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CHANGES IN CHILDREN'S PHYSIOLOGICAL RESPONSE TO ANGER AND CONDUCT PROBLEMS ACROSS EARLY SCHOOL YEARS

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ABSTRACT

Previous studies have found that self-regulation of emotion improves over time in children as they mature. The current study built upon this research and aided in understanding the potential developmental trajectories of physiological and behavioral indicators related to self-regulatory capabilities in children with different levels of behavioral risk. The purpose of the study was to examine the specific mechanisms through which presumed development in self-regulation occurs by investigating physiological (respiratory sinus arrhythmia; RSA) and behavioral (externalizing behaviors) regulation across the first 3 years of elementary school. The study was conducted in a longitudinal manner, and participants were recruited from kindergarten classes in 10 different elementary schools. After an initial aggressive behavior rating scale assessment, 207 children were placed into the high aggression group and 132 children were placed into the comparison group. Assessments took place annually from kindergarten through second grade and included an emotion induction task consisting of scenes from the movie, *The Lion King*. Children's RSA was examined at baseline, during the anger scene, and during a neutral scene immediately following the anger scene. Children's externalizing behavior was reported each year by their classroom teacher. Results showed no developmental changes or group differences for RSA reactivity. Developmental changes and group differences were found for RSA recovery. While group differences were found for conduct problems, no developmental changes were observed for conduct problems. The findings highlight the necessity to provide early intervention for children who demonstrate early indicators of behavioral problems at school entry.

KEYWORDS: respiratory sinus arrhythmia (RSA), conduct problems, anger, self-regulation, development

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Chapter 1

Introduction

Theory of Emotion

In general, emotions are defined as being a form of communication patterns of perception, experience, physiology, and action, that occur due to challenges that individuals face in their physical and social surroundings (Keltner & Gross, 1999). Therefore, emotions are typically short in duration and emerge in response to stimuli experienced by the individual in an effort to initiate their regulatory response to the external environment (Keltner & Gross, 1999). In this sense, emotions serve as solutions to problems in the environment, and can be thought of as having a functional basis (Keltner & Gross, 1999). Consequently, emotions often serve as specific and efficient responses to problems associated with survival. (Munkejord, 2009). When faced with emotion-provoking situations, individuals experience emotions as a reaction to the scenario they are presented with.

Anger is considered to be a negative emotion, or an emotion that causes an individual to feel unpleasant, due to the fact that individuals express this emotion as a result of events that are viewed as frustrating or block one's goals (Carven & Harmen-Jones, 2009). Consequences occur as a result of the environment in which the emotion is elicited, in that emotions are functional constructs that help regulate our relationships with the environment. Although there are beneficial consequences associated with experiencing emotions, the way emotions are expressed can also introduce negative repercussions if done so in a way that negatively affects other individuals (Keltner & Gross, 1999). Therefore, emotions need to be expressed and regulated in a way that supports socially-adaptive behaviors (Keltner & Gross, 1999). For example, in the case of anger, anger is generated when we do not get what we want, and that motivates us to fight for it. Individuals experience anger because an important goal was viewed as being obstructed, which implies that the anger is usually directed toward another person, animal, or oneself. If a child inappropriately responds to anger, such as in using physical contact (e.g., aggressive behaviors), these behaviors might disrupt their relationship with parents, teachers, or peers, which can impede their longer-term socio-emotional adjustment. Anger can also manifest in scenarios where individuals feel a lack of control and power, as well as during times of injustice or moral violations (Wranik & Scherer, 2010). However, it is expected that anger should not be expressed in certain behavioral ways or not expressed at all according to social constructs. Despite minor variations as to why humans experience anger and how they express anger, the previous examples all share a common theme in that one experiences anger as a result of the violation of what "ought" to be (Carven & Harmen-Jones, 2009).

Anger results as a behavioral response in an effort to remove the violation of what "ought" to be, and change the behavior of others, while also returning to a state of working towards a desired place or goal (Carven & Harmen-Jones, 2009). In the case of young children, they are often thought to get angry more easily, or more likely to express anger in more disruptive ways (e.g., throw a tantrum, aggressive behaviors toward others) than older children, and it is during the process of development that children learn to regulate such emotions or express emotions in more socially-adaptive ways. The development of self-regulation throughout early childhood is assumed to support the transition to more regulated responses in emotionally-provoking situations. However, multiple levels of responses (e.g., physiological, behavioral) are often involved in emotionally-provoking situations, and it is not clear which specific changing processes underlie the development of self-regulation.

Demonstrating early disruptive behaviors may be linked to underlying difficulties in children's physiological responses that make it harder for them to self-regulate and control their behaviors or negative emotions. Disruptive behavior has been found to decline from infancy into childhood, as children learn to inhibit these behaviors over time, presumably through socialization (Vazsonyi & Kelly, 2007). Although aggression is rare at the time of school entry, small groups of children stand out as exhibiting more disruptive behavior than their peers throughout childhood (Vazsonyi & Kelly, 2007).

Therefore, children can be split into high-risk or low-risk groups based on an assessment of their aggressive behavior. Children who demonstrate high aggression are considered to be high-risk in comparison to non-aggressive children of the same age because they respond differently to anger in terms of physiology and behavior. Prior studies have identified early aggressive behavior as a developmental precursor for future conduct problems (Broidy et al., 2003). Studies of that nature have been based on high risk youth and typically developing children, and have found that there is continuity in disruptive behavior when exhibited during childhood (Broidy et al., 2003). As a result, it is important to examine whether there are developmental differences between those identified as high-risk children and other children who demonstrate appropriate socially-adaptive behavioral adjustments. If a child shows behavioral problems at the time of school entry, it may be harder for that child to build adaptive relationships with their teachers and peers. This is because it is in these relationships that children's behaviors are socialized and they experience the expected developmental improvement of behavior. As a result, it would be expected that children with early behavioral problems would show less improvement, or even escalation, in behavioral problems over time in comparison to low-risk groups of children. A similar argument can also be made for physiological regulation. A child with early disruptive behaviors, may spend more time being in a state of dysregulated physiological arousal, and have fewer resources or a lower ability to recover when facing challenging situations. In the long term, these factors may lead to a distinct pattern of development in their physiology.

States of bodily excitement allow individuals to distinguish between different emotional experiences that result in peripheral body expressions. Peripheral body expressions involve voluntary movement of the body, such as striking an object when angry (Critchley, 2005). The amygdala is a neural structure that receives sensory information from other parts of the brain, and when the information signals a possible threat, the amygdala initiates changes in bodily arousal through the autonomic nervous system (Lang, 2010). The autonomic nervous system is involved in the physiology of emotion because it is the regulatory route of internal bodily functions (Critchley, 2005). The physiological changes that occur in the body due to anger can be considered adaptive responses that occur as a result of a threat or an obstruction of an important goal. They are considered adaptive responses because the physiological changes in the body provide the increased resources needed to meet the metabolic demands of behavior in order to resolve the threat or obstruction.

Studying the behavioral response to emotional experiences that provoke anger is important because behavioral responses are thought to occur as a result of the individual's reaction to the emotion. Oftentimes, anger can prompt physical actions that can include causing physical harm or inflicting pain on other individuals, creating a sense of discomfort in order to force the other person/people involved to feel a similar way. These aggressive behaviors may be an immediate "solution" for the individual experiencing anger to reach a desired state. For example, a child may feel angry if the child believes another child took his toy from him and might attack in order to get it back. However, these behaviors do not serve longer-term adaptive goals, because they often inflict distress on others and disrupt interpersonal relationships.

Importance of Self-Regulation

Self-regulation plays a large role in emotion regulation in children, and involves biological and behavioral factors. Self-regulation, but more explicitly, emotion regulation, refers to the skills that allow children to modulate emotional expressions and experiences (Perry, et al., 2011). Physiological reactivity reflects an individual's response to environmental stimuli, and, thus, reactivity can be considered part of the emotional response pattern (Quas, et al., 2000). Self-regulation determines if an individual will choose to act on the emotional response experienced, and is used to manage and change how an individual experiences physiological changes to emotion, and how individuals express themselves behaviorally (Eisenberg, et al., 2010). This could involve better regulation of the expression of the emotion or better recovery to a state of normalcy after experiencing the emotion. Emotion regulation skills are crucial for children's adaptive functioning due to the fact that emotion regulation involves the ability of an individual to respond to different scenarios in a socially-adaptive manner (Graziano & Derefinko, 2013). More specifically, self-regulation involves autonomic reactivity, which deals with the regulation of an individual's emotional state in reaction to stressful events.

Understanding the development of a child's self-regulation process is one of the most important facets in order to understand the process of development in general (Eisenberg, et al., 2010). Moreover, the ability of a child to regulate behavior is related to the development of different brain areas that provide mechanisms for understanding self-regulation (Posner & Rothbart, 2000). Mechanisms of self-regulation in normal individuals can be used to identify markers of developmental problems (Posner & Rothbart, 2000), and therefore emotion regulation is a factor that can be used to predict if positive or atypical developmental outcomes are occurring (Eisenberg, et al., 2010). However, it is important to realize that individual differences in emotional reactivity and self-regulation do exist (Posner & Rothbart, 2000). Maladjustment may be a function of failing to meet typical emotion-related regulation milestones, such as learning the socially-adaptive way to express emotions (Eisenberg, et al., 2010).

Importance of the Development of Self-Regulation over Early Childhood Years

The preschool period represents a critical time of emotional development for children as the socio-emotional skills they acquire will affect their emotional competence and ability to cope with emotion-provoking stimuli in the increasingly demanding social context of formal schooling (Denham et al., 2003). From the first few years of life, children progress from relying on caretakers in order to regulate their emotions to learning how to calm themselves (Eisenberg, et al., 2010). In doing so, each individual learns the mechanisms that help them reorient themselves and exhibit effortful control. Effortful control involves inhibiting behavior that is deemed as reactive to stimuli, and previous research has shown that emergence of effortful control occurs during infancy, but continuous gains in effortful control are made in school aged children (Eisenberg, et al., 2010). As a result, because of the role that effortful control plays in self-regulation, effortful control has been linked to developmental processes (Eisenberg, et al., 2010). Additionally, effortful control can be used to assess maladjustments in development that contribute to developmental delays, often resulting in the inability to regulate emotional experiences (Eisenberg, et al., 2010).

It is important to study children during the transition to school because that is the time period in which early emotion regulation skills develop and are of critical importance (Denham et al., 2003). An individual's ability to self-regulate their expression of emotion develops over the first few years of life and remains fragile during the preschool and early school years due to the unfolding of social influences of behavior that begin when a child is surrounded by other children their age (Eisenberg et al., 1995). In addition, maturation of biological systems within the body lays the foundation for an individual to develop more sophisticated processes, including self-regulation of emotions (Calkins & Keane, 2004). In particular, maturation of the parasympathetic nervous system (PNS) during early childhood plays a key role in the regulation of emotion. Vagal regulation of the heart, measured using respiratory sinus arrhythmia (RSA), is a physiological measure thought to be related to self-regulatory behavior in childhood (Calkins & Keane, 2004). As a reflection of parasympathetic influence, RSA reflects maturation of the PNS, and can therefore be associated with emotional reactivity (Calkins & Keane, 2004). Furthermore, the developmental perspective includes not just how emotional reactions at one age differs from another age, but also how earlier behavior evolves to a later behavior (Stroufe, 1997). As a result, studying children in a longitudinal manner provides the opportunity to study the progress of maturation of their PNS, while also seeing how they compare to other children their age.

Respiratory Sinus Arrhythmia (RSA)

The parasympathetic nervous system (PNS), sometimes referred to as the “rest and digest” system because of its role in conserving energy, is responsible for modulating an individual’s response to stimuli in order to return them to a non-aroused state during recovery from that stressor (Quas, et al., 2000). Parasympathetic control can be studied using respiratory sinus arrhythmia (RSA), which is a measure of high frequency variability in heart rate (HR) that is controlled by the vagus nerve (Obradovic & Boyce, 2012). This is meaningful because the vagus nerve is a fundamental component of the PNS and is responsible for the regulation of critical aspects of human physiology, including RSA. RSA refers to the variation in heart rate that occurs across the respiratory cycle. In addition, RSA is the parameter used because it relates to vagal tone, which refers back to the vagus nerve. Therefore, vagal tone monitors the functional output by efferent pathways sent out by the vagus nerve in an effort to regulate body systems and motor functions that are a part of the PNS (Porges, 2007). Vagal influence is a brake that slows heart rate in the absence of a challenge, so when referring to vagal suppression, this means that vagal influence is removed and HR increases when coping with environmental factors (Hinnant & El-Sheikh, 2009). Under conditions of high parasympathetic control, heart rate speeds during inhalation and slows during exhalation (Berntson, Quigley, Lozano, 2007). Additionally, polyvagal theory suggests that an individual’s capacity to respond to challenges in a controlled manner is driven by parasympathetic control of cardiac arousal, which is measured using RSA (Porges, 2007). Because RSA reflects the output of prefrontal networks that associate internal responses with external cues, it can be used to measure how an individual reacts to emotional stimuli (Fortunato, et al., 2013).

RSA reactivity reflects the response to stimuli, with RSA withdrawal generating a faster HR, reflecting a decrease in parasympathetic control. Research has proposed that RSA withdrawal enables an individual to cope with challenging scenarios by increasing heart rate. Therefore, it has been previously hypothesized that greater levels of RSA withdrawal are associated with better self-regulation skills that are observed during the process of regulating emotions (Graziano & Derefinko, 2013). On the other hand, RSA augmentation generates a slower HR, reflecting an increase in parasympathetic control, implying a decrease in physiological arousal. Therefore, RSA can be used to examine how the PNS relates to the process of emotions because autonomic reactivity, such as changes in HR, are influenced by the PNS (Obradovic & Boyce, 2012). Furthermore, the polyvagal theory emerged as a model of how neural regulation was involved in the autonomic nervous system and states that primary emotions, such as anger, are related to autonomic function (Porges, 2007). In this sense, successful vagal regulation refers to suppressing RSA during challenging states, a process also known as RSA withdrawal (Graziano & Derefinko, 2013). The theory has made it possible to interpret vagal regulation in response to environmental challenges, due to the fact that vagal regulation represents an individual's ability to try and restore homeostasis (Graziano & Derefinko, 2013).

Furthermore, anger is known to provoke a change in RSA from baseline due to the fact that anger is an emotional response to environmental factors that is often accompanied by physiological reactivity. Responding to events that result in the expression of anger is accompanied by cardiovascular effects including faster breathing and increased HR (Kreigbig, 2010). These physiological symptoms represent a decrease in activity in the parasympathetic nervous system that prepare an individual to meet the demands of their environment (Funkenstein, 1955). Furthermore, other negative emotions have apparent overlaps in comparison to anger, and anger is considered to be most closely related to fear in that they result in similar physiological changes. This is partly due to the fact that they are both negative emotions, but also because they result in almost all of the same cardiovascular and vagal effects (Kreibig, 2010).

During development, the PNS undergoes maturation that plays a role in regulation of state and emotion (Calkin & Keane, 2004). Additionally, previous studies of young children have found that children show weak to moderate stability in measures of the PNS, including RSA, during rest and reactivity (Alkon, et al., 2011). This means that a child's RSA response to stimuli could fluctuate as they develop overtime. Furthermore, if it is hypothesized that RSA withdrawal is associated with physiological regulation of emotions, then the magnitude of this response should increase over the course of the preschool years (Calkin & Keane, 2004). Previous studies have found that baseline RSA was not stable over the course of three time points and significantly increased from ages three to five (Perry, et al., 2013). This is because, during the preschool years, the child is developing regulation responses and gaining control over behavioral skills as previously discussed (Calkin & Keane, 2004). Therefore, as children age, and learn to better regulate their behavior, they may also exhibit better physiological regulation of their cardiac response to stimuli (Calkin & Keane, 2004).

Current Study

How school aged children regulate their emotional response to various scenarios has been a subject of study for many years due to its relevance in child development. Polyvagal theory and RSA have emerged in the past 30 years, and provide a theoretical and physiological explanation as to what happens when an individual experiences an emotional response and the process involved in handling the emotion-provoking scenario. These theories provide an explanation for how specific patterns of RSA reactivity when facing emotion-provoking stimuli may more efficiently support socially-adaptive emotional expressions and behavioral responses. Furthermore, it is not to be expected that every individual will react in the same manner to emotion-provoking stimuli or develop self-regulating mechanisms at the same rate throughout childhood. Therefore, it is important to study children in a longitudinal manner, as well as compare them to other children their age. However, few studies have specifically examined the role child development plays in self-regulation of emotion in a longitudinal manner; that is how RSA reactivity and recovery in response to emotion provoking stimuli change over the course of a few years.

In an effort to expand on the knowledge of child emotion regulation, the current study built upon previous research that found that development played a role in the process of self-regulating emotions in children. Therefore, the aim of this study was to examine the specific mechanisms through which presumed development in self-regulation occurs, whether that be through demonstrating physiological responses that would support more efficient regulation, or that their physiological arousal recovers faster after the emotional stimuli, or that they have learned to express behaviors in a socially adaptive way. In doing so, how children manifest development in self-regulation was investigated in terms of reactive RSA, arousal recovery, and externalized behavior from kindergarten through second grade. It was expected that RSA would decrease from baseline to the anger movie scene (reactivity), and subsequently increase in response to a neutral scene (recovery). Therefore, it was hypothesized that as children matured, that is moved to the next grade in school, they would show a greater RSA decrease during the anger movie, and then a greater increase during the arousal recovery period. Also, it was predicted that the children in the high-risk group would show less of a decrease in RSA during the movie, and then less of an increase during the arousal recovery period in relation to the comparison group. Additionally, it was hypothesized that children low in externalizing behaviors, that is scoring lower on the strengths and difficulties questionnaire, would have decreased symptoms over time. Meanwhile, those high in externalizing behaviors, that is scoring higher on the strengths and difficulties questionnaire, might have increased symptoms over time because early evidence of aggression predicts greater instability.

Chapter 2

Methods

Participants

This study was conducted as a longitudinal clinical trial in Harrisburg, Pennsylvania (see Gatze-Kopp, et al., 2012 for full details). At the start of the study, kindergarten teachers from 10 different elementary schools completed an aggressive behavior rating scale assessment for each child in their classroom during Fall of the school year. The assessment consisted of a 10-item questionnaire that was adapted from The Teacher Observation of Child Adaption – Revised (Werthamer-Larsson, Kellam, & Wheeler, 1991), and evaluated each child for oppositional and aggressive behaviors. From the assessment, children were ranked in order of oppositional and aggressive behavior within each classroom, and families of children in upper quartile of aggressive behavior were contacted for participation. Additionally, children from the lowest quartile of aggressive behavior were contacted in order to serve as the comparison group in the study. Ultimately, 207 children of the 1,192 children screened participated in the research project as part of the upper quartile aggression group, and 132 children were selected from the lowest quartile of aggression. The study began when the children were in kindergarten and ended in the second grade. Of the 207 participants in the high-risk aggression group, two-thirds of the children were male and were an average of 5.94 years of age (M_{age} = 5.94, SD = 0.39) at the time of enrollment. The 132 children in the comparison group did not differ from the high-risk group with regard to sex (see Table 1 for Descriptive Statistics). However, children in the high-risk group were significantly younger than the comparison group of children by an average of 4 months, (M_{age} = 6.13, SD = 0.38). Additionally, the racial demographics were representative of the region (see Table 1 for Descriptive Statistics).

Procedure

Psychophysiological assessments took place annually from kindergarten through second grade and were conducted in a recreational vehicle that was driven to each school site and served as a mobile laboratory. Prior to participation in the study, parental consent and child assent was obtained. Once the child was inside the mobile laboratory, they completed two tasks, during which electrodermal, cardiac, and electrophotography (EEG) measures were recorded. Assessments began with a cognitive control task, followed by a short break, and then an emotion induction task. However, for the purpose of the current study, only the emotion induction task was focused on.

The emotion induction task lasted approximately 12-minutes and consisted of 4 discrete scenes excerpted from *The Lion King* that depicted fear, sadness, happiness, and anger. The study began with a 2-minute star baseline movie, and then the four emotional clips were shown in the order of fear, sadness, happiness, and anger. Following each emotion invoking movie clip, a 30-second neutral clip was shown in order to reduce the carryover effects of other emotions that were tested. The neutral clip was followed by a 30-second fixation baseline to establish the participants baseline for the next emotion sequence. The presentation of the movie clip and timing intervals were controlled throughout the study using E-Prime II software. For the current study only data from the anger scene were examined. The anger clip was approximately 2 minutes in length and featured the main character and protagonist, Simba, fighting Scar, the evil antagonist. Clips were selected from *the Lion King* because the target character, Simba, was a cartoon, therefore, no racial matching could occur between the protagonist and the child participant. Additionally, the animated movie consisted of multiple streams of emotion-conveying sensory stimuli including color, storyline, setting, and musical score (Fortunato, et al., 2013). In this study, the initial star movie was used as the baseline measure, and the neutral movie clip following the anger movie scene was considered as the recovery period.

Measurements

RSA

During the movie clip, each child participant's cardiac measurements were recorded continuously at 500 Hz via Biolab 2.4 acquisition system. Cardiac measures were collected using 3 disposable, pre-gelled cardiac electrodes that were placed over the participant's distal right collar bone, lower left rib, and lower right rib. The electrocardiograph (ECG) data collected were inspected and corrected as necessary by trained research assistants. The research assistants were responsible for correcting the ECG data that were collected during the study by confirming that the R peak of the QRS wave was marked correctly. The inspected data were then used to calculate the variables in the study. Additionally, respiration was estimated from an impedance wave that was measured with four additional cardiac electrodes. It was verified that the respiratory frequency within each epoch was within the 0.12 - 1.04 Hz range established for calculating RSA.

For all viable periods, RSA was derived through spectral analysis (using a 0.12-1.04 Hz frequency band), using the fast Fourier transform, of the inter-beat interval time series that were obtained from the ECG. RSA was calculated in 30-second epochs across the anger movie scene, resulting in four individual epochs that were then averaged. RSA reactivity was calculated by subtracting the RSA value during star baseline from the RSA value obtained during the anger movie clip. Additionally, RSA recovery was calculated by subtracting the RSA value obtained during the anger movie clip from the RSA value obtained during the neutral scene depicting resolution following the emotional clip. Therefore, positive values of RSA reactivity represent RSA augmentation, while negative values of RSA reactivity represent RSA withdrawal during the anger scene from star baseline. Positive values of RSA recovery represent RSA augmentation, while negative values of RSA recovery represent RSA withdrawal during the neutral scene.

Externalizing Behaviors

Children's level of externalizing behavior was measured in the classroom using teacher responses from a brief version of the Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997), which assessed children's adjustment, including a Conduct Problems subscale assessing oppositional and aggressive behaviors (five items; "Often fights with other children or bullies them"), using a three-point Likert-type scale. The three-point Likert-type scale was scored as 0 representing not true, 1 representing somewhat true, and 2 representing certainly true. The items for each subscale were summed (range of summed score = 0-10), and used as indicators for externalizing symptoms. The externalizing symptom scores were normally distributed across the entire 0-10 range and were moderately correlated across the years assessed (see Table 2 for Correlation Values). The measures were treated as continuous variables due to the fact that the severity of symptoms was normally distributed in the sample and spanned the full range of the scale. The internal consistency of the conduct problems subscale was satisfactory at all three time points (Cronbach's alpha: Kindergarten = 0.858; Grade 1 = 0.849; Grade 2 = 0.858).

Statistical Analysis

Preliminary analyses were conducted to obtain the bivariate correlations among the study variables (see Table 2 for Correlation Values). Repeated-measures ANOVA was used to test the main research question because this study aimed to determine if there were changes in mean scores of RSA reactivity, RSA recovery, and externalizing symptoms over kindergarten, first grade, and second grade. Moreover, this study aimed to examine whether the high-risk and low-risk groups (i.e., children in the upper versus lower quartile in their classrooms based on teacher ratings of oppositional/aggressive behaviors at school entry) differ in their developmental trajectories of these measures. Therefore, separate repeated-measures ANOVA analyses were run for RSA reactivity, RSA recovery, and externalizing behavior, using time (kindergarten, 1st grade, 2nd grade) as the within-subject predictor and group (high risk versus low risk) as the between-subject predictor. Gender was a covariate in this study because it was found to be correlated with other variables of the study, including conduct problems. In this case, entering gender as a covariate in all analyses using ANOVA accounted for the influence that gender might play on RSA or conduct problems, improving the accuracy of the analysis. The threshold of statistical significance was determined by an alpha level of 0.05. All analyses were preformed using SPSS v26.

Table 1. *Means, Standard Deviations, Minimums, and Maximums of Main Study Variables*

Variable	Comparison Group			At – Risk Group			*t*
	M (SD)	Minimum	Maximum	*M(SD)*	Minimum	Maximum	
Age	6.13 (0.38)	5.35	7.47	5.94 (0.39)	5.23	7.26	4.25**
CP K	0.38 (0.72)	0.00	3.00	3.87 (2.82)	0.00	10.00	- 13.31**
CP G1	1.08 (2.02)	0.00	8.00	3.78 (2.87)	0.00	10.00	- 8.51**
CP G2	1.14 (2.02)	0.00	8.00	3.84 (2.82)	0.00	10.00	-8.16**
RSA reactivity K	- 0.12 (0.67)	- 2.83	1.50	- 0.03 (0.75)	- 2.16	3.39	- 0.94
RSA recovery K	0.13 (0.70)	- 1.77	2.17	0.16 (0.71)	- 2.29	3.12	- 0.37
RSA reactivity G1	- 0.13 (0.65)	- 2.17	1.27	- 0.11 (0.73)	- 3.61	1.64	- 0.23
RSA recovery G1	0.08 (0.59)	- 1.32	2.20	0.25 (0.71)	- 1.95	2.73	- 1.90
RSA reactivity G2	- 0.05 (0.57)	- 1.68	1.53	- 0.20 (0.64)	- 2.90	1.68	1.93
RSA recovery G2	0.17 (0.71)	- 1.62	2.28	0.17 (0.73)	- 2.92	2.39	- 0.10
		n (%)			*n* (%)		
Gender							
Male		81 (61.4%)			137 (66.2%)		
Female		51 (38.6%)			70 (33.8%)		
Race							
Black		87 (65.9%)			151 (72.9%)		
Caucasian		13 (9.8%)			16 (7.7%)		
Hispanic		30 (22.7%)			39 (18.8%)		
Asian		2 (1.5%)			1 (0.5%)		

Note. K = kindergarten; G1 = first grade; G2 = second grade; CP = conduct problems subscale; RSA = respiratory sinus arrhythmia. Positive values of RSA reactivity represent RSA augmentation, while negative values of RSA reactivity represent RSA withdrawal during the anger scene from star baseline. Positive values of RSA recovery represent RSA augmentation, while negative values of RSA recovery represent RSA withdrawal during recovery from the anger scene. The last column indicated the test statistics of the independent sample t-tests on the differences between the two groups. * $p < 0.05$. ** $p < 0.01$.

Table 2. *Bivariate Correlations Among Study Variables*

	1	2	3	4	5	6	7	8
1. CP K	-							
2. CP G1	.546**	-						
3. CP G2	.518**	.677**	-					
4. RSA reactivity K	.141*	- .036	- .040	-				
5. RSA recovery K	.019	.065	.124	- .334**	-			
6. RSA reactivity G1	.084	- .080	- .124	.290**	- .012	-		
7. RSA recovery G1	.003	.013	.101	- .134*	.000	- .375**	-	
8. RSA reactivity G2	- .155*	.008	.059	.059	- .035	.126	- .025	-
9. RSA recovery G2	.039	- .014	- .025	.056	.051	.113	.127	- .191**

Note. K = kindergarten; G1 = first grade; G2 = second grade; CP = conduct problems subscale; RSA = respiratory sinus arrhythmia. Positive values of RSA reactivity represent RSA augmentation, while negative values of RSA reactivity represent RSA withdrawal during the anger scene from star baseline. Positive values of RSA recovery represent RSA augmentation, while negative values of RSA recovery represent RSA withdrawal during recovery from the anger scene. * $p < 0.05$. ** $p < 0.01$.

Chapter 3

Results

Preliminary Analysis

For all three grade levels, kindergarten, first grade, and second grade, RSA reactivity and RSA recovery were significantly negatively correlated. This indicated that a greater decrease in RSA from baseline to movie was correlated with a greater increase in RSA afterwards from movie to recovery. Additionally, conduct problems in kindergarten were significantly correlated with RSA reactivity both in kindergarten and in second grade, although in opposite directions. This indicated that an increase in RSA from baseline to movie during the second-grade assessment was correlated with higher levels of conduct problems at kindergarten, and that a decrease in RSA from baseline to movie during the kindergarten assessment was concurrently correlated with higher levels of conduct problems. However, when further analyses were run using ANOVA, conduct problems in kindergarten were not significantly correlated with RSA reactivity in kindergarten or in second grade.

RSA Reactivity

Mauchly's test indicated that the assumption of sphericity was not violated ($\chi^2(2) = 4.78$, $p = 0.09$). A repeated measures ANOVA indicated that across the two groups, RSA reactivity did not differ significantly across the three time points ($F(2, 370) = 1.46$, $p = 0.23$); group status (i.e., low-risk versus high-risk group) did not have any significant main effect on RSA reactivity either ($F(1, 185) = 2.43$, $p = 0.12$; See Table 3). No main effect was found for the between-subject covariate (i.e., gender; $F(1, 185) = 1.22$, $p = 0.27$). Additionally, the interactions between within-subject and between-subject factors were not significant (time x group, $F(2, 370) = 0.54$, $p = 0.59$; time x gender, $F(2, 370) = 1.03$, $p = 0.36$; See

Table 3), suggesting that the two groups, or boys versus girls, did not differ in the developmental trajectory of RSA reactivity across the three years.

Table 3. *RSA Reactivity ANOVA*

Variable	df	Error	*F*	*p*
Within-subject factor				
Time	2	370	1.46	0.23
Between-subject factors				
Gender	1	185	1.22	0.27
Group	1	185	2.43	0.12
Interactions				
Time x Gender	2	370	1.03	0.36
Time x Group	2	370	0.54	0.59

Note. df = degrees of freedom. * p < 0.05. ** p < 0.01.

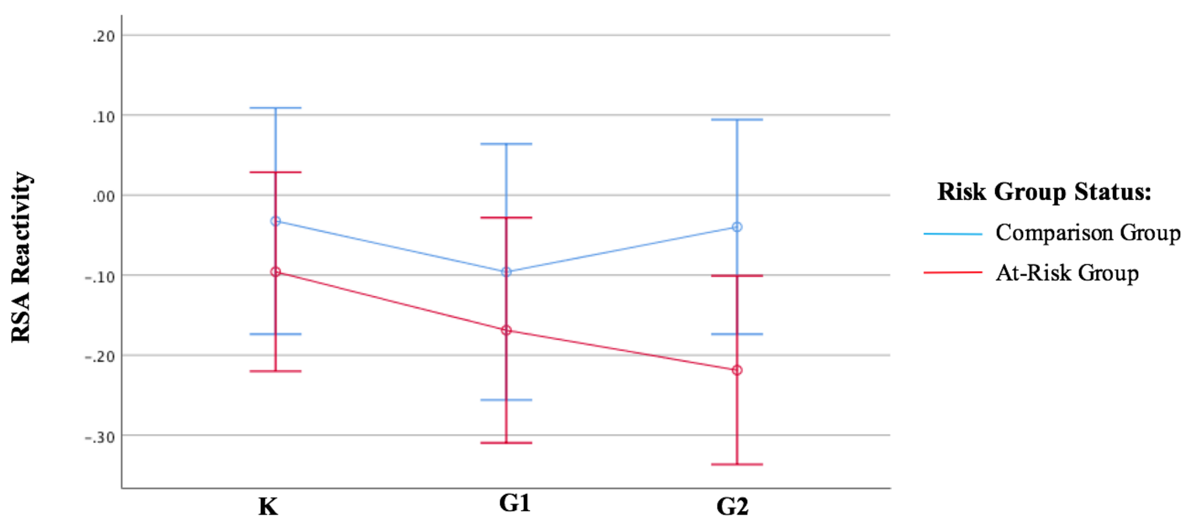

Figure 1. *Estimated Means of RSA Reactivity*

RSA Recovery

Mauchly's test indicated that the assumption of sphericity was not violated ($\chi^2(2) = 0.97$, p = 0.62). A repeated measures ANOVA indicated that across the two groups, RSA recovery did differ significantly across the three time points ($F(2, 0.36) = 4.21$, $p < 0.05$). A post hoc pairwise comparison revealed that there was a marginally significant increase in RSA recovery scores from kindergarten to first grade ($p = 0.07$) indicating that in first grade, children showed slightly greater increase in RSA during the neutral movie compared to the preceding anger movie than they did in kindergarten. However, no significant differences were found in the RSA recovery scores between kindergarten and second grade, or between first grade and second grade. Group status (i.e., low-risk versus high-risk group) also had a significant main effect on RSA recovery ($F(1, 181) = 4.38$, $p < 0.05$; See Table 4). Children in the at-risk group generally had significantly higher levels of RSA recovery (i.e., greater RSA increase during the recovery period compared to the movie) in comparison to the comparison group (See Table 4). No main effect was found for the between-subject covariate (i.e., gender; $F(1, 181) = 0.95$, $p = 0.33$). Interactions between within-subject factors were not significant (time x gender, $F(2, 0.36) = 2.67$, $p = .07$; time x group, $F(2, 0.36) = 0.70$, $p = 0.50$; See Table 4), suggesting that the two groups, or boys versus girls, did not differ in the developmental trajectory of RSA recovery across the three years.

Table 4. *RSA Recovery ANOVA*

Variable	df	Error	*F*	*p*
Within-subject factor				
Time	2	0.36	4.21	0.02*
Between-subject factors				
Gender	1	181	0.95	0.33
Group	1	181	4.38	0.04*
Interactions				

Time x Gender	2	0.36	2.67	0.07
Time x Group	2	0.36	0.70	0.50
Pairwise Comparison				
K-G1				0.07
K-G2				0.33
G1-G2				0.39

Note. df = degrees of freedom; K = kindergarten; G1 = first grade; G2 = second grade. * p < 0.05. ** p < 0.01.

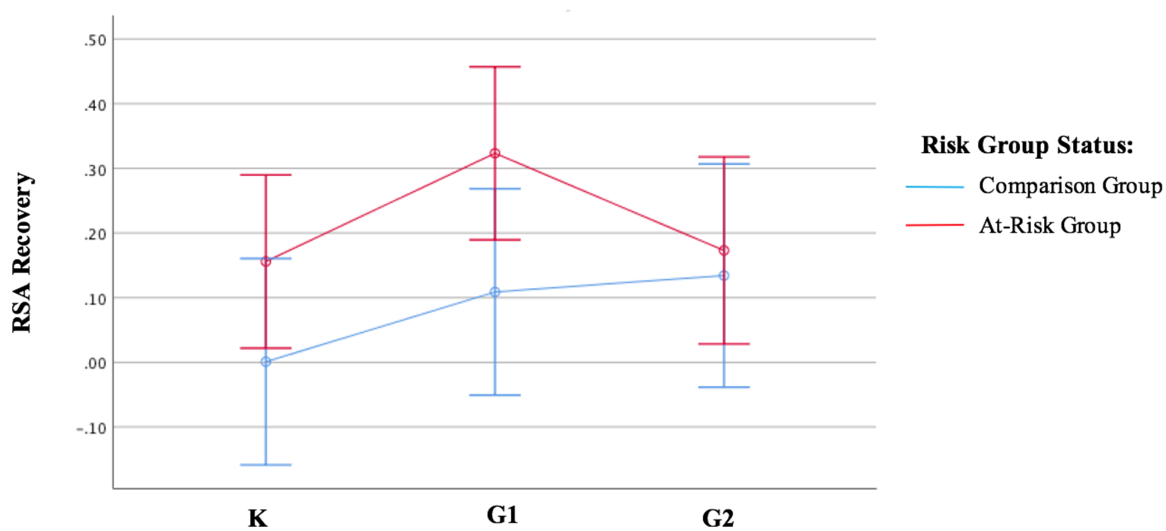

Figure 2. *Estimated Means of RSA Recovery*

Conduct Problems

Mauchly's test indicated that the assumption of sphericity was not violated ($\chi^2(2) = 3.44$, p = 0.18). A repeated ANOVA determined that externalized behaviors, measured via conduct problems, did not differ significantly across the three time points ($F(2, 372) = 1.51$, $p = 0.22$). However, group status (i.e., low-risk versus high-risk group) had a significant main effect on conduct problems ($F(1, 186)$ = 126.52, $p < 0.01$), and a main effect was found for the between-subject covariate (i.e., gender; $F(1, 186)$ =

4.07, $p < 0.05$) as well. This suggests males have higher levels of conduct problems in comparison to females, and children in the at-risk group have higher levels of conduct problems in comparison to the comparison group across the three years (See Table 5). Interactions between within-subject factors were not significant (time x gender, $F(2, 372) = 0.15$, $p = 0.86$; time x group, $F(2, 372) = 1.05$, $p = 0.35$; See Table 5), suggesting that the two groups, or boys versus girls, did not differ in the developmental trajectory of conduct problems across the three years.

Table 5. *Conduct Problems ANOVA*

Variable	df	Error	*F*	*p*
Within-subject factor				
Time	2	372	1.51	0.22
Between-subject factors				
Gender	1	186	4.07	0.05*
Group	1	186	126.52	0.00**
Interactions				
Time x Gender	2	372	0.15	0.86
Time x Group	2	372	1.05	0.35

Note. df - degrees of freedom. * p < 0.05. ** p < 0.01.

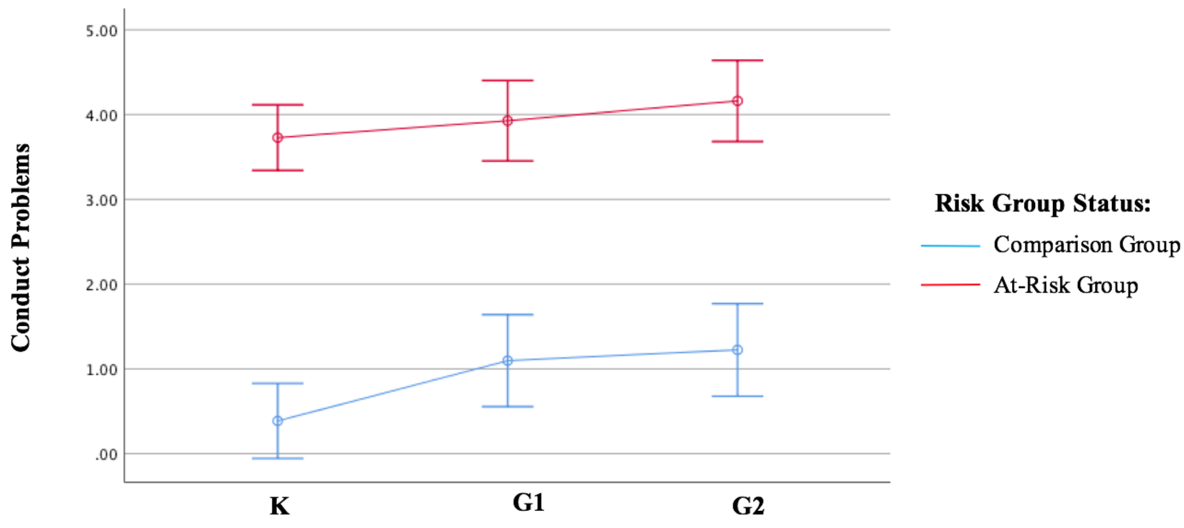

Figure 3. *Estimated Means of Conduct Problems*

Chapter 4

Discussion

The purpose of the current study was to examine the specific mechanisms through which presumed development in self-regulation occurs by investigating how children manifest development in self-regulation in terms of reactive RSA, arousal recovery, and externalized behavior from kindergarten to second grade. In this analysis, RSA reactivity, RSA recovery, and conduct problems were assessed in response to an anger provoking movie clip over the course of three years in young children. No developmental changes or group differences were found for RSA reactivity. Developmental changes and group differences were found for RSA recovery, while group differences, but not developmental changes were found for conduct problems. The current study provides additional research and aids in understanding the potential developmental trajectories of physiological and behavioral indicators related to self-regulatory capabilities in children with different levels of behavioral risks. In addition, the findings highlight the necessity to provide early intervention for children who demonstrate early indicators of behavioral problems at school entry.

RSA Reactivity

RSA reactivity did not differ across kindergarten, first grade, and second grade, nor did it differ between the low-risk group or the high-risk groups of children. Furthermore, there was no significant difference between the two groups in the developmental trajectory of their RSA reactivity across the three years. RSA withdrawal did occur in response to the anger movie clip, but the children did not experience a greater RSA withdrawal as they moved to the next grade. Although these results did not support the hypothesis that children would show a greater RSA decrease during the anger movie as they moved to the next grade, it was important to consider the implications of these findings. RSA withdrawal occurs in response to stimuli that decreases parasympathetic control, and greater amplitude of RSA withdrawal has been associated with better self-regulation in children in previous studies (Graziano & Derefinko, 2013). However, in this specific sample, over the age range of kindergarten, first grade, and second grade, developmental changes in self-regulation of emotions in response to anger stimuli were not observed. These findings did not align with previous studies, as a significant age effect on increases in RSA suppression has been reported in the past (Calkins & Keane, 2004). The different findings could be attributed to the fact that the Calkins and Keane’s sample consisted of children 2 years of age to 4.5 years of age, prior to entering kindergarten, whereas children in the current sample were older. Additional studies have also found that approximately 46% of children experienced an increase in RSA withdrawal over time from ages three to five, and that RSA baseline also increased with age (Perry, et al., 2013). The younger age range may be a time in which more development and maturation in parasympathetic functioning occurs, so by the time children reach kindergarten, first grade, and second grade, we may no longer observe developmental changes in their RSA reactivity to an emotional stimulus. The emotions addressed in previous studies are also important to assess, in that it could also provide an explanation for the variation of results. Previous studies have provoked emotions such as empathy, frustration, and stress in their analysis of RSA reactivity, some of which may not be considered high intensity emotions that result in physiological changes as in the case of negative emotions, such as anger.

One possibility that may warrant examination by future research is that, as the children moved to the next school grade, physiological systems other than the PNS were more subject to developmental changes. One possible system could be the sympathetic nervous system (SNS), which was not examined in the current study. An additional explanation could include habituation, in that children may have experienced smaller RSA withdrawal to the same perceived levels of emotional stimuli, because they had watched the movie multiple times and could have become familiar with it. This would result in no increase in RSA withdrawal as they moved to the next grade level because the children were less emotionally affected by the anger movie clip, which counter-acted the developmental effects on RSA reactivity. Furthermore, preliminary analyses assessing correlations found that conduct problems were significantly correlated with RSA reactivity in kindergarten and second grade, while the ANOVA analyses found that conduct problems were not significantly correlated with RSA reactivity in kindergarten and second grade. This could be attributed to the fact that the ANOVA analyses incorporated gender as a covariate, improving the accuracy of the analysis.

RSA Recovery

RSA recovery significantly differed across kindergarten, first grade, and second grade, and significantly differed between the low-risk and high-risk groups. However, there was no significant difference between the two groups in the developmental trajectory of their RSA recovery across the years. Although RSA recovery did significantly differ between the low-risk and high-risk groups, it was initially predicted that the low-risk group would exhibit a better recovery. However, that was not the case, and the results suggested that the high-risk group had a greater amplitude of RSA recovery (i.e., a greater increase in RSA during the neutral movie compared to the preceding anger movie). This could be attributed to the fact that the high-risk group had greater RSA withdrawal in response to the anger stimuli in comparison to the low-risk group, although the difference was not statistically significant (see Figure 2). Therefore, in terms of RSA recovery, the high-risk group had greater room to re-engage parasympathetic control, which could have resulted in a better RSA recovery value. The developmental trajectory of RSA recovery has rarely been studied before. Therefore, the current study is one of the first efforts to examine this trajectory. The analysis showed that the increase in RSA recovery from kindergarten to first grade was significant, while no significant differences were found in the RSA recovery scores between kindergarten and second grade, or between first grade and second grade. The implications of these findings are important to consider due to the fact that other studies have listed RSA recovery as a topic of future research (Hinnant & El-Sheikh, 2009). There is initial support that lower levels of RSA recovery are related to maladaptive emotion regulation strategies in children (Santucci, et al., 2008). Future studies could assess the RSA recovery process and determine how it is consistent with polyvagal theory. In addressing RSA recovery as a point of future research, previous studies have hypothesized that an ideal profile of RSA would be characterized by a faster recovery from suppression to baseline RSA levels (Hinnant & El-Sheikh, 2009).

Conduct Problems

Although conduct problems did differ between the low-risk group and high-risk groups, as well as between male and females, there was no evidence in change in symptom severity for either group. The results did not support the hypothesis that children would externalize their emotions less and, subsequently, would exhibit less conduct problems as they progressed to the next grade. However, support for this hypothesis can provide meaningful information for programs designed to enhance classroom behavior and academic performance. Future studies could continue to test this hypothesis by means of modifications to the current study’s design, such as changing the type and exposure timing of emotional stimuli. The findings suggest that males have higher levels of conduct problems in comparison to females. Previous studies have also found this same pattern and have speculated that gender differences in externalizing behavior may be a function of socialization, as boys and girls learn gender-specific rules for what they should and should not display. Girls are often judged more negatively than boys for expressing anger and, as a result, girls do not express the emotion of anger as often as boys (Cole, Zahn-Waxler, & Smith, 1994). Additionally, the differences in conduct problems between the at-risk group and the comparison group that were evident in kindergarten remained stable across the next two years. Furthermore, over the specific age range of kindergarten, first grade, and second grade, and in this specific sample, decreased scores on conduct problem assessments were not observed. In fact, for both groups the mean scores increased over time, although not significantly. Previous studies have found that approximately half of the children that presented with initial externalizing behavioral issues, experienced a decrease in externalizing problems across time (Fanti & Henrich, 2010). The Fanti and Henrich findings may only show improvement in behavior across half of the children because the sample population consisted mostly of low-income families living in at-risk communities with children from two to twelve years-of-age, which was a wider age gap than in the current study (Fanti & Henrich, 2010). The sample of the current study was collected from a relatively high-risk school district, similar to the Fanti and Henrich study. Fanti and Henrich's study showed that approximately half of the children with early-onset behavioral problems showed improvements in behavior over time, and, on average, the current sample (the high-risk group) seemed to belong to the other half of the Fanti and Henrick study that did not improve. This could be because many of the children in the current study did not have access to the resources or environment that they needed to improve, such as supportive parenting being low due to the various stressors parents are exposed to or the school not providing adequate resources to help children with difficulties. Additionally, the lack of age effect found in the current study could be explained due to the fact that the current study only occurred over the course of three grade levels, while studies, such as Fanti and Henrich, were carried out to a later point in childhood. Therefore, the children might not have been given sufficient time to demonstrate change. Therefore, these previous findings make the need for intervention apparent in order to teach socially-adaptive behavior, and also makes its apparent that future research is needed to examine individual differences in developmental trajectories.

Chapter 5

Limitations

This study is also subject to some limitations that may influence the interpretability of the results. First, although the current study only focused on the anger movie clip, the children in the study were presented four emotional movie clips (fear, sadness, happiness, and anger). Therefore, the fixed presentation order of the emotional movie clips may have introduced a limitation because there may have been carryover physiological effects from the previous emotions. This could have resulted in findings that were not as intense as expected for the anger clip, due to the fact that it was always presented last.

Second, it is also important to note that this was a longitudinal clinical trial, and, as a result, the children viewed the same anger movie clip three times during the duration of the study. Therefore, repeated use of the same stimulus risked habituation or the expectation effect. Due to repeated exposure to the same anger movie clip, the children could have remembered the clip, and therefore had a diminished emotional response. However, there was no trend of habituation in the findings of the current study. Future studies could avoid desensitization by taking the 2-minute anger movie clip used in the current study and splitting it into 3 different parts. Therefore, the content shown would differ across the three time points, but the stimuli would be of the same intensity.

Third, the current study focused only on maturation of the PNS and how the PNS was subject to developmental changes. Only focusing on one indicator of physiological activity neglected to consider how other physiological systems could have played a role in the regulation process and developed over this period of time. For example, the sympathetic nervous systems (SNS), also known as the “fight or flight” system, could have developed, resulting in findings that were not consistent with previous studies. Additionally, other cognitive processes could have developed over time in these children and resulted in the regulation of emotions, taking some of the stress off of the PNS. Therefore, the interdependence of many physiological parameters must be considered.

Finally, throughout the current study, the physiological and behavioral indicators were analyzed separately. However, the relationship between the developmental trajectory of RSA parameters and that of conduct problems were not assessed. The relationship between these physiological and behavioral indicators could have provided an additional viewpoint to the analysis of the current study by providing possible ways in which changes in RSA can affect externalized behaviors and vice versa throughout development. This could have been beneficial in assessing the interdependence of the internalizing and externalizing behaviors and how they work together to regulate emotional responses.

Chapter 6

Future Directions

The purpose of the current study was to assess the development of the regulation of emotions based on RSA reactivity, RSA recovery, and conduct problems in children over the course of their kindergarten, first grade, and second grade school years. Future research should focus on the developmental trajectories of school aged children over a longer period of time beginning in kindergarten, and continuing into middle school. This extended period of time would provide the opportunity to determine when the majority of the development of emotion regulation occurs, and establish when children's emotion regulation processes fully mature.

Furthermore, RSA was the main physiological indicator of the PNS assessed in the current study. Future studies should assess how other physiological parameters, including heart rate, blood pressure, or body temperature to name a few, change as a result of an emotional response and change over a period of time. In doing so, studies could assess the interdependence of physiological processes throughout the body, and assess how they work together to regulate an individual's response to emotion provoking stimuli.

As mentioned in the limitations, physiological and behavioral parameters were analyzed separately in the current study. Although the relationship between physiological and behavioral parameters should be assessed in the future, environmental influences of these indicators should also be considered for inclusion in future studies. Environmental influences could change developmental trajectories in school aged children. Assessing how such influences could play a role in their emotional response, specifically children's externalized behaviors, is an interesting aspect of the regulation of emotions that should be considered. This could provide insight on the role that bullying and peer pressure play in emotion regulation development, as well as how parental care can alter how children regulate their emotions.

The current study expanded on the knowledge of the child emotion regulation process and built upon previous research that found that development played a role in the process of self-regulation of emotions in children. Studying the mechanisms of development of emotion regulation in school aged children is necessary in order to combat current social issues that are prevalent in children today. Understanding the development of emotion regulation of anger specifically could be used to understand the underlying issues behind behavioral problems and other maladjustments in children.

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RESEARCH EXPERIENCE

Child Brain Development Lab — **University Park, PA**
Research Assistant — *Jan 2019 – May 2020*
- Cleaned EKG data collected from the current study and coded data that was previously cleaned
- Completed honors thesis project on how children regulate emotions as they mature

RELEVANT EXPERIENCE

Advanced Surgical Hospital — **Washington, PA**
Nursing Assistant — *May 2018 – Present*
- Worked to care for patients, learn how a hospital functions, and chart paperwork
- Collaborated with nurses to document patient information and transport patients
- Shadowed doctors to view orthopedic procedures and office visits involving proper patient care

LifeLink PSU — **University Park, PA**
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- Mentored special needs students by assisting in developing their academic and social skills
- Assisted in transitioning students into productive members of society for life after college

LEADERSHIP EXPERIENCE

Family Service Club — **University Park, PA**
Secretary — *Aug 2018 – May 2020*
- Founder of club that raised money to benefit the Ronald McDonald House in Hershey, PA
- Organized and participated in fundraisers to raise money for the Ronald McDonald House
- Communicated with our advisor to keep her involved in the club's mission

The National Society of Leadership and Success — **University Park, PA**
Active Member — *Sep 2017 – May 2020*
- Partook in speaker broadcasting events given by successful and prestigious individuals
- Established and achieved weekly goals with a Success Network Team

Women's Club Basketball — **University Park, PA**
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- Dedicated 10 hours a week to practice, traveling, and competitive tournaments
- Served as a leader for new members to transition onto the team
- Participated in fundraisers and events to raise money for THON

Delta Gamma Fraternity **University Park, PA**
Alpha Chi 2016 Class Member *Sep 2016 – May 2020*

- Partook in fundraisers to raise money for THON such as canvasing and Yankee Candle sales
- Supported our THON families at Hershey Medical Center through collection drives and visits
- Worked with 120 women to determine ways to raise money and awareness for Service for Sight

HONORS

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Phi Eta Sigma Co-Ed Honors Fraternity
Corey Adam's Scholarship
Trinity High School Class of 2016 Valedictorian