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Respiratory Sinus Arrhythmia Reactivity to Others' Emotions as Predictors of Internalizing Symptoms during Middle Childhood

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RESPIRATORY SINUS ARRHYTHMIA REACTIVITY TO OTHERS' EMOTIONS AS PREDICTORS OF INTERNALIZING SYMPTOMS DURING MIDDLE CHILDHOOD

by

JACKSON M. GRAY

Under the Direction of Erin C. Tully, PhD

ABSTRACT

A growing body of theory and research has implicated cardiac vagal activity, indexed by measures of respiratory sinus arrhythmia (RSA), in the emotion dysregulation underlying internalizing psychopathology; however, the majority of these studies are with adolescent or adult samples. Middle childhood is a critical period for children's social emotional development as peer relationships become increasingly important and related to children's psychological adjustment, and it immediately precedes the increases in rates of internalizing symptoms observed in adolescence. Findings suggest that children with internalizing problems may exhibit a reduced capacity for emotion regulation and some tend to be physiologically hyper-reactive to others' sadness while others tend to be disengaged and hypo-reactive. Thus, I predict that high internalizing symptoms will be associated with low resting RSA and both excessive and blunted RSA reactivity to sadness (i.e., a positive quadratic association). Less is known about how children with internalizing problems react physiologically to positive emotions, such as happiness, or recover after happy or sad situations. Some studies suggest that internalizing problems may be associated with sustained physiological arousal following sadness (low RSA recovery), physiological hypo-reactivity to happiness (blunted RSA reactivity), and poor sustainability of the physiological effects of happiness (high RSA recovery). Electrocardiograms were recorded from 114 children (ages 7-11) while they watched a series of happy-, sad-, and neutral-valence emotional videos featuring other children. Parents reported on children's level of internalizing symptoms. Results of the current study add to the extant literature supporting low resting RSA and excessive, but not blunted, RSA reactivity to sadness as predictors of internalizing problems during middle childhood. In contrast, blunted RSA reactivity to sadness, RSA reactivity to happiness and RSA recovery after happiness and sadness were not associated with internalizing problems during this time. These results suggest that internalizing psychopathology in middle childhood is more closely linked to an individual's trait-like capacity for physiological emotion regulation and dysregulation of withdrawal-motivation based emotions (sadness) in the moment than dysregulation of approach-based emotions (happiness). Future longitudinal studies are needed to better understand the developmental progression of internalizing liabilities from childhood to adolescence.

INDEX WORDS: Respiratory sinus arrhythmia, Emotion dysregulation, Internalizing psychopathology, Physiological reactivity, Middle childhood

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DEDICATION

I dedicate this dissertation to my family and friends for their unwavering support, encouragement, and understanding, throughout this journey. In particular, I would like to thank my parents, John and Ann Gray, who have served as teachers, role models, and advocates for me throughout my life. I can confidently say that I would not be the person I am today without their unconditional love and guidance. I am so appreciative to them for instilling the importance of education and kindness in all my pursuits.

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1 INTRODUCTION

Internalizing disorders (e.g., depression, anxiety) are among the most prevalent psychiatric disorders (Costello, Foley, & Angold, 2006; Costello, Mustillo, Erkanli, Keeler, & Angold, 2003; Merikangas, Nakamura, & Kessler, 2009; Polanczyk, Salum, Sugaya, Caye, & Rohde, 2015) and are associated with significant impairments in social functioning (Gazelle & Ladd, 2003; Hirschfeld et al., 2000; Jacob, Suveg, & Whitehead, 2014; Rudolph, Flynn, & Abaied, 2008). Emotion dysregulation is a core process underlying the development, severity, and persistence of internalizing psychopathology (Beauchaine, 2015; Cole & Hall, 2008; Kemp et al., 2010), but how this dysregulation is expressed at the physiological level, particularly during social situations, remains unclear.

Middle childhood is an important stage for children’s social and emotional development, as the amount of time spent with peers and expectations for social independence increase dramatically (Abe & Izard, 1999; Lancy & Grove, 2011). It is also the developmental stage that immediately precedes increases in rates of depression and social anxiety observed in late childhood and adolescence (Schneier, Johnson, Hornig, Liebowitz, & Weissman, 1992; Thapar, Collishaw, Pine, & Thapar, 2012). These characteristics make it a critical period for examining potential risk factors of internalizing problems. The purpose of the current study is to investigate, in a sample of youths of middle childhood age, associations between physiological regulation in response to others’ emotions and level of internalizing symptoms to better understand patterns of physiological emotion dysregulation both during and after happy and sad situations as potential correlates of internalizing problems in children.

1.1 Emotion Regulation and Dysregulation

Emotions are reactions to environmental events that involve rapid mobilization of physiological, cognitive, and behavioral subsystems and allow for action in the service of goal-directed behavior (e.g., sustaining a relationship, overcoming an obstacle, relinquishing an unattainable goal, escaping danger; (Cole & Hall, 2008; Gross, 2014; Levenson, 1999; Thayer & Lane, 2000; Thompson, 2011). Recent frameworks conceptualize emotional experience as a process that encompasses both reactive and regulatory components (Campos, Walle, Dahl, & Main, 2011; Kappas, 2011; Levenson, 1999; Thompson, 2011). Reactivity refers to the generation of affective arousal in response to environmental events, whereas regulation refers to the automatic or volitional behaviors, skills, and strategies that modulate, inhibit, and enhance emotional reactions, especially their intensive and temporal features, to meet situational demands and accomplish one's goals (Beauchaine, 2015; Cole, Michel, & Teti, 1994; Thompson, 1994, 2011). Thus, all emotional experiences are thought to involve regulatory processes to some degree (Campos et al., 2011; Camras & Shuster, 2013; Kappas, 2011; Tamir, 2011; Thompson, 2011).

At their core, emotional experiences serve evolutionary and socially adaptive functions, such as motivating us to act and guiding our behavior (Bechara, Damasio, & Damasio, 2003; Frijda, 1986), helping us adapt to changing environmental demands (Gross & Muñoz, 1995), and communicating information about others' thoughts and intentions (Keltner & Haidt, 1999; Lopes, Salovey, Coté, & Beers, 2005). Fredrickson's (2001) "broaden and build" theory of positive emotions provides a framework within which to understand the adaptive functions of positive and negative emotions in guiding behavior. According to this theory, the experience of negative emotions narrows a person's momentary thought-action repertoire to specific action tendencies by calling to mind an urge to act in a particular, adaptive way (Fredrickson, 2001). For instance, sadness is a response to loss or failure and is associated with an urge to withdraw, and its expression signals to others a need for social support and help (Goetz, Keltner, & Simon-Thomas, 2010; Hofmann, 2014). Conversely, positive emotions have the opposite effect of broadening momentary thought-action repertoires by facilitating non-specific, or 'free activation' tendencies, which have been defined as aimless, unasked-for readiness to engage in whatever interaction presents itself (Fredrickson, 2001; Fredrickson & Branigan, 2005; Frijda, 1986). These thought-action consequences of positive emotional experiences like happiness, are thought to promote social engagement behaviors, such as the urge to play, and serve to build enduring personal resources including supportive social bonds (Fredrickson, 2001, 2003; Fredrickson & Branigan, 2005).

These behavioral outputs of emotion-generated thought-actions are adaptive to the extent that the valence, timing, magnitude, and duration of the emotional experience are appropriate to the demands of the situation (Levenson, 1999; Tamir, 2011; Thompson, 2011). In other words, emotional experiences that are regulated to be optimally reactive to the situation will produce adaptive responses. When functioning properly, emotion regulation processes allow for flexible adaptation to changing situational demands (Bonanno & Burton, 2013; Thayer & Lane, 2000). This flexibility is especially important for successful social interactions, which require dynamic regulation of one's own emotional experiences in response to changes in the emotional behaviors of others.

In contrast, emotion dysregulation comprises a pattern of inflexible or ineffective modulation of emotional experiences that interferes with appropriate goal-directed behavior (Beauchaine, 2015; Cole & Hall, 2008; Cole et al., 1994). For instance, feeling happy and laughing at another child's sadness over having to move to a new school or feeling sad and crying at a friend's birthday party when he or she is happily opening presents would be considered dysregulated emotional responses, as they do not match the emotional context in which they occurred and would interfere with the individual's goals of social reciprocity and developing social bonds. Emotion dysregulation has been shown to predict poor social functioning (Eisenberg, Fabes, Guthrie, & Reiser, 2000; Lopes et al., 2005; Rubin, Bukowski, & Parker, 2006) and less satisfactory social relationships (English, John, & Gross, 2013), and at extreme levels, to confer vulnerability to internalizing psychopathology (Cole & Hall, 2008; Gross & Muñoz, 1995; Sheppes, Suri, & Gross, 2015).

1.2 Internalizing Psychopathology during Middle Childhood

Anxiety and depression are among the most common psychiatric disorders, with worldwide prevalence rates of 6.5% for any anxiety disorder and 2.6% for any depressive disorder during childhood and adolescence (Polanczyk et al., 2015). Depressive disorders and anxiety disorders very often co-occur in youth and anxiety often temporally precedes and predicts later depression, which suggests they may have shared etiological influences (Hettema, Kuhn, Prescott, & Kendler, 2006; Kessler et al., 2005; Zahn-Waxler, Klimes-Dougan, & Slattery, 2000). A higher-order dimensional latent 'internalizing' factor has been shown to account for the co-occurrence and shared features of both anxiety and depressive disorders (Hankin et al., 2016; Watson, 2005). Internalizing psychopathology is thought to represent a tendency to internalize psychological distress (Achenbach & Rescorla, 2001) that is often expressed through social avoidance and withdrawal behaviors (Garber & Weersing, 2010; Rubin et al., 2006; Rubin, Coplan, & Bowker, 2009).

The developmental processes underlying internalizing psychopathology are thought to emerge early in childhood (Abe & Izard, 1999; Rubin, Burgess, Kennedy, & Stewart, 2003; Zahn-Waxler et al., 2000). Behavioral inhibition (BI) is a temperament trait characterized by physiological dysregulation associated with reductions in tonic parasympathetic nervous system (PNS) activity and tonic elevations in sympathetic nervous system (SNS) activity (Beauchaine, 2001; Fox, Henderson, Rubin, Calkins, & Schmidt, 2001; Kagan, 2008). BI manifests as socially inhibited behaviors during infancy and childhood (Rubin et al., 2003; Rubin et al., 2009) and predisposes children to develop anxiety, worry, and depression (Fox et al., 2001; Hirshfeld-Becker et al., 2007; Kagan, 2008; Wichmann, Coplan, & Daniels, 2004). These inhibited social behaviors typically emerge prior to clinically significant symptoms of internalizing psychopathology (Dodge, 1993) and contribute to dynamic processes in which vulnerable children who are high in BI respond to social situations in dysregulated ways that increase their risk for developing internalizing problems (Rubin et al., 2009; Rudolph et al., 2008; Wichmann et al., 2004).

For instance, when witnessing another child's sadness, behaviorally inhibited children may internalize blame for the child's sadness, ruminate or worry, and experience prolonged, intense physiological arousal that leads them to engage in escape and social withdrawal behaviors. These behaviors may serve to reduce aversive physiological arousal and reinforce their avoidance of social situations, thus decreasing opportunities to develop age-appropriate social skills (Rubin et al., 2006), increasing their likelihood of future social rejection (Nelson, Rubin, & Fox, 2005; Rubin et al., 2009), and leading them to develop low self-esteem and negative self-perceptions of their social skills and peer relationships (Abe & Izard, 1999; Nelson et al., 2005; Rudolph et al., 2008), thereby heightening their risk for internalizing psychopathology (Hay, Payne, & Chadwick, 2004; Rudolph et al., 2008).

Middle childhood is a potentially vulnerable developmental stage for these social risk processes. Relative to earlier developmental periods, middle childhood is a time when the proportion of social interactions involving peers is increasing (Abe & Izard, 1999; Rubin et al., 2006), peer relationships become increasingly related to children's psychological adjustment (Hay, Payne, & Chadwick, 2004; Hymel, Rubin, Rowden, & LeMare, 1990; Lancy & Grove, 2011), and children are increasingly aware of social norms violations related to socially inhibited behaviors, as they run contrary to age-specific expectations for social interaction and relationship involvement (Rubin et al., 2009). Additionally, children begin to develop trait-like self-concepts during middle childhood, largely as the result of repetitive emotion experiences in their expanding social contexts (Abe & Izard, 1999; Nelson et al., 2005). Children's dysregulated emotional experiences, particularly at the physiological level, in these social contexts may provide an important clue to understanding risk for internalizing psychopathology during middle childhood as this developmental period immediately precedes the increases in rates of depression and social anxiety observed in late childhood and adolescence (Schneier et al., 1992; Thapar et al., 2012).

1.3 Distinct Dysregulation Liabilities within Internalizing Psychopathology

Internalizing disorders tend to co-occur in individuals, with comorbidity estimates ranging from 30% to 70% (Cannon & Weems, 2006; Costello et al., 2003; Zahn-Waxler et al., 2000). Researchers have investigated whether a smaller set of factors explain the patterns of covariance among internalizing disorders and correlations among symptoms. These studies support a hierarchical structure wherein one general factor accounts for a large proportion of the covariance across all internalizing psychopathologies (Cannon & Weems, 2006; Watson, 2005). This general internalizing factor is associated with a liability toward emotion dysregulation (Tully & Iacono, 2016), which predisposes individuals to experience one or more, typically negative, emotions (e.g., sadness, anxiety, fear) in inappropriate contexts, at inappropriate levels of intensity, or for inappropriate durations of time (Beauchaine, 2015; Cole & Hall, 2008). This dysregulation is associated with inflexibility at various levels of functioning, including physiological, cognitive, and social, and can lead individuals with internalizing symptoms to become ‘stuck’ in defensive and disorganized behavioral patterns that are not responsive or appropriate to the environmental demands (Bylsma, Morris, & Rottenberg, 2008; Porges, 2007; Rottenberg, Gross, & Gotlib, 2005; Thayer & Lane, 2000, 2002).

Additionally, studies of the meta-structure of internalizing psychopathology have consistently found evidence supporting two related but distinct internalizing liabilities that influence how emotion dysregulation manifests in children with internalizing problems (Tully & Iacono, 2016). Some children with internalizing problems exhibit a liability to experience low levels of positive affect and importantly, low physiological reactivity to emotional stimuli that reflects ‘emotional context insensitivity’ (Bylsma et al., 2008; Cannon & Weems, 2006; Rottenberg, 2007; Rottenberg et al., 2005). In negative emotional situations, such as seeing other children in distress, children with this vulnerability may be disengaged and physiologically hypo-reactive, such that they fail to mobilize the physiological resources needed to respond effectively. In contrast, other children with internalizing problems exhibit a liability to experience physiological hyperarousal in response to stressful and negative emotional stimuli (Cannon & Weems, 2006; Tone & Tully, 2014). Children with this vulnerability may be physiologically hyper-reactive to negative emotional situations, such that they become overaroused and distressed and engage in fight/flight behaviors.

I propose that evaluating relations between physiological emotion regulation and internalizing psychopathology within the framework of these two liabilities is critical for advancing our understanding of physiological processes underlying internalizing psychopathology in children and may reveal two distinct sets of physiological correlates of internalizing psychopathology. More specifically, I expect some children with high internalizing symptoms will tend to be physiologically hypo-reactive and display little change in physiological arousal levels from baseline in sad social situations (i.e., watching videos of children expressing sadness) while other children with high internalizing symptoms will be physiologically hyper-reactive and display excessively large changes in physiological arousal from baseline in sad social situations.

1.4 Respiratory Sinus Arrhythmia as a Physiological Marker of Emotion Regulation

The autonomic nervous system (ANS) has been shown to be a key system in the generation and regulation of the physiological arousal involved in emotional responding (Appelhans & Luecken, 2006; Levenson, 2014). The ANS comprises an inhibitory parasympathetic nervous system (PNS) and an excitatory sympathetic nervous system (SNS), which often interact antagonistically to produce different degrees of physiological arousal (Appelhans & Luecken, 2006; Beauchaine, 2001). Respiratory sinus arrhythmia (RSA), which refers to the ebbing and flowing of heart rate across the respiratory cycle (Porges, 2001, 2007; Porges, Doussard-Roosevelt, & Maiti, 1994), is thought to index PNS influence on the heart and provides a peripheral marker of top-down physiological emotion regulation (Beauchaine, 2015; Porges, 2007; Thayer & Lane, 2000). Empirically based models of RSA detail how a set of interrelated neural circuits involved in the regulation of physiological arousal, known as the central autonomic network (CAN;(Porges, 2001, 2003, 2009; Thayer & Lane, 2000, 2009), developed evolutionarily to support adaptive biobehavioral responses in social contexts, such as social engagement (e.g., vocalization, listening, facial expressions), mobilization (e.g., fight or flight behaviors), and immobilization (e.g., feigning death; (Porges, 2001, 2003, 2007). The CAN comprises prefrontal cortical areas, like the orbitofrontal cortex (OFC) and medial prefrontal cortex (mPFC), that exert top-down inhibitory influences on subcortical limbic structures involved in emotional responding, such as the amygdala (Thayer & Lane, 2000, 2009).

The primary output of this network is mediated through inhibitory parasympathetic neurons via the myelinated vagus nerve, which functions as an active 'vagal brake' on the heart that allows the CAN to flexibly regulate the physiological arousal involved in emotional responding (Porges, 2007; Porges et al., 1994; Thayer & Lane, 2000). Measures of RSA purportedly index the state of the vagal brake and by proxy, the efficiency of central and autonomic nervous system integration (Porges, 2007; Porges et al., 1994; Thayer & Lane, 2000). At rest (i.e., a neutral situation that does not require an emotional response), high levels of RSA are considered adaptive as they reflect a greater capacity for flexible physiological emotion regulation, whereas low levels of RSA reflect inflexible modulation of emotional experience to contextual demands or a general liability to emotion dysregulation (Appelhans & Luecken, 2006; Thayer & Lane, 2000).

Producing an adaptive response during an emotional situation depends critically upon the CAN's capacity to modulate physiological arousal via the vagal brake quickly and flexibly in response to changes in the internal and external environment (Appelhans & Luecken, 2006; Bonanno & Burton, 2013; Thayer & Lane, 2000). Through a process known as 'neuroception,' a complex neural process that continuously evaluates risk and safety in the environment independent of cognitive awareness, the vagal brake modulates one's physiological state to support either defensive or social engagement behaviors (Porges, 2007, 2009). When the environment is perceived as safe, the inhibitory influence of the vagal brake is increased (indexed by increases in RSA), slowing the heart, dampening SNS and hypothalamic-pituitary-adrenal (HPA) activity, and promoting general attention to the environment, relaxation, and social engagement behaviors (Porges, 2007). By contrast, when presented with stressful or negative emotional situations, the vagal brake is withdrawn (reflected by decreases in RSA), which reduces PNS influence and allows SNS activity and heart rate to increase in order to mobilize the physiological and cognitive resources needed to effectively cope and respond (Porges, 2007; Porges et al., 1994). Rapid engagement and disengagement of the vagal brake on the heart allows for the interruption of ongoing behavior and redeployment of metabolic resources to other tasks and flexible responding to rapid changes in the environment (Porges, 2009; Thayer & Lane, 2000).

Importantly, by examining RSA in response to others' emotions, it is possible to measure the dynamic regulation of the vagal brake both during an emotional situation and after the encounter has ended, thus providing indices of physiological emotion regulation throughout an emotional situation (Porges, 2001, 2003, 2007; Porges et al., 1994). In response to another child's sadness, a moderate, temporary decrease in RSA is adaptive as it corresponds to rapid disengagement of the vagal break on the heart that allows for mobilization of physiological resources needed to effectively respond to the situation and then re-engagement of the vagal brake to facilitate physiological recovery. Similarly, in response to another child's happiness, a sustained increase in RSA is thought to be adaptive as it reflects a physiological state that promotes social engagement behaviors, which build enduring personal resources (Fredrickson, 2001). However, when the vagal brake is dysregulated (reflected by blunted or excessive, sustained decreases in RSA during emotional situations), it can lead to physiological hypo- or hyper-reactivity and the attentional, emotional, and physiological inflexibility associated with internalizing psychopathology (Rottenberg, Clift, Bolden, & Salomon, 2007; Rottenberg et al., 2005; Thayer & Lane, 2002).

1.5 Low Resting RSA and General Emotion Dysregulation

Low resting RSA is indicative of a reduced trait-like capacity for flexible physiological emotion regulation (Appelhans & Luecken, 2006; Balzarotti, Biassoni, Colombo, & Ciceri, 2017; Porges, 2007; Thayer & Lane, 2000). As such, I propose low resting RSA provides a measure of the general emotion dysregulation liability and will be associated with more internalizing symptoms in children. Support for this prediction comes from previous studies, which have consistently found associations between low resting RSA and several forms of internalizing psychopathology, including depression (Kemp et al., 2010; Rottenberg et al., 2007), anxiety (Dieleman et al., 2015; Friedman, 2007; Henje Blom, Olsson, Serlachius, Ericson, & Ingvar, 2010), panic disorder (Friedman & Thayer, 1998), social anxiety disorder (Schmitz, Krämer, Tuschen-Caffier, Heinrichs, & Blechert, 2011), parasuicidal behaviors (Crowell et al., 2005), and somatic complaints (Dietrich et al., 2011).

Studies have also shown low resting RSA is associated with core processes common across all internalizing disorders. For instance, individuals with low resting RSA have been shown to exhibit negative attention biases, evidenced by faster attentional engagement with and delayed disengagement from negative emotional stimuli (Miskovic & Schmidt, 2010; Park & Thayer, 2014; Park, Van Bavel, Vasey, & Thayer, 2013). Low resting RSA is also associated with poor cognitive control over unwanted thoughts (Gillie, Vasey, & Thayer, 2015), perseverative forms of cognition such as worry and rumination (Brosschot, Van Dijk, & Thayer, 2007; Ottaviani, Shapiro, Davydov, Goldstein, & Mills, 2009; Ottaviani et al., 2016; Woody, McGeary, & Gibb, 2014), and self-reported difficulties with emotion regulation (Williams et al., 2015). With respect to social functioning, low resting RSA is associated with low social competence (Beauchaine, 2001), low empathy for others' distress (Fabes, Eisenberg, & Eisenbud, 1993), and socially inhibited behaviors during childhood (Fox et al., 2001; Rubin et al., 2009). Collectively, these studies provide evidence to support low resting RSA as a trait-like marker of general emotion dysregulation liability that is associated with high levels of internalizing psychopathology.

1.6 Dysregulated RSA Reactivity to Negative Emotions in Internalizing Psychopathology

While resting RSA provides an index of an individual's trait-like capacity for flexible physiological emotion regulation, with low levels representing a general liability for internalizing problems, measures of RSA reactivity to others' emotions provide important information about how physiological emotion regulation unfolds across an emotional situation, as well as how physiological reactivity may be disturbed among children with internalizing symptoms. RSA reactivity or phasic changes in RSA is often quantified by measuring the difference between baseline levels of RSA and RSA levels during some sort of task, challenge, or mood induction. In stressful or challenging situations, RSA is thought to decrease in order to mobilize the physiological resources necessary to effectively respond to the situation (Porges, 2007; Porges et al., 1994). Failure to do so may reflect an inability to shift focus from internal homeostatic demands that impedes the individual's ability to cope and respond appropriately to current situational demands, thereby increasing their risk of internalizing problems (Bonanno & Burton, 2013; Bylsma et al., 2008; Gentzler, Wheat, Palmer, & Burwell, 2013; Santucci et al., 2008; Schmitz et al., 2011). However, studies have also shown that excessively large decreases in RSA can have a similar effect by eliciting physiological hyperarousal and personal distress (Calkins, Graziano, & Keane, 2007; Fortunato, Gatzke-Kopp, & Ram, 2013; Pang & Beauchaine, 2013). The meta-structure framework of internalizing psychopathology may help clarify these mixed findings. From this perspective, the physiological emotion dysregulation underlying internalizing psychopathology can be expressed as two different patterns of maladaptive physiological responding during negative emotional situations, blunted or hypo-reactivity and excessive or hyper-reactivity.

1.6.1 Blunted RSA Reactivity to Negative Emotions

Several lines of research provide evidence that moderate reductions in RSA from baseline during stressful cognitive or social tasks and negative emotion inductions is adaptive (Beauchaine, 2001, 2015; Kogan et al., 2014) and, conversely, blunted or a lack of RSA reactivity is maladaptive and may index emotion dysregulation (Graziano & Derefinko, 2013). Blunted RSA reactivity to negative emotional situations reflects inflexible modulation of one's physiological state in response to changing contextual demands and disengagement from one's environment (Bonanno & Burton, 2013; Bylsma et al., 2008; Rottenberg et al., 2007). This emotional context insensitivity pattern of physiological reactivity is common among individuals with depression (Bylsma et al., 2008; Rottenberg, 2007). I propose that this blunted RSA reactivity provides a measure of the physiological hypo-reactive dysregulation liability.

In a meta-analysis of children's RSA reactivity during a variety of challenging tasks, including social stressors, cognitively challenging tasks, and negative mood/stress inductions, smaller decreases in RSA from baseline to task were associated with more internalizing problems (small effect size) and more cognitive/academic problems (Graziano & Derefinko, 2013). Similarly, Gentzler et al., (2009) found that children who showed smaller decreases in RSA from baseline while watching a sad video clip taken from an animated film were rated by their parents as having lower levels of adaptive emotion regulation skills and were at increased risk for developing depressive affective symptoms (i.e., depressed mood, irritability, and anhedonia) compared to those who showed larger RSA decreases. Further, in response to a social stress test, children diagnosed with social phobia were found to exhibit less of a decrease in RSA during the task compared to children without a diagnosis (Schmitz et al., 2011). The researchers interpreted this lack of RSA reactivity in response to stress or negative mood inductions as reflecting physiological inflexibility to changing environmental demands that would restrict an individual's ability to cope with a stressful situation and/or differentiate stressful from non-stressful situations (Schmitz et al., 2011).

1.6.2 Excessive RSA Reactivity to Negative Emotions

In contrast to these findings, several studies have also shown that excessively large decreases in RSA, particularly during emotional evocation tasks, can be maladaptive and linked with internalizing psychopathology (Beauchaine, 2001, 2015; Fortunato et al., 2013; Pang & Beauchaine, 2013). Furthermore, since emotion evocation studies typically use social emotional stimuli, such as video clips of people displaying negative emotional reactions, excessive decreases in RSA may also reflect maladaptive personal distress empathic responses and subsequent social withdrawal or escape behaviors (Tone & Tully, 2014). I propose that these excessive decreases in RSA to negative emotional stimuli reflect the physiological hyper-reactive dysregulation liability. For instance, higher internalizing symptoms were associated with greater RSA decreases in response to fear- and sadness-inducing film clips from an animated movie in a sample of young children (Fortunato et al., 2013). Similarly, in a study conducted by Pang and Beauchaine (2013), in which they evaluated RSA reactivity to a sad film clip among children with clinical depression, compared to those with conduct disorder, comorbid conduct and depression, and healthy controls (i.e., no psychiatric diagnoses), depressed children exhibited greater decreases in RSA compared to those with only conduct problems or healthy controls; with the comorbid group demonstrating the greatest RSA decreases.

Tasks using different types of stress-inducing stimuli than emotional videos have produced similar results. Third-grade children who were rated as anxious solitary and peer-excluded by their classmates demonstrated larger decreases in RSA relative to the normative group during an interpersonal stressor involving a simulated peer rejection experience (Gazelle & Druhen, 2009). Similarly, Boyce et al. (2001) found that children with high internalizing problems based on parent and teacher ratings, demonstrated greater decreases in RSA and poorer RSA recovery from a stressor task that included social, cognitive, physical, and emotional challenges compared to children with no problems, externalizing problems, and mixed internalizing/externalizing problems.

Taken together, these studies suggest that in response to negative emotions, both blunted RSA reactivity (i.e., minimal decreases in RSA from baseline to task) and excessive RSA reactivity (i.e., excessive decreases in RSA from baseline to task) are expressions of physiological emotion dysregulation liability associated with high internalizing symptoms. Thus, moderate levels of RSA reactivity in response to negative emotional stimuli appear to be the most adaptive (Beauchaine, 2001) as they reflect the optimal balance of mobilizing the physiological resources needed to effectively respond to the particular situation without the excessive reactivity that leads to physiological hyperarousal and rigid, defensive behavioral response patterns (Thayer & Lane, 2000, 2002). Despite this theoretical rationale, no studies to my knowledge have examined a possible quadratic association between RSA reactivity to others' sadness and internalizing symptoms. Studies that examine strictly linear associations between RSA reactivity and internalizing symptoms may be masking the true nature of the association by forcing linear interpretations, which could potentially explain the mixed findings of previous studies. Indeed, several recent meta-analyses and review articles have highlighted the need for researchers to consider both linear and nonlinear patterns of RSA reactivity to emotion challenges (Balzarotti et al., 2017; Graziano & Derefinko, 2013; Hamilton & Alloy, 2016). Thus, I predict a positive quadratic association between children's physiological reactivity to others' sadness and their internalizing symptoms, such that both hypo-reactivity (reflected by minimal decreases in RSA) and hyper-reactivity (reflected by excessive decreases in RSA) will be associated with high internalizing symptoms (see Figure 1).

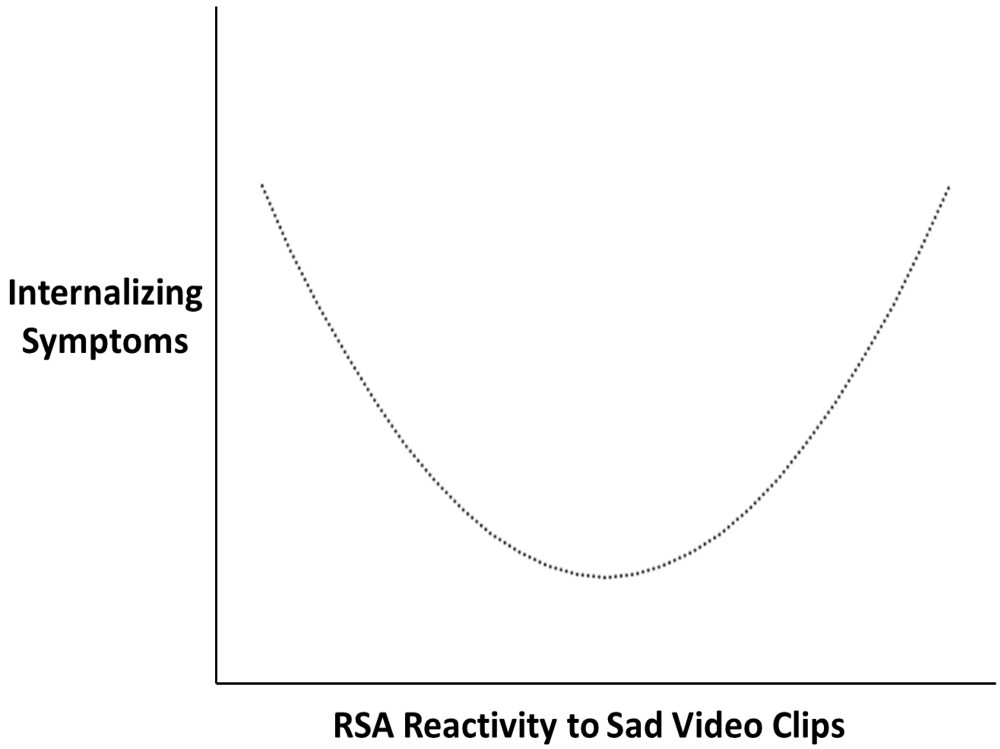

Figure 1. Hypothesized quadratic function of RSA reactivity to sad video clips on children's internalizing symptoms.

1.6.3 Rigid RSA Recovery Following Negative Emotions

The vast majority of studies examining RSA as a marker of physiological emotion dysregulation have focused primarily on individuals' baseline RSA or RSA reactivity in response to affective stimuli, with very few studies examining how RSA recovers after the stimuli or stressor has been removed. This is surprising given that flexible physiological regulation is thought to be marked not only by one's capacity to temporarily suppress RSA but also to restore baseline RSA levels after the stressful or negative encounter has ended (Bonanno & Burton, 2013; Thayer & Lane, 2002). Failure to do so may reflect sustained reductions in top-down regulation of emotional arousal associated with prolonged physiological and amygdala reactivity and continued activation of defensive systems, which are key mechanisms underlying anxiety (Friedman, 2007), depression (Siegle, Steinhauer, Thase, Stenger, & Carter, 2002), and cardiovascular disease and mortality associated with depression and anxiety (Chalmers, Quintana, Abbott, & Kemp, 2014; Grippo & Johnson, 2009; Thayer, Åhs, Fredrikson, Sollers, & Wager, 2012). I propose that poor physiological recovery after witnessing other children's sadness (indicated by smaller increases in RSA from task to recovery period) reflects the rigid behavioral pattern associated with internalizing psychopathology.

Studies have consistently shown that RSA increases during recovery and relaxation periods after various types of stressful or negative mood inductions among individuals with no psychopathology (Azam et al., 2015; Sokhadze, 2007). While research on the correlates of RSA recovery is limited, there is some evidence to suggest that less RSA recovery following a stressful or challenging task is associated with emotion dysregulation and internalizing psychopathology. Children with high internalizing symptoms (Boyce et al., 2001) and adults with social anxiety (Movius & Allen, 2005) exhibited less RSA recovery after stressful challenges than those with fewer symptoms. Additionally, Berna et al. (2014) found that undergraduate students who were classified as having either high or low emotion regulation difficulties, based on quartile splits of their scores on self-report measures of emotion dysregulation, showed similar decreases in RSA while watching anger-inducing video clips. However, during a subsequent relaxation period, the low emotion regulation difficulty group returned to baseline levels of RSA while the high emotion regulation difficulty group did not (Berna, Ott, & Nandrino, 2014). Finally, studies have also shown that among healthy adults, rumination (Key, Campbell, Bacon, & Gerin, 2008) and worry (Brosschot et al., 2007), core features of anxiety and depressive disorders, are predictors of poor RSA recovery following a stressor, which is thought to be due to a prolongation of the cognitive representation of the stressor and continued activation of defensive systems (Thayer & Lane, 2002).

Taken together, these studies provide support for low RSA recovery following stressful or negative emotion induction tasks as a measure of emotion dysregulation. Thus, I predict that children who display lower RSA recovery after witnessing other children's sadness will have higher levels of internalizing symptoms.

1.7 Dysregulated RSA Reactivity to Positive Emotions in Internalizing Psychopathology

Compared to the number of studies on RSA reactivity to stressful or negative emotion inductions, surprisingly few studies have examined RSA reactivity to positive emotional stimuli. The meta-structure framework of internalizing problems focuses largely on individuals' dysregulated reactions to negative emotions and relatively less is known about regulation of responses to others' positive emotions among individuals with internalizing problems. Middle childhood is a potentially critical period for studying emotion regulation in response to witnessing others' positive emotions because during this period peer relationships become increasingly important (Rubin et al., 2006) and children's capacity to share positive affect with other children is associated with higher ratings of popularity, social competence, and social satisfaction (Dougherty, 2006; Hubbard & Coie, 1994; Jacob et al., 2014).

Theories of RSA posit that increases in RSA are associated with the experience of positive emotions, reflecting a physiological state that promotes social engagement behaviors (Porges, 2001, 2003, 2007). This notion of the promotion of social engagement behaviors that stems from an increase in parasympathetic activity (indexed by increases in RSA) during positive emotional states is consistent with the hypothesized non-specific action, "free activation" (Frijda, 1986) tendencies and thought-action repertoire broadening effects of positive emotions in Fredrickson (2001)'s "broaden-and-build" theory. Similar to how the presentation of pleasant images during emotion-modulated startle paradigms cues the individual to a context that is incompatible with the defensive behavioral reaction (Vaidyanathan, Patrick, & Cuthbert, 2009), the presentation of positive emotional stimuli (e.g., appropriately prosodic voices and warm, expressive faces) signals a safe environment via neuroception, which recruits the vagal brake to promote autonomic states that support the prosocial behaviors of the social engagement system (Porges, 2007).

Although research on the physiological experience of positive emotions is relatively limited, some studies provide evidence to support associations between increases in RSA and the experience of positive emotional states. Studies with infants have shown that RSA levels increase during engaging social interactions (Porges, 2001) and when positive emotion states are induced by presenting them with a new toy to play with (Bazhenova & Porges, 1997). Matsunaga et al. (2009) found that adults' RSA increased relative to baseline while watching a positive emotional video about love, and these increases were positively correlated with activity in the mPFC and OFC and negatively correlated with activity in the amygdala. However, several studies have not found this increase in RSA or have found decreases during positive emotion inducing film clips, which has led some researchers to assert that RSA reactivity may be associated more with the arousal of emotions than with the valence (Fortunato et al., 2013; Frazier, Strauss, & Steinhauer, 2004; Shiota, Neufeld, Yeung, Moser, & Perea, 2011).

There are several lines of research that suggest internalizing psychopathology is associated with dysregulated positive emotions (Cannon & Weems, 2006; Hankin et al., 2016; Jacques & Mash, 2004). Low positive affect has been associated with depressive disorders (Cannon & Weems, 2006; Hankin et al., 2016) and social anxiety disorder (Kashdan, 2007;

Kotov, Watson, Robles, & Schmidt, 2007). Further, low positive affect is associated with reduced activation and volume in reward-related brain areas that are also involved in physiological regulation, including the OFC and mPFC (Der-Avakian & Markou, 2012; Treadway & Zald, 2011). Additionally, children with internalizing psychopathology may have difficulty identifying and engaging with the positive emotions of others. For instance, depression and social anxiety have been shown to be negatively correlated with positive empathy (Morelli, Lieberman, & Zaki, 2015), and children with these disorders have been found to be less accurate in identifying happy expressions of others compared to children without them (Schepman, Taylor, Collishaw, & Fombonne, 2012; Simonian, Beidel, Turner, Berkes, & Long, 2001); however, these findings have not always been consistent. These deficits may interfere with children with high internalizing symptoms' ability to experience happiness in happy social contexts.

Studies that have examined physiological reactivity to positive emotional stimuli in relation to internalizing psychopathology have found that individuals with high internalizing problems exhibit different patterns of physiological reactivity than individuals without them. Cyranowski, Hofkens, Swartz, Salomon, and Gianaros (2011) found evidence that adult women with depression exhibited lower RSA during a love inducing imagery task than non-depressed women who exhibited the expected increase in RSA. In contrast, Fortunato et al. (2013) found no significant association between young children's RSA reactivity to happy emotional videos and their level of internalizing symptoms. Other studies using an emotion-modulated startle paradigm have shown that individuals with depression and individuals with high levels of self-reported anxious apprehension, anxious arousal, or anhedonic depression did not exhibit the typical attenuated blink response when the acoustic signal was paired with pleasant affective stimuli (Kaviani et al., 2004; Larson, Nitschke, & Davidson, 2007; Vaidyanathan et al., 2009).

In sum, these studies provide some support for the notion that RSA increases are associated with the experience of positive emotional states and reflect better physiological emotion regulation. Further, studies of physiological reactivity to positive emotional stimuli in relation to internalizing psychopathology have shown that individuals with internalizing symptoms exhibit decreased physiological reactivity in positive emotional situations, indicating physiological emotion dysregulation (Cyranowski et al., 2011; Larson et al., 2007). To extend previous work in this area, I will examine children's RSA reactivity to emotional videos depicting other children's happiness in relation to their levels of internalizing symptoms. Specifically, I propose that smaller increases in RSA from baseline during the positive emotional videos will be associated with more internalizing symptoms; however, given the paucity of research in this area, this hypothesis is quite tentative.

1.7.1 Poor Sustainability of RSA Recovery Following Positive Emotions

Perhaps the least studied area with regard to RSA reactivity to emotional stimuli is RSA recovery following a positive emotion induction. In the absence of empirical work, I return to theories of positive emotions to guide my hypothesis. As detailed in Fredrickson's (2001) broaden and build theory, positive emotions broaden one's attentional scope and thought-action behavioral repertoire, which in turn increases flexibility and engagement with the social environment and facilitates the development of intellectual, physical, social and psychological resources, including high quality social relationships, creativity and problem solving skills, optimism and resilience, and cardiovascular health (Fredrickson, 2003). Importantly, these outcomes often endure long after the initial positive emotion has dissipated (Fredrickson, 2003).

Thus, it follows that the suspected physiological processes underlying positive emotions (i.e., an increase in RSA) would also endure after the positive emotional stimuli has been removed. Although RSA reactivity was not measured explicitly, a study by Kok and Fredrickson (2010) illustrates how the experience of positive emotions can increase levels of RSA over the long term. These researchers found that initial baseline levels of RSA predicted increases in social connectedness and the experience of positive emotions over the course of a 9-week period, which in turn predicted increases in baseline RSA independent of initial RSA levels, providing evidence of an upward spiral relationship (Kok & Fredrickson, 2010).

The ability to sustain the effects of positive emotions appears to be compromised among individuals with high internalizing symptoms. Seeley et al. (2016) found that both individuals with GAD and those with no psychiatric diagnoses exhibited increases in RSA when viewing happiness-inducing film clips relative to baseline; however, only the control group maintained this effect during the recovery period, whereas the individuals with GAD exhibited a return to baseline levels of RSA (i.e. levels of RSA in the recovery period were not significantly different than RSA levels in the baseline period; Seeley et al., 2016). Further, studies of cognitive biases associated with depression have shown that individuals with depression have reduced attentional engagement with positive images (Kellough, Beevers, Ellis, & Wells, 2008) and fail to show the bias to preferentially recall positive over neutral memories that is exhibited by individuals with no history of psychopathology (Gotlib, Roberts, & Gilboa, 1996; LeMoult & Gotlib, 2018). Together, the findings of these studies suggest that individuals with internalizing psychopathology may have difficulty sustaining the effects of positive emotions, reflecting a general emotion dysregulation liability. Thus, I predict that poorer sustainability of the physiological reactivity to positive emotions, indicated by larger decreases in RSA from task to recovery, will be associated with more internalizing symptoms.

1.8 Overview of the Current Study and Hypotheses

To summarize, emotion dysregulation interferes with adaptive social functioning by impeding an individual's ability to produce emotional responses in line with situational demands (Cole & Hall, 2008; Cole et al., 1994; Eisenberg et al., 2000). Findings from several lines of research indicate that individuals with internalizing psychopathology exhibit physiological emotion dysregulation (see Beauchaine, 2015), however, how that dysregulation unfolds across social situations, such as when observing other children's happiness and sadness, remains unclear. The majority of studies using RSA as a measure of physiological emotion dysregulation have focused on linear relations between RSA reactivity to sadness and internalizing psychopathology, and these studies have produced mixed findings, with some studies finding blunted decreases in RSA (i.e., physiological hypo-reactivity) are associated with internalizing symptoms (Graziano & Derefinko, 2013), others finding that excessive decreases in RSA (i.e., physiological hyper-reactivity) are associated with internalizing symptoms (Fortunato et al., 2013), and still others finding no association between RSA reactivity and internalizing symptoms (Seeley et al., 2016). These mixed findings suggest the association between RSA reactivity to sadness may be nonlinear. Additionally, relatively few studies have examined RSA reactivity to positive emotional stimuli and RSA recovery after positive or negative emotional situations in relation to internalizing psychopathology. Thus, the current study is designed to investigate associations between children's physiological dysregulation during social emotional situations and their internalizing symptoms using measures of resting RSA, RSA reactivity, and RSA recovery in response to other children's displays of happiness and sadness. The goal of this study is to better understand patterns of physiological emotion dysregulation in response to others' sadness and happiness as potential risk factors for internalizing psychopathology during middle childhood.

This study will expand previous research by focusing on the patterns of physiological regulation in response to others' emotions during middle childhood, an important developmental period that has been understudied relative to the abundance of research on internalizing problems in adults and adolescents and on RSA in adults and infants. Not only is middle childhood the developmental stage just prior to the dramatic increases in prevalence and severity of anxiety and depression during preadolescence and adolescence (Schneier et al., 1992; Thapar et al., 2012), but it is also an important period for children's social and emotional development, as peer relationships become increasingly related to children's psychological adjustment (Hay et al., 2004; Hymel, Rubin, Rowden, & LeMare, 1990; Rubin et al., 2006) and expectations for social independence are increasing (Lancy & Grove, 2011). Additionally, emotion dysregulation can contribute to maladaptive social withdrawal behaviors and increase the risk for social rejection during middle childhood (Rubin et al., 2009; Wichmann et al., 2004), which makes it a critical period for examining physiological dysregulation during social situations.

I make the following hypotheses: : (1) I predict that lower resting RSA, reflecting the general emotion dysregulation liability and a vulnerability toward inflexible modulation of emotional experiences to situational demands, will be associated with higher levels of children's internalizing symptoms. (2) I predict there will be two distinct patterns of physiological emotion dysregulation when witnessing other children's sadness that are associated with high levels of internalizing symptoms. That is, I predict there will be a positive quadratic association between children's physiological reactivity to other children's sadness and their level of internalizing symptoms, such that both hypo-reactivity (indicated by minimal RSA decreases) and hyper-reactivity (indicated by excessive RSA decreases) will be associated with high levels of internalizing symptoms and moderate reactivity will be associated with low levels of internalizing symptoms. (3) I predict that children with higher levels of internalizing symptoms will become 'stuck' in rigid, physiological emotional states after witnessing another child's sadness, indicated by lower RSA recovery (i.e., smaller increases in RSA from task to recovery period). (4) I predict that physiological hypo-reactivity when witnessing other children's happiness, indicated by smaller RSA increases, will be associated with higher levels of internalizing symptoms in children. (5) Given the paucity of research on RSA recovery after happiness, restricted range for recovery among children with high internalizing symptoms predicted above, and limited power to detect the effect (described below), I make the following exploratory hypothesis: I predict that children with low internalizing symptoms will have sustained increases in RSA after witnessing other children's happiness and children with high internalizing symptoms will have poorer sustainability of their minimal physiological reactivity, indicated by larger decreases in RSA from task to recovery period.

2 METHOD

2.1 Participants

One hundred and fourteen children (50.4% boys) and their mothers participated in the current study as part of a larger study designed to examine emotion-related correlates of internalizing symptoms during childhood. Children were ages 7-11 years (*M*age = 9.13; *SD* = 1.10); however, 82.6% of children were between the ages of 8-10 years. The ethnicity of the children was as follows: 56.6% White not of Hispanic origin, 36.3% African-American, 4.4% biracial/multi-racial, 1.8% Hispanic, and 0.9% Asian-American. The majority of mothers were biologically related to the participating child (95.6%), married (69.9%) or in a stable relationship (9.0%), and had obtained at least a college degree (78.8%). Families had a mean annual household income of $133,004.95 (SD = $199,097).

2.1.1 Recruitment

Participants in the current study were recruited from two sources and at two different times. Eighty-one of the families completed two visits, which will hereafter be referred to as Time 1 and Time 2. Children participated in the Time 1 visit when they were between the ages of four and six years (*M*age = 5.34; *SD* = 0.47; 50.8% boys). The remaining 33 families were recruited to increase the sample size for the Time 2 study. The original Time 1 families and the new Time 2 families were recruited using the same recruitment procedures. Families who had previously consented to being contacted about research participation and whose contact information is maintained in a Subject Pool Database by Georgia State University Department of Psychology faculty and families who responded to online advertisements (e.g., Craigslist) that provided a brief description of the study were contacted via telephone or email to provide additional details about the study, complete screening measures, and schedule a visit to the FEELINGS Lab at Georgia State University if they met inclusion criteria. A description of the screening procedure for eligible children used at both Time 1 and Time 2 is provided below. All families who participated in the Time 1 study were invited back to participate at Time 2. Only data collected at Time 2 will be used in the current study.

2.1.2 Screening

Screening procedures were utilized to obtain a sample of children who were at high risk for internalizing symptoms and children who were at low risk for internalizing symptoms. At both Time 1 and Time 2, potential families were contacted by telephone or email and asked to rate items about their child's social anxiety and depression-related symptoms and answer questions about other conditions that would make it difficult for them to participate in the current study (e.g., intellectual disability, autism spectrum disorder, cerebral palsy). Children were considered eligible for the current study if they demonstrated (a) high risk for anxiety, (b) high risk for depression, (c) high risk for anxiety and depression, or (d) low risk for anxiety and depression. At Time 1, children's levels of anxiety and depression were assessed using the social anxiety scale from the Revised Preschool Anxiety Scale (R-PAS; (Edwards, Rapee, Kennedy, & Spence, 2010) and the Preschool Feelings Checklist (PFC; (Luby, Heffelfinger, Koenig-McNaught, Brown, & Spitznagel, 2004), respectively. At Time 2, children's anxiety and depression levels were assessed using the social anxiety scale from the Spence Children's Anxiety Scale-Parent Version (SCAS; (Spence, 1998) and the PFC, respectively. Although the PFC was originally designed for preschool-aged children and no version exists for school-aged children, researchers have continued to use it as a screening instrument for elevated depression symptoms in children similar in age to those in the current sample (Luby et al., 2004). High risk was defined as scores that were greater than or equal to the mean score of the normative community samples for the R-PAS (Edwards et al., 2010) and SCAS (Spence, 2017) and/or the scores Luby, Si, Belden, Tandon, and Spitznagel (2009) used to identify at-risk children in their study; whereas low risk was defined as scores one standard deviation below the mean of the normative samples on the R-PAS and SCAS or a score of 0 on the PFC (Edwards et al., 2010; Luby et al., 2004, 2009; Spence, 2017).

At Time 1, 49% of the families screened were eligible to participate. The final sample at Time 1 consisted of 99 families whose children were screened in and participated and 23 participating families whose children did not go through the full screening process because they were recruited before the eligibility criteria were implemented. Of those families that were screened in and participated, 37 children had high anxiety scores, 18 children had high depression scores, 16 children had high depression and anxiety scores, and 28 children had low anxiety and depression scores. At the Time 2 visit, 62.7% of the families screened were eligible to participate, of which 34 eligible families participated. Of those families that were screened in and participated, 16 children had high anxiety scores, 2 children had high depression scores, 7 children had high anxiety and depression scores, and 9 children had low anxiety and depression scores.

2.2 Procedure

The current study was approved by the International Review Board (IRB) and procedures were carried out in accordance with the IRB's standards. Participation entailed one approximately three-hour visit to the FEELINGS Lab at Georgia State University during which they completed a series of tasks related to emotion processing, family discussion, and executive functioning. They also completed measures of child and parent psychological functioning, parenting practices, empathy, emotion regulation, and physical information administered by trained undergraduate and graduate research assistants as part of a larger study. Upon their arrival to the lab, the mothers and their children underwent assent and consent procedures. They were then moved to an adjacent room, where they were both outfitted with electrodes for electrocardiogram (ECG) recording. The ECG equipment was tested to ensure a good signal was being received, at which point the children were escorted back to the other room to complete a computer task and various self-report measures while their mother completed the emotional video paradigm, described below. After viewing the emotional videos themselves, mothers were asked to provide consent to allow us to show them to their children. Children participated in the emotional video paradigm about halfway through the visit, which provided them ample time to become acclimated to the ECG equipment and to the lab environment. Upon completion of the study protocol, families were compensated $50 and children were allowed to pick a small prize for their participation.

2.3 Materials and Design

2.3.1 Emotional Video Paradigm

As part of the larger study, children participated in a total of four tasks during which ECG measures were recorded. Specific to the present study, children participated in a 19-minute emotion induction task wherein they watched a series of happy-, sad-, and neutral-valence emotional videos. Previous research has indicated that video clips are especially effective in inducing emotion relative to other mood inducing procedures (Schaefer, Nils, Sanchez, & Philippot, 2010; Westermann, Spies, Stahl, & Hesse, 1996). Video segments were taken from various films and the internet and were viewed by a team of graduate and undergraduate students who rated their reactions to the videos on overall valence and ten specific emotions. A description of the video selection and validation procedure is provided below. Nine video segments (three happy, three neutral, and three sad) were selected and used to elicit the target emotions in the current study. The neutral videos consisted of three nature scenes: mountains, sunsets, and canyons. Nature videos are regularly used to collect baseline measurements of RSA as they fully engage participants' attention and do not induce emotion (Rottenberg et al., 2005). The happy video segments involved a young girl opening birthday presents and being surprised with a trip to Disneyland (170s), a boy toddler hearing his parents' voices for the first time (81s), and a clip from the movie *Step Mom* where a young boy and girl dance and sing a fun song with their mom (104s). The sad videos consisted of a young girl crying while listening to a sad song her deceased mother used to sing to her (68s), a clip from the movie *Christmas Shoes* that shows a young boy who does not have enough money to buy a Christmas present for his dying mother (135s), and a clip from the movie *My Dog Skip* that features a young boy crying over his dying dog (127s). Before each emotion clip, a brief description of the video was displayed on the screen to give the clip some context and provide the name of the child in the clip. For example, prior to the *My Dog Skip* video, a written message appeared on screen and an audio recording played, saying, “Willy’s dog was hit by a car and was hurt badly.” The happy and sad video clips were shown in two blocks based on emotion, with the three sad clips played in succession and three happy clips played in succession to allow for persistent emotion throughout the block and to provide segments that were as long as is recommended by the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology guidelines (Task-Force, 1996).

The videos were presented on a Dell computer with a 17” monitor using E-Prime software Version 2.0 (Psychology Software Tools, 2013) to synchronize videos with the ECG recordings. Children were seated approximately 65 centimeters from the screen while the researcher sat behind them, out of sight, and pretended to do work while monitoring that the child was paying attention. Children were instructed to not talk to the researcher during the task and to sit up straight, remain still, and watch all the videos carefully. The children used headphones to listen to the videos and the volume was set to the same level for each child. The paradigm began with a three-minute neutral video to provide a measure of children’s resting RSA. Afterwards, one of the two emotion blocks was presented. Following each emotion block, a two-minute neutral video played. The first minute was used to assess children’s RSA recovery from the previous emotional videos and the second minute was used as a baseline measurement to assess children's RSA reactivity to the next set of emotional videos. See Figure 2 for a depiction of the format of the emotional video task. To control for order effects, 10 video presentation orders were created using a balanced Latin square design so that each neutral clip appeared in all three locations, the order of the emotion blocks (i.e., happy and sad) were counterbalanced, and that each emotional video clip appeared before and after all the others in the block. Participants were then randomly assigned to one of these 10 orders. See Figure 3 for a depiction of the 10 video clip order presentations. Once the entire emotional video paradigm was complete, the children rated how they felt and how they thought the main character(s) in each emotional video felt using the Self-Assessment Manikin (SAM) pictorial rating scale (Bradley & Lang, 1994), which is described below.

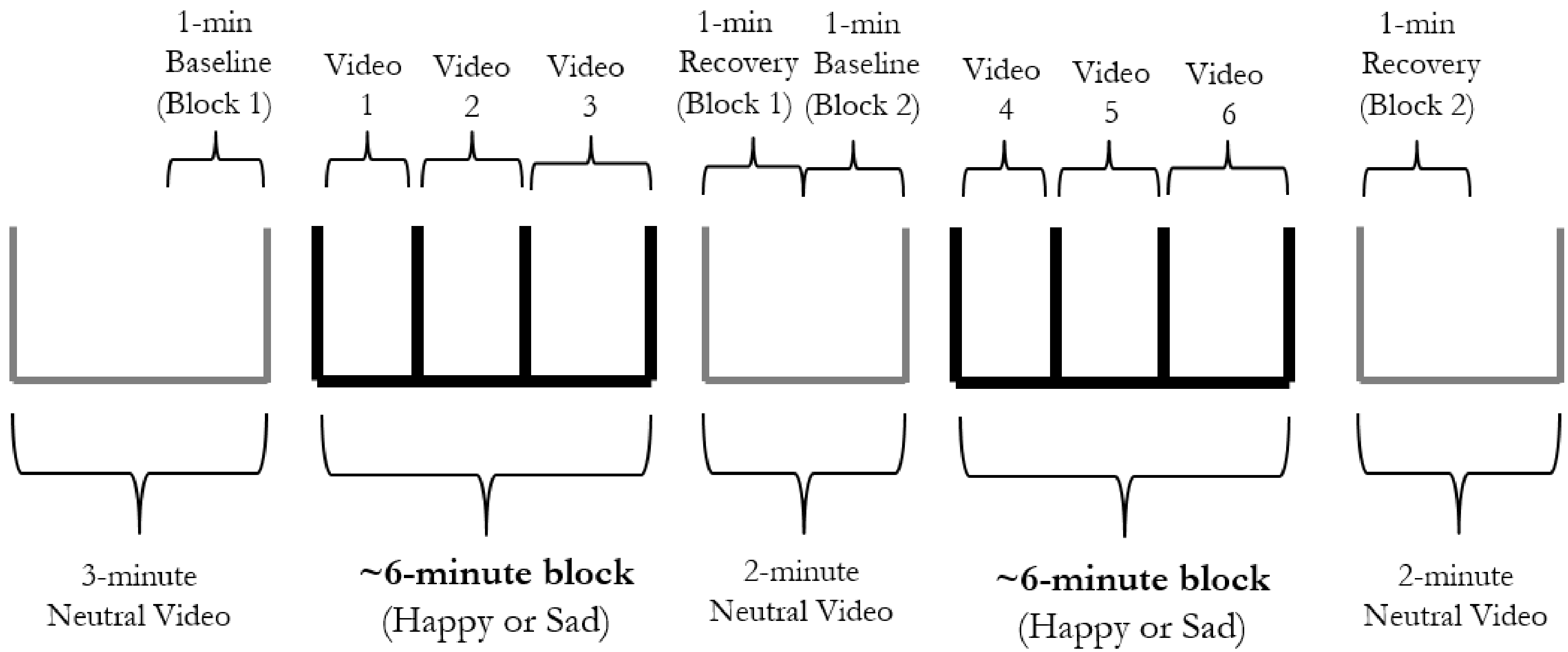

Figure 2. Format of the Emotional Video Paradigm

Presentation Order

Order 1	Mountains	Disneyland Birthday Present	Toddler Hearing Parents	*Step Mom*	Sunsets	Sad Song	*Christmas Shoes*	*My Dog Skip*	Canyons
Order 2	Mountains	Toddler Hearing Parents	*Step Mom*	Disneyland Birthday Present	Canyons	*Christmas Shoes*	*My Dog Skip*	Sad Song	Sunsets
Order 3	Sunsets	*Step Mom*	Toddler Hearing Parents	Disneyland Birthday Present	Canyons	*My Dog Skip*	*Christmas Shoes*	Sad Song	Mountains
Order 4	Sunsets	Toddler Hearing Parents	Disneyland Birthday Present	*Step Mom*	Mountains	*Christmas Shoes*	Sad Song	*My Dog Skip*	Canyons
Order 5	Canyons	*Step Mom*	Disneyland Birthday Present	Toddler Hearing Parents	Sunsets	*My Dog Skip*	Sad Song	*Christmas Shoes*	Mountains
Order 6	Canyons	Sad Song	*Christmas Shoes*	*My Dog Skip*	Sunsets	Toddler Hearing Parents	*Step Mom*	Disneyland Birthday Present	Mountains
Order 7	Mountains	*Christmas Shoes*	*My Dog Skip*	Sad Song	Canyons	*Step Mom*	Toddler Hearing Parents	Disneyland Birthday Present	Sunsets
Order 8	Mountains	*My Dog Skip*	*Christmas Shoes*	Sad Song	Canyons	Toddler Hearing Parents	Disneyland Birthday Present	*Step Mom*	Sunsets
Order 9	Canyons	*Christmas Shoes*	Sad Song	*My Dog Skip*	Sunsets	*Step Mom*	Disneyland Birthday Present	Toddler Hearing Parents	Mountains
Order 10	Sunsets	*My Dog Skip*	Sad Song	*Christmas Shoes*	Mountains	Disneyland Birthday Present	Toddler Hearing Parents	*Step Mom*	Canyons

Figure 3. *Emotional video presentation orders*

2.3.2 Selection of Emotional Videos

Videos have long been used by researchers to elicit emotions in the laboratory and several empirically validated emotion video libraries have been created by researchers. However, the videos contained in these libraries are often designed for an adult population (i.e., display content that is not appropriate for children), short in duration, or featured animated characters, which do not reflect the types of social situations children will encounter in the real world. Thus, a first step for our study was to create a set of video clips that featured real children expressing specifically happiness or sadness. First, I reviewed segments of old films and videos on the internet (e.g., Youtube) and selected 15 clips that were potentially suitable for the study and featured a variety of emotion-eliciting situations and characters that varied in observed race and gender. When necessary, clips were edited to remove extraneous segments (e.g., when the storyline deviated from the dying dog). Then, using similar procedures as in previous research (Gotlib, Krasnoperova, Yue, & Joormann, 2004), the 15 videos were viewed independently by nine graduate and undergraduate students who rated their reactions to the clips on overall valence anegative emotions (repulsion, fear, anger, sadness), neutrality, and two empathy-related emotions (compassion, love). Following Samson, Kreibig, Soderstrom, Wade, and Gross (2016), valence was rated on a scale from 1 (*very negative*) to 6 (*very positive*) while the different emotions were rated on a scale from 1 (*not at all*) to 6 (*very strong*). Video clips met inclusion criteria for the happy condition if they received an average rating (across raters) of greater than 4 on the happiness item and less than 2 on all of the negative emotion and neutral items. Clips similarly met inclusion criteria for the sad condition if they received an average rating of greater than 4 on the sadness item and less than 2 on all of the positive and neutral items. These selection criteria are at least as stringent as those used in previous studies to select emotional photos and videos (Gotlib et al., 2004; Samson et al., 2016). Among the videos that met inclusion criteria, three happy and three sad videos were selected to maximize the diversity of emotion-eliciting situations, maximize the empathy emotion ratings, and equate valence ratings across the happy and sad conditions. No significant differences were found between the magnitude of the valence of the average of the selected happy (M = 4.37, SD = 1.70) and sad (M = 4.93, SD = 1.33) clips, $t(8) = -1.512$, $p = .169$. See Table 1 for the ratings of the selected videos.

2.3.3 Measures

2.3.3.1 Demographic information

Mothers completed a basic demographic information form developed for the study. Information collected included child's age, gender, race/ethnicity, and grade-level, mother's level of education and marital status, and household annual income, among other things.

Table 1. *Emotional Video Researcher Ratings for Selected Video Clips*

			Positive Emotions			Negative Emotions					Empathy-Related	
Video	Valence	Arousal	Happiness	Amusement	Pride	Sadness	Anger	Repulsion	Fear	Neutrality	Compassion	Love
Happy Clips												
Disneyland Birthday Present	4.89 (1.54)	3.44	5.44	4.78	1.00	1.11	1.00	1.11	1.11	1.78	3.00	4.11
Step Mom	3.89 (2.15)	3.67	4.44	4.33	1.11	1.00	1.00	1.00	1.22	1.56	1.67	3.56
Toddler Hearing Parents	4.33 (2.12)	2.44	4.67	3.67	1.22	1.56	1.00	1.00	1.22	1.89	3.78	4.11
Sad Clips												
Sad Song	2.00 (1.32)	1.56	1.11	1.44	1.11	5.67	1.22	1.44	1.22	1.22	5.44	3.56
Christmas Shoes	2.33 (1.58)	2.11	1.44	1.22	1.44	5.33	1.56	1.56	2.22	1.33	5.67	3.33
My Dog Skip	1.89 (1.27)	1.44	1.00	1.11	1.11	5.67	1.22	1.44	1.22	1.22	5.44	3.33

**Note*. Mean rating scores are presented. Standard deviation for Valence ratings is presented in parentheses

2.3.3.2 Respiratory sinus arrhythmia

This study's procedure for recording, scoring, and calculating indices of RSA are consistent with the recommendations by the Task Force of the European Society of Cardiology and the North American Society of Pacing Electrophysiology (1996). During the emotional video paradigm, ECG were recorded using three 10-mm Ag/Cl disposable electrodes filled with 7% chloride liquid electrolyte gel. Electrodes were arranged in a standard Lead II formation, with one electrode on the child's left and right clavicles and one electrode on the left rib cage. Raw ECG signals were recorded using the Biopac MP150 data acquisition system and an ECG100C amplifier and were digitized and displayed using AcqKnowledge v4.3 software (Biopac Systems, Inc., Goleta, CA). The signal was sampled at 1,000 Hz and band pass filtered between 0.5 and 35 Hz to improve signal quality. The signal was re-sampled using a cubic-spline interpolation at a resampling frequency of 8 Hz to generate a continuous time-domain representation of heart rate. Detection of R waves and calculation of interbeat intervals (IBI), defined as the temporal distances between successive R waves (Task Force, 1996), was conducted offline using the AcqKnowledge's peak detection algorithm. IBIs were then visually inspected for possible artifacts due to movement or ectopic beats and suspected artifacts were corrected manually by a team of trained research assistants. Cleaned IBIs were subsequently submitted to power spectral analysis in the frequency spectrum of 0.00 to 3.00 Hz. Employing a fast Fourier transformation, power spectral density was quantified in the high frequency (HF; .15-.40 Hz) band, which corresponds to the rate of spontaneous respiration (Berntson et al., 1997). Spectral densities were calculated in one minute epochs and averaged to obtain a single value (Task Force, 1996). HF power scores were normalized through natural log transformations, as is common practice to reduce skew, and the resulting values were used as indicators of RSA, reported in units of $\ln(\text{ms})^2$.

Measures of resting RSA were calculated from the final two minutes of the first neutral video in order to account for an orienting effect on RSA and to ensure children were habituated to their surroundings. To assess children's physiological responses to the emotional videos, *RSA reactivity* was measured by subtracting children's baseline RSA levels (i.e., the final minute of the preceding neutral video) from their levels of RSA during the subsequent emotion block (averaged across six one-minute epochs). Note that the sad emotion block was not quite six minutes in duration, so the final epoch during this phase was approximately 32 seconds, which is still an acceptable duration to calculate RSA (Fortunato et al., 2013). Thus, $\Delta RSA_{reactivity}$ scores less than zero correspond to a decrease in RSA from baseline during the emotion phase, whereas $\Delta RSA_{reactivity}$ scores greater than zero indicate an increase in RSA from baseline during the emotion phase. *RSA recovery* was measured by subtracting the mean RSA levels during the emotion phase from the RSA level during the following recovery phase (i.e., the first minute of the following neutral video). Thus, $\Delta RSA_{recovery}$ scores less than zero indicate a decrease in RSA from emotion phase to recovery, whereas $\Delta RSA_{recovery}$ greater than zero indicate an increase in RSA from emotion phase to recovery.

2.3.3.3 Internalizing symptoms

Mothers completed the parent version of the *Childhood Behavior Checklist* (CBCL; Achenbach & Rescorla, 2001). The CBCL is a 113-item measure for children aged 6–18 years that assesses the presence of symptoms of emotional and behavioral problems during the previous 6 months. Items on the CBCL are rated on a 3-point Likert scale, which ranges from 0 (*Not True*) to 2 (*Very True or Often True*) and yield scores on several empirically-derived scales.

Scores on the 32-item Internalizing Problems scale, which consists of the Anxious/Depressed, Withdrawn/Depressed, and Somatic Complaints syndrome scales, were used in the current study. Examples of items on each of these scales include "Self-conscious or easily embarrassed," "Would rather be alone than with others," and "Overtired without good reason," respectively. Items on these scales are summed to create a total Internalizing Problems score. Possible scores on this scale range from 0-64, with higher scores indicating the presence of more internalizing problems. The CBCL is one of the most widely used measures of child adjustment problems and the Internalizing Problems scale has been shown to have good internal consistency in a community sample of children (α = .90; Achenbach & Rescorla, 2001) and across 31 different cultures/societies (mean α = .83; (Rescorla et al., 2007). The Internalizing Problems scale has also demonstrated good test-retest reliability (r = .91; Achenbach & Rescorla, 2001) and convergent validity, as evidenced by strong correlations with neuroticism (Dutra, Campbell, & Westen, 2004) and sadness (Eisenberg et al., 2009). The internal consistency reliability for the Internalizing Problems scale in our sample was α = .89.

2.3.3.4 Self-Assessment Manikin

To ensure that the happy and sad emotional videos induced the intended emotion, children rated the emotional experience of the main character(s) and their own experience of each emotional video using the valence scale of the Self-Assessment Manikin (SAM) pictorial rating scale (Bradley & Lang, 1994). This scale ranges from 1 (*happy, smiling face*) to 9 (*unhappy, frowning face*). After the emotional video paradigm was complete, children selected one figure that most accurately reflected their emotional experience while watching each video. The SAM has frequently been used to assess individuals' reactions to emotional stimuli (Moran, Mehta, & Kring, 2012). To remind the children about which video they were supposed to be rating, each form included a picture of the main character(s) and a brief description of the video. Rating forms were presented in the same order as the presentation of videos.

2.3.3.5 Children's physical information interview

Mothers also completed a semi-structured interview with a research assistant that was specifically designed for this study to gather information about children's general health, including factors that have been known to influence heart rate. Information that was collected included mother and children's body mass index (BMI), medications, and medical conditions.

2.4 Data Analysis

All analyses were performed using SPSS version 23 for Windows (PASW Statistics 23, Release Version 23.0.0; SPSS, Inc., 2009, Chicago, IL, www.spss.com). Hypotheses were tested using a series of hierarchical multiple linear and nonlinear regression analyses. Prior to running the regression analyses, all continues predictor variables were mean centered. Dummy variables were created for the categorical covariates gender, race, video order (i.e., whether sad or happy videos appeared first), and recruitment group (i.e., children recruited at Time 1 vs. Time 2). Girls and White race served as the reference groups as these groups have been shown to differ significantly in RSA relative to boys and Other race groups, respectively (Beauchaine, 2001; El-Sheikh, 2005; Hinnant, Elmore-Staton, & El-Sheikh, 2011).

Age and BMI have also been shown to be associated with RSA (Calkins & Keane, 2004; Hinnant et al., 2011) and internalizing symptoms (Pederssen, Vitaro, Barker, & Borge, 2007) and, thus, were included as covariates. Further, according to the law of initial values (Block & Bridger, 1962) higher physiological baseline functioning facilitates greater physiological response during challenges. Thus, baseline RSA was included as a covariate in all analyses of RSA reactivity and recovery. As noted above, $\Delta RSA_{Reactivity}$ terms were created by subtracting children's baseline RSA levels (i.e., the final minute of the preceding neutral video) from their mean levels of RSA during the subsequent emotion video segment (averaged across six one-minute epochs) and $\Delta RSA_{Recovery}$ terms were created by subtracting the mean RSA levels during the emotion video segment from the RSA level during the following recovery phase (i.e., the first minute of the following neutral video).

For all hypotheses, children's scores on the Internalizing Problems scale of the CBCL was used as the outcome variable. The regression models for all hypotheses included covariates, including age, race, gender, and BMI, in Step 1. For hypotheses 2-5, video order was included as an additional covariate in Step 1, baseline RSA was included in Step 2, and the linear $\Delta RSA_{Reactivity}$ or $\Delta RSA_{Recovery}$ term was included in Step 3. Finally, for hypothesis 2, a quadratic term for RSA reactivity to sadness was computed by squaring the linear $\Delta RSA_{Reactivity}$ Sadness term and was included in Step 4. The assumptions of regression were evaluated for all analyses.

2.4.1 Power Analysis

Power for the proposed analyses were calculated using G*Power 3.1 (Faul, Erdfelder, Buchner, & Lang, 2009) with an alpha level of .05 and a sample of 114 participants. Although no studies matched the current study's design and hypotheses in terms of variables examined, methods of statistical analysis, and sample age, studies best fitting the current study parameters were used to provide estimates of expected effect sizes. Table 2 displays descriptions of the selected studies' parameters the effect sizes from these studies and the estimated power to detect the current study's five hypotheses effects. Estimated power based on the previous literature is strong for the first four hypotheses. Furthermore, at the time this project was proposed, data were available to conduct a preliminary test of the first hypotheses using a subset of the current sample. This preliminary test yielded a similar effect size (f^2=0.171) to the Forbes, Fox, Cohn, Galles, and Kovacs (2006) study, which further supported the sufficiency of the current sample size.

Table 2. *Description of Studies Used in Power Analysis to Estimate Power in the Current Study*

Hypothesis	Study	Sample	Findings	Effect Size	Power (Current Sample)
1	Forbes et al., 2006	*N* = 57 children M_{age} = 33.4	Low resting RSA associated with high internalizing symptoms on the CBCL	f^2= 0.176	0.988
2	Kogan et al., 2014	*N* = 120 adults M_{age} = 33.4	Negative quadratic association between resting RSA and prosociality	f^2= 0.067	0.865
3	Berna et al., 2014	*N* = 70 women M_{age} = 20.89	Less RSA recovery after anger video among individuals with high emotion regulation difficulties	f^2= 0.099	0.914
4	Cyranowski et al., 2011	*N* = 30 women M_{age} = 29.83	Depressed women demonstrated lower RSA during affection inducing imagery task	f^2= 0.25	0.999
5	Seeley et al., 2016	*N* = 157 adults M_{age} = 28.00	Individuals with no psychiatric diagnoses maintained increases in RSA after happy video while individuals with GAD returned to baseline levels of RSA	η_p^2 = 0.018	0.515

With respect to the fifth hypothesis, the power analysis suggests the current study is underpowered to detect the expected effect. As described previously in this document, very few studies have examined RSA recovery following a positive emotion induction. The study conducted by Seeley et al. (2016) is most similar to the current study design, but the sample age and statistical analysis (i.e., ANOVA) were quite different from the current study. The effect in a sample of children using multiple regression may be different than the effect reported by Seeley et al. (2016). Given the paucity of research on RSA recovery to positive emotions, it seems important to test the hypothesis; however, nonsignificant results will be interpreted cautiously in the context of this potentially limited power and potential range restriction of my RSA reactivity to happiness variable.

3 RESULTS

3.1 Descriptive Statistics

Means and standard deviations for all continuous variables are presented in Table 3. An individual's score on a self-report or parent-report measure was dropped if more than 25% of the items were skipped by the participant, which resulted in one missing case for the internalizing symptoms scale of the CBCL. Six more cases were dropped due to errors during the ECG recording. Additionally, one mother did not consent to showing her child the videos and another child got too upset watching the sad videos to complete the paradigm, which resulted in a total of 106 cases included in analyses.

Table 3. *Means and Standard Deviations for all Continuous Variables*

	Mean	*SD*	Range
Resting RSA	7.600	1.191	4.50 – 10.40
Pre-Sad Baseline RSA	7.628	1.147	4.00 – 10.25
$\Delta RSA_{Reactivity}$ Sadness	-0.154	0.577	-1.79 – 1.79
$\Delta RSA_{Recovery}$ Sadness	0.207	0.513	-1.05 – 1.53
Pre-Happy Baseline RSA	7.588	1.276	4.50 – 10.56
$\Delta RSA_{Reactivity}$ Happiness	-0.205	0.541	-1.62 – 1.47
$\Delta RSA_{Recovery}$ Happiness	0.268	0.525	-1.14 – 1.83
CBCL Internalizing Problems	2.080	1.144	0.00 – 4.69
Age	9.098	1.059	7.08 – 11.83
BMI	17.645	4.610	9.10 – 38.60

Note. Square root transformation of CBCL Internalizing Scale is presented. Logarithmic transformations of RSA variables are presented. RSA = respiratory sinus arrhythmia; BMI = body mass index; *SD* = standard deviation.

Repeated-measures ANOVA indicated that the sad videos in the emotional video paradigm elicited significant mean level changes in RSA, $F(1.74, 182.78) = 6.69$, $p = .003$. Contrasts revealed that RSA levels decreased significantly from baseline to the sad video segment, $F(1, 105) = 7.58$, $p = .007$, and then increased significantly from the sad video segment to the recovery period, $F(1, 105) = 17.19$, $p < .001$ (see Figure 4). The happy videos in the emotional video paradigm elicited similar significant mean level changes in RSA, $F(2, 210) = 13.74$, $p < .001$, with contrasts revealing a significant decrease in RSA level from baseline to the happy video segment, $F(1, 105) = 15.27$, $p < .001$, and then a significant increase in RSA from the happy video segment to the subsequent recovery period, $F(1, 105) = 27.51$, $p < .001$ (see Figure 5).

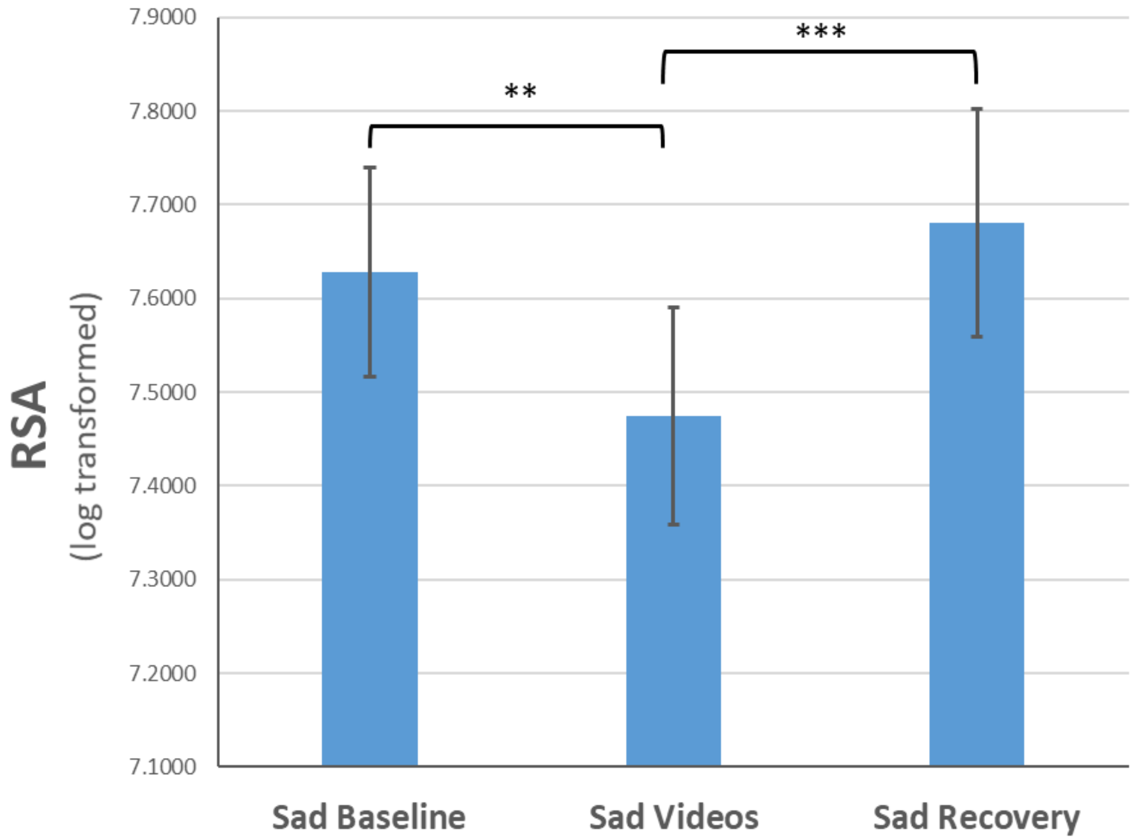

Figure 4. Plot of mean RSA levels in the full sample during sad portion of emotional video paradigm. Error bars indicate 1 standard deviation above and below the mean. **p < .01, ***p < .001

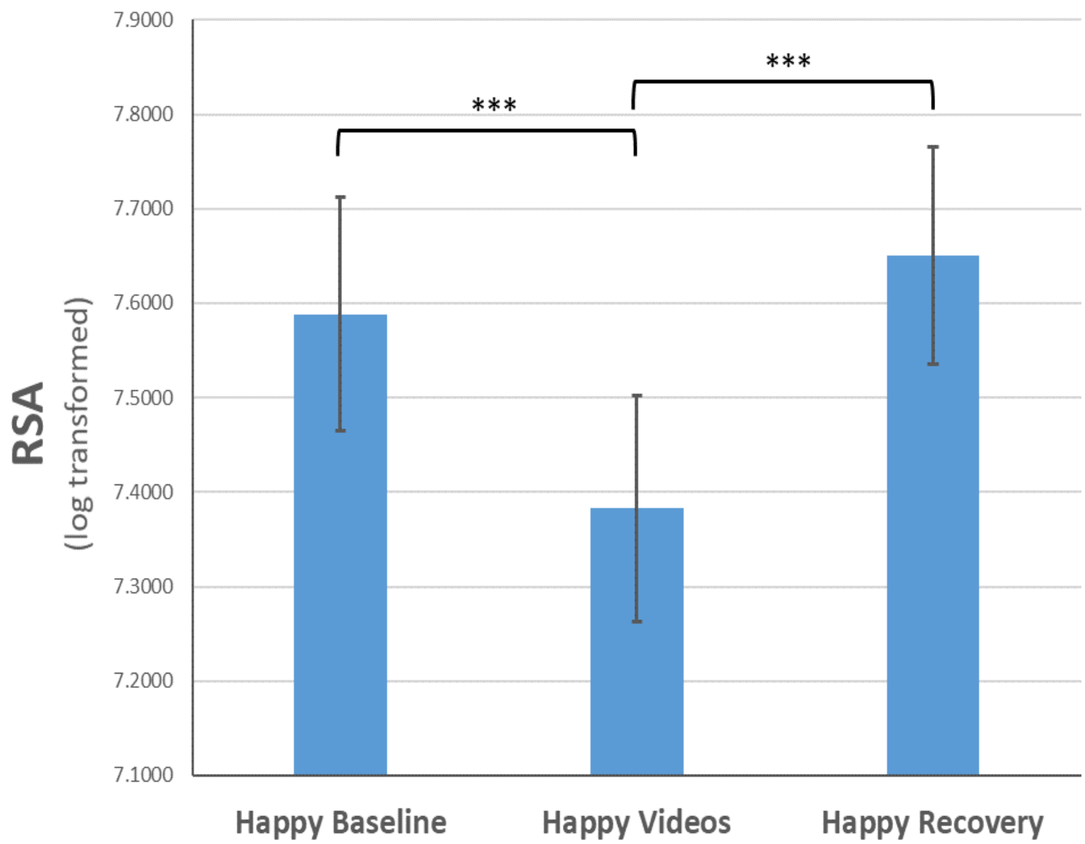

Figure 5. Plot of mean RSA levels in the full sample during happy portion of emotional video paradigm. Error bars indicate 1 standard deviation above and below the mean. ***p < .001

Zero-order correlations between all continuous variables are presented in Table 4. Resting RSA, Pre-Sad Baseline RSA, and Pre-Happy Baseline RSA were all significantly positively correlated with one another and negatively correlated with internalizing problems and significantly. Also, $\Delta RSA_{Reactivity}$ Sadness was significantly positively correlated with $\Delta RSA_{Reactivity}$ Happiness, indicating that children who were highly reactive to the sad video clips (i.e., showed large RSA decreases from baseline to the sad video segment) also tended to be highly reactive to the happy video clips. Further, $\Delta RSA_{Recovery}$ Sadness was significantly negatively correlated with $\Delta RSA_{Reactivity}$ Happiness and significantly positively correlated with $\Delta RSA_{Recovery}$ Happiness. In other words, children who demonstrated greater recovery after watching the sad videos (i.e., showed large increases in RSA from the sad video segment to the post-sad video recovery segment) also tended to be highly reactive to the happy videos and demonstrated greater recovery after watching the happy videos. Finally, $\Delta RSA_{Reactivity}$ Happiness was significantly negatively correlated with $\Delta RSA_{Recovery}$ Happiness and significantly negatively correlated with age. That is, children who were highly reactive to the happy videos (i.e., showed large decreases in RSA from baseline to the happy video segment) also demonstrated greater recovery after the happy videos and were also older. With regards to emotion video ratings, happy video ratings were significantly positively correlated with Resting RSA, Pre-Sad Baseline RSA, and Pre-Happy Baseline RSA, all r's $\geq .263$, all p's $\leq .007$, indicating that children with higher RSA at rest experienced more happiness during the happy videos. Sad video ratings were significantly negatively correlated with internalizing problems, $r = -.202$, $p = .038$, indicating that children with higher internalizing symptoms experienced more sadness during the sad videos. No other correlations between emotion video ratings and the continuous variables in this study were significant.

Table 4. *Zero-Order Correlations between all Continuous Variables*

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1. Resting RSA	-									
2. Pre-Sad Baseline RSA	.893**	-								
3. $\Delta RSA_{Reactivity}$ Sadness	.099	-.170	-							
4. $\Delta RSA_{Recovery}$ Sadness	.101	-.025	-.161	-						
5. Pre-Happy Baseline RSA	.926**	.871**	.149	.045	-					
6. $\Delta RSA_{Reactivity}$ Happiness	-.144	-.054	.192*	-.239*	-.293**	-				
7. $\Delta RSA_{Recovery}$ Happiness	-.037	-.112	-.141	.253*	-.112	-.404**	-			
8. CBCL Internalizing Problems	-.265**	-.219**	-.137	-.019	-.242**	-.053	.126	-		
9. Age	-.176	-.154	.036	-.026	-.158	.233*	-.166	-.055	-	
10. BMI	.024	-.033	.109	-.062	.036	-.023	-.061	-.004	.108	-

Note. Square root transformation of CBCL Internalizing Scale is presented. Logarithmic transformations of RSA variables are presented. RSA = respiratory sinus arrhythmia; BMI = body mass index *p < .05; **p <.01

A series of t-tests were run to test for differences in the study's continuous variables (internalizing symptoms, measures of RSA, age, BMI) by gender, race, video order (i.e., whether sad or happy videos appeared first), and recruitment group (i.e., children recruited at Time 1 vs. Time 2). Boys (M = 0.33, SD = 0.51), relative to girls (M = 0.09, SD = 0.50), demonstrated greater increases in RSA in the recovery period following the sad emotional videos, t = -2.43, p = .016, d = 0.48, but did not differ significantly in mean levels of internalizing symptoms, age, BMI, or any other measures of RSA (all t's ≤ |1.08|, all p's ≥ .285, all d's ≤ 0.21). No significant differences were found in any study variables by race (all t's ≤ |1.80|, all p's ≥ .075, all d's ≤ 0.35), video order (all t's ≤ |1.37|, all p's ≥ .172, all d's ≤ 0.27) or recruitment group (all t's ≤ |1.94|, all p's ≥ .055, all d's ≤ 0.41).

3.2 Manipulation Check

A series of one-sample t-tests were run to test whether the happy and sad emotional videos actually elicited the intended emotional experience in children. Children's SAM valence ratings of their own emotional experience of each video were compared to a value of 0, which represents the absence of an emotional experience on the SAM rating scale. As expected, children reported having a significantly happy emotional experience while watching the happy videos (all t's ≥ 21.15, all p's < .001, all d's ≥ 2.05), and a significantly sad emotional experience while watching the sad videos (all t's ≤ -12.57, all p's < .001, all d's ≥ 1.22). These findings indicate that the emotional video paradigm was successful in inducing the intended emotions.

3.3 Test of Study Hypotheses

3.3.1 Testing of regression assumptions

The assumption of normality was examined using the Kolmorgorov-Smirnov test of normality in conjunction with histograms and Q-Q plots. The distribution of internalizing problems, the dependent variable, was skewed (skewness = 1.125, *SE* = .235) and differed significantly from a normal distribution, $D(106) = .166$, $p < .001$, so a square root transformation of this variable was used in analyses. Examination of Q-Q plots of the residuals of each regression analysis using this square root transformed variable revealed no notable deviations from the expected linear line, thus indicating normality of residuals. Additionally, Kolmogorov-Smirnov tests of normality were run on the residuals from each of the regression models. The results indicated that none of the regressions yielded residuals that differed significantly from a normal distribution.

To evaluate the assumption of linear regression that there is a lack of multicollinearity, tolerance values were examined in analyses using linear terms for the independent variables. Tolerance values of < .10 are assumed to indicate a potential problem with collinearity (Cohen, West, & Aiken, 2003). No tolerance values < .10 were found. Tolerance values were not examined in analyses using a quadratic term for the independent variable in the final step as this term is necessarily highly correlated with the linear term included in the previous steps and this collinearity does not usually present a problem (Jaccard & Turrisi, 2003).

To check for multivariate outliers, the Cook's *D* statistic was calculated for each regression model. Cook's *D* combines information about the residuals and leverage and measures the effect of deleting individual data points. As recommended by Fox (1991), cases with Cook's *D* values greater than 4/(n-k-1) are considered to have undue influence on the outcome of the regression analysis and thus, were removed from analysis. The number of removed cases for each hypothesis are described below.

3.3.2 Regression analyses

3.3.2.1 Hypothesis 1

Five cases were found to have undue influence on the outcome of the regression analysis and were removed from analysis. Results from the regression analyses of internalizing symptoms on resting RSA are displayed in Table 4. None of the covariates included in Step 1 were significant predictors of children's internalizing symptoms. As expected, when resting RSA was added in Step 2, it significantly predicted children's internalizing symptoms above the effects of gender, age, race, and BMI. As shown in Figure 6, there was a negative association between resting RSA and children's internalizing symptoms, such that lower levels of resting RSA were associated with higher levels of internalizing symptoms. Thus, Hypothesis 1 was supported.[1]

Table 5. *Hierarchical Linear Regression of Internalizing Symptoms on Resting RSA*

Predictors	ΔR^2	*B*	*SE*	β	*p*
Step 1	.024				.668
Gender		.012	.221	.006	.956
Age		.033	.110	.031	.765
Race		-.323	.221	-.148	.147
BMI		-.008	.024	-.033	.750
Step 2	.150				.000
Resting RSA		-.370	.089	-.397	.000

Note. Unstandardized and standardized regression coefficients are presented. Gender was represented as a dummy variable with female serving as the reference group. Race was represented as a dummy variable with White serving as the reference group. Video Order was represented a dummy variable with Sad/Happy serving as the reference group. *SE* = standard error; RSA = respiratory sinus arrhythmia; BMI = body mass index.

[1] Additional analyses were run using the Anxious-Depressed and Withdrawn-Depressed scales of the CBCL (which comprise the Internalizing Problems scale used in this study) as outcome variables. Similar to the findings with the Internalizing scale, there was a significant negative linear association between resting RSA and anxious-depressed symptoms, β = -.358, $p < .001$, such that lower resting RSA was associated with higher levels of anxious-depressed symptoms. The association between resting RSA and withdrawn-depressed symptoms was not significant, β = -.172, $p = .092$.

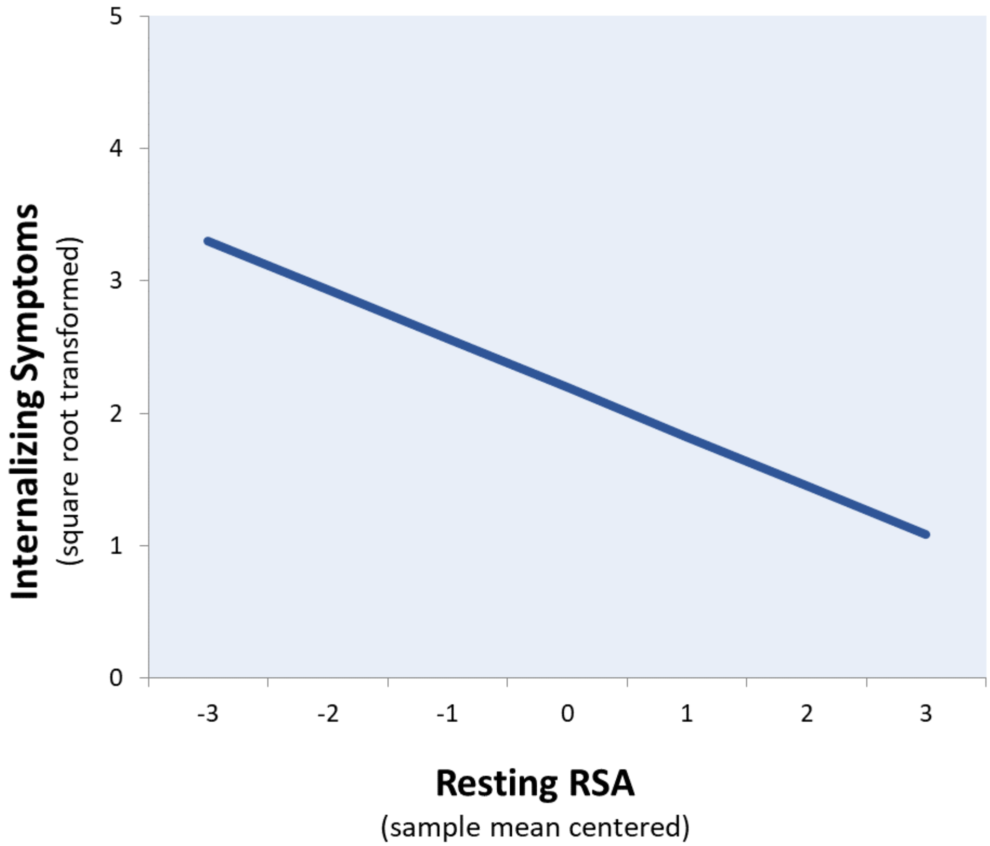

Figure 6. Plot of the linear association between resting RSA and children's internalizing symptoms

3.3.2.2 Hypothesis 2

Four cases were found to have undue influence on the outcome of the regression analysis and were removed from analysis. Results from the regression analyses of internalizing symptoms on the quadratic effect of $\Delta RSA_{Reactivity}$ to sadness are displayed in Table 5. None of the covariates included in Step 1 were significant predictors of children's internalizing symptoms. Baseline RSA (i.e., the 1-minute of neutral video immediately preceding the start of the sad videos) was added in Step 2, and higher levels of baseline RSA were found to significantly predict lower levels of internalizing symptoms. Similarly, when the linear effect of $\Delta RSA_{Reactivity}$ to sadness was added in Step 3, it significantly predicted internalizing symptoms above the effects of baseline RSA, gender, age, race, BMI, and video order. Contrary to my hypothesis, the quadratic effect of $\Delta RSA_{Reactivity}$ to sadness included in Step 4 was not a significant predictor of children's internalizing symptoms. Figure 7 shows the plot of the quadratic effect of $\Delta RSA_{Reactivity}$ to sadness on children's internalizing symptoms. There was a significant negative linear association between $\Delta RSA_{Reactivity}$ to sadness and children's internalizing symptoms, such that larger decreases in RSA from baseline while watching the sad videos were associated with higher levels of internalizing symptoms. These results partially support Hypothesis 2 in that low levels (indicating large decreases in RSA) but not high levels (indicating increases in RSA) of $\Delta RSA_{Reactivity}$ were associated with high levels of internalizing problems, i.e., the association was a negative linear effect and not positive quadratic effect.[2]

[2] Additional analyses were run using the Anxious-Depressed and Withdrawn-Depressed scales of the CBCL as the outcome variables. There was a significant negative linear association between $\Delta RSA_{Reactivity}$ to sadness and anxious-depressed symptoms, $\beta = -.227$, $p = .023$, such that larger decreases in RSA from baseline to the sad video segment were associated with higher levels of anxious-depressed symptoms. The quadratic association between $\Delta RSA_{Reactivity}$ to sadness and anxious-depressed symptoms was not significant, $\beta = -077$, $p = .444$. Neither the linear, $\beta = -.078$, $p = .457$, nor the quadratic, $\beta = .076$, $p = .485$, association between $\Delta RSA_{Reactivity}$ to sadness and withdrawn-depressed symptoms was significant.

Table 6. *Hierarchical Curvilinear Regression of Internalizing Symptoms on RSA Reactivity to Sadness*

Predictors	ΔR^2	*B*	*SE*	β	*p*
Step 1	.035				.631
Gender		-.031	.221	-.014	.888
Age		.026	.110	.024	.811
Race		-.340	.220	-.156	.126
BMI		-.009	.024	-.039	.704
Video Order		.201	.221	.093	.366
Step 2	.083				.003
Baseline RSA		-.280	.093	-.298	.003
Step 3	.047				.023
$\Delta RSA_{Reactivity}$ Sadness		-.432	.188	-.228	.023
Step 4	.015				.190
$\Delta RSA_{Reactivity}$ Sadness ^{2}		.140	.182	.133	.190

Note. Unstandardized and standardized regression coefficients are presented. Gender was represented as a dummy variable with female serving as the reference group. Race was represented as a dummy variable with White serving as the reference group. Video Order was represented a dummy variable with Sad/Happy serving as the reference group. *SE* = standard error; RSA = respiratory sinus arrhythmia; BMI = body mass index.

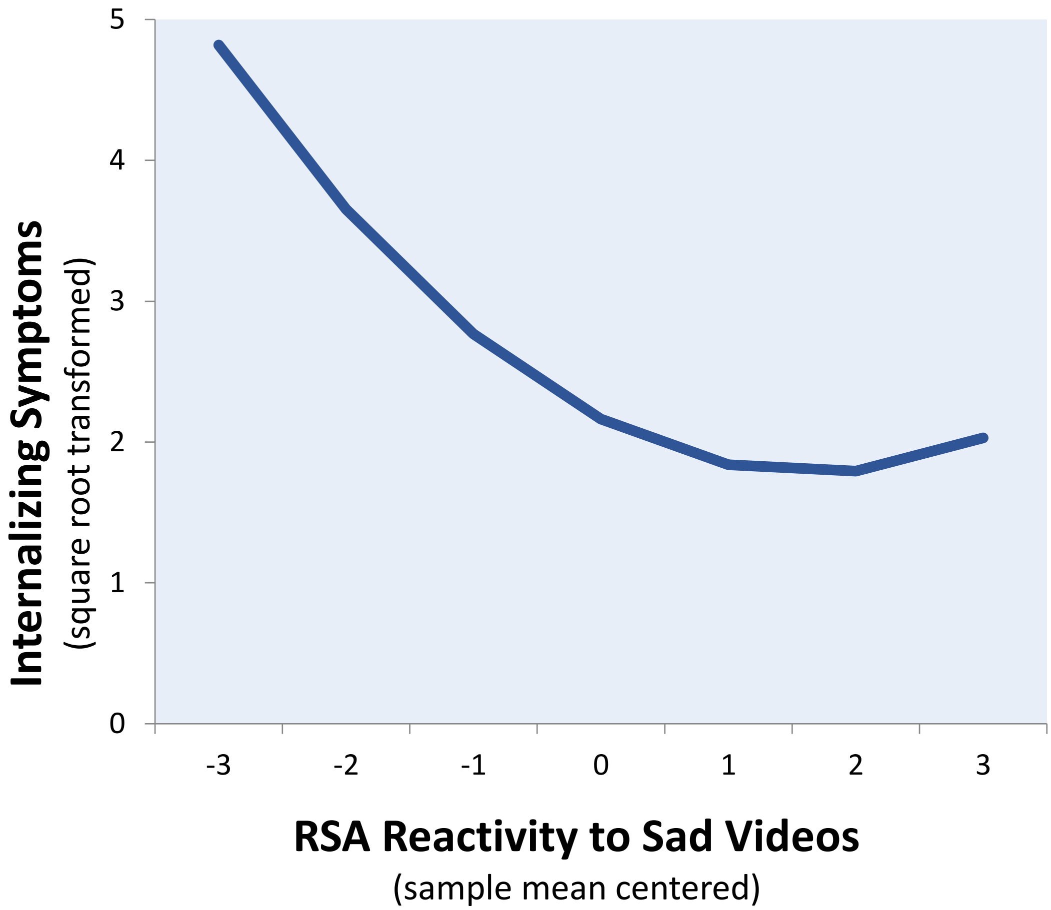

Figure 7. Plot of the quadratic association between RSA reactivity to sad videos and children's internalizing symptoms

3.3.2.3 Hypothesis 3

Five cases were found to have undue influence on the outcome of the regression analysis and were removed from analysis. Results from the regression analyses of internalizing symptoms on the linear effect of $\Delta RSA_{Recovery}$ from sadness are displayed in Table 6. None of the covariates included in Step 1 were significant predictors of children's internalizing symptoms. When Baseline RSA was added in Step 2, higher levels of baseline RSA was found to significantly predict lower levels of internalizing symptoms. Unexpectedly, the linear effect of $\Delta RSA_{Recovery}$ from sadness included in Step 3 was not a significant predictor of children's internalizing symptoms above the effects of baseline RSA, gender, age, race, BMI, and video order (see Figure 8). Thus, Hypothesis 3 was not supported.[3]

Table 7. *Hierarchical Linear Regression of Internalizing Symptoms on RSA Recovery from Sadness*

Predictors	ΔR^2	*B*	*SE*	β	*p*
Step 1	.030				.708
Gender		.058	.223	.027	.795
Age		-.015	.108	-.015	.888
Race		-.319	.222	-.147	.153
BMI		-.007	.024	-.030	.771
Video Order		.165	.221	.076	.459
Step 2	.098				.002
Baseline RSA		-.317	.097	-.322	.002
Step 3	.004				.525
$\Delta RSA_{Recovery}$ Sadness		.089	.140	.064	.525

Note. Unstandardized and standardized regression coefficients are presented. Gender was represented as a dummy variable with female serving as the reference group. Race was represented as a dummy variable with White serving as the reference group. Video Order was represented a dummy variable with Sad/Happy serving as the reference group. *SE* = standard error; RSA = respiratory sinus arrhythmia; BMI = body mass index.

[3] Additional analyses were run using the Anxious-Depressed and Withdrawn-Depressed scales of the CBCL as the outcome variables. The association between $\Delta RSA_{Recovery}$ from sadness and anxious-depressed symptoms was not significant, β = .083, *p* = .409, nor was the association between $\Delta RSA_{Recovery}$ from sadness and withdrawn-depressed symptoms, β = -.010, *p* = .922.

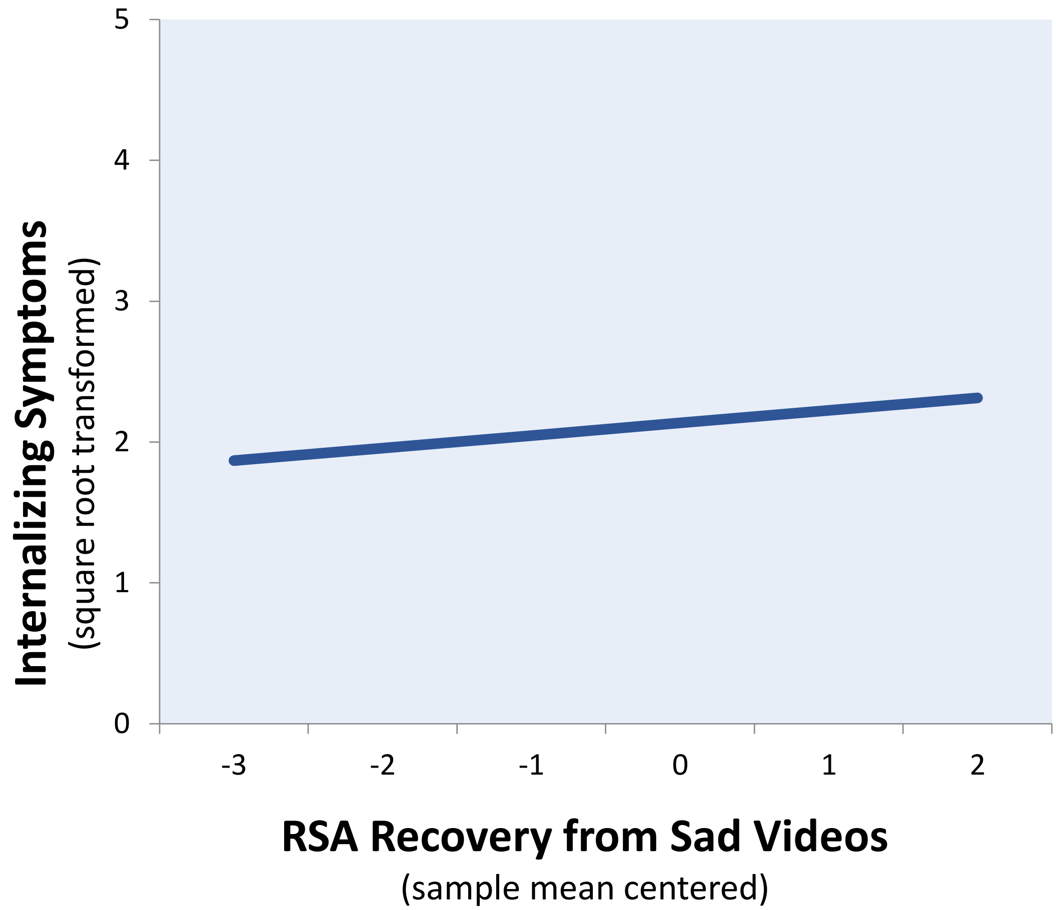

Figure 8. Plot of the linear association between RSA recovery from sad videos and children's internalizing symptoms.

3.3.2.4 Hypothesis 4

Five cases were found to have undue influence on the outcome of the regression analysis and were removed from analysis. Results from the regression analyses of internalizing symptoms on the linear effect of $\Delta RSA_{Reactivity}$ to happiness are displayed in Table 7. None of the covariates included in Step 1 were significant predictors of children's internalizing symptoms. In Step 2, higher baseline RSA significantly predicted lower levels of internalizing symptoms. Contrary to the hypothesis, the linear effect of $\Delta RSA_{Reactivity}$ to happiness included in Step 3 was not a significant predictor of children's internalizing symptoms above the effects of baseline RSA, gender, age, race, BMI, and video order (see Figure 9). Thus, Hypothesis 4 was not supported.[4]

Table 8. *Hierarchical Linear Regression of Internalizing Symptoms on RSA Reactivity to Happiness*

Predictors	ΔR^2	*B*	*SE*	β	*p*
Step 1	.031				.702
Gender		-.071	.212	-.033	.738
Age		-.037	.110	-.034	.738
Race		-.171	.214	-.079	.425
BMI		-.010	.023	-.042	.666
Video Order		.249	.212	.115	.242
Step 2	.109				.001
Baseline RSA		-.313	.087	-.367	.001
Step 3	.012				.262
$\Delta RSA_{Reactivity}$ Happiness		-.239	.212	-.114	.262

Note. Unstandardized and standardized regression coefficients are presented. Gender was represented as a dummy variable with female serving as the reference group. Race was represented as a dummy variable with White serving as the reference group. Video Order was represented a dummy variable with Sad/Happy serving as the reference group. *SE* = standard error; RSA = respiratory sinus arrhythmia; BMI = body mass index.

[4] Additional analyses were run using the Anxious-Depressed and Withdrawn-Depressed scales of the CBCL as the outcome variables. The association between $\Delta RSA_{Reactivity}$ to happiness and anxious-depressed symptoms was not significant, β = -.107, *p* = .293, nor was the association between $\Delta RSA_{Reactivity}$ to happiness and withdrawn-depressed symptoms, β = -.118, *p* = .268.

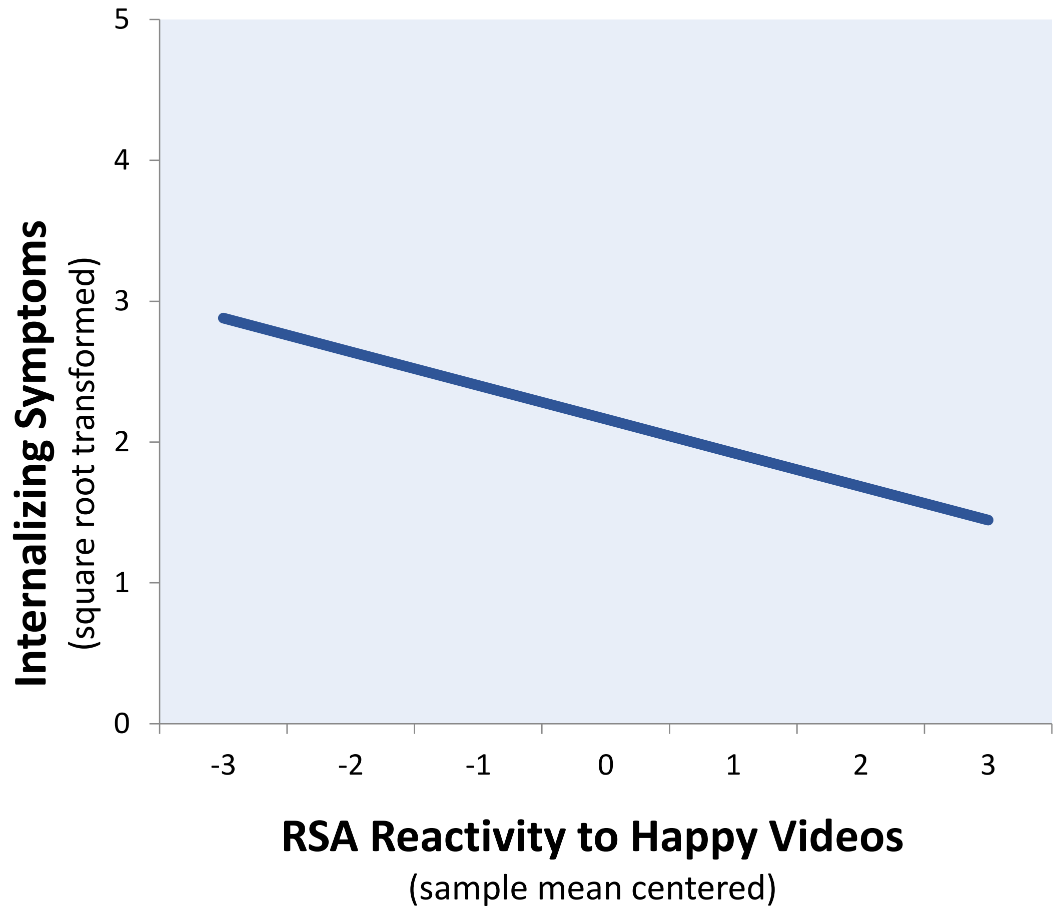

Figure 9. Plot of the linear association between RSA reactivity to happy videos and children's internalizing symptoms

3.3.2.5 Hypothesis 5

Five cases were found to have undue influence on the outcome of the regression analysis and were removed from analysis. Results from the regression analyses of internalizing symptoms on the linear effect of $\Delta RSA_{Recovery}$ from happiness are displayed in Table 8. None of the covariates included in Step 1 were significant predictors of children's internalizing symptoms. In Step 2, higher levels of baseline RSA significantly predicted lower levels of internalizing symptoms. Contrary to the hypothesis, the linear effect of $\Delta RSA_{Recovery}$ from happiness included in Step 3 was not a significant predictor of children's internalizing symptoms above the effects of baseline RSA, gender, age, race, BMI, and video order (see Figure 10). Thus, Hypothesis 5 was not supported.[5]

Table 9. *Hierarchical Linear Regression of Internalizing Symptoms on RSA Recovery from Happiness*

Predictors	ΔR^2	*B*	*SE*	β	*p*
Step 1	.042				.523
Gender		-.022	.224	-.010	.921
Age		-.009	.108	-.008	.934
Race		-.412	.222	-.188	.066
BMI		-.005	.024	-.021	.838
Video Order		.174	.222	.080	.435
Step 2	.113				.001
Baseline RSA		-.302	.085	-.347	.001
Step 3	.002				.667
$\Delta RSA_{Recovery}$ Happiness		.072	.166	.043	.667

Note. Unstandardized and standardized regression coefficients are presented. Gender was represented as a dummy variable with female serving as the reference group. Race was represented as a dummy variable with White serving as the reference group. Video Order was represented a dummy variable with Sad/Happy serving as the reference group. *SE* = standard error; RSA = respiratory sinus arrhythmia; BMI = body mass index.

[5] Additional analyses were run using the Anxious-Depressed and Withdrawn-Depressed scales of the CBCL as the outcome variables. The association between $\Delta RSA_{Recovery}$ from happiness and anxious-depressed symptoms was not significant, β = .049, *p* = .620, nor was the association between $\Delta RSA_{Recovery}$ from happiness and withdrawn-depressed symptoms, β = .014, *p* = .897.

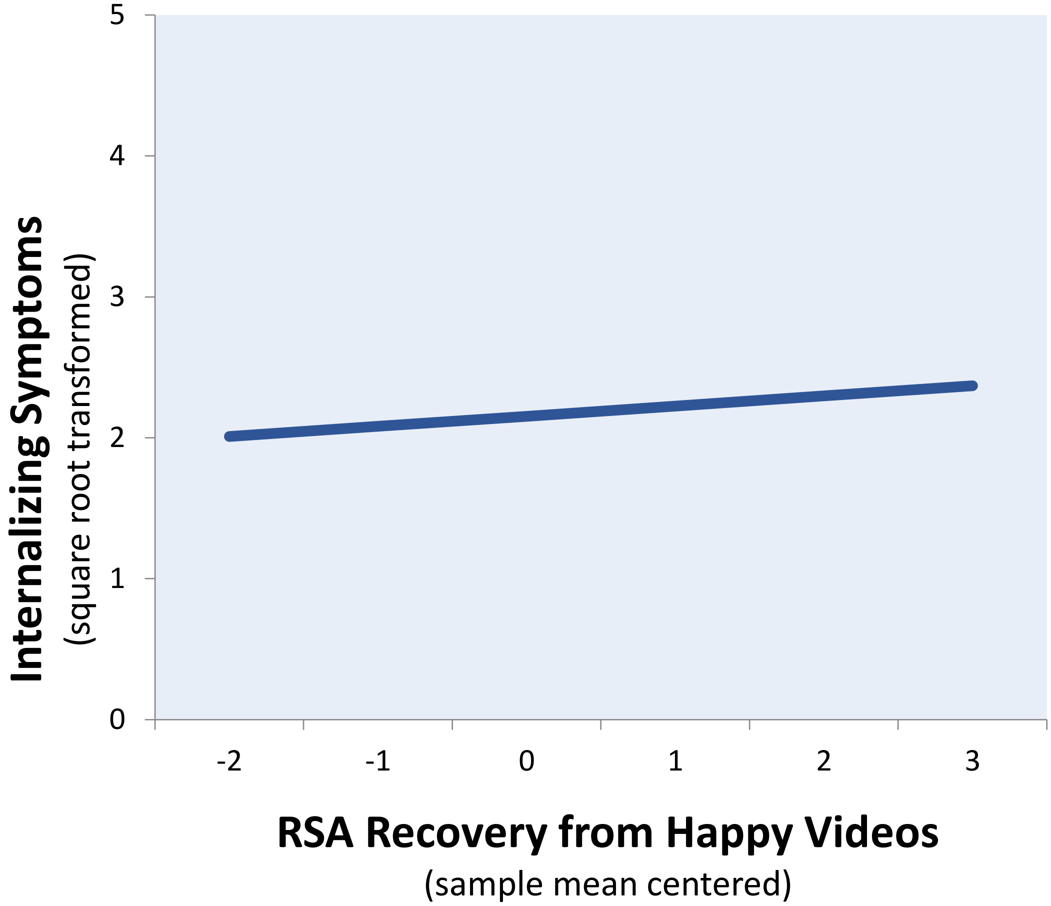

Figure 10. Plot of the linear association between RSA recovery from happy videos and children's internalizing symptoms.

In summary, Hypothesis 1 was supported; there was a significant negative association between resting RSA and children's internalizing symptoms, such that lower resting RSA was associated with higher internalizing symptoms. Hypothesis 2 was partially supported; while the quadratic effect of $\Delta RSA_{Reactivity}$ to sadness was not significant, the linear effect was. Greater decreases in RSA from baseline to the sad video segment were associated with higher levels of internalizing symptoms. Finally, Hypotheses 3-5 were not supported; there was no significant associations between $\Delta RSA_{Recovery}$ from sadness, $\Delta RSA_{Reactivity}$ to happiness, or $\Delta RSA_{Recovery}$ from happiness and children's internalizing symptoms. Similar results were found using the Anxious-Depressed scale of the CBCL as the outcome variable. No significant associations were found using the Withdrawn-Depressed scale.

4 CONCLUSIONS

A growing body of theory and research has implicated cardiac vagal activity (indexed by RSA) in the emotion dysregulation underlying internalizing psychopathology (Appelhans & Luecken, 2006; Beauchaine, 2015; Porges, 2007; Thayer & Lane, 2000), but the majority of these studies have focused on resting RSA or RSA reactivity to stress in general in adolescent or adult samples. Far fewer studies have examined phasic changes in RSA during social emotional situations in relation to internalizing psychopathology, particularly during middle childhood. Examining phasic changes in children's RSA both during and after observation of other children's happiness and sadness in relation to their level of internalizing symptoms, can lead to a better understanding of how physiological emotion regulation unfolds across social emotional situations, which has direct implications for understanding the social-cognitive risks for internalizing problems that emerge during middle childhood. The current study adds to the extant literature supporting the idea that low resting RSA and excessive, but not blunted, RSA reactivity to sadness predict internalizing problems during middle childhood. In contrast, RSA reactivity to happiness and RSA recovery after happiness and sadness were not associated with internalizing problems during this time. These results suggest that internalizing psychopathology in middle childhood is more closely linked to an individual's trait-like capacity for physiological emotion regulation and dysregulation of negative emotions, such as sadness, in the moment than positive emotions, such as happiness. Furthermore, consistent with the increased prevalence rates of anxiety relative to depression during middle childhood, the association between internalizing problems and excessive physiological reactivity to sadness was specific to anxious-depressed symptoms as opposed to withdrawn-depressed symptoms.

4.1 Resting RSA

Resting RSA is thought to indicate an individual's trait-like capacity for flexible physiological emotion regulation (Appelhans & Luecken, 2006; Balzarotti et al., 2017; Porges, 2007; Thayer & Lane, 2000), and I hypothesized that low resting RSA provides a measure of the liability toward emotion dysregulation associated with internalizing psychopathology in children. This hypothesis was supported in that there was a significant negative association between resting RSA and children's internalizing symptoms, such that lower levels of resting RSA were associated with higher levels of internalizing symptoms. As described previously, the physiological arousal systems involved in emotional responding are under tonic inhibitory control via parasympathetic influences that are measured by RSA (Appelhans & Luecken, 2006; Berntson et al., 1997). One interpretation of this finding is that, when this inhibitory control is low, as is the case for individuals with low resting RSA, it may reflect poor top-down regulation of prefrontal cortical areas over subcortical limbic structures and inflexible disinhibition of sympathoexcitatory influences, which promotes over-activation of the fight-or-flight response and overly persistent activation of defensive systems, thereby limiting an individual's ability to track and respond flexibly to changing environmental demands via a compromised ability to inhibit inappropriate responses (Thayer & Lane, 2000). Ultimately, this can lead to difficulties detecting and experiencing 'safety' when it is in fact present, attentional biases to negative or threatening information, and negatively-biased information processing, and can lead individuals to become 'stuck' in defensive and disorganized behavioral patterns (Clark & Beck, 201; Bylsma et al., 2008; LeMoult & Gotlib, 2019; Porges, 2007; Thayer & Lane, 2000). Further, the physiological state indexed by low resting RSA (i.e., tonic reductions in PNS activity and tonic elevations in SNS activity) is thought to underlie the temperament trait behavioral inhibition, which predisposes children to develop anxiety, worry, and depression (Fox et al., 2001; Hirshfeld-becker et al., 2007; Kagan, 2008; Rubin et al., 2009; Wichmann et al., 2004).

The present findings are consistent with previous studies that have found associations between low resting RSA and several forms of internalizing psychopathology, including depression (Kemp et al., 2010; Rottenberg et al., 2007), anxiety (Dieleman et al., 2015; Friedman, 2007; Henje Blom et al., 2010), panic disorder (Friedman & Thayer, 1998), and parasuicidal behaviors (Crowell et al., 2005). However, the majority of these associations have been found in adolescent and adult samples, whereas studies of young children have often found no association between resting RSA and internalizing symptoms (Fortunato et al., 2013). Thus, the current study extends the literature by providing support for low resting RSA as a correlate of internalizing symptoms during middle childhood and suggests low resting RSA could be a potential risk factor for internalizing problems and a potential marker of the emotion dysregulation liability.

4.2 RSA Reactivity to Sadness

Based on previous studies of the meta-structure of internalizing psychopathology (Tully & Iacono, 2016), I proposed that the physiological emotion dysregulation liability underlying internalizing psychopathology would be expressed as two distinct patterns when observing others' sadness – under-regulation and over-regulation. I thus hypothesized that both blunted RSA reactivity to displays of sadness, reflecting the physiological hypo-reactive dysregulation liability, and excessive RSA reactivity to displays of sadness, reflecting the physiological hyper-reactive dysregulation liability, would be associated with high internalizing symptoms in children. Contrary to my prediction, the quadratic association between RSA reactivity to sadness and children's internalizing symptoms was not significant. There was, however, a significant linear association, such that excessive RSA reactivity (i.e., larger decreases in RSA from baseline in response to other children's sadness) were associated with higher levels of internalizing symptoms than were smaller decreases in RSA. These results partially support my second hypothesis in that children who demonstrated physiological hyper-reactivity, but not children who demonstrated physiological hypo-reactivity, were reported to have higher levels of internalizing symptoms.

According to Porges (2007), the inhibitory influence of the vagal brake is withdrawn (reflected by decreases in RSA) during stressful or negative emotional situations in order to mobilize the necessary physiological resources needed to effectively respond to the situation. However, excessive vagal withdrawal (hyper-reactivity) can lead to physiological hyperarousal and hypervigilance, which can contribute to physical and cognitive internalizing symptoms such as stress, anxiety, and worry (Thayer & Lane, 2000; Boyce et al., 2001). Greater decreases in RSA may also indicate a stronger empathic reaction to other children's sadness. Empathy typically functions as an adaptive characteristic and has been associated with strong social relationships (Chow, Ruhl, & Buhrmester, 2013), social engagement (Bailey, Henry, & Von Hippel, 2008), and resilience (Shiner & Masten, 2012); however, as outlined in Tone and Tully (2014)'s model of risky empathy development, among children with a proclivity to experience physiological hyperarousal in distressing interpersonal situations, greater empathy can actually increase the risk for certain internalizing conditions by evoking maladaptive personal distress responses and social withdrawal behaviors. If these withdrawal behaviors are successful in reducing aversive physiological arousal and distress, children's avoidance of social situations is reinforced, thus depriving them opportunities to develop age-appropriate social skills (Rubin et al., 2006), increasing their likelihood of future social rejection and peer victimization (Nelson et al., 2005; Rubin et al., 2009), and leading some to develop negative self-appraisals and negative self-esteem Abe & Izard, 1999; Nelson et al., 2005; Rudolph et al., 2008), thereby increasing their risk for internalizing problems (Hay, Payne, & Chadwick, 2004; Rudolph et al., 2003; 2008).

Unexpectedly, there was no significant association between blunted RSA reactivity to sadness and children's internalizing symptoms. This may be due to the developmental progression of the emotion dysregulation liabilities in internalizing psychopathology. As mentioned previously, anxiety is more likely than depression to onset during childhood, depression is most often comorbid with anxiety in childhood, and anxiety tends to precede and predict later depression (Hettema et al., 2006; Tully & Iacono, 2016; Zahn-Waxler et al., 2000). It follows that the liability to experience physiological hyperarousal to negative emotional stimuli, which is more often associated with anxiety disorders, would onset earlier in childhood. The general internalizing liability may become more differentiated across development as age-related expressions of genes that are specific to certain internalizing attributes begin to emerge (i.e., negative thought processes; Tully & Iacono, 2016). Middle childhood is a time when peer relationships become increasingly related to children's psychological adjustment relative to earlier developmental periods (Hay et al., 2004; Hymel et al., Lancy & Grove, 2011) and children are just beginning to develop more trait-like self-concepts (Abe & Izard, 1999; Nelson et al., 2005). However, during this time children may still lack the cognitive abilities to develop stable and pathological cognitive styles, such as negative schema and attributional styles and hopelessness about the future, which do not become consolidated and associated with internalizing problems until early adolescence (Abela & Hankin, 2008; Beck, 1976; Turner & Cole, 1994; Kaslow, Adamson, & Collins, 2000).

The stabilization of these dysfunctional cognitive processes in adolescence would help explain the increases in rates of depression observed during this period (Thapar et al., 2012) and why there was no association between blunted RSA reactivity to sadness and internalizing symptoms in the current study. According to the emotion context insensitivity hypothesis, depression is a defensive motivational state that evolved to bias against action in situations where behavior is perceived to be wasteful or futile, which ultimately leads to environmental disengagement and reduced reactivity to emotional stimuli (Bonanno & Burton, 2013; Bylsma et al., 2008; Rottenberg et al., 2007). From this perspective, children in the current study may have not yet fully developed the stable negative cognitive styles that bias their perceptions of themselves, their abilities, and their expectations of the future that would lead some to exhibit blunted physiological reactivity in social emotional situations. Thus, the physiological emotion dysregulation liability associated with high internalizing symptoms may be expressed as excessive RSA reactivity and physiological hyperarousal in negative social emotional situations during middle childhood until the emergence of more stable negative cognitive styles in adolescence, at which point, some children with high internalizing symptoms may express this physiological dysregulation liability as blunted RSA reactivity to emotional stimuli. Consistent with this interpretation, I found that whereas excessive RSA reactivity to sadness was associated with anxious-depressed symptoms, there was no association between RSA reactivity to sadness and withdrawn-depressed symptoms. An interesting avenue for future research would be to follow these children longitudinally to see if different relations between patterns of RSA reactivity to emotional stimuli and internalizing symptoms emerge in adolescence.

4.3 RSA Recovery after Sadness

Contrary to my third hypothesis, no significant association between children's RSA recovery after witnessing other children's sadness and their level of internalizing symptoms was found. This finding is inconsistent with the few previous studies showing that children and adults with high internalizing symptoms or emotion regulation difficulties exhibited less RSA recovery following emotionally stressful or challenging tasks (Berna et al., 2014; Boyce et al., 2001; Brosschot et al., 2007; Key et al., 2008; Movius & Allen, 2005). Possible reasons for the discrepant findings across studies may be the nature of the sample or the particular tasks. With regards to the sample, the vast majority of studies that have found significant associations between poor RSA recovery following a stressor and high internalizing symptoms have utilized adult samples (Berna et al., 2014; Brosschot et al., 2007; Key et al., 2008; Movius & Allen, 2005). Similar to the other negative thought processes described above, negative perseverative cognitions, such as worry and rumination, which are hallmark features of depression and GAD, may not fully stabilize or be consistently associated with internalizing symptoms until the transition from childhood to adolescence (Lakdawalla Hankin, & Mermelstein, 2007).

There has been far less research on RSA recovery in relation to internalizing symptoms in children and the few studies have produced mixed results. This may be due to the various types of stressor tasks used in these studies. The only study that found low RSA recovery to be associated with high internalizing symptoms assessed recovery following a cognitive stressor task that involved reciting back strings of digits from memory (Boyce et al., 2001), whereas, another study that assessed RSA recovery after watching a sad video clip found no significant association with internalizing symptoms (Gentzler et al., 2009). Thus, it may be that cognitive stressors are more distressing than emotional stressors during middle childhood. Alternatively, the active involvement of the child in the cognitive task may be more likely to trigger a pattern of negatively biased, self-referent information processing in children with high internalizing symptoms that could have maintained their elevated levels of physiological arousal compared to tasks involving passive viewing of sad emotional videos. Future research could explore this possibility by utilizing personally-relevant emotional stimuli to induce negative emotions or setting up simulated negative social interactions using a confederate to see if a similar pattern emerges in children with high internalizing symptoms. It is also possible that the nature videos children viewed after the sad videos could have had a calming effect that may have helped reduce the physiological arousal they experienced when witnessing other children's sadness, such that it masked differences in recovery rate for children with high and low internalizing symptoms. Alternatively, the nature videos could have served as a distraction, which has been shown to reduce rumination (Broderick, 2005; Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008).

4.4 RSA Reactivity to Happiness

My hypothesis that in general RSA would increase during positive emotional states but that children with high internalizing symptoms would exhibit smaller RSA increases in response to other children's displays of happiness was not supported. Unexpectedly, children in the current study exhibited significant decreases in RSA from baseline while viewing other children's happiness and there was no association between RSA reactivity to happiness and children's level of internalizing symptoms. Interestingly, children still reported subjective experiences of happiness on the SAM rating scales after watching the happy videos, which suggests that changes in RSA may be associated with emotional arousal, independent of valence. Recently researchers have proposed that decreases in RSA followed by increases in physiological arousal to positive emotions may reflect increased motivational engagement and facilitation of approach-related behaviors (Kreibig, Gendolla, & Scherer, 2010; Shiota et al., 2011). Indeed, previous studies have also demonstrated RSA decreases during positive emotional states in young children and young adults (Fortunato et al., 2013; Frazier et al., 2004; Shiota et al., 2011); however, infant and adult studies have found the opposite to be true (Bazhenova & Porges, 1997; Cyranowski et al., 2011; Matsunaga et al., 2009; Porges, 2001; Seeley et al., 2016). The differences across studies may be due to the type of positive emotions induced. In her review of autonomic nervous system activity in emotion, Kreibig (2010) found that different positive emotions are associated with different patterns of RSA reactivity. Specifically, happiness has consistently been shown to be associated with decreases in RSA, whereas other positive emotions, such as love, are associated with increases in RSA. The social affiliative nature of love, as opposed to happiness, may be more likely to involve parasympathetic activation, which is consistent with Porges' polyvagal theory of RSA (Porges, 1997; 2001) and would explain why some studies found an increase in RSA during positive mood inductions (Cyranowski et al., 2011; Matsunaga et al., 2009; Porges, 2001).

There was no significant association between RSA reactivity to happiness and children's internalizing symptoms. While research on RSA reactivity during positive emotional states in relation to internalizing psychopathology is limited, one study found that while both depressed and non-depressed women demonstrated a significant increase in RSA from baseline during a guided imagery task about love, depressed women's levels of RSA increased less and were significantly lower than the non-depressed women during the imagery task (Cyranowski et al., 2011). Again, the difference in the positive emotion being induced (love vs. happiness) could explain the difference between these results and the results of the current study. The current study findings are more similar to the Fortunato et al. (2013) study, which found that young children demonstrated decreases in RSA while watching a happiness-inducing video clip, but there was no association between this RSA reactivity and children's internalizing symptoms. Taken together, the significant association between excessive RSA reactivity to sadness and internalizing symptoms and the lack of association between RSA reactivity to happiness and internalizing symptoms, suggests that internalizing psychopathology is better characterized by physiological dysregulation of withdrawal-motivation based emotions (e.g., fear and sadness) during middle childhood (Fortunato et al., 2013; McNaughton & Corr, 2009).

4.5 RSA Recovery after Happiness

My exploratory hypothesis that children with low internalizing symptoms will have sustained increases in RSA after witnessing other children's happiness and children with high internalizing symptoms will have poorer sustainability of their physiological reactivity, indicated by larger decreases in RSA from task to recovery period was not supported. Children in the current study demonstrated a decrease in RSA from baseline to the happy videos, followed by a post-video increase during the recovery period that was not significantly associated with their level of internalizing symptoms. These findings are in contrast with a previous study, which found that adults with and without GAD demonstrated similar increases in RSA from baseline while watching an amusing film clip but that only the control group maintained this effect, whereas individuals with GAD returned to levels of RSA that were not significantly different than their baseline RSA (Seeley et al., 2016). The difference between these findings and the results of the current study is likely due to the fact that the participants in the Seeley et al. (2016) study exhibited an increase in RSA during the amusement task, whereas the children in the current study exhibited decreases in RSA and thus, did not have the same kind of reactivity to sustain. This may be due to the nature of the baseline task. Specifically, the Seeley et al. (2016)

study assessed emotion-related changes in RSA while participants watched a video clip, but assessed baseline RSA while participants sat quietly in a room, which requires less attentional engagement. This design does not account for the “orienting effect” to the method of emotion induction (Bradley, 2009; Stekelenbrg & van Boxtel, 2002). Researchers have found that perception of and orienting toward novel stimuli or features of the environment is associated with heart rate deceleration, which could be due to increased PNS activity (Bradley, 2009; Shiota et al., 2011). This suggests that any changes in RSA from the sitting still baseline to watching an amusing video that Seeley et al. found may be related to attention being oriented to the task of watching videos rather than the emotion being induced by the video.

Given that the children in the current study exhibited a significant decrease in RSA from baseline to the happy videos rather than the increase in RSA that I originally hypothesized, it may not be adaptive if these physiological effects were sustained. As stated previously, according to theories of RSA, prolonged physiological arousal over time can lead to hypervigilance and put strain on one’s biological systems, which can increase the risk for cardiovascular disease and mortality (Chalmers et al., 2014; Porges, 2007; Thayer & Lane, 2007; Thayer, Yamamoto, & Brosschot, 2010; Thayer et al., 2012). However, these theories were developed to and largely focus on the link between PNS activity (measured by RSA) and the dysregulation of negative emotions, not positive emotions. Furthermore, RSA provides a measure of PNS activity, which is just one system involved in the modulation of physiological arousal and discrete emotions may involve profiles across multiple autonomic systems (Beauchaine, 2001; Shiota et al., 2011). Thus, the physiological arousal associated with happiness may differ from the physiological arousal associated with negative emotions in important ways. Future studies could examine this possibility by including measures that help tease apart different aspects of autonomic responding, such as cardiac pre-ejection period (PEP; i.e., the time between left ventricular depolarization and ejection into the aorta), which provides a measure of beta-adrenergic sympathetic influence (Beauchaine, 2001) or skin conductance responses (SCR), which reflect cholinergic sympathetic innervation.

4.6 Limitations & Future Directions

The current results should be evaluated in light of several study limitations. Due to the correlational nature of the current study, causal inferences are not possible. Additional limitations relate to the current sample. Despite a portion of my sample being at elevated risk for internalizing symptoms, the sample as whole was still quite normative given the sample's distribution on the CBCL. Also, approximately half of the sample were reported to have no symptoms of depression whatsoever as measured by the Affective Problems scale of the CBCL. This may be reflective of the development period in which these children were assessed as middle childhood precedes the rise in rates depressive disorders and certain anxiety disorders that occur in adolescence (Kessler et al., 2001; Schneier et al., 1992; Thapar et al., 2012); however, caution should still be taken when generalizing these findings to clinically recruited samples. As noted above, longitudinal research that follows children from middle childhood into adolescence is needed in order to better understand the developmental progression in physiological emotion dysregulation liabilities in internalizing psychopathology and how they may relate to changes in symptom expression.

Furthermore, I designed the emotional video paradigm to comply with the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology (Task-Force, 1996) recommendations regarding the duration of RSA recordings (i.e., five minutes), which led me to combine multiple emotion clips into a single block and use a balanced Latin square design to counterbalance the order of presentation of the videos across participants. This allowed me to control for order effects but prevented a more detailed examination of how changes in RSA unfold across the emotional block (e.g., some children with high internalizing symptoms may have exhibited an immediate decrease in RSA followed by an increase as they attempt to disengage from the stimuli) and precluded examining RSA reactivity to emotion across multiple trials. This would be an interesting avenue for future research as it would allow researchers to measure how children adapt physiologically to emotional situations over time. Also, while I utilized emotional videos, which research has shown to be an especially effective method for inducing emotions (Schaefer et al., 2010), using the same video clips for all participants may lead to some loss in personal impact. Relatedly, although the emotional clips used in the current study were of a social nature (i.e., featured real children expressing different emotions), they did not involve an actual social interaction. Future studies may benefit from using other elicitation methods, such as relived experiences, which will be more personal, or simulated social interactions with confederates, which would more accurately reflect the types of social situations children encounter in the real world.

By gathering self-report ratings of children's subjective emotional experience, I was able to ensure that the emotional video clips elicited the intended emotions; however, I did not collect ratings of children's subjective emotional experience prior to starting the emotion video paradigm or during the neutral nature videos. Thus, I was unable to assess how changes in children's physiological reactivity relate to changes in their subjective experience. Researchers posit that videos depicting nature or landscape scenery are good for collecting baseline measurements of RSA as they fully engage participants' attention and induce little emotion in participants (Rottenberg et al., 2005); however, as noted above, I cannot rule out the possibility that these videos may have had a calming effect that could have accelerated reduction in physiological hyperarousal experienced after witnessing other children's sadness to the point that it masked differences in recovery rate for children with high and low internalizing problems. Additionally, I was not able to control for children's use of explicit emotion regulation strategies, which could have potentially increased or decreased their level of RSA reactivity. Previous research has demonstrated that some emotion regulation strategies, such as reappraisal and suppression, are associated with increases in RSA (Butler, Wilhelm, & Gross, 2006), while other strategies, such as distraction are linked to decreases in RSA (McGreevy, Bonanno, & D'Andrea, 2015). Future studies that experimentally manipulate emotion regulation strategies in the laboratory setting could lead to a better understanding of the differential effects such strategies may have RSA. Another interesting avenue for future research would be to examine whether *patterns* of RSA functioning (i.e., interactions between baseline RSA, RSA reactivity, and RSA recovery) predict aspects of internalizing psychopathology.

4.7 Clinical Implications

Findings from the current study may have important implications for the treatment of internalizing psychopathology in children. The results indicate that low resting RSA is associated with high internalizing symptoms. Thus, interventions that directly influence RSA, such as heart rate variability biofeedback and relaxation training, may help reduce internalizing problems. Indeed, several small-scale studies have shown this type of training to be successful in reducing symptoms of anxiety and depression in adults (Henriques, Keffer, Abrahamson, & Horst, 2011; Lehrer & Gevirtz, 2014; Reiner, 2008; Siepmann, Aykac, Unterdorfer, Petrowski, & Mueck-Weymann, 2008), as well as anxiety symptoms in children (Pop-Jordanova, 2009). In these studies, biofeedback equipment is used to help teach and increase the effectiveness of relaxation strategies by providing real time feedback of their effects on physiological reactivity. Additionally, the study conducted by Siepmann et al. (2008) showed increased RSA relative to baseline in depressed patients following the completion of the biofeedback program and at a follow-up visit two weeks later, suggesting that these interventions may be able to produce lasting physiological changes.

Additionally, certain emotion regulation and relaxation strategies, such as diaphragmatic breathing, mindfulness meditation, and reappraisal, have been shown to increase RSA and reduce physiological arousal in the moment (Butler et al., 2006; Christou-Champi, Farrow, & Webb, 2015; Ditto, Eclache, & Goldman, 2006; Lehrer & Gevirtz, 2014). The finding that children with internalizing symptoms exhibit excessive decreases in RSA and physiological hyperarousal in sad social situations suggests that they may particularly benefit from the use these strategies. Middle childhood in particular may reflect a developmental window of opportunity for early intervention for high-reactivity children. Specifically, if children are able to effectively employ these strategies to reduce aversive levels of physiological arousal in the moment, they may engage in less social withdrawal behaviors, thus providing them with more opportunities to develop age-appropriate social skills, and reducing the likelihood of social rejection and peer victimization, thereby disrupting the cycle that can lead to increased depression and the stabilization of pathological cognitive styles in adolescence.

4.8 Conclusion

In sum, results of the current study provide support for low resting RSA as a correlate of internalizing symptoms during middle childhood and suggests low resting RSA could be a potential risk factor for internalizing problems and a potential marker of the emotion dysregulation liability. Additional support was found for excessive, but not blunted, RSA reactivity in response to other children's displays of sadness as a correlate of internalizing symptoms during middle childhood and a potential risk factor for internalizing problems reflecting a liability to physiological hyperarousal. This study also found that RSA recovery after sadness, RSA reactivity to happiness, and RSA recovery after happiness were not significantly associated with children's internalizing symptoms during this time. Taken together, these results suggest that internalizing psychopathology is better characterized by physiological dysregulation of withdrawal-motivation based emotions (e.g., fear and sadness) in the moment than of approach-based emotions (e.g., happiness) during middle childhood (Fortunato et al., 2013; McNaughton & Corr, 2009). These results provide a foundation for further investigation of how physiological reactivity during social emotional situations confer risk for internalizing psychopathology in middle childhood. Future longitudinal studies are needed to better understand the developmental progression of internalizing liabilities from childhood to adolescence.

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