, which enables an individual to engage and disengage with the environment, is considered important for social development (Porges, Doussard-Roosevelt, Portales, & Greenspan, 1996).

Whereas emotionality —how intensely one experiences emotional states— is indexed by sympathetic arousal, emotion regulation is indexed by parasympathetic modulation. Cardiac vagal tone, an index of the parasympathetic influence on the heart, has emerged as a psychophysiological marker for many aspects of behavioral functioning, including emotion regulation, in both children and adults. Assessing the functional output of the vagal pathways on the heart is accomplished by quantifying the amplitude of respiratory sinus arrhythmia (RSA), a component of heart rate variability. Measurement of this component of vagal tone has been used as a method to assess, on an individual basis, both stress and stress vulnerability (Porges, 1995). Research has indicated that RSA, under controlled respiratory conditions, is uninfluenced by variations in sympathetic activity, and provides a reasonable sensitive index of cardiac vagal tone, even when alterations in parasympathetic tone are small (Grossman, Stemmler, & Meinhardt, 1990). Furthermore, findings suggest that cardiac vagal tone is responsive to varying behavioral demands, and is associated with behavioral measures of reactivity, the expression of emotion, and self-regulation skills (Porges, Doussard-Roosevalt, & Maiti, 1994).

Although there is an extensive literature evaluating baseline vagal tone and its relation to behavior, the relation between individual differences in the ability to regulate cardiac vagal tone and behavior has been theoretically vague. Porges' (1995) polyvagal theory introduces a model to explain the relation between vagal tone during steady states (i.e., baseline vagal tone) and vagal reactivity (i.e., the vagal “brake” or vagal regulation) in response to environmental challenges. According to polyvagal theory, baseline measures of vagal tone represent the organism’s ability to maintain homeostasis and the ‘potential responsiveness’ of the organism. The vagal “brake,” on the other hand, is conceptualized as an ‘adaptive neural physiological mechanism’ that enables the organism to modulate arousal by engaging and disengaging with the environment. Engaging and disengaging strategies refers to an organism’s ability to shift focus from a state of over-arousal to one of under-arousal in order to maintain physiological homeostasis. The vagal “brake” also indexes the ability of the organism to sustain a shift in resources from a steady state to one with metabolic demands. Thus, individual differences in the vagal “brake” can be assessed by measuring changes in vagal tone from baseline to an attention-demanding or challenging state (Porges et al., 1996).

Based upon this theory, infants who have difficulties in regulating the vagal brake (i.e., decreasing cardiac vagal tone or suppressing it) during social and/or attention tasks would have difficulties developing appropriate social interactions requiring reciprocal engagement and disengagement strategies. Although using a small sample, Porges et al. (1996) demonstrated that infants with difficulties in suppressing vagal tone during a social/attention task at 9 months of age had significantly more behavioral problems at 3 years of age. Additional research efforts have since provided an extensive list of vagal tone correlates that includes temperamental variables as well as internalizing and externalizing behaviors (Beauchaine, 2001). High levels of vagal tone have been associated with uninhibitiveness, assertiveness, empathy, ability to deal with new situations, sociability, expressiveness, temperamental reactivity, reactivity to frustration, sustained attention, and social competence for boys (Fabes, Eisenberg, & Eisenbud, 1993; Fox, 1989; Fox & Field, 1989; Calkins, 1997; Stifter & Jain, 1996; Suess, Porges, & Plude, 1994; Eisenberg, Fabes, Murphy, Maszk, Smith, & Karbon, 1995). Most of these correlates, however, refer only to baseline levels of vagal tone.

Eisenberg et al. (1995; 1996) found that girls' baseline vagal tone was related to low levels of social competence (as assessed by peer nominations) while boys' baseline vagal tone was related to high levels of social competence. This conflicting finding may be due to gender stereotypes and different expectations for boys and girls. Girls' uninhibited, assertive behavior may be viewed as indicative of low social and prosocial functioning. The present study will attempt to replicate Eisenberg et al. (1995; 1996) assessment of gender differences in the relation between social competence and baseline vagal tone, and will also examine gender differences in vagal regulation.

There are relatively few findings concerning the vagal "brake" or vagal regulation, even fewer in the realm of children's social competence. Evidence to support Porges' vagal "brake" is limited but positive. Calkins and Dedmon (2000) investigated physiological regulation of 2-year-old children displaying symptoms of externalizing problems and children displaying few externalizing symptoms. Their results confirmed Porges' theory by finding that children with externalizing problems displayed significantly and consistently lower vagal regulation during the challenging situations than nonexternalizing children. Research has also provided evidence for the role of vagal regulation during cognitive tasks (DeGangi, DiPietro, Greenspan, & Porges, 1991; Suess et al., 1994). In addition, vagal regulation has been associated with children's behavioral regulation strategies during affect-eliciting situations and as a protective factor against externalizing problems associated with parental conflict (Calkins, 1997; El-Sheikh, Harger, & Whitson, 2001; El-Sheikh, 2001).

Only two studies have assessed vagal regulation's relation with children's social competence. Cole, Zahn-Waxler, Fox, Usher, & Welsh (1996) found no significant difference between expressive and inexpressive groups in terms of vagal regulation. However, the study was limited by the use of only one brief mood induction story for obtaining a vagal regulation measure. In contrast, Stifter and Corey (2001) found that infants, who were able to suppress vagal tone during a cognitive challenge task, were rated by the experimenters as more socially approaching. Thus, there is partial support for the hypothesis that children who are able to suppress vagal tone have a greater capacity for social functioning; however, there have not been any studies directly testing the association between Porges' vagal "brake" and social competence as measured by children's peer status.

The present study sought to examine the relation between vagal regulation and children's social competence, as well as behavioral problems, in kindergarten. The first question addressed in this study was whether children with lower levels of vagal regulation are at an increased risk of negative peer status. Research on peer status reveals that socially competent children are more successful at regulating their emotions. For example, Gottman and Mettetal (1986) found that popular boys were better able to make the transition from rough and tumble play to less arousing play than less popular boys, which suggests that popular boys are able to regulate their arousal more efficiently than their less popular counterparts. In addition, Eisenberg et al. (1993) found that children with high emotional intensity and low regulation were more likely to have low social skills and low sociometric status. Unfortunately, the few studies that examined the relation between emotion regulation and peer status did not incorporate a physiological regulation measure (Eisenberg et al., 1993; 1995; 1996; Gottman & Mettetal, 1986; Gunnar et al., 1997; Gunnar et al., 2003).

Gender differences were expected, given the findings by Eisenberg et al., (1995; 1996) which indicated high baseline levels of vagal tone to be associated with positive social functioning only for boys. Hence, it was expected that higher baseline vagal tone will be related to positive peer status for boys only, but greater vagal regulation scores will be related to positive peer status for both boys and girls. Because peer status is an outcome measure of social competence obtained from a group's perspective, it would also be important to assess an individual's level of social competence measured by social skills. Thus, moderating factors such as social skills were assessed to determine if greater social skills can help a child overcome low physiological regulation to insure positive peer status. It was expected that children with low levels of vagal regulation, but who have good social skills, will have positive peer status.

The second question examined in this study was whether appropriate vagal regulation (i.e., vagal suppression) and baseline vagal tone are related to fewer behavioral problems in elementary school children as reported by teachers and peers (i.e., peer nominations such as “fights a lot”, “wild”, “bossy,” and “sneaky”). Research on Porges’ (1996) vagal “brake” model, demonstrated that infants with difficulties in suppressing vagal tone during a social/attention task at 9 months of age had significantly more behavioral problems at 3 years of age. El-Sheikh (2001) and Calkins and Dedmon (2000) have also examined vagal regulation as a buffer to behavioral problems associated with stress. Due to such findings, parental distress and early child behavior problems (at 2 years of age) were controlled during analyses. It was hypothesized that children with higher vagal regulation would have fewer behavioral problems, in particular those associated with aggression.

The last question examined in this study addressed the relation of vagal regulation and baseline vagal tone with children’s social skills, as well as reactivity to problem situations associated with peer interactions (e.g., peer provocation). Past research on the relation between emotion regulation and children’s reactivity to problem situations and social skills have shown that children who are unable manage negative affect have difficulty managing peer conflict situations (Dunn & Brown, 1994; Stocker & Dunn, 1990) and show less social skills (Eisenberg et al., 1993). Therefore, it was hypothesized that children with greater vagal regulation and higher baseline vagal tone will show higher levels of social skills and less negative reactivity to problem situations.

CHAPTER II

METHOD

Participants

Participants for this study included 335 five-year old children obtained from three different cohorts as part of a larger ongoing longitudinal study that began when children were 2 years old. This study focused on the 5-year assessment. Participants were initially recruited at 2 years of age through child day care centers, the County Health Department, and the local Women, Infants, and Children program. In order to obtain a broad, community-based sample of children with a wide range of disruptive behavior, potential participants were screened on the Child Behavior Checklist (CBCL; Achenbach, 1992).

From Cohort 1, 474 children were screened. Sixty-five percent of these families were European American, 30% were African American and 5% were Asian or Hispanic. Hollingshead (1975) scores classified 61% of the families as middle class, 25% as lower class, and 14% as upper class. From this large sample, 154 children were selected. Forty-four of the children had externalizing scores on the CBCL in the clinical or borderline clinical range (t-scores of 60 or above), 27 of the children had both externalizing and internalizing scores above the clinical or borderline clinical range, and 83 of the children scored below the clinical or borderline clinical range for both internalizing and externalizing. The final sample of children selected from this cohort for participation was racially and economically diverse (65% European American; mean

Hollingshead score = 39.2), primarily from intact families (77%), and consisted of 78 male and 76 female children.

From Cohort 2, 492 children were screened. Seventy-three percent of these families were European American, 24 % were African American and 3% were biracial. Seventy-three percent of the families were classified as middle class, 15% as lower class, and 12% as upper class. From this large sample, 153 children were selected. Forty-eight of these children had externalizing scores on the CBCL in the clinical or borderline clinical range, with t-scores of 60 or above, 24 of the children had both externalizing and internalizing scores above the clinical or borderline clinical range, and 81 of the children scored below the clinical or borderline clinical range for both internalizing and externalizing. The final sample of children selected from this cohort for participation was racially and economically diverse (68% European American; mean Hollingshead score = 39.7), primarily from intact families (84%), and consisted of 71 male and 82 female children.

Children that comprised Cohort 3 came from an already ongoing longitudinal study which began when the children were six-months-old. At six-months of age, 346 infants were screened for their level of frustration based on parent responses to a subscale of a temperament questionnaire (Distress to Limits; Infant Behavior Questionnaire [IBQ], Rothbart, 1981) and infant responses during two frustration-eliciting laboratory tasks (Barrier Task and Arm Restraint; LAB-TAB, Goldsmith & Rothbart, 1993). Out of these children, 162 infants were selected based on their parent's rating on the IBQ and the laboratory assessment (Calkins, Dedmon, Gill, & Johnson, 2002). Of the selected sample, 85 infants scored at or above the 50th percentile on both the laboratory index of frustration and maternal report of distress to limits (easily frustrated group) and 77 scored below the 50th percentile on both the laboratory index and maternal report of distress to limits (less frustrated group). This six-month selected sample was racially and economically diverse (80% European American; mean Hollingshead score = 35.7), primarily from intact families (79%), and 79 were male and 83 female. This sample was followed from six months of age until they were four-years old. At the thirty –month laboratory visit, mothers were asked to complete the CBCL. Of the originally selected sample of 162, 140 mothers agreed to fill out the questionnaire.

Therefore, for this study, Cohort 3 consists of these 140 children who have CBCL data in toddlerhood. Eleven of these children had externalizing scores on the CBCL in the clinical or borderline clinical range (t-score of 60 or above), 10 of the children had both externalizing and internalizing scores above the clinical or borderline clinical range, and 119 of the children scored below the clinical or borderline clinical range for both the internalizing and externalizing subscales. The final sample of children selected from this cohort was racially and economically diverse (71% European American; mean Hollingshead score = 38.7), primarily from intact families (79%) and consisted of 66 males and 74 females.

There were 335 families who participated in the 5-year laboratory assessment. Attrition for the 5-year assessment was due to due to several factors, including families moving out of the county (n = 32), families refusing to continue the study (n = 21), and families who could not be located (n = 51)**.** There were no significant differences between those families that continued participating in the study and those that moved, dropped out, or could not be located. Not all children who participated in the laboratory assessment, however, were able to participate during the sociometric assessment.

In terms of the sociometric assessment, a total of 246 children participated in the kindergarten assessment, while 266 teachers completed a packet of questionnaires. Attrition for the school visit was due to parents not giving consent (n = 57), families not returning the consent form in time (n = 107), and the school being too far away (n = 6). In addition, the principals were given the option to refuse participation in the school assessment part of the study, although this occurrence was relatively rare (n = 31).

Materials

Social Skills. To assess the children's social skills, teachers and parents completed the kindergarten version of the Social Skills Rating System (SSRS, Gresham & Elliot, 1990). The SSRS is a 30-item behavior rating scale designed to assess children's social behavior. The form lists a variety of social behaviors; raters indicate the frequency with which the child engages in each behavior (0=never, 1=sometimes, 2=very often) and how important each of these behaviors is for the child's development (0=not important, 1=important, 2=critical). A social skill standard score is derived from these items along with three subscales (Cooperation, Assertion, Self-Control). The SSRS has well-established internal consistency (alphas range from .78 to .95), reliability (test-retest reliability correlations range from .75 to .93), and criterion-related validity with the CBCL (Gresham & Elliot, 1990). The present study examined the social skill standard score, and the cooperation, assertion, and self-control subscale scores.

Behavior Problems. To assess the children's behavior problems, teachers and parents completed the elementary school version of the Behavior Assessment System for Children (BASC; Reynolds & Kamphaus, 1992). The BASC is a widely used behavior checklist that taps emotional and behavioral domains of children's functioning. The teacher elementary school version used for children ages 2 1/2-5 contains 109 items whereas the version used for children ages 6-11 contains 148 items. Each item is rated on a four-point scale with respect to the frequency of occurrence (never, sometimes, often, almost always). The measure yields age- and gender-normed T scores on broad internalizing, externalizing, and behavior symptom domains as well as nine specific content scales. The BASC has well-established internal consistency, reliability and validity (Doyle, Ostrander, Skare, Crosby, & August, 1997; Reynolds & Kamphaus, 1992) and is widely used for the purpose of diagnostic assessment. For the purpose of the present study, the externalizing scale score, aggression, hyperactivity, and attention problems were examined.

Reactivity to Problem Situations. To assess how children react to different problem situations, teachers completed the Taxonomy of Problem Situations (TOPS) questionnaire (Dodge, McClaskey, & Feldman 1985). The TOPS is a widely used measure that taps into children's social competence responses in different problem situations. The teacher elementary school version used for children ages 5-11 contains 60 items. For each item, teachers are asked to rate on a 1-5 scale (1=never, 2=rarely, 3=sometimes, 4=usually, and 5=almost always) how much a problem this situation was for the child and how likely the child would be to respond in an inappropriate manner in this situation. The measure yields several domains including peer group entry (child's task is to initiate inclusion into the peer group), response to peer provocation (child's task is to preserve self-integrity while maintaining peer status), response to failure (child loosing a game), response to success (being identified as superior to the peer group), social expectations (clear social norms exist for the child's behavior), teacher expectations (the teacher has established clear norms for child behavior) as well as reactive and proactive aggression. The TOPS has well-established internal consistency (Cronbach's Alphas range from .89 to .97) and reliability (test-retest reliability correlations range from .57 to .72 for factor scores, and .79 for total score; Dodge et al., 1985). For the purpose of the present study, the peer group entry score, response to peer provocation, response to failure, response to success, and reactive as well as proactive aggression scores were examined.

Emotion Regulation. To assess children's behavioral display of emotion regulation, teachers completed the Emotion Regulation Checklist (ER Checklist; Shields & Cicchetti, 1997). The ER Checklist is a 24-item questionnaire that yields two subscales: the Negativity/Lability scale, which represents negative affect and mood lability, contains 10 items (Cronbach's Alpha = .77) and the Emotion Regulation scale contains 14 items (Cronbach's Alpha = .68). The two scales are negatively correlated ($r = -.50$, $p<.001$). For the purpose of the present study, only the emotion regulation scale was examined.

Sociometric Measures. The total number of nominations each child receives from his or her peers is calculated and standardized within each classroom in order to derive z-scores representing the number of “like least” and “like most” nominations. The total number of “like least” nominations is subtracted from “like most” scores to generate a Social Preference Index (Coie, Dodge, & Coppotelli, 1982). This procedure is the accepted form of establishing a child’s overall likeability within the classroom. As social preference scores decrease, a child’s likeability or overall peer status also decreases. The standardized social preference score was used as the dependent variable in this study. In addition, z-scores for the eight additional behavioral categories are computed to provide a peer-reported index of social behavior for all target children.

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

Porges’ (1985) method of calculating RSA was used to analyze the IBI data. This method applies an algorithm to the sequential heart period data. The algorithm uses a moving 21-point polynomial to detrend periodicities in HP slower than RSA. Then, a band-pass filter extracts the variance of HP within the frequency band of spontaneous respiration in young children, 0.24-1.04 Hz. Although lower frequency bands may be studied, research with young children has consistently examined this band and identified associations to child functioning (Huffman, Bryan, del Carmen, Pederson, Doussard-Roosevelt, & Porges, 1998; Porges et al., 1996; Stifter & Fox, 1990). The estimate of RSA is derived by calculating the natural log of this variance and is reported in units of $\ln(\text{msec})^2$. RSA was calculated every 30 seconds for the 5 minute baseline period and all other challenge episodes greater than 3 minutes in length. For tasks that last less than 3 minutes, RSA was calculated every 15 seconds. These epoch durations are typical for studies of short duration tasks (Huffman et al. 1998). The mean RSA of the 15 and 30 sec epochs within each episode was used in subsequent analyses. If the standard deviation across the epochs was greater than 1.00 for RSA (indicating a high degree of variability over the course of the episode and calling into question the validity of the mean RSA value), that episode was excluded from subsequent analyses.

Procedures

The focus of this study involved an assessment at the kindergarten period, which included parent and teacher reports of the child's social and behavioral functioning and a sociometric assessment of peer-reported behavior and peer status. In addition, to assess children's physiological regulation, a laboratory visit was also included.

Sociometric Assessment and Nominations

Parents of the participating children consented to have their child participate in a sociometric assessment in his or her classroom. In addition, although the county school system consented to the research, each principal at each of the schools had the authority to disallow this procedure within his or her respective school. The parents of all children in each target child's classroom were asked to provide consent to have their children participate in this phase of data collection. Sociometric interviews were conducted from October to May during the kindergarten year as to allow time for classmates to become familiar with each other. A modified version of Coie, Dodge, and Coppotelli’s (1982) original procedure was used. Trained graduate students individually interviewed each child for whom parental consent was granted. Pictures were used as prompts during the interview to aid in gathering reliable peer report data with kindergarten children. To increase the stability of measurement for the sociometric nominations, cross-gender nominations were permitted (Terry & Coie, 1991).

Modifications to the Coie et al. (1982) procedure were as follows: Children were asked to provide unlimited nominations of children they "liked most" and “liked least" (Terry, 2000). This procedure has been shown to reduce measurement error and allows for reliable assessments of sociometric status with fewer classmates than is required by the standard limited-choice sociometric procedure. In addition, following Keane and Dennis (2001), children were asked to nominate classmates for eight additional behavioral categories including: starts fights, shares, cries, is sneaky, acts wild, gets picked on, is shy, and bosses others. For the purpose of this study, nominations for "like most" and "like least" were used to determine peer status. Given the young age of the participants, children were trained on sample items until they understood the task, and sociometric interviewers were rigorously trained to ensure quality data collection. Scripts detailing several specific examples of the behaviors of interest were provided to explain these constructs to children who were confused or were having difficulty.

Laboratory Assessment

Mothers were asked to accompany their children to the laboratory where the children were assessed using several procedures in a laboratory playroom. First, the experimenter placed three disposable pediatric electrodes in an inverted triangle pattern on the child's chest while the mother was seated at a table next to the mother. The electrodes were connected to a preamplifier, the output of which was transmitted to a vagal tone monitor (VTM-I, Delta Biometrics, Inc, Bethesda, MD) for R-wave detection. The vagal tone monitor displayed ongoing HR and computed and displayed RSA (vagal tone) every 30 seconds. A data file containing the interbeat intervals (IBIs) for the entire period of collection was transferred to a laptop computer for later artifact editing (resulting from child movement) and analysis. The onset and end of each challenge episode was marked on the computer file of the IBI data through the use of an electronic signal controlled by the experimenter.

Baseline episode. This episode consisted of a 5-minute segment of the videotape "Spot," a short story about a puppy that explores its neighborhood. While this episode was not a true baseline given that the child's attention was engaged in an external stimulus, it was sufficient to keep the child sitting quietly and showing little affect. Given the ages of the subjects, such stimulus was necessary in order to keep the child seated at the table and to limit movement artifact in the HR data. Following the baseline episode, the child was observed in several situations designed to elicit physiological stress and coping.

Effortful control #1. This episode consisted of a 6-minute segment in which the child was asked to draw shapes (circles and star) between boundary lines at varying speeds (slow and fast).

Mother-child interaction#1. This episode consisted of a 6-minute segment in which the mother was asked to teach her child how to make a puppet.

Mother-child interaction #2. This episode consisted of a 6-minute segment in which the child worked on an easy puzzle for 2 minutes and then on a harder puzzle for 4 minutes. The child was allowed to interact with the mother but was encouraged not to.

Effortful control #2. This episode consisted of a 4-minute segment in which the child was asked to recognize only the shapes in the pictures presented. For example, a child was shown a picture of a chicken with triangles and had to say only the triangles and not the chicken. Children were instructed to answer as fast as they could.

Attention episode. This episode consisted of a 3-minute segment in which the child was asked to place beads in a sorting container. The child performed this task while alone in the room.

Positive episode. This episode consisted of a 4-minute segment in which the child was surprised with a pop up snake and then was instructed to surprise his/her mother.

Frustration episode. This episode consisted of a 4-minute segment in which the filmer presented the experimenter and child with candy to be evenly divided. However, the experimenter proceeds to share the candy unevenly, eats some of the child's candy, and slowly takes all the candy away from the child while preventing the child from eating it.

CHAPTER III

RESULTS

Data Reduction

Given the large number of measures from the physiological assessment, a reduction in the number of challenge episodes was necessary. Since it was crucial to obtain the most challenging episodes, the top three tasks (attention, mother child interaction #1, and mother child interaction #2) were chosen due to their high percentage of children who suppressed vagal tone, indicating appropriate engagement in the task. These tasks were used to calculate three vagal regulation scores, which were obtained by subtracting each challenge episode vagal tone from baseline vagal tone. Descriptives for baseline vagal tone, tasks vagal tone, and the vagal regulation scores are presented in Table 1. As the table indicates, the data files of some children were not included in some of the analyses. Several situations led to missing data across the 3 tasks. A few children would not allow the experimenter to apply the HR electrodes (1% of missing). In addition, the HR data collection equipment failed on several occasions (6% of missing). A third explanation for missing data was that the child pulled on, or touched, the HR leads from the beginning of the collection procedure (4%). Individual trials may have also been compromised due to excessive movement artifact affecting greater than 5% of the data in the HR file. Multivariate analyses indicated no differences between children with complete HR data and those with missing data.

Preliminary Analysis

Given the different reporters and the varying procedures for data collection (laboratory assessment and school assessment), the number of participants varied from assessment to assessment. Sample sizes for each measure are reported along with the descriptives in Table 2. Each separate analysis used all available data. In addition, although the children were initially selected on the basis of scores on the CBCL and placed into particular groups, in the present study the child's externalizing score on the CBCL was treated as a continuous variable and controlled for during all analyses. Examination of CBCL scores indicated that they were normally distributed.

Preliminary multivariate analyses examined whether there were any gender, race, height, weight, and SES differences in all of the study measures. These analyses indicated that there were a number of gender differences on various study measures. Means for boys and girls across all study measures are presented in Table 2. As the table indicates peers reported boys as more "wild" than girls whereas teachers rated boys as more assertive and having more attention problems than girls. Because it was a goal of the study to examine gender differences between vagal regulation and children's social competence and behavior problems, separate analyses were conducted for boys and girls. Additional preliminary analyses revealed no relations between the measures of SES, race, height, and weight and the study outcome measures. Therefore, these factors were not considered in subsequent analyses.

Vagal Tone and Social Preference

The first goal of this study was to examine the relation between vagal tone measures (baseline vagal tone and vagal regulation) and children's peer status. To address this research question, Pearson's correlations were computed, separately by gender. Baseline vagal tone was not statistically related to social preference for boys ($r = -.03$, $p > .05$, $n = 80$) or girls ($r = .05$, $p > .05$, $n = 108$). Due to the moderate relation between baseline vagal tone and vagal regulation during an attention task ($r = .37$, $p < .001$, $n = 288$), the first mother child interaction task ($r = .44$, $p < .001$, $n = 291$), and the second mother child interaction task ($r = .39$, $p < .001$, $n = 294$), baseline vagal tone was controlled for during all analyses involving vagal regulation. Furthermore, due to past findings linking vagal regulation with parental distress and behavioral problems (El-Sheikh, 2001; Calkins and Dedmon, 2000), parental distress and early child behavior problems (CBCL externalizing scores at 2 years of age) were controlled during all analyses involving vagal regulation. These analyses found that vagal regulation during an attention task was positively related to social preference for girls ($r = .20$, $p < .05$, $n = 99$) but not for boys ($r = .08$, $p > .05$, $n = 76$). The two correlations were not significantly different from each other (Fisher's r to z, $p = .44$). Due to the non-significant findings between vagal regulation during the first mother child interaction task ($r = -.03$, $p > .05$, $n = 76$ for boys and $r = .13$, $p > .05$, $n = 99$ for girls) and the second mother child interaction task ($r = .00$, $p > .05$, $n = 76$ for boys and $r = .07$, $p > .05$, $n = 99$ for girls) with social preference, these variables were dropped from further analysis.

In addition, the few studies that have looked at vagal regulation have found that between 15-35% of children fail to engage in vagal regulation during challenging tasks (Donzella et al., 2000; Calkins, 1997). It remains unclear as to why these children fail to suppress vagal tone. Furthermore, it remains unknown if the importance of vagal regulation lies in the amount of regulation exhibited or simply as an all or none mechanism with no extra benefits gained from larger amounts of regulation. Therefore, to determine if these children's inability to suppress vagal tone during challenging tasks represent a significant physiological detriment, vagal regulation was also examined as a categorical variable. Children who suppressed vagal tone across all three challenging tasks (vagal suppression scores greater than 0) were compared to children who failed to suppress vagal tone across all three challenging tasks (vagal suppression scores of 0 or less). A t-test revealed a significant difference in social preference ($t = -2.00$, $p < .05$) with boys who were able to suppress vagal tone across all three tasks ($n = 62$) obtaining significantly higher social preference scores than boys who failed to suppress vagal tone across all three tasks ($n = 13$). No significant differences emerged for girls.

Although peer status or social preference is an important component of social competence, it is also an outcome measure obtained from a group's perspective. Therefore, it is important to consider how an individual's level of social competence, indexed by social skills, moderates the relation between vagal regulation and peer status. To determine how an individual's level of social skills influence the effect of vagal regulation on peer status, regression analyses were conducted. In the first step of the regression, the controlling variables (early externalizing problems, parental distress, and baseline vagal tone) were entered. In the second step, the main effects of social skills (as reported by teachers) and vagal regulation were entered. Finally, in the third step, the interaction term was entered. These analyses revealed that the addition of the interaction term was not statistically significant for either boys (F change =.002, p =.96) or girls (F change = .061, p = .81).

Vagal Tone and Behavior Problems

The second goal of the present study was to examine the relation between vagal tone measures and children's behavior problems. Once again, Pearson's partial correlations were conducted, separately by gender. These correlations are presented in Table 3. As the table indicates, baseline vagal tone, for boys, was positively related to being nominated by peers as "wild" (r = .23, p<.05, n = 80) as well as teacher report of reactive aggression (r = .22, p<.08, n = 67). No significant relations emerged for girls between baseline vagal tone and any of the behavioral problems variables as reported by peers, teachers, and parents. No gender differences were found when comparing separate correlations for boys and girls (Fisher's r to z, p = .55 and p = .32).

In regards to vagal regulation, for boys, peer nominations of "sneaky" behavior was negatively related to vagal regulation (r = -.32, p<.01, n =77). No significant correlations between peer report of behavior problems and vagal regulation emerged for girls. Fisher's r to z revealed a significant gender difference between the correlation of peer reported "sneaky" (p <.04), with boys (r = -.32) demonstrating a stronger negative relation with vagal regulation than girls (r = .00). In terms of teacher report of behavioral problems, no significant correlations emerged for boys or girls. In addition, no significant correlations emerged between behavior problems as reported by mothers and vagal regulation. Due to only one significant finding between vagal regulation, a physiological measure of emotion regulation, and children's behavior problems, exploratory analysis were done with an overt measure of emotion regulation (teacher report) and children's behavior problems.

First, to determine the relation between vagal regulation and teacher report of emotion regulation, correlations were conducted, separately by gender. The correlations between teacher report of emotion regulation and vagal regulation were non-significant($r = -.14$, $p>.05$, $n = 69$ for boys and $r = .06$, $p >.05$, $n = 90$ for girls). Next, post hoc correlations found that for boys, teacher report of emotion regulation was negatively related to externalizing problems ($r = -.50$, $p<.001$, $n =68$), hyperactivity ($r = -.40$, $p<.001$ $n =68$,), aggression ($r = -.52$, $p<.001$, $n =68$), and attention problems ($r = -.51$, $p<.001$, $n =68$). Similarly for girls, emotion regulation was negatively related to externalizing problems ($r = -.27$, $p<.01$, $n = 92$), hyperactivity ($r = -.18$, $p<.08$, $n = 92$), aggression ($r = -.34$, $p<.001$, $n = 92$), and attention problems ($r = -.32$, $p<.01$, $n = 92$). No gender differences were found when comparing separate correlations for boys and girls (Fisher's r to z, $p = .09$, $p = .14$, $p = .17$, and $p = .15$).

Once again, in an effort to clarify the importance of vagal regulation in terms of its amount of regulation or simply as an all or none mechanism, vagal regulation was also examined as a categorical variable. To control for Type I error, MANOVAs were conducted, separately by gender, to assess differences in behavioral problems between children who were able to suppress vagal tone across all three challenging tasks and children who failed to suppress vagal tone across all three challenging tasks. The MANOVAs were not significant for boys (F = .653, p = .81) or girls (F = .827, p = .64).

Vagal Tone and Children's Social Skills and Reactivity to Problem Situations

The third goal was to examine the relation between vagal tone measures and children's social skills and reactivity to problem situations. In order to accomplish this goal, Pearson's partial correlations were conducted and are presented in Tables 4 and 5. There were no significant correlations between baseline vagal tone and children's reactivity to problem situations. However, as indicated in Table 4, several statistically significant correlations did emerge between vagal regulation and children's reactivity to problem situations.

For girls, vagal regulation was negatively related to encountering difficulty entering a peer group (r = -.23, p<.01, n = 105), responding to a peer's provocation (r = -.17, p<.08, n = 105), and having difficulty responding to failure (r = -.21, p<.05, n = 105). No statistically significant relations emerged for boys between vagal regulation and reactivity to problem situations. Once again, no gender differences were found when comparing separate correlations for boys and girls (Fisher's r to z, p = .08, p = .50, and p =.46).

In terms of teacher report of social skills, as indicated in Table 5, baseline vagal tone, for girls, was negatively correlated with overall social skills (r = -.21, p<.05, n = 112) and cooperation (r = -.21, p<.05, n = 112). Fisher's r to z revealed a significant gender difference between the correlation of teacher reported overall social skills (p <.05), with girls (*r* = -.21) demonstrating a stronger negative relation with baseline vagal tone than boys (*r* = .07). No significant correlations emerged between baseline vagal tone and peer report of prosocial skills ("shares"). In terms of parent report of social skills, baseline vagal tone for boys was negatively correlated with overall social skills (r = -.21, p< .05, n = 107) and self-control (r = -.22, p< .05, n = 107). No significant relation emerged for girls between baseline vagal tone and parent report of social skills. In addition, no gender differences were found when comparing separate correlations for boys and girls (Fisher's r to z, p = .24, and p = .14)

In terms of the relation between vagal regulation and children's social skills as reported by teachers, significant correlations emerged only for girls, with overall social skills being positively related to vagal regulation (r = .20, p<.05, n = 102). For peer reports, being nominated by peers as someone who "shares" was positively correlated to vagal regulation (r = .23, p<.05, n = 99). Once again, this relation was only evident for girls. No gender differences, however, were found when comparing separate correlations for boys and girls (Fisher's r to z, p = .16, and p = .23). No significant relations emerged between vagal regulation and parent report of social skills for either boys or girls.

Once again vagal regulation was examined as a categorical variable. To control for Type I error, MANOVAs were conducted, separately by gender, to assess differences in social skills and reactivity to problem situations between children who suppressed vagal tone across the three challenging tasks and children who failed to suppress vagal tone across the three tasks. The MANOVAs were not significant for boys (F= .676, p =.61) or girls (F = .741, p = .57).

Testing a Model: Behavior Problems or Social Skills as the Mediator of Vagal Regulation and Social Preference

Due to the significant relation between vagal regulation and social preference, exploratory analyses were conducted to examine whether social skills or behavior problems mediated the effects of vagal regulation on social preference. In order to test mediation, procedures recommended by Baron and Kenny (1986) were followed. First, the independent variable must predict the mediator. Second, the independent variable must predict the dependent variable. Third the mediator must predict the dependent variable. Perfect mediation holds if the independent variable has no significant effect on the dependent variable when the mediator is controlled.

Because vagal regulation was only associated with social preference for girls, the mediational model for boys could not be tested. In addition, since vagal regulation was not found to be associated with any behavior problems for girls, behavior problems could not be tested as a mediator. However, as seen in Figure 1, all the relevant correlations needed to test social skills as the mediator were statistically significant. Vagal regulation was significantly associated with social skills, as reported by both peers and teachers. Social skills were also significantly associated with social preference. To examine whether social skills ("sharing"), as reported by peers, mediated the relation between vagal regulation and social preference, four regression equations were computed. These results are presented in Table 6. In the first regression, vagal regulation during an attention task predicted "sharing" even after controlling for early externalizing problems, parental distress, and baseline vagal tone. In the second step, vagal regulation also predicted social preference. Finally, when sharing was controlled (along with early externalizing problems, parental distress, and baseline vagal tone), vagal regulation no longer predicted social preference.

Similar to findings with social skills as reported by peers ("sharing"), the relation between vagal regulation during an attention task and kindergarten social preference was mediated by teacher report of overall social skills. These results are presented in Table 7.

CHAPTER IV

DISCUSSION

The present study was designed to examine the relation between vagal tone measures (baseline vagal tone and vagal regulation) and children's social competence and behavioral problems. Specifically, it examined whether higher levels of vagal regulation were related to greater social competence and fewer behavioral problems in kindergarteners as observed by teachers, parents, and peers. In addition, vagal regulation was examined as a categorical variable to determine if its importance lies in the amount of physiological regulation or simply an all or none system of regulation. Lastly, a mediational analysis was used to address the potential mechanisms in which vagal regulation influences children's social status.

First, the relations between vagal tone measures and children's social status were examined. Baseline vagal tone was not associated with social preference. This non-significant finding contradicts Eisenberg et al. (1995) finding that girls' baseline vagal tone was related to low social status while boys' baseline vagal tone was related to high social status. This conflicting finding may be due to Eisenberg and colleagues not controlling for children's externalizing problems as well as only obtaining same sex peer nominations to derive a social preference score, which may have prevented a pure assessment of social status. As such, it appears that baseline vagal tone may not be a useful physiological marker for predicting social status. On the other hand, vagal regulation during an attention task was modestly related to social preference for girls. This finding was partially consistent with my hypotheses and with the work of other investigators such as Stifter and Corey (2001) who found that infants with greater levels of vagal regulation during a cognitive challenge task were rated by the experimenters as more socially approaching. This study extends this finding by using an older population as well as obtaining a peer assessment of social competence.

Furthermore, these findings partially support Porges and colleagues' (1996) vagal "brake" as a neurophsyiological mechanism for appropriate social behavior. It also supports the differentiation of the two dimensions of vagal tone (baseline vagal tone and vagal regulation) as only vagal regulation was associated with children's social functioning. Moreover, the additional finding that the categorical examination of vagal regulation was significant for boys but not girls suggests possible gender differences in the role of physiological regulatory processes in children's social functioning. Exploratory analyses comparing the mean social preference scores of high regulators versus low regulators were performed to investigate this notion. For boys, both the high and low regulators had significantly higher social preference scores than the non-regulation group; for girls, only the high regulation group had significantly higher social preference scores than the non-regulation group. These findings suggest that for boys, an all or none system of regulating is necessary to ensure proper social functioning with no gains obtained with excess regulation. On the other hand, for girls, perhaps greater physiological regulation is what ensures better social functioning rather than simply an all or none system of regulating. Future research should investigate whether these gender differences in how regulation relate to social preference is also evident behaviorally or limited only to physiological regulation.

Another goal of this investigation was to examine the relations between vagal tone measures and children's behavioral problems. Only for boys was baseline vagal tone associated with behavior problems, with greater levels of baseline vagal tone associated with being nominated by peers as "wild" as well as marginally associated with teacher-reported reactive aggression. These findings lend support for previous research linking high levels of baseline vagal tone to uninhibited behavior as well as temperamental reactivity, both of which may characterize "wild" behavior as well as reactive aggression (Reznick, 1989; Calkins, 1994). In terms of vagal regulation, only one significant relation emerged with children's behavioral problems. As expected, for boys, vagal regulation was negatively associated with peer reports of "sneaky" behavior. This finding is somewhat consistent with my hypotheses and suggests that children with higher levels of vagal regulation are less likely to engage in behavioral problems. However, given the large number of correlations, this finding should be interpreted with caution. The lack of more definitive findings may call into question the link between vagal regulation and behavior problems suggested by previous researchers (Porges, 1996; Calkins and Dedmon, 2000).

The lack of correlation between vagal regulation and children's behavior problems in the present study may be due to a couple of factors. First, this is the only study that has appropriately controlled for both early externalizing problems and parental distress. These variables previously have been found to be associated with vagal regulation and behavior problems but have never been controlled in studies examining vagal regulation (El-Sheikh, 2001; Calkins and Dedmon, 2000). Post hoc analyses, without controlling for early behavior problems or parental distress, confirmed this assertion as a significant negative relation between vagal regulation and externalizing problems, including hyperactivity and aggression, surfaced for boys. Lastly, this is the first study to examine the relation between vagal regulation and behavior problems in kindergarteners, whereas other studies have focused primarily on infants and toddlers (Porges, 1996; Calkins and Dedmon, 2000). It is possible that developmental differences in physiological maturation as well as cognitive development between these population groups can account for the different findings. Perhaps through learning and socialization practices, children by kindergarten have learned how to overcome their physiological capacity to regulate and are able to regulate themselves behaviorally even though physiologically they are not. Post hoc correlations between vagal regulation and an overt measure of emotion regulation (teacher report) confirmed this assertion as no significant relation emerged between the physiological measure of emotion regulation (vagal regulation) and teacher-reported emotion regulation.

This dissociation between physiology and behavior has also been observed in the emotional expression research (Barr, 1999; Quas, Hong, Alkon, & Boyce, 2000). For example, Barr (1999) reported no differences in either heart rate or vagal tone between infants with and without colic while undergoing physical exams, even though considerable behavioral differences (i.e., crying) emerged between the two groups. Other exploratory analysis between teacher report of emotion regulation (overt behavior) and externalizing problems further provides evidence for this assertion as children who are reported by teachers as having greater emotion regulation exhibited fewer externalizing problems such as aggression and hyperactivity. Therefore, this study's more controlled examination of the relation between vagal regulation and children's behavior problems suggests that by this later developmental period, the relation between children's physiological regulation and behavior problems is not evident as children have learned to exhibit overtly appropriate emotion regulation despite their physiological functioning. Understanding how the dissociation between physiology and behavior develops is an important avenue for future research. Examining socialization practices (e.g., parenting methods) as well as the impact learning (e.g., modeling parenting behavior) has on children's emotion regulation development, both behaviorally and physiologically, will undoubtedly contribute to our understanding in this domain.

The relations between vagal tone measures and children's reactivity to problem situations were also examined. Once again, baseline vagal tone was not associated with any outcome variables. In regards to vagal regulation, the findings suggest that girls with higher levels of vagal regulation are less likely to respond in a negative manner to problem situations such as a peer's provocation, entering a peer group, and responding to failure. These findings are consistent with my hypothesis that higher levels of vagal regulation facilitate children's ability to regulate their reactivity to stressful circumstances and help them engage in more appropriate social behavior in dealing with such situations. This result is also consistent with other data indicating that children who are unable to manage negative affect have difficulty managing peer conflict situations (Dunn & Brown, 1994; Stocker & Dunn, 1990). Again, these findings were applicable only to girls, suggesting a possible gender difference in the role that vagal regulation plays in social behavior.

Another goal of this investigation was to examine the relations between vagal tone measures and children's social skills. Overall, baseline vagal tone was negatively associated with social skills for boys (as reported by parents) and girls (as reported by teachers). This finding suggests that children with higher levels of temperamental reactivity are less likely to exhibit good social skills. This finding is somewhat in line with previous research that has found girls with higher levels of baseline vagal tone exhibiting inferior social skills (Eisenberg et. al., 1996). The negative relation of baseline vagal tone and social skills for boys, however, is a new finding as Eisenberg and colleagues (1996) found no association between baseline vagal tone and social skills for boys. This discrepant finding could be explained by how different reporters interpret uninhibited behavior, which is associated with high levels of baseline vagal tone (Reznick, 1989). Eisenberg and colleagues' (1996) finding used teacher reports, whereas this study's finding included both parent and teacher reports. Perhaps teachers interpret uninhibited behavior as negative for girls, which is consistent with Eisenberg and colleagues' (1996) finding, whereas parents may interpret boys' uninhibited behavior as negative. Future research should investigate how different reporters interpret boys' and girls' uninhibited behavior.

Regardless of how high a child's baseline vagal tone level was, the current study controlled for baseline vagal tone to examine the relation between vagal regulation, a physiological index of emotion regulation, and children's social skills. This study's findings suggest that girls with higher levels of vagal regulation are more likely to exhibit better overall social skills as reported by teachers and to be nominated as someone who "shares" by peers. These findings extend support for the function of vagal regulation or the vagal "brake" in social behavior in several ways. First, this is the first study using an older population sample (kindergarteners) to provide evidence for Porges and colleagues' (1996) vagal "brake" theory as it directly relates to children's social competence —in the form of better individual social skills—, not merely fewer behavior problems as past research had found (Porges, 1996; Calkins and Dedmon, 2000). This study also expands the vagal "brake" theory by including a large enough sample to find possible gender differences in how physiological regulation influences social behavior. Considering that Porges and colleagues (1996) developed the vagal "brake" theory using a small sample, gender differences were unlikely to appear. The current study's large sample enabled a better comparison of how such a theory may play out for boys versus girls.

Gender differences in physiological functioning is not a new phenomenon. Research in the cardiovascular health literature has found that women exhibit greater parasympathetic influence on cardiac regulation while men exhibit greater sympathetic influence (Barnett, et. al., 1997; Kuo, Lin, Yang, Li, Chen, and Chou, 1999). Significantly greater parasympathetic influence on the heart, with lesser sympathetic input, appears to be a protective factor for women during periods of cardiac stress (Airaksinen, Ikeheimo, Linnaluoto, Tahvanainen, and Huikuri, 1998; Raemakers, Ector, Aubert, Rubens, and Van de Werf, 1998). However, all of these studies examining gender differences in cardiac regulation have focused on adults and purely medical issues. No study to date has examined how gender differences in cardiac regulation develop or its functionality across development. It is possible that the function of the vagal "brake" changes with development. Childhood may be a time when cardiac functioning facilitates social behavior, but as the child learns more complex social behaviors, the same physiological mechanisms becomes a protective factor for extremely stressful situations where arousal levels intensify. The non-significant findings between vagal regulation and children's behavioral problems may signify a learned ability to cope with moderate arousal levels that comprise everyday events. It is possible, however, that when arousal levels intensify (e.g., heart attack), the vagal "brake" mechanism becomes more evident through behavioral determinants (e.g., speeding up one's heart beats to increase the survivability of a heart attack). This study's initial finding of significance only for girls warrants future studies to determine possible differences in how boys' and girls' physiology influences their social behavior.

Due to the significant finding between vagal regulation and children's social competence, exploratory analysis were conducted to explore possible mechanisms by which vagal regulation affects children's social competence. Based on Porges' Polyvagal theory, it was expected that the role of vagal regulation in children's social competence lies in its ability to increase a child's social skills repertoire rather than simply decreasing their behavior problems. Thus, in exploring the linkage between vagal regulation and social preference, it was of particular importance to determine whether it was through better social skills or fewer behavior problems that vagal regulation related to social status. It was also important to determine if this mechanism differed for boys and girls. Using Baron and Kenny's (1986) mediational approach, I tested two models in which an individual's social skills or behavior problems, evidenced in the kindergarten classroom, would serve as mediators between vagal regulation and social status.

A mediational model for boys was not possible to test as there was no significant relation between vagal regulation and social status. For girls, "sharing" behavior, as reported by peers, and overall social skills, as reported by teachers, mediated the relation between vagal regulation and social status. Behavior problems could not be tested as a mediator due to the insignificant relation with vagal regulation for girls. Possible reasons for a non-significant finding between vagal regulation and girls' behavior problems lie in the developmental significance of appropriate physiological regulation. It may be that the connection between physiological regulation and behavior problems is more salient early on when a child's cognitive development is in its infancy. This explains past findings linking greater vagal regulation with fewer behavior problems in toddlers (Calkins and Dedmon, 2000; Porges, 1996). However, as the child's cognitive system develops, the link between physiological regulation and behavior may become managed through more advanced cognitive processes of which social skills is a result. For example, it is cognitively less demanding to punch a peer reactively as a result of a stolen a toy compared to talking and problem solving, which have more cognitive demands. This suggests that vagal regulation has an effect on girls' social status by increasing their social skills repertoire, which in turn assures greater peer status.

In summary, this study's results provide partial support for the role of vagal regulation in children's social competence. For girls, it appears that greater vagal regulation facilitates better peer status by increasing their social skills repertoire including their ability to deal with problem situations with peers. On the other hand, for boys, no clear relation emerged between the amount of vagal regulation and social competence although the significant examination of vagal regulation as a categorical variable (only for boys) suggested a possible gender difference in the importance of vagal regulation. An important question that should be further investigated is potential gender differences in the role of vagal regulation in children's social functioning. Is the role of the vagal "brake," as a neurophysiological mechanism for social behavior, limited to girls or is it simply delayed in boys. It is possible that as boys cognitively catch up with girls, they would begin to use the vagal "brake" for more complex social behavior (i.e., problem solving)? On the other hand, the gender gap in the use of this physiological mechanism could increase. Nevertheless, these are important questions for future longitudinal research to answer to better understand the role of physiological regulation in the development of children's social competence.

This study has several important strengths. First, the design employed multiple reporters (peers, teachers, and parents) including physiological data derived from several challenging episodes insuring appropriate arousal levels. In addition, peers were included as a source of information, not only in terms of assessing social status within the classroom, but also as reporters of behavior problems. Second, the study drew from a community-based sample that included children with varying degrees of behavior problems. Lastly, it was the first study to examine potential gender differences in cardiac regulation in early childhood and its influences on social behavior. The differences found between the role of vagal regulation for girls compared to boys enhances the argument that researchers should continue to consider the child's gender when examining regulatory processes. Despite the strengths of this study, it is clear that although many of the relations tested were significant, they were modest in magnitude and accounted for only a small portion of the variance. Thus, other factors such as socialization practices and parenting techniques should be considered in future research.

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APPENDIX A: TABLES

Table 1. Descriptive Statistics for RSA and RSA change

	M	*SD*	*Min*	*Max*	N
Age 5 RSA					
Baseline RSA	6.08	1.15	3.28	9.42	298
Attention RSA	5.58	1.13	2.72	8.85	288
Mother Child Interaction #1 RSA	5.52	1.08	2.89	8.51	291
Mother Child Interaction #2 RSA	5.50	1.10	2.34	9.00	294
Age 5 RSA change					
Attention	.50[a]	.75	-1.77	3.24	288
Mother Child Interaction #1	.57[a]	.65	-1.48	3.10	291
Mother Child Interaction #2	.58[a]	.73	-3.17	3.23	294

RSA; respiratory sinus arrhythmia

[a] *Positive change scores indicate greater decrease from baseline to task*

Table 2. Descriptive Statistics for Study Variables for Boys and Girls

	Boys			Girls		
	M	*SD*	*N*	*M*	*SD*	*N*
5 year (Peer)						
"fight"	.52	1.03	110	-.38	.70	136
"share"	-.33	.95	110	.28	.96	136
"wild" *	.62	.99	110	-.39	.71	136
"sneaky"	.44	1.11	110	-.29	.79	136
"bossy"	.28	1.04	110	-.22	.89	136
Social preference	-.18	.98	110	.08	.92	136
5 year (Teacher)						
Social Skills						
Overall Social Skills	101.5	12.7	118	100.8	13.8	146
Cooperation	14.4	4.17	118	16.1	4.00	146
Assertion *	12.3	3.62	118	13.4	3.54	145
Self-control	14.2	4.05	118	14.6	3.81	145
Reactivity to Problem Situations						
Peer Group entry	12.4	4.8	119	12.6	4.79	145
Response to Provocation	27.1	9.9	119	24.3	8.82	143
Response to Failure	21.0	8.2	119	18.8	6.80	144
Response to Success	5.25	2.27	119	4.75	1.92	145
Behavior Problems						
Reactive aggression	15.5	7.89	95	13.9	7.04	119
Proactive aggression	11.2	5.92	95	10.6	5.31	118
Hyperactivity	50.9	10.5	116	45.1	9.42	144
Aggression	48.9	10.6	115	47.2	8.12	144
Attention Problems *	51.0	11.2	117	45.1	9.95	144
Externalizing	49.7	10.1	115	45.9	8.24	143
5 year (Parent)						
Social Skills						
Overall Social Skills	99.6	15.8	152	99.5	17.3	173
Cooperation	11.7	3.32	152	12.8	3.32	173
Assertion	15.7	2.92	149	16.2	2.70	173
Self-control	12.4	3.40	152	13.2	3.37	173
Behavior Problems						
Hyperactivity	48.7	11.25	153	45.6	11.1	175
Aggression	47.1	9.38	153	44.9	9.50	175
Attention Problems	52.3	11.14	153	48.8	12.2	175
Externalizing	47.7	10.45	153	44.8	10.2	175

*****significant gender difference at $p < .05$

Table 3. Correlations between Peer, Teacher, and Mother Report of Behavior Problems and Vagal Tone Measures

	5 yr Baseline Vagal Tone		5 yr Vagal Regulation	
	Boys	Girls	Boys	Girls
Peer Nominations				
"fight"	-.01	.04	-.13	-.03
"wild"	.23*	.14	-.04	-.09
"sneaky"	.01	.10	-.32**	.00
"bossy"	.15	.10	-.13	-.11
Teacher Report				
Hyperactivity	.15	.16	-.17	.12
Aggression	-.02	.06	-.16	.01
Proactive Aggression	.20	-.02	-.16	-.18
Reactive Aggression	.22+	.06	-.06	-.17
Attention Problems	-.05	.12	-.10	-.02
Externalizing	.09	.11	-.17	.06
Parent Report				
Hyperactivity	-.03	-.03	-.14	.07
Aggression	.01	-.06	.00	.03
Attention Problems	.01	-.03	-.06	-.02
Externalizing	-.01	-.02	-.11	.05

+p<.08, *p <.05, **p<.01

Table 4. Correlations between Teacher Report of Reactivity to Problem Situations and Vagal Tone Measures

	5 yr Baseline Vagal Tone		5 yr Vagal Regulation	
	Boys	Girls	Boys	Girls
Response to Group Entry	.09	.07	-.11	-.23*
Response to Provocation	.13	.14	-.09	-.17+
Response to Success	.17	.06	-.09	-.13
Response to Failure	.08	.14	-.10	-.21*

+p<.08, *p <.05, **p<.01

Table 5. Correlations between Teacher, Peer, and Parent Report of Social Skills and Vagal Tone Measures

	5 yr Baseline Vagal Tone		5 yr Vagal Regulation	
	Boys	Girls	Boys	Girls
Teacher Report				
Social Skills	.07	-.21*	-.01	.20*
Assertion	.12	-.09	-.12	.15
Cooperation	.04	-.21*	.08	.11
Self-Control	.06	-.16	.08	.15
Peer Report				
"share"	-.01	-.07	-.04	.23*
Parent Report				
Social Skills	-.21*	-.06	.00	.00
Assertion	-.13	-.12	-.07	-.01
Cooperation	-.15	-.02	.02	.03
Self-Control	-.22*	-.03	-.08	.11

*p <.05, **p<.01

Table 6. Regression Analysis Testing Girls' Sharing (peer report) as a Mediator of the Relation Between Vagal Regulation and Social Preference

Predictor	β	R^2	R^2 Change	F change
1. Vagal Regulation as a Predictor of Sharing:				
2yr- Parent CBCL Externalizing T Score	-.12	.02	.02	ns
2yr- Parent Distress	.26	.08	.06	6.73**
5yr- Baseline Vagal Tone	-.03	.08	.00	ns
5yr- Vagal Regulation	.23	.13	.05	5.24*
2. Vagal Regulation as a Predictor of Social Preference:				
2yr- Parent CBCL Externalizing T Score	-.21	.05	.05	5.01*
2yr- Parental Distress	.24	.09	.04	5.55*
5yr- Baseline Vagal Tone	.05	.10	.01	ns
5yr- Vagal Regulation	.20	.13	.03	3.71+
3. Sharing as a Predictor of Social Preference:				
2yr- Parent CBCL Externalizing T Score	-.24	.06	.06	6.41**
2yr- Parental Distress	.22	.10	.04	5.47*
5yr- Sharing	.62	.46	.36	70.34**
4. Sharing as a Mediator:				
2yr- Parent CBCL Externalizing T Score	-.21	.05	.05	5.05*
2yr- Parental Distress	.24	.09	.04	5.55*
5yr- Baseline Vagal Tone	.05	.10	.01	ns
5yr- Sharing	.63	.47	.37	70.69**
5yr- Vagal Regulation	.05	.47	.00	ns

+p<.08, *p <.05, **p<.01

Table 7. Regression Analysis Testing Girls' Social Skills (teacher report) as a Mediator of the Relation Between Vagal Regulation and Social Preference

Predictor	β	R^2	R^2 Change	F change
1. Vagal Regulation as a Predictor of Social Skills:				
2yr- Parent CBCL Externalizing T Score	-.34	.11	.11	13.89**
2yr- Parent Distress	.07	.12	.01	ns
5yr- Baseline Vagal Tone	-.20	.16	.04	5.19*
5yr- Vagal Regulation	.20	.19	.03	3.84*
2. Vagal Regulation as a Predictor of Social Preference:				
2yr- Parent CBCL Externalizing T Score	-.21	.05	.05	5.01*
2yr- Parental Distress	.24	.09	.04	5.55*
5yr- Baseline Vagal Tone	.05	.10	.01	ns
5yr- Vagal Regulation	.20	.13	.03	3.71+
3. Social Skills as a Predictor of Social Preference:				
2yr- Parent CBCL Externalizing T Score	-.21	.04	.04	4.67*
2yr- Parental Distress	.21	.08	.04	4.12*
5yr- SSRS-Social Skills Standard Score	.28	.15	.07	8.28**
4. Social Skills as a Mediator:				
2yr- Parent CBCL Externalizing T Score	-.18	.03	.03	3.45+
2yr- Parental Distress	.21	.07	.04	4.16*
5yr- Baseline Vagal Tone	.05	.08	.01	ns
5yr- SSRS-Social Skills Standard Score	.31	.16	.08	9.38**
5yr- Vagal Regulation	.15	.18	.02	ns

+p<.08, *p <.05, **p<.01

APPENDIX B: FIGURE

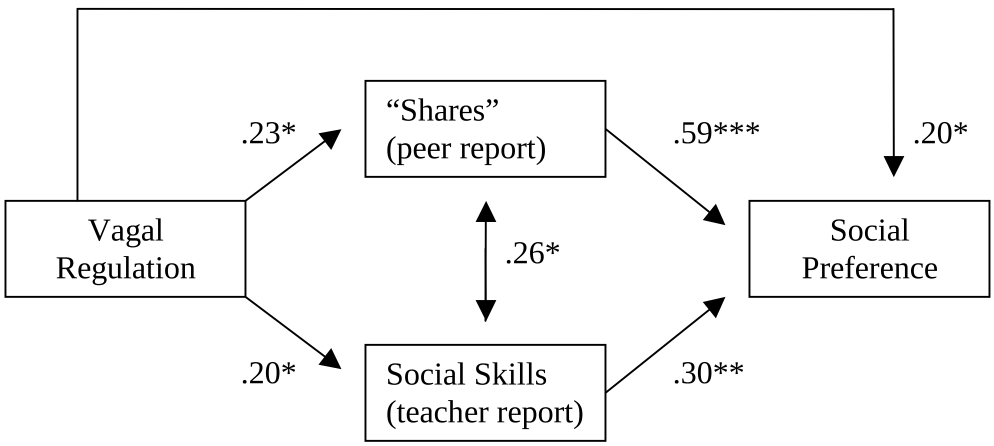

Figure 1. Correlations among vagal regulation, “shares”, social skills, and social preference for girls. Values reported are partial correlations presented schematically; they do not represent a test of the overall model. *p<.05, **p<.01, ***p<.001