Physiological and Social Cognitive Correlates of Preschool Physical and Relational Aggression: A Short-Term Longitudinal Study

A DISSERTATION
SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL
OF THE UNIVERSITY OF MINNESOTA
BY

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

Nicki R. Crick, Adviser

July, 2011

Acknowledgements

Many thanks to my adviser, Nicki Crick, and my committee members, Megan Gunnar, Andy Collins, and Jeff Simpson, for advice, guidance, and feedback throughout this process. Bonny Donzella and Pete Ralston provided invaluable logistical advice that made this dissertation possible.

Thanks also to my family who has supported me the entire way through this journey, even when they were not entirely sure what I was doing or why I was doing it.

Finally, thanks to Cyndi and an amazing group of friends who have encouraged, challenged, and supported me along the way.

Abstract

This study examined physiological correlates and predictors of relational and physical aggression in early childhood. Preschoolers' baseline heart rate, blood pressure, and respiratory sinus arrhythmia (RSA) were measured in the fall. At the same assessment, heart rate and RSA reactivity were measured while listening to stories of peer conflict, and participants engaged in two effortful control tasks. Teachers reported on physical and relational aggression in the fall and the spring. With respect to baseline physiology, low baseline heart rate and higher RSA were associated with increased physical aggression only among children with lower effortful control scores. Higher baseline RSA predicted increased relational aggression, again only for children with lower effortful control scores. Among children with poorer effortful control, diastolic blood pressure positively predicted relational aggression and negatively predicted physical aggression. Greater heart rate increases and RSA decreases to stories of peer conflict were uniquely associated with elevated classroom physical aggression. These findings suggest the utility of examining the roles of baseline physiology and physiological reactivity in the development of aggressive behavior. Implications of these findings for the development of intervention and prevention programs targeting early physical and relational aggression are discussed.

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Introduction

Over the past 15 years, researchers have undertaken the goal of more fully describing the range of aggressive behaviors children use to inflict harm on one another, broadening the scope of forms of aggression to include relational, as well as physical and verbal aggression. As opposed to physical aggression, which involves harm or threat of harm to one's body or possessions, relational aggression includes behaviors that inflict harm through damage or threat of damage to children's relationships (e.g., Crick & Grotpeter, 1995). Using a variety of measurement approaches, including observational-, self-, peer-, and teacher-reports, behaviors representing relational and physical aggression consistently emerge as distinct, though correlated, factors (Crick, Casas, & Mosher, 1997; Crick & Grotpeter, 1995). Furthermore, empirical evidence suggests individuals engage in relationally aggressive behavior throughout the lifespan (e.g., Crick, Ostrov, Burr, Cullerton-Sen, Yeh, & Ralston, 2006; Linder, Crick, & Collins, 2002; Rose, Swenson, & Waller, 2004).

Recently, research efforts aimed at elucidating the development of relationally aggressive behaviors have begun to focus on early childhood, and preschool in particular, as a key period in which relational aggression emerges. In brief, these studies suggest that relationally aggressive behaviors emerge in children as young as 30 months (Crick et al., 2006). Engagement in relational aggression is fairly stable across a preschool year (Burr, Ostrov, Jansen, Cullerton-Sen, & Crick, 2005; Ostrov & Crick, 2007; Ostrov, 2008) and across two preschool years for girls (Crick et al., 2006). Furthermore, peer rejection is consistently associated with relational aggression in preschool (Crick et al., 1997; Ostrov & Crick, 2007), with some support for increased depressive symptoms as well (Crick et al., 1997), suggesting there may be negative outcomes of engagement in early relational aggression.

While a number of predictors of engagement in relational aggression have been identified, one area that has lacked empirical attention in the development of relational aggression is psychophysiology. In the course of identifying possible biological or genetic markers of physically aggressive behavior, autonomic nervous system arousal and reactivity, as indicated by heart rate, respiratory sinus arrhythmia (RSA), skin conductance, and blood pressure, have been shown to be relatively robust correlates of physical aggression/antisocial behavior (e.g., Beauchaine, 2001; Lorber, 2004). Given the contribution of these physiological measures to our understanding of the etiology and developmental course of physical aggression, empirical examination of the role of physiology in the development of relational aggression seems warranted.

This paper aims to address two major limitations that characterize the literature on physiology and physical aggression. First, the bulk of this work involves participants in middle childhood or adolescence, and a relatively small number of studies focus on early childhood. Second, many of the studies in this area focus on physical forms of aggression and participant groups often comprised largely of males (c.f., Maliphant, Hume, & Furnham, 1990; Rogeness, Cepeda, Macedo, Fischer, & Harris, 1990), to the exclusion of relational aggression and the inclusion of female participants. In fact, to date, only two studies have investigated the autonomic nervous system correlates of relational aggression (Murray-Close & Crick, 2007; Sijtsema, Shoulberg, & Murray-Close, 2011), and neither of these targeted young children. A more complete understanding of the association between physiological correlates of physically and relationally aggressive behavior in boys and girls in early childhood has implications for successful prevention programs in the preschool years.

Baseline Physiological Arousal and Aggression

Three measures of baseline autonomic nervous system arousal are included in this study: heart rate (HR), blood pressure (BP), and respiratory sinus arrhythmia (RSA). Although heart rate and blood pressure are enervated through both the sympathetic and parasympathetic branches of the autonomic nervous system, RSA is primarily under parasympathetic control. Each measure of physiology will be reviewed, as each is thought to reflect somewhat different individual differences and relate differently to aggression in particular. Due to the paucity of psychophysiological research on relational aggression, the literature and theory reviewed below focus on physical aggression and externalizing behavior problems. The purpose of this study is to begin exploring associations between physiology and relational aggression.

Baseline heart rate. Numerous studies have documented the relation between physical aggression and low autonomic nervous system arousal, particularly as indexed by heart rate, in children, adolescents, and adults across a wide age range. Mean level differences in resting heart rate have been found between extreme groups of aggressive/disruptive children relative to typical/control groups (e.g., Maliphant & Watson, 1990; Rogeness et al., 1990; van Goozen, Matthys, Cohen-Kettenis, Buielaar, & van Engeland, 2000; van Goozen et al., 1998). Additionally, heart rate has been negatively associated with teacher and parent reports of aggression/externalizing problems on continuous measures, such as the Child Behavior Checklist (e.g., Baker et al., 2009; El-Sheikh, Ballard, & Cummings, 1994; Kindlon, et al., 1994; Maliphant et al., 1990; Raine, Venables, & Mednick, 1997; proactive aggression: Scarpa, Tanaka, & Haden, 2008; van Goozen et al., 1998; Zahn-Waxler, Cole, Welsch, & Fox, 1995). Several recent meta-analyses have estimated the effect size of the relation between heart rate and aggression in children to be between -.44 and -.51 (Lorber, 2004; Ortiz & Raine, 2004). In fact, Ortiz and Raine (2004) called the low heart rate-aggression association the “best-replicated biological correlate of antisocial behavior in child and adolescent populations” (p. 159). Although there have been studies that have failed to find this relation (e.g., Posthumus, Bocker, Raaijmakers, van Engeland, & Matthys, 2009; Zahn & Kruesi, 1993), the overwhelming majority have replicated the negative association between heart rate and aggression.

Two primary theories have been advanced to explain this relation: fearlessness and sensation-seeking. Both ideas rest on the premise that low heart rate indexes personality-like individual differences in fearlessness and sensation-seeking, which in turn increase the likelihood of engagement in physically aggressive behavior. Fearlessness theory (e.g., Raine, 1993) posits that low heart rate indicates a lack of fear in a mildly arousing situation (e.g., having heart rate measured by a researcher). Children who experience less fear in these situations are thought to experience less fear in everyday life. Because physically aggressive acts likely involve a certain amount of fearlessness to execute, and because a lack of fear may impair learning the negative consequences of aggression (e.g., fear conditioning), fearlessness has been suggested as a likely mechanism in the ability to carry out and maintain levels of aggressive behavior. In one empirical examination of this theory, van Goozen, Snoek, Matthys, van Rossum, and van Engeland (2004) examined the startle reflex of children with disruptive behavior disorders and a control group. While no group differences in startle response to negative stimuli were found, within the disruptive behavior group, severity of delinquency was associated with the magnitude of the startle response. Specifically, children with higher delinquency scores had lower startle responses during negative stimuli, providing some preliminary support for the fearlessness theory.

Sensation seeking theory (e.g., Raine, 1993), on the other hand, suggests that low levels of autonomic nervous system arousal present an uncomfortable state for individuals, analogous to boredom. Children may thus turn to aggression to increase their arousal levels. Sijtsema and colleagues (2010) found support for sensation seeking, as indexed by fun-seeking and adventurism in adolescence, as a mediator of the association between low baseline heart rate at age 11 and antisocial behavior at age 16 among boys but not girls. In a prospective examination of the sensation-seeking hypothesis, Raine, Reynolds, Venables, Mednick, and Farrington (1998) noted an association between stimulation-seeking at age 3 and aggressive behavior at age 11. Importantly, these findings were specific to aggressive behavior; the same relation was not found for non-aggressive antisocial behavior. In a study of sensation seeking in adolescence, Gatzke-Kopp, Raine, Loeber, Stouthamer-Loeber, and Steinhauer (2002) examined the relation between low ANS arousal as measured by skin conductance level and delinquency and sensation-seeking in adolescent boys. Consistent with the sensation-seeking hypothesis, individuals high on delinquency had significantly lower skin conductance than those low on delinquency. However, boys high on sensation-seeking, regardless of delinquency status, also had lower skin conductance than low sensation-seeking, low-delinquency boys.

While the sensation-seeking hypothesis suggests that children with low ANS arousal seek sensation as a means of increasing their arousal (Raine, 1993), it does not specify why aggression or antisocial behavior is a primary way that children raise their arousal levels. That is, one might engage in more constructive acts as a way to raise arousal, such as playing sports or dancing. Scarpa and colleagues (2008) note that low ANS arousal has been associated with a variety of individual differences, including risk taking, sensation seeking, and impulsivity, which could in turn lead to aggression or other more positive behaviors, depending on socialization pressures and other factors. In their study of at-risk middle childhood aged participants, low heart rate only predicted aggression in children who directly experienced community violence, suggesting that community violence socialized children with low arousal toward aggressive acts (Scarpa et al., 2008).

Child factors, as well, may influence the expression of individual differences related to low ANS arousal, particularly in samples of lower risk children. Because one of the key developmental tasks in the preschool years involves regulating behavior and emotions, self-regulation abilities vary widely in preschool (Kochanska, Murray, & Coy, 1997). Furthermore, poor emotion and behavior regulation predict engagement in physical aggression at a variety of ages (e.g., Muris, van der Pennen, Sigmond, & Mayer, 2008; Zhou et al., 2007). Thus self-regulation appears to be a promising candidate as a moderator of the low ANS arousal/aggression link. In other words, low ANS arousal should be a stronger predictor of aggressive behavior among children with poorer self-regulation than among children with better self-regulation skills because children with low arousal who are better regulated should be able to seek sensation in more appropriate ways than those with poorer regulation abilities.

In the literature on temperament in childhood, effortful control has been examined as a construct reflecting self-regulation. Specifically, effortful control refers to the ability to suppress a dominant response in favor of a subdominant one and includes the components of inhibitory control, attentional focusing, and perceptual sensitivity (e.g., Rothbart, Ahadi, & Evans, 2000). Effortful control, specifically, has been negatively associated with aggressive behavior in a number of studies throughout childhood (e.g., Muris, 2006; Muris et al., 2008; Olson, Sameroff, Kerr, Lopez, & Wellman, 2005; Valiente, Eisenberg, Spinrad, & Reiser, 2006). Because the current study attempted to examine physiology/aggression links in a lower-risk population, effortful control was chosen as a measure of self-regulation that would reflect individual differences among preschoolers, as opposed to screening for clinical-level self-regulation problems.

Baseline blood pressure. The investigation of blood pressure in childhood has an established history in health and medical fields, and these studies suggest blood pressure is moderately stable across childhood. For example, de Swiet, Fayers, and Shinebourne (1992) noted moderate correlations in blood pressure readings from ages 1 through 10. Similarly, Suh and colleagues (1999) noted stability in both systolic and diastolic blood pressures from age 6 to 17. Because diastolic blood pressure can be difficult to measure in infants, Fuentes, Notkola, Shemeikka, Tuomilehto, and Nissinen (2002) measured only systolic blood pressure in 6 month old infants, but noted significant predictions to SBP at age 15 in a population-based study. Furthermore, a recent meta-analysis indicated that systolic and diastolic blood pressure measured in childhood predict blood pressure in adulthood (Chen & Wang, 2008). Thus ample evidence suggests that blood pressure can be meaningfully measured in the preschool period with the expectation of moderate stability in childhood.

The association between blood pressure and aggressive/antisocial behavior in children has been both less investigated and more equivocal than the heart rate-aggression relation. Several studies of middle childhood aged children have documented positive associations between baseline blood pressure and aggression/delinquency in at-risk samples (younger brothers of delinquents: Pine et al., 1996; family history of hypertension: Schneider, Nicolotti, & Delamater, 2002). In contrast, Rogeness and colleagues (1990) compared children admitted to a psychiatric hospital for conduct disorder or depression/anxiety and found lower systolic blood pressure in the group of children with undersocialized conduct disorder. van Goozen and colleagues (1998) also noted lower resting systolic blood pressure among boys with high scores on the CBCL narrow-band aggression subscale. On the whole, these studies suggest a possible relation between blood pressure and aggressive behavior; however the nature and direction of this association requires considerable further clarification.

Theoretical explanations for the relation between blood pressure and aggressive behavior are somewhat less clear. From a perspective focused on anger and hostility, tied to an adult cardiovascular disease-prevention model, *increased* resting blood pressure has been linked to Type-A behavior (e.g., hostility, covert anger) and conduct problems (e.g., Jorgensen, Johnson, Kolodzeij, & Schreer, 1998; Pine et al., 1996). In comparison, research from an ANS underarousal model has found preliminary support for a negative association between baseline blood pressure and aggression/antisocial behavior (e.g., van Goozen et al., 1998). The theoretical perspective of researchers in this area has influenced important methodological characteristics of these studies, such as measurement of aggressive/antisocial behavior, the nature of the sample recruited, and confounds selected for measurement and control. Thus comparison among these studies has been challenging. Given that the sample in the present study was not selected for high risk characteristics, such as a family history of hypertension or a sibling with a criminal record, which have been associated with positive blood pressure-aggression associations, it is anticipated that blood pressure will be negatively related to aggression in this study.

Baseline RSA. Measures of heart rate and blood pressure are multiply-determined through both sympathetic and parasympathetic nervous system inputs. However respiratory sinus arrhythmia is a measure of variability in heart rate that occurs during respiration and is considered a measure of parasympathetic nervous system activity. More specifically, RSA is theorized to reflect the activity of the vagus, the 10th cranial nerve, on the heart (Berntson et al., 1997; Porges, 2001). Polyvagal theory (Porges, 2001) proposes a significant role for the myelinated vagus, which is specific to mammals, in social communication and attention, including enervation of eye, ear, mouth, and face muscles. In other words, the vagus is involved in both modulating sensitivity to incoming stimuli (through looking and hearing, in particular) and verbal and non-verbal social communication (through speaking and facial expressions).

Baseline RSA is theorized to relate to trait-like emotionality and temperament, with higher baseline RSA predicting increased attention to and engagement with the environment (Beauchaine, 2001; Calkins, 1997). Baseline RSA increases with age across childhood (Alkon et al., 2003; Calkins & Keane, 2004). Studies suggest high stability of baseline RSA in two week test-retest paradigms (Alkon et al., 2003) and moderate rank order stability in early childhood over periods as long as two and a half years (e.g., Calkins & Keane, 2004; Fox & Field, 1989; Porges, Doussard-Roosevelt, Portales, & Suess, 1994).

Theory suggests that baseline RSA should be positively related to social competence, positive emotionality, and empathy in childhood and negatively related to aggressive behavior because higher baseline RSA reflects more competent emotional responding (Beauchaine, 2001). In fact, numerous studies have demonstrated positive associations between baseline RSA and adaptive social behaviors (DeGangi, Porges, Sickel, & Greenspan, 1993; Doussard-Roosevelet, Montgomery, & Porges, 2003; Eisenberg et al., 1995 (boys only); Fox & Field, 1989) and emotion regulation (Eisenberg et al., 1995 (boys only); Gottman & Katz, 2002) across early and middle childhood. Furthermore, RSA has been negatively associated with externalizing behavior problems (e.g., Calkins & Dedmon, 2000 (for boys); Eisenberg et al., 1995 (for boys); Field et al., 1996; Pine et al., 1996; Pine et al., 1998). In a recent, small meta-analysis, Kibler, Proser, and Ma (2004) noted a significant negative association between baseline RSA and misconduct, including externalizing behavior problems.

Several recent studies, however, have provided conflicting evidence. For example, Calkins, Blandon, Williford, and Keane (2007) noted positive associations between baseline RSA measured at age two and externalizing behavior at age five. Null findings have also been reported (Calkins & Dedmon, 2000 (for girls); Calkins, Graziano, & Keane, 2007; Graziano, Keane, & Calkins, 2007; Eisenberg et al., 1995 (for girls)). One commonality among studies reporting positive or null associations between RSA and problem behaviors is the methodology involved. In all five studies reported above, baseline RSA was measured while children watched a video. It should be noted that use of the video was confounded with participant age; the video methodology was used to encourage younger children to sit quietly during baseline measurement. The video methodology was not used in studies reporting negative associations between RSA and behavior problems. Given that decreases in RSA (vagal withdrawal) have been associated with sustained attention (Suess, Porges, & Plude, 1994), it may be the case that children who were able to attend to the video showed lower RSA during the "baseline" reading due to vagal withdrawal, rather than actual tonic RSA levels. Thus, lower RSA in these studies may be less a reflection of baseline RSA than attentional abilities. If so, then the role of sustained attention may explain positive associations noted between "baseline" RSA and behavior problems using this methodology.

These methodological differences suggest a need for future work that carefully addresses the measurement of both baseline RSA and behavior problems. No study to date has examined baseline RSA and relational aggression. However, RSA in particular, may be a fruitful area for relational aggression research. Polyvagal theory (Porges, 2001) suggests a key role for the vagus in social communicative behaviors. Since engagement in relational aggression in the preschool period requires fairly advanced social communicative behaviors, particularly as compared to engagement in physical aggression, RSA may show differential associations with physical as compared to relational aggression.

Limitations in studies of baseline physiology and aggression. The literature on ANS arousal and aggression has several limitations. Many of these studies have focused on older children or adult criminals with extremely wide variation in the definitions of aggression/antisocial behavior (e.g., Tremblay, 2000). Raine and colleagues (1997), in a prospective study, demonstrated specificity in the association between low resting heart rate and later antisocial/aggressive behavior; the same relation was not found with nonaggressive antisocial behavior. This and similar findings suggest a need for precision in the specification of aggressive acts.

Further, the exclusion of girls and relational aggression in many examinations of physiological correlates of aggression has significantly limited our understanding of analogous processes in girls. Although Ortiz and Raine (2004) cited equivalent effect sizes for the low heart rate and physical aggression association for boys and girls, the number of studies including girls and their respective sample sizes were limited. The inclusion of relational aggression, as well, may help to more fully elaborate the relation between heart rate, blood pressure, RSA, and physical and relational aggression in both boys and girls.

One primary question that requires empirical examination is the extent to which hypotheses related to the baseline physiology/physical aggression link apply to relational aggression. There are several reasons to question the appropriateness of these hypotheses, particularly in regard to autonomic arousal. First, functionally, engagement in relational aggression has not been established to increase autonomic activity in the same way engagement in physical aggression has. Thus, it is not yet clear whether the sensation-seeking hypothesis necessarily applies to relational aggression. Additionally, feelings of anger, particularly when combined with rumination, have been related to increases in autonomic activity, especially blood pressure for adults (e.g., Hogan & Linden, 2004). To the extent that relational aggression may involve the ability to suppress anger enough to effectively deliver a relationally aggressive attack, the possibility exists that relational aggression may involve differential associations with autonomic activity. Finally, researchers are beginning to suggest that associations between ANS arousal and physical aggression may reflect a common underlying genetic contribution to both factors (e.g., Baker et al., 2009). A preliminary behavior genetics investigation suggests relational and physical aggression share similar genetic contributions, which may support the notion that physical and relational aggression are two separate expressions of one underlying genetic or physiological risk factor (Brendgen et al., 2005). Clearly more work is needed to empirically address these questions.

Physiological Reactivity and Aggression

Although baseline measures of physiology provide important insights into the ways trait-like individual differences may influence aggressive behavior, physiological reactivity has the potential to inform our understanding of children's state-like or phasic reactions in response to a particular stimulus. Physiological reactivity refers to the change from baseline of a physiological measure in response to a particular stimulus or experience. Heart rate and RSA reactivity will be reviewed, due to the size of the literatures in this area with respect to the study of aggression.

Heart rate reactivity. Heart rate reactivity has been implicated in the etiology of aggressive and disruptive behavior problems. However fewer studies have been conducted examining heart rate reactivity compared to resting heart rate, and theoretical approaches to heart rate reactivity-aggression links are conflicting. On the one hand, researchers have hypothesized that heart rate hyper-reactivity to stimuli should predict increased aggression (Beauchaine, 2001; Rappaport & Thomas, 2004). From this perspective, increases in heart rate to stimulus are thought to result from an exaggerated fight-flight response. Thus individuals who over-mobilize physiological resources in response to threat or stress may be more likely to engage in aggressive behavior, particularly at a lower threat threshold than individuals with more moderate heart rate reactivity. To date, however, empirical support for this hypothesis is limited. Eisenberg and colleagues (1996) found that children of early elementary age who demonstrated greater heart rate increases while watching a film about a child burned in a fire had elevated teacher-reported behavior problems.

On the other hand, it is possible that the ANS underarousal at rest that characterizes aggressive individuals might also pertain to their ANS reactivity (Raine, 1993). That is, aggressive individuals could experience both reduced resting heart rate and heart rate reactivity, as part of a broader pattern of blunted ANS arousal and reactivity. In support of this hypothesis, Hubbard and colleagues (2002) noted that 2nd graders with reduced heart rate reactivity in anticipation of interacting with an angry peer were more likely to engage in teacher-reported reactive physical aggression in the classroom.

Two challenges in interpreting findings on heart rate reactivity-aggression associations are the limited number of studies, particularly during childhood, and the variability in the stimuli used in the quantification of reactivity. Although some studies include negatively-valenced stimuli (e.g., a distress film; Eisenberg et al., 1996), others use tasks such as mental arithmetic or puzzle completion tasks (e.g., Schneider et al., 2002). In a meta-analysis, Lorber (2004) teased apart these inconsistencies, providing some clarity on the issue. Overall, heart rate reactivity was positively related to aggression among adults, but not adolescents (an insufficient number of studies on aggression in children precluded their inclusion in the meta-analysis). Heart rate reactivity was also positively related to conduct problems in both children and adults. In examining stimulus valence as a moderator of heart rate reactivity–aggression associations, divergent findings emerged. Specifically, heart rate reactivity to negatively valenced stimuli was positively associated with aggression (d = .31); however, heart rate reactivity to non-negative stimuli, such as mental arithmetic, was negatively associated with aggression (d = -.34) across age groups (Lorber, 2004). In other words, physically aggressive individuals may show elevated heart rate reactivity to negatively-toned emotional events, but heart rate hyporeactivity to non-negative stimuli.

In one of two examinations of physiological reactivity and relational aggression, heart rate reactivity while recalling an experience of relational victimization was not associated with teacher-reported relational aggression in the classroom among 5th graders (Murray-Close & Crick, 2007). It should be noted that that study did find associations between blood pressure reactivity and relational aggression for girls only. However, reduced heart rate reactivity predicted increased engagement in physical aggression for boys only. In the second study, Sijtsema and colleagues (2011) noted that blunted heart rate reactivity to a computer rejection game was associated with relational aggression in a sample of 12 year old girls. The two existing studies on this topic provide conflicting findings; however the stimuli used to elicit reactivity were considerably different.

In the current study, children's heart rate reactivity was assessed during stories of peer conflict. Children who report more hostile intent by the peer in the stories may experience the task as more negatively toned. As such, hostile intent attributions should be positively related to heart rate reactivity. Furthermore, heart rate reactivity during the stories is predicted to relate positively to classroom aggression, in line with meta-analytic findings positively associating heart rate reactivity to negative stimuli and aggression. However, given recent conflicting patterns of heart rate reactivity associated with relational aggression, these hypotheses should be considered exploratory.

RSA Reactivity. Whereas baseline RSA reflects trait-like emotionality and temperament, RSA reactivity is thought to index an individual's ability to regulate emotion and attention (Beauchaine, 2001; Calkins, 1997). RSA suppression/withdrawal, as indexed by decreases in RSA from baseline to task, is consistently related to more advanced social skills and peer competence (Calkins, 1997; Calkins & Dedmon, 2000; Calkins & Keane, 2004; Doussard-Roosevelt et al., 2003; Graziano, Keane, & Calkins, 2007; Porges, Doussard-Roosevelt, Portales, & Greenspan, 1996;) and emotion regulation (Blandon, Calkins, Keane, & O'Brien, 2008; Gottman & Katz, 2002;

Hessler, & Katz, 2007). Furthermore, reduced suppression of RSA to challenge, theorized to indicate less adaptive regulation in the face of external demands (Beauchaine, 2001; Porges, 2001), is associated with increased behavior problems (Porges et al., 1996; Graziano, Keane, & Calkins, 2007 (boys only); Hinnant & El-Sheikh, 2009). Although Graziano, Keane, and Calkins (2007) did not note this association for girls, it may be the case that inclusion of relational and physical aggression as outcome variables may provide a picture of behavior problems most relevant to both boys and girls. In fact, Sijtsema and colleagues (2011) found that blunted RSA reactivity, in combination with social cognitive risk factors, was associated with increased relational aggression among 12 year old girls. Thus, preliminary evidence suggests this association may pertain to relational as well as physical aggression.

Family risk appears to play a key role in the association between RSA withdrawal and behavior problems. Katz (2007) suggested that in the context of domestic violence, vagal augmentation (increasing RSA from baseline to challenge) reflects hypervigilance. Consistent with this hypothesis, preschoolers who augmented RSA to challenge and lived in homes with high levels of marital violence perpetrated by the father experienced more symptoms of oppositional defiant disorder, relative to children who suppressed RSA and had similar levels of domestic violence. In a similar vein, children at-risk due to parental alcohol abuse and marital conflict were protected from developing externalizing problems when they were better able to suppress RSA to challenge (El-Sheikh, 2001; El-Sheikh, Harger, & Whitson, 2001).

In sum, RSA withdrawal appears to be related to more competent emotional and social functioning and fewer behavior problems, and thus may serve as a protective factor for children from risky home environments. In keeping with the idea that children are beginning to regulate aggressive impulses in preschool discussed previously, less competent emotion regulation may result in aggressive peer interactions. Thus reduced RSA withdrawal, and in some cases RSA augmentation, should predict elevated rates of both physical and relational aggression.

Physiology Summary

In sum, research has documented a pattern of reduced baseline heart rate, baseline RSA, and RSA reactivity (e.g., less suppression from baseline to task) and elevated heart rate reactivity to negative stimuli among children with aggressive and externalizing behavior problems. The data on baseline blood pressure and aggression conflict, and consensus and strong theory have yet to be advanced in this area. With respect to relational aggression, only two studies have examined heart rate reactivity, with conflicting findings. Although hypotheses with respect to relational aggression are exploratory given the lack of previous research in this area, it is possible that the physiological profiles of physically and relationally aggressive preschoolers may be similar. If so, these findings would support the notion that relational and physical aggression are two manifestations of a similar underlying profile. However, given a number of findings that suggest unique features of relationally aggressive preschoolers relative to physically aggressive preschoolers (e.g., greater exclusivity in friendships, Sebanc , 2003), it may be the case that the two forms of aggression are associated with different physiological profiles in early childhood. As such, physiological variables that discriminate physical and relational aggression are of particular interest.

Social Information Processing – Intent Attributions

Children’s physiological reactivity to peer conflicts may be particularly relevant to the development of persistent behavior problems. Crick and Dodge’s (1994) Social Information Processing (SIP) theory on the role of social cognition in children’s peer interactions has influenced thinking and research on the development of aggressive behavior problems in children and may also inform studies of physiological reactivity. The 6-step SIP model describes the ways in which cognition influences interactions with others and guides behavioral responding. In particular, the second of six steps in the model, Interpretation of Cues, has generated a large body of research with respect to physical aggression. Interpretation of cues involves the individual’s attributions of cause and intent for the interaction partner’s actions. For example, after getting bumped from behind in line for recess, a child may attribute benign cause and intent (e.g., the child tripped and bumped into me accidentally) or hostile cause and intent (e.g., the child was mad at me, so he pushed me from behind on purpose). The primary aspect of SIP of concern for this paper is the nature of children’s attributions of intent.

Children's hostile intent attributions have been well studied over the past several decades, and findings have been well-replicated. Consistently, more hostile intent attributions predict increased levels of physical aggression among children and adolescents (Dodge, 2006). Hostile intent attributions have been shown not only to predict future aggressive behavior, but have also been implicated as a mechanism that underlies the stability of externalizing behavior problems. For example, Burks, Laird, Dodge, and Pettit (1999) demonstrated that social information processing patterns, including hostile attribution biases, partially mediated associations between externalizing problems in Kindergarten and 8th grade (Burks et al., 1999). Because hostile intent attributions may contribute to the stability of aggression, understanding associations between these biases and aggression in early childhood may be particularly important for intervention efforts. Furthermore, including physiological reactivity, in addition to children's verbal reports of intent attributions, may broaden our understanding of social cognitive processes in aggressive behavior development.

Classic studies of intent attributions have focused on physical forms of aggression and social information processing methods more relevant to physical aggression than relational aggression (e.g., Dodge et al., 2003). However, in a series of studies, Crick and colleagues (Crick, 1995; Crick, Grotpeter, & Bigbee, 2002) developed similar methodologies that assess attribution biases related to relational provocations. Findings suggested that in middle childhood, children engaging in high levels of relational aggression reported more hostile intent attributions to relational provocations than children not in the relational aggression extreme group. On the other hand, high physically aggressive children reported more hostile intent attributions to instrumental provocations than children not in the extreme physical aggression group. From these studies, it appears that aggressive children are not globally hostile. Instead, relationally aggressive children exhibit biased social cognition specific to relationship-based conflicts, whereas physically aggressive children exhibit biases specific to instrumental conflicts.

There have, however, been failures to replicate these findings. Crain, Finch, & Foster (2005) noted no associations between hostile intent attributions to relational provocations and engagement in relational aggression among 4th-6th grade girls, and Hayward and Fletcher (2003) found the expected association for boys, but an inverse pattern for girls. Although Crain and colleagues (2005) developed new vignettes and procedures, Hayward and Fletcher (2003) used the original Crick (1995) measure. In an attempt to clarify these discrepant findings, Godleski and Ostrov (2010) used the NICHD Study of Early Child Care and Youth Development to address methodological and analytical differences in the studies above. In the categorical or extreme groups approach, hostile attributions to relational provocations were higher among the comorbid (high physical and high relational aggression) aggression group than the low aggression group. However, the relational aggression-only group, defined as one standard deviation above the mean on relational aggression scores, was not significantly different from other groups on hostile intent attributions to relational provocations. In the dimensional approach, hostile attributions to instrumental provocations averaged over 3rd through 5th grade positively predicted continuous teacher reports of *both* relational and physical aggression in 6th grade.

Given that intervention programs targeting hostile attribution biases have shown effectiveness in reducing relational aggression (Leff et al., 2009), this issue appears to be more complex than simple bivariate associations between attribution biases and relational aggression. In fact, Mathieson and colleagues (in press) noted that hostile intent attributions to relational provocations were associated with engagement in relational aggression only among girls with specific relational vulnerabilities, including high rejection sensitivity and relational victimization. Future research is needed to clarify the role of intent attributions in relational aggression that includes moderators of this association, particularly in early childhood where this topic has not yet been systematically addressed.

Specific Aims

Based on the existing literature, this study was designed to address the following goals. The first goal was to examine associations between baseline physiology and physical and relational aggression in a preschool sample. No study to date has included baseline measures of physiology and relational aggression. In keeping with the fearlessness and sensation-seeking hypotheses noted above (Raine, 1993), low baseline physiological arousal, as indexed by heart rate and blood pressure, should predict higher levels of engagement in physical and relational aggression. However, aggressive behavior is just one method of raising arousal levels, and a variety of more prosocial options, such as playing tag or dancing, could serve the same purpose. Thus it was further hypothesized that effortful control would moderate this association, such that low baseline arousal would more strongly predict engagement in aggression for children low in effortful control than children high in effortful control. Baseline measurements of RSA were also collected and expected to relate negatively to physical aggression. However, these analyses were exploratory with respect to relational aggression, and the direction of effect was not specified.

The second goal of this study addressed physiological reactivity while children listened to stories about peer conflict (social information processing vignettes). In keeping with past theory on peer conflict and physiological reactivity, heightened physiological responses to peer conflict are thought to reflect exaggerated fight/flight reactions (Murray-Close & Crick, 2007). Thus, children who show greater heart rate reactivity to stories about peer conflict were predicted to engage in more aggression in the classroom. Blunted RSA reactivity, on the other hand, has been associated with less competent social behavior and was expected to predict physical and relational aggression. Further, the association between physiological reactivity and aggression was expected to be stronger for similar aggression/provocation forms than dissimilar forms. In other words, children with heart rate increases to stories about relational provocations should engage in more relational aggression in the classroom compared to engagement in physical aggression.

Cognitive appraisals of intent during ambiguous peer conflict should also influence children's use of aggressive behavior (Crick & Dodge, 1994). The third goal of this study was to extend past work examining children's social information processing, specifically hostile attribution biases, to the preschool age group. This work has been conducted with older children (e.g., Arsenio, Adams, & Gold, 2009; Crick et al., 2002), and intervention/prevention efforts would benefit from understanding whether hostile attribution biases are evident in relationally aggressive children as early as preschool. In this study, more hostile intent attributions were expected to predict engagement in classroom physical and relational aggression, and this association was expected to be stronger for similar forms of provocation/aggression than dissimilar forms.

Because of the exploratory nature of this study, concurrent physiological assessment, child-report, and teacher-report measures provided new descriptive information regarding preschool social development. In addition, the fourth goal of this study was to examine these associations over a preschool year to allow for identification of predictors of future relational and physical aggression. The physiological variables were of particular interest for this hypothesis, and the analyses were exploratory. The literature on baseline arousal and physical aggression is the most advanced with respect to this goal, suggesting that lower heart rate, in particular, should make a unique contribution to future physical aggression over time (e.g., Raine et al., 1997). In preschool, when children are only beginning to use relational aggression in relatively unsophisticated ways, it is unclear whether longitudinal associations between physiology and aggression should be anticipated. Therefore, this analysis was conducted in an exploratory fashion.

Finally, given that some studies have demonstrated age and sex differences in associations between physiology, aggression, and social cognition, age and sex were examined as moderators. Because both forms of aggression and all physiological measures undergo developmental change in the preschool period, it was anticipated that age would be a significant moderator of physiology/aggression associations. In particular, physiology/aggression links may be stronger for older preschoolers, where physiology and aggression are more stable, than younger preschoolers. Sex differences in preschool with respect to physical aggression are well-documented; however sex differences in relational aggression have been difficult to replicate with young children; therefore for theoretical reasons sex was examined as a moderator.

Hypotheses

This study examined the following hypotheses:

H1: Lower baseline arousal, as indexed by heart rate and blood pressure, will be associated with more physically and relationally aggressive behavior. Baseline RSA is also predicted to be negatively related to physical aggression. Associations between RSA and relational aggression are exploratory.

H2: Effortful control will moderate the association between baseline physiology and aggression such that this association will be stronger for children with lower effortful control scores than those with higher effortful control scores.

H3: Children who show heightened heart rate and blunted RSA reactivity to the peer conflict vignettes will engage in more teacher-reported relational and physical aggression in the classroom.

> H3A: Further, this association will be stronger for similar provocation/ aggression form combinations (e.g., relational stories and relational aggression) than dissimilar form combinations (e.g., relational stories and physical aggression).

H4: Children with more hostile intent attributions to peer provocations will engage in more classroom aggression of both types than children with less hostile intent attributions.

> H4A: This association will be stronger for similar provocation/aggression form combinations (e.g., hostile intent responses to relational stories and relational aggression) than dissimilar form combinations (e.g., hostile intent responses to relational stories and physical aggression).

H5: Baseline physiology and physiological reactivity in the fall will predict physical aggression in the spring. Analyses with respect to spring relational aggression are exploratory.

H6: Age and sex will be investigated as moderators of associations between physiology and aggression. Associations between physiology and both forms of aggression are anticipated to be stronger among older preschoolers than younger preschoolers. Sex is not anticipated to moderate these associations.

Method

Participants

Participants included 94 children (50 boys, 44 girls) from eight classrooms in two preschools in a large Midwestern city. At the time of the fall data collection, children ranged in age from 34.60 months to 63.77 months ($M = 49.67$; $SD = 7.13$). Consent forms were sent home to the families of all 140 preschool children who spoke English and were not on an individual education plan (IEP), and parents of 94 children (67.14%) agreed to allow their child to participate.

Demographic data were available for 75 of 94 participants whose parents completed questionnaires as part of a larger study. These reports indicated that the overall sample was 77.6% Caucasian, 9.2% Asian, 2.6% African-American, and 10.4% of another or multiple races. Annual household income was less than $40,000 for 5.3%, between $40,000 and $60,000 for 10.7%, between $60,001 and $80,000 for 16.0%, between $80,001 and $100,000 for 9.3%, and was above $100,000 for 58.7% of families.

Of the 94 children with parental consent, 3 were absent during the entire fall data collection phase. Eight children did not assent to any portion of the child assessment, and an additional 14 children did not assent to wearing the heart rate monitor. Independent samples t-tests were used to examine whether the 22 children who refused either the entire child assessment or the portion involving wearing the heart rate monitor differed from the portion of the sample that did wear the heart rate monitor. Analyses using the primary teacher report variables at time 1 and 2 (relational and physical aggression, effortful control, and age) suggest that there were no significant differences between the two groups on these study variables. There were, however, nonsignificant trends of note. Compared to the subset of the sample that wore the heart rate monitor, children who refused to wear the heart rate monitor tended to be younger ($t(31.62) = -1.77$, $p < .10$) and have lower effortful control scores in fall only ($t(28.27) = -1.84$, $p < .10$).

Procedures

Data collection occurred at two time points: a fall assessment approximately two months after the beginning of the school year (time 1) and a spring assessment approximately 5 months after time 1 (time 2). At time 1, the researcher introduced the study during large group activities in each classroom, when teachers typically read stories and sang songs with the class. Children with parental consent were approached during free play and asked if they would like to participate in the study. Those children who agreed completed the physiological, social cognitive, and effortful control assessments in a quiet room at the preschool. Teachers reported on children’s aggression and effortful control at time 1 and time 2. Because teachers could have completed up to 18 questionnaires, depending on the consent rate for their classroom, each teacher received a thank you gift of a $50 Target gift card. No child report measures were collected at time 2. All study measures and procedures were approved by the Institutional Review Board at the University of Minnesota.

Measures

Physical and relational aggression. To capture children's relationally and physically aggressive behavior in the classroom, teachers completed the Preschool Social Behavior Scale—Teacher Form (PSBS-TF; Crick et al., 1997). The PSBS-TF has been successfully used in past research with preschoolers, demonstrating good reliability and validity (e.g., Crick et al., 2006). Teachers rated each item on a 1 (Very Untrue) to 5 (Very True) scale. The relational aggression subscale consists of 8 items (e.g., "When mad at a peer, this child keeps that peer from being in the play group"). The physical aggression subscale includes 7 items (e.g., "This child pushes or shoves other children"). Items demonstrated excellent reliability at both time 1 and 2 ($\alpha = .90$ relational, $\alpha = .94$ physical; $\alpha = .93$ relational, $\alpha = .92$ physical, respectively) and mean scores were calculated for each subscale.

Effortful control. A multi-informant approach was used to measure effortful control. In the fall, teachers completed a 12-item measure of effortful control adapted from the Children's Behavior Questionnaire-Short Form (CBQ; Rothbart, Ahadi, Hershey, & Fisher, 2001). These items were culled from those comprising the Inhibitory Control and Attentional Focusing subscales that were appropriate for teacher completion. Although the Effortful Control factor for the CBQ typically includes two additional scales, Low Intensity Pleasure and Perceptual Sensitivity, past studies have utilized a less time-intensive measurement approach for teacher reports. For example, Gunnar, Tout, de Haan, Pierce, and Stanbury (1997) included portions of the Attentional Focusing, Inhibitory Control, and Task Completion subscales, rated on a 1 to 5 scale to capture Effortful Control reliably. As Task Completion is no longer part of the CBQ forms, teachers rated items pertaining to Attentional Focusing (e.g., "When drawing or coloring in a book, s/he shows strong concentration") and Inhibitory Control (e.g., "Can wait before entering into new activities if s/he is asked to do so") on a 1 (Never or almost never) to 5 (Always or almost always) scale. The 12 items demonstrated excellent reliability in this sample (Cronbach's alpha = .94).

Additionally, children participated in two tasks designed to assess effortful control, modified from the Effortful Control Battery (38- and 52-month assessments; Kochanska, Murray, Jacques, Koenig, & Vandegeest, 1996). In the "Walk the Line" task, designed to measure children's ability to slow motor activity, children ran as fast as they could twice across a 12 foot line, and then walked as slowly as they could across the line twice. In order to increase engagement in the game and add an emotional element, children were asked to pretend to be a tiger for the fast trials and pretend to be a turtle for the slow trials. The Walk the Line score was calculated by subtracting the mean time of the run trials from the mean time of the walk trials. Two coders independently timed all activities from video after undergoing a training session and practice coding as a group. Times for each trial were highly correlated for the two coders (*r*s ranging from .97 to 1.00) and 98.72% of times for each trial were within one second.

The second task, Dinky Toys, involved the child seated at a table with hands on lap. The researcher placed a container of attractive stickers in front of the child and asked the child to tell the researcher which sticker s/he would like while keeping hands on lap. This task was modified to include stickers instead of small toys because policies at the preschools involved in this study prohibited children from receiving gifts for participation. Therefore, stickers were chosen for children to put by their pictures on a chart to “show you’ve already played the game.” The child’s ability to keep his/her hands on lap was coded from video by two trained coders. To verify reliability after the training procedure, 22% of videos were coded by both coders. Coders rated children’s behavior on a 0 (removes sticker from container) to 4 (keeps hand on lap) scale (Kappa = .90).

Scores from the two tasks and teacher reports were correlated (tasks: $r(80) = .25$, $p < .05$; teacher and race: $r(81) = .23$, $p < .05$; teacher and dinky toys: $r(81) = .34$, $p < .01$), thus scores were standardized and summed to compute a composite score of effortful control.

Physiological assessment. Three aspects of physiology were of interest: heart rate, respiratory sinus arrhythmia (RSA), and blood pressure. Polar heart rate monitors were used to continuously record interbeat intervals during the assessment for offline calculation of heart period and RSA. Teachers placed the Polar heart rate monitor around each child’s torso before the child left the classroom. Past work has demonstrated the validity of Polar monitors for the collection of heart rate data (Gamelin, Berthoin, & Bosquet, 2006; Kingsley, Lewis, & Marson, 2005).

Interbeat intervals were artifact edited off-line with MxEdit (Brain-Body Center, University of Illinois at Chicago), and heart period for each epoch of interest (see below) was calculated as the average milliseconds between beats. Heart period refers to the length of time between heart beats; therefore larger heart period values are associated with slower heart rate and shorter heart period values are associated with faster heart rates. In presenting the results below, analyses will be conducted (and coefficients presented) based on heart period. However, the results will be discussed in terms of heart rate for ease of interpretation.

The Porges-Bohers filter was used to calculate RSA with established respiration settings for children (Porges, 1985). Two researchers (including the author) trained to criteria established by Porges in using MxEdit for artifact editing and RSA calculation. Both researchers artifact edited and scored approximately 14% of participants' physiological data and scores were highly correlated (*r*s > .98; *p*s < .0001 for all comparisons).

A Dinamap 8100 monitor and occlusion cuff on the child's left arm was used to measure systolic blood pressure (SBP) and diastolic blood pressure (DBP). Participants sat in a child-sized chair with their feet flat on the ground while the Dinamap monitor recorded heart rate and blood pressure during the approximately 20 second assessment. For this study, heart rate from the Polar monitor was used in analyses because it is averaged over a longer time span; however, heart rate as measured by the Dinamap monitor and the Polar monitor (heart period) were highly correlated ($r(65) = -.90$; $p < .001$).

Baseline physiological assessments of heart rate, RSA, and blood pressure occurred at the beginning of the assessment. After familiarizing the participant with the room and beginning wireless heart rate recording with the Polar monitor, one blood pressure reading was taken. The researcher then read a three minute neutral story (a portion of *The Little House*, Burton, 1978), and blood pressure was again recorded following the story. Because the two blood pressure readings were correlated ($r(64) = .57$, $p < .001$ for SBP; $r(64) = .61$, $p < .001$ for DBP), mean systolic blood pressure and diastolic blood pressure scores were calculated for use in further analyses. Three children were missing the first reading due to equipment malfunction. Because the two blood pressure readings were substantially correlated for the sample, the second reading was used as the blood pressure score for these three children missing the first reading. Interbeat interval during the entire three minute story served as the basis for calculation of baseline heart period and RSA in MxEdit.

Physiological reactivity was calculated for heart rate and RSA during three portions of the assessment. First, four neutral vignettes (see below for description of all vignettes) totaling approximately two minutes in length served as the baseline for reactivity calculations. Vignettes were chosen to serve as the neutral reactivity baseline instead of the baseline story described above because children responded verbally to a question after each story. Thus reactivity calculations were made with heart period and RSA estimates calculated from episodes in which children's required responses were similar. In fact, heart period and RSA values during the baseline story and neutral vignettes were highly correlated ($r(63) = .95$, $p < .001$ for heart period; $r(63) = .93$, $p <$

.001 for RSA); however the neutral vignettes were used in reactivity calculations for theoretical reasons.

Following the neutral vignettes, participants heard vignettes describing physical/instrumental provocations or relational provocations in a counterbalanced order. Heart rate reactivity scores were calculated by subtracting the estimate from the task vignettes from the estimate for the estimate for the neutral vignettes to account for the inverse association between heart period and heart rate. This procedure resulted in two reactivity scores: heart rate change to relational stories and heart rate change to instrumental stories. These scores should be interpreted such that positive change scores indicate *increases* in heart rate from baseline to task, and negative change scores indicate *decreases* in heart rate from baseline to task. RSA change scores were calculated by subtracting the RSA score during neutral vignettes from the RSA score for task vignettes, resulting in two scores: RSA change to relational stories and RSA change to instrumental stories. Positive RSA change scores indicate increases in RSA from baseline to the target vignette (vagal augmentation). Negative RSA change scores indicate decreases in RSA from baseline to task (vagal suppression).

Hostile attribution bias. Three blocks of four short stories, or vignettes, were used to assess children’s hostile attribution bias (Appendix C). After each vignette, participants rated whether the child in the story was trying to be mean on a scale from 1 to 3 (e.g., “Do you think that kid was trying to be mean or not trying to be mean?” If trying to be mean: “A little mean or really mean?”). The first block consists of neutral vignettes involving children playing nearby one another without interacting. Some element of negative affect was involved in the stories, however the two children never interact, and their behavior is independent of one another. The final two blocks were counterbalanced between instrumental and relational conflicts. These blocks describe peer conflicts in which the intent of the provocateur is ambiguous, and the source of the conflict is either relational (e.g., not getting invited to a birthday party) or instrumental (e.g., getting bumped into in line).

Six of the final eight vignettes were based on those used in a previous study (Assessment of Preschoolers' Social Information-Processing (APSIP); Casas & Crick, unpublished). However, to increase the length of the vignettes for the purposes of physiological recording, existing stories were embellished with additional details, and two additional stories were created, resulting in two blocks of vignettes, one instrumental and one relational, with four vignettes per block. Each block, including follow up question, lasted approximately two minutes. A past investigation suggests the original vignettes were effective in assessing social information processing in preschool aged children (Casas & Crick, unpublished). Children's responses to the modified vignettes in this study demonstrated acceptable reliability ($\alpha = .83$ for relational; $\alpha = .85$ for instrumental). Both subscales approximate the normal distribution (skew = .63 for relational, .25 for physical; kurtosis = -.95 for relational, -1.44 for instrumental) and have mean values near the midpoint of the scale (M= .68 for relational and .86 for instrumental). These statistics indicate that there is sufficient variability in children's attributions of hostile intent to justify their use as a measure of individual differences in children's hostile attribution biases.

Results

Preliminary Analyses

Missing data due to children's unwillingness to wear the heart rate monitor, equipment error, and absences resulted in different numbers of participants in many of the analyses; sample sizes will be presented individually. Descriptive data for the primary study variables are included in Table 1. An examination of skew and kurtosis values suggested that the four aggression items (relational and physical aggression in the fall and spring) had high, positive skew and kurtosis values. Log transformations were used to normalize variable distributions. These transformations were successful with the relational aggression variables, and made improvements in the distribution of the physical aggression variables; however fall and spring physical were not fully improved. For ease of interpretation, untransformed values are presented in Table 1.

Independent samples t-tests were used to evaluate mean level sex differences in study variables. There were no sex differences in any of the physiological variables. However, three of the behavioral measures did differ between boys and girls. Boys were rated as more physically aggressive by their teachers in the fall ($t(76.09) = 2.25$, $p < .05$; mean for boys = 1.26; mean for girls = 1.07) and spring ($t(67.53) = 2.55$, $p < .05$; mean for boys = 1.23; mean for girls = 1.05) than girls. Girls had higher scores relative to boys on the effortful composite of behavioral tasks and teacher report ($t(78) = -4.86$, $p < .001$; mean for boys = -1.01; mean for girls = 1.07). There were no additional sex differences.

Manipulation Check

Because the social information processing vignettes have not been used for physiological assessment in young children, several steps were taken to evaluate this methodology. Calkins and Keane (2004) suggest empirically examining whether stimuli provoke mean levels changes in RSA and heart rate. Although it was not expected that all children would find the vignettes distressing, reactivity was examined given the novelty of the assessment in this age group. Paired samples t-tests suggested that heart period was significantly shorter (heart rate increased) during the relational ($t(60) = 3.36$; $p < .01$) and instrumental ($t(58) = 2.00$; $p < .01$) vignettes than during the neutral stories. With respect to RSA, children showed, on average, decreases in RSA from the neutral to the instrumental and relational vignettes; however, this difference only reached statistical significance for the instrumental stories ($t(58) = 2.13$; $p < .05$). There were no significant differences for task heart rate or RSA between the relational and instrumental stories.

Neutral vignettes were created to provide a baseline from which to calculate physiological reactivity. Because speaking has been suggested to influence RSA (Sloan, Korten, & Myers, 1991), a baseline measure requiring similar speaking responses as those in the task condition has been suggested in studies of physiological reactivity (e.g., Bar-Haim, Fox, VanMeenen, & Marshall, 2004). Although the characters in the neutral vignettes did not interact, paired samples t-tests were conducted to confirm that children did, in fact, rate the neutral vignettes as less hostile than the instrumental or relational vignettes. Results confirmed this difference; neutral vignettes had significantly lower hostile intent ratings than instrumental ($t(69) = 7.68$; $p < .001$) or relational ($t(69) = 5.12$; $p < .001$) provocations.

Finally, order effects were examined. Typically, the social information processing interview is administered by alternating relational and instrumental conflict stories and asking a number of follow up questions. Pursuant to the goals of this research only one question from the SIP interview was presented to participants ("Do you think that kid was trying to be mean?"). Additionally, provocation forms were blocked together to allow for physiological reactivity recording. Taken together, these two factors could have caused some spillover or priming of hostility from the first block into the second. To examine whether participants were primed to attribute hostile intent in the second block of stories after already hearing the first block, order effects were examined. Independent samples t-tests indicated that there were group differences; however the findings were not consistent with spill-over order effects. Children who heard the instrumental provocations first gave more hostile answers to the relational provocations (M = .85) than the children who heard the relational provocations first (M = .49; $t(76) = 2.28$, $p < .05$). However, children who heard the instrumental provocations first also attributed marginally more hostile intent to the instrumental stories (M = 1.00) than the group who heard relational provocations first (M = .70; $t(76) = 1.81$, $p = .07$). Thus it may be the case that even though the order was randomized, children with more hostile intent attributions happened to receive the instrumental provocations first. Order (dummy coded as 1 or 2) was controlled in analyses involving hostile attribution biases, although it was never a significant predictor.

Analysis Plan

Hypotheses 5 and 6 were examined concurrently with hypotheses 1 through 4. In cases where age moderated associations under consideration, these findings are noted. Although sex was examined as a moderator, it was never a significant moderator in any of the analyses conducted. Furthermore, analyses are presented for both fall and spring aggression measures to allow for easier comparison of results. When using hierarchical linear regressions to predict one form of aggression, the opposite form at the same time point was used as a control (e.g., physical aggression in the fall was controlled in analyses predicting relational aggression in the fall). This is a conservative approach that allows for examination of the unique effects of physiology or social cognition on a particular form of aggression.

Hypothesis 1

Zero order correlations were conducted to examine associations between baseline physiology, as indexed by heart rate, RSA, systolic blood pressure, and diastolic blood pressure, and classroom aggression (Table 2). Heart rate was negatively associated with fall and spring physical aggression ($r(67) = .48$, $p < .001$; $r(66) = .32$, $p < .05$, respectively; note correlations conducted using heart period) and fall and spring relational aggression ($r(67) = .33$, $p < .01$; $r(66) = .25$, $p < .05$, respectively; note correlations conducted using heart period). Higher baseline RSA was associated with increased fall and spring physical aggression ($r(67) = .44$, $p < .001$; $r(66) = .27$, $p < .05$, respectively) and increased fall relational aggression ($r(67) = .24$, $p = .05$). Systolic blood pressure was unrelated to either form of aggression at either time point. Diastolic blood pressure was negatively associated with spring physical aggression ($r(67) = -.31$, $p = .01$). When examining age and sex as moderators of these associations, the results were unchanged, and moderation analyses were not significant. However, when controlling for the concurrent opposite form of aggression, only findings pertaining to physical aggression remained.

Hypothesis 2

Hypothesis 2 pertained to the role of effortful control as a moderator of associations between baseline physiology and aggression. Age, sex, and the opposite form of concurrent aggression were entered in the first step of the models as controls, and step two included the centered effortful control composite and physiological measure in question. Finally, in step three, the effortful x physiology interaction was entered. Simple slopes were evaluated at one standard deviation above and below the mean to interpret results. Due to concerns about power with the addition of interaction terms, age and sex were not examined as moderators in interactions with effortful control and physiology.

Effortful control was a significant moderator of associations between heart rate and aggression. When controlling for concurrent relational aggression, the effortful control x heart rate interaction significantly predicted fall (model $F(6,58) = 10.83$, $p < .01$; $R^2 = .53$; EC x HR $\beta = -.37$, $p < .001$) and spring (model $F(6,57) = 7.80$, $p < .01$; $R^2 = .45$; EC x HR $\beta = -.22$, $p < .05$) physical aggression. Analysis of simple slopes suggested that lower baseline heart rate was associated with increased physical aggression only among children with lower levels of effortful control. Heart rate and physical aggression were not associated for children with high levels of effortful control (see Figures 1 and 2). A similar pattern was found for fall relational aggression when not controlling for concurrent physical aggression; however, when physical aggression was entered in the model as a control, this finding was no longer significant.

Effortful control was also a significant moderator of RSA – aggression associations. When controlling for the opposite form of concurrent aggression, RSA was positively associated with physical aggression in fall (model $F(6,58) = 6.68$, $p <$

.01; R^2 = .41; RSA x EC β = -.25, $p < .05$) and spring (model F(6,57) = 7.35, p < .01; R^2 = .44; RSA x EC β = -.21, $p < .05$) and fall relational aggression (model F(6,58) = 3.36, p < .01; R^2 = .26; β = -.21, RSA x EC $p < .10$) at a trend level, only among children low in effortful control. For children with higher effortful control scores, RSA and aggression were not related (see figures 3, 4, and 5).

Analyses examining effortful control as a moderator of blood pressure – aggression associations while controlling for the opposite form of aggression evidenced a slightly different pattern. Diastolic blood pressure significantly predicted spring physical (model F(6,59) = 9.51, p < .01; R^2 = .49; DBP x EC β = .34, $p = .001$) and relational (model F(6,59) = 4.49, p < .01; R^2 = .31; DBP x EC β = -.25, $p < .05$) aggression scores among children with low effortful control scores. However, the direction of effects was opposite; DBP positively predicted relational aggression in the spring and negatively predicted spring physical aggression among children low in effortful control (see figures 6 and 7). Among children with higher effortful control scored, DBP did not predict either form of aggression. Systolic blood pressure was unrelated to physical and relational aggression.

Hypotheses 3 and 3a

For hypothesis 3, associations between heart rate and RSA reactivity and classroom aggression were of interest. Zero-order correlations are presented in Table 3. Fall physical aggression was associated with heart rate reactivity to relational provocations ($r(61) = .30$, $p < .05$), and spring physical aggression was associated with increased heart rate reactivity to instrumental ($r(59) = .33$, $p = .01$) and relational ($r(60) = .39$, $p < .01$) vignettes. In each case, children whose heart rate increased during instrumental and relational provocations engaged in higher levels of physical aggression. Additionally, spring physical aggression was associated with greater decreases in RSA during the relational provocations at a trend level ($r(60) = -.24$, $p = .06$). These associations persisted when controlling for age and sex.

An examination of the role of age and sex as moderators of these associations was undertaken using hierarchical linear regression in a similar manner to the regressions above for baseline physiology. Due to the potential order effects noted, order was included as a covariate in these analyses. Relational aggression was unrelated to physiological reactivity. A number of effects emerged in the prediction of physical aggression. None of the sex interaction analyses were significant; however age moderated 4 of the 8 regression predicting physical aggression. Age moderated associations between heart rate reactivity to both instrumental and relational stories and physical aggression in the fall and the spring. Heart rate change during the instrumental stories was positively associated with fall (model $F(7,51) = 3.13$, $p < .01$, $R^2 = .30$; ΔHR x age $\beta = -.22$, $p < .10$) and spring (model $F(7,51) = 5.61$, $p < .001$, $R^2 = .44$; ΔHR x age $\beta = -.21$, $p < .10$) physical aggression among younger preschoolers but not older preschoolers (see figures 8 and 9). In both of these regressions, the change in R^2 for the second step was significant, but the interaction predictors were marginally significant.

Age significantly moderated the relation between change in heart rate to relational vignettes and fall physical aggression (model $F(7,53) = 4.40$, $p = .001$, $R^2 = .37$; ΔHR x age $\beta = -.25$, $p = .05$). For older preschoolers, heart rate change was negatively related to fall physical aggression, but for younger preschoolers, heart rate change to relational vignettes was positively related to fall physical aggression (see figure 10). In predicting spring physical aggression, however, the addition of age and sex interactions explained a significant amount of variance (ΔR^2 = .08, $p < .05$ model $F(7,52) = 5.92$, $p < .01$; $R^2 = .44$), however neither of the predictors entered at that step reached significance. Instead, main effects of change in heart rate to relational provocations (β = .41, $p < .05$) and spring relational aggression (β = .44, $p < .01$) were found. For the whole sample, children with greater increases in heart rate to the relational stories engaged in more physical aggression in the spring.

For change in RSA to the vignettes, only one interaction emerged. Age moderated the relation between RSA change to instrumental vignettes and fall physical aggression ($F(7,51) = 2.98$, $p < .05$; $R^2 = .29$; ΔRSA x age β = .30, $p < .05$). For younger preschoolers, change in RSA to instrumental vignettes was negatively associated with fall physical aggression, but there was no association between RSA change and physical aggression for older preschoolers (see figure 10).

Hypothesis 3a addressed the question of whether physiological reactivity to a specific type of provocation would be more strongly associated with the similar form of aggression than reactivity to the dissimilar form. To address this question, regressions were conducted with age, sex, and the opposite form of concurrent aggression entered at step 1, reactivity to instrumental and relational provocations at step 2, and interactions between each measure of reactivity and sex and age at step 3 (e.g., ΔHR_instrumental x age, ΔHR_relational x age, ΔHR_instrumental x sex, ΔHR_relational x sex). None of these regressions predicted a significant amount of variance in relational aggression at either time point. Three of the four regressions predicting fall and spring physical aggression were significant, and the step 3 interactions resulted in significant changes in

R^2. However, none of the main effect or interaction predictors in these equations were significantly associated with physical aggression at either time point.

Inspection of correlations between the independent variables in these models suggested problems with multicolinearity, particularly with respect to interactions between physiological reactivity and age ($r(56) = .73$, $p < .001$ for age interactions with ΔHR to RA and PA; $r(56) = .49$, $p < .001$ for age interactions with ΔRSA to RA and PA). Because age was a significant moderator of associations between reactivity and aggression when each measure of physiology was included separately in hypothesis 3, an alternative approach was undertaken to probe these associations. The dataset was split at the age mean (49.61 months) and regressions predicting aggression were conducted for each age group. At step 1, sex and the opposite concurrent form of aggression were entered. Physiological reactivity to both relational and instrumental vignettes was entered simultaneously at the second step to examine unique contributions of physiological reactivity to the prediction of classroom aggression.

In these analyses, both heart rate and RSA reactivity predicted fall physical aggression only. In both cases, these associations were significant for younger preschoolers. When controlling for concurrent relational aggression, heart rate reactivity to relational provocations uniquely predicted fall physical aggression (model $F(4,18) = 9.81$, $p = .001$, $R^2 = .69$; $\beta = .58$, $p < .01$). Younger preschoolers who showed greater increases in heart rate during the relational vignettes engaged in more physical aggression in the fall. For RSA reactivity, younger preschoolers who showed greater decreases in RSA to instrumental provocations had higher fall physical aggression scores (model $F(4,18) = 6.57$, $p < .01$, $R^2 = .59$; $\beta = -.38$, $p < .05$). No other associations were significant.

Hypotheses 4 and 4a

Associations between hostile intent attributions and classroom aggression were first examined through zero-order correlations. Hostile intent attributions to both instrumental and relational provocations were unrelated to classroom aggression. Age and sex were not significant in moderation analyses. Similar to results for hypothesis 4, hypothesis 4a indicated that hostile attributions to neither instrumental nor relational provocations uniquely predicted classroom aggression.

Discussion

The current study was designed to examine associations between baseline physiological arousal, physiological reactivity, and classroom engagement in physical and relational aggression in early childhood. Although a long research literature exists linking baseline ANS underarousal to physical aggression (e.g., Lorber, 2004), this association had not yet been examined with respect to relational aggression. Similarly, a number of studies have begun to address RSA and heart rate reactivity with respect to physical aggression, but to date few studies have examined these associations with relational aggression during childhood (c.f. Murray-Close & Crick, 2007; Sijtsema et al., 2011). The focus on physical aggression, and in some cases the use of samples comprised only of boys or girls, has limited our understanding of the development of aggression in both boys and girls.

Baseline Physiology

The first goal of this study was to examine associations between ANS arousal, as measured by baseline heart rate, blood pressure, and RSA, and relational and physical aggression in the classroom. Bivariate associations between baseline heart rate and blood pressure measures and relational and physical aggression were consistent with ANS underarousal theories, such as sensation-seeking and fearlessness theories (Raine, 1993). Lower heart rate predicted increased fall and spring physical and relational aggression. Additionally, lower diastolic blood pressure was associated with increased physical aggression in the spring. However, when controlling for the opposite form of aggression, only associations between baseline physiology and physical aggression remained. As noted below, the unique association between relational aggression and baseline physiology emerges only among preschoolers with poorer self-regulation abilities.

Children engaging in high levels of fall and spring physical aggression and high fall relational aggression had higher baseline RSA levels. The literature on baseline RSA and externalizing behavior problems has produced mixed findings. Some studies that have focused on the early childhood period, however, have demonstrated null or positive associations between baseline RSA and externalizing problems (e.g., Calkins, Blandon et al., 2007; Calkins, Graziano, & Keane, 2007). As noted in the introduction, these studies share a common methodology: measurement of baseline RSA while children watched a neutral film to encourage participants to sit quietly during the baseline measurement. Children who were more attentive to the video may have experienced RSA suppression, indicative of increased attention (Suess et al., 1994) during the baseline period. Thus children who were not able to consistently attend to the video may have had higher “baseline” RSA; these children may also be more likely to engage in externalizing behaviors. In this study, a neutral story was read aloud to children to encourage compliance with sitting quietly. It is possible that this technique had a similar effect on baseline RSA as the video procedure used in the studies by Calkins, Blandon, and colleagues (2007) and Calkins, Graziano, and Keane (2007). Methodological issues will be discussed further below.

A second goal of this study was to examine whether self-regulation, as measured by effortful control, would moderate associations between baseline arousal and aggression. In this case, a consistent pattern of results emerged. Baseline physiology-aggression associations only emerged for children low in effortful control. For children higher in effortful control, there were no associations between physiology and either physical or relational aggression. A number of effects were found for children with low effortful control. For example, lower heart rate predicted increased physical aggression in the fall and spring, and lower DBP predicted higher levels of physical aggression in the spring. These findings extend the literature suggesting that low baseline arousal is related to externalizing behaviors to include the moderating role of self-regulation. While some children with low ANS arousal may use aggression to raise arousal levels, these findings suggest the possibility that preschoolers with better self-regulation skills may choose more prosocial, or less antisocial, ways to raise arousal levels.

In contrast, higher DBP predicted spring relational aggression among children with lower effortful control scores, when controlling for the effects of physical aggression. This positive association is in keeping with some studies noting elevated blood pressure among hostile and aggressive children (Pine et al., 1996) and a number of studies noting high baseline blood pressure in children demonstrating hostile, Type A personality patterns (Jorgensen et al., 1998). It may be the case that even at a young age, relationally aggressive children may experience more hostility and covert anger than children who engage in less relational aggression. That this association emerged after controlling for concurrent physical aggression, which was *negatively* associated with DBP, suggests that in this sample, baseline diastolic blood pressure discriminated physical and relational aggression uniquely. It is possible that the hostile, controlling behaviors associated with Type A personality features may be more relevant to relational aggression than the often undercontrolled nature of early childhood physical aggression.

A similar pattern emerged for RSA. Among children low in effortful control, higher baseline RSA was associated with increased fall and spring physical aggression and fall relational aggression. Again, for children with higher levels of effortful control, RSA and aggression were not associated. This set of findings, in particular, suggests a need for future research with varying methodology to replicate these results. If the baseline measures do, as suggested above, reflect in part children's ability to attend to a neutral story, then the association between higher RSA and aggression among children low in effortful control should be interpreted with caution. It may be the case that self-regulation and RSA are correlated as a function of study design, and this measure of baseline RSA is more reflective of ability to attend to a neutral story than a true, resting measure of RSA. Nevertheless, these findings suggest that baseline RSA may be informative in the study of early childhood relational aggression as well as physical aggression.

These results suggest an important narrowing of the sensation-seeking hypothesis in the preschool age group, pointing to the role of self-regulation, indexed here as effortful control. It may be the case that only in the context of poorer self-regulation abilities does ANS underarousal increase risk of engagement in physically or relationally aggressive behavior in preschool. Furthermore, these findings may help to explain inconsistencies in past research examining ANS arousal and aggression in early childhood that did not take into account the moderating role of self-regulation.

Because behavior and emotion regulation are key developmental tasks in early childhood, undergoing rapid improvement and increasing cognitive control (Kochanska et al., 1997; Zelazo, 2004), multi-age preschool classrooms present a wide range of ages and regulation abilities. While age and effortful control were positively related in this study, as would be expected, age was not a significant moderator of associations between baseline physiology and aggression, whereas effortful control was. This suggests that effortful control is not merely a proxy for age or age-linked advances in self-regulation. Rather, individual differences in effortful control appear to uniquely moderate associations between physiology and aggression. Furthermore, these findings point to the potential usefulness of behavior and emotion regulation-focused intervention efforts, particularly among children with low physiological arousal, to reduce classroom physical and relational aggression.

Physiological Reactivity

The third goal of this study was to examine whether children's physiological reactivity to stories about ambiguous peer conflicts would predict their engagement in physical and relational aggression. Rather than reactivity to a uniform experience, such as a negative mood induction, reactivity to ambiguous peer provocations was selected for this study because social information processing theory (Crick & Dodge, 1994) suggests that children's cognitive interpretations and reactions to these experiences should meaningfully relate to their behavior. Differences in physiological reactivity to these stories, then, may also relate to differences in classroom behavior, such as aggression. Results from this study provide preliminary support for this hypothesis in the prediction of physical aggression, but not relational aggression. Furthermore, age may play a moderating role in associations between heart rate and RSA reactivity and physical aggression.

Findings with respect to physical aggression differed by time point and provocation type. In both the fall and spring, greater heart rate increases during the instrumental provocations were associated at a trend level with increased physical aggression among younger preschoolers. However, no associations were noted between heart rate reactivity and physical aggression among older preschoolers. Interestingly, heart rate reactivity to relational provocations also predicted fall and spring physical aggression. Engagement in fall physical aggression was associated with blunted heart rate reactivity to relational vignettes for older preschoolers but greater heart rate increases to relational vignettes for younger preschoolers. Finally, regardless of age, children experiencing greater heart rate increases during the relational vignettes engaged in more spring physical aggression. When heart rate change scores for both instrumental and relational vignettes were entered simultaneously, heart rate increases during the relational vignettes uniquely predicted fall physical aggression among younger preschoolers only. Heart rate increases during the peer provocation vignettes may indicate a stress response. In a classroom setting, for example, this stress response to an ambiguous peer provocation, in turn, may increase the likelihood of engagement in aggressive responding.

The lack of specificity in these findings is contrary to hypotheses, particularly the unique effect of heart rate change to relational provocations, above instrumental provocations, on fall physical aggression. It may be the case that during early childhood, differentiation of instrumental compared to relational threats is not as advanced as it is in later childhood. Alternatively, themes of belonging and inclusion may be particularly important to younger preschoolers, many of whom may be entering preschool for the first time. As a result, younger preschoolers' heart rate hyper-reactivity to the relational vignettes may reflect greater sensitivity to peer and relationship conflict. Relational provocations can certainly be acted upon with physical forms of aggression, and that may be the case for these younger preschoolers.

With respect to RSA reactivity, engagement in fall physical aggression was uniquely associated with greater decreases in RSA during instrumental provocations among younger preschoolers only. The procedures of this study were not designed to result in strong negative affect. Much of the literature in this area uses tasks that induce significant emotional reactions in participants (e.g., frustration while completing a difficult task, watching a frightening movie clip), and as result, these studies generally seem to demonstrate larger average RSA change scores than those in the present study. It is possible, then, that rather than reflecting emotion regulation, given that the stories were not designed to elicit strong emotions, RSA suppression in this study reflects increased attention to the vignettes (Suess et al., 1994). If so, then these results suggest that younger preschoolers engaging in fall physical aggression may demonstrate increased attention or vigilance to instrumental provocations.

The prevalence of age moderation effects with respect to physiological reactivity should be noted. Two factors are particularly relevant to the strength of associations between physiological reactivity and physical aggression for younger children. First from a statistical perspective, age and physical aggression were inversely related; as a result, there is considerably more variation in the physical aggression scores of younger preschoolers relative to older preschoolers at both time points. This reduced variance likely influenced the ability to detect associations between physiological reactivity and physical aggression among older preschoolers. Secondly, as preschoolers' abilities to regulate emotion and attention increase over early childhood, moderate physiological reactions may not be as strongly associated with behavioral reactions. That is, with more advanced emotion and behavior regulation skills, older preschoolers may perceive malicious intent from a peer's actions and demonstrate a physiological response. However, better regulation skills may allow some children to inhibit aggressive responding, even in the face of heightened physiological arousal.

The general lack of unique physiological reactivity predictors of relational aggression is somewhat surprising. However, Sijtsema and colleagues (2011) noted that associations between RSA reactivity and relational aggression were moderated by a number of social cognitive risk factors, such as peer rejection and rejection sensitivity, which were not measured in this study. Furthermore, a number of studies have recently pointed to the utility of examining functions of aggressive behavior (e.g., proactive or reactive) in physiological studies of aggression. Specifically, proactive aggression, which includes goal-directed aggressive behaviors enacted with little emotional display, is thought to be most closely related to baseline physiological arousal, whereas reactive aggression, characterized by highly emotional aggressive behavior, has been more associated with physiological reactivity (Hubbard et al., 2002; Scarpa & Raine, 1997; Scarpa et al., 2008). Because the measures of aggression used here did not distinguish between proactive and reactive functions of aggression, the lack of findings may follow from differential associations between proactive and reactive functions of aggression. The possibility exists that this difference in function may be more relevant to early relational aggression than physical aggression. Future studies examining baseline and reactive physiology that take into account both proactive and reactive functions of aggression as well as social cognitive risk factors will be useful in addressing this issue.

Social Cognition

The final goal of this study was to examine whether children's social information processing patterns related to the attribution of a peer's intent were related to engagement in aggression. Across time points and forms, children's hostile intent attributions were unrelated to engagement in classroom aggression. With respect to physical aggression, these findings are somewhat surprising. Although the bulk of the work in this area has focused on middle childhood and adolescence, some studies have demonstrated similar associations in early childhood (e.g., Schultz, Izard, & Ackerman, 2000; Webster-Stratton & Lindsay, 1999). For example, in a study with a large, national dataset, Runions & Keating (2007) noted the expected positive association between children's hostile intent attributions in preschool and externalizing behavior problems in both preschool and kindergarten. Some studies have noted difficulty in the measurement of intent attribution measurement in early childhood due to less advanced cognitive functioning (e.g., Cassidy, Kirsh, Scolton, & Parke, 1996), and these studies reported null associations between intent attributions and behavior problems. However, in the current study, neither the floor nor ceiling effects in children's intent attributions that were noted in previous research were found in this sample. Even still, it is possible that preschoolers' less advanced hypothetical and abstract thinking may have influenced their ability to accurately understand and respond to the vignettes. Future studies examining the potential moderating role of cognitive functioning will be required to examine this possibility.

The lack of findings with respect to relational aggression and hostile attribution biases are in keeping with a number of recent studies that have not found associations between intent attributions and relational aggression (e.g., Crain et al., 2005; Hayward & Fletcher, 2003). Participants in both of these previous studies were older than the current sample, however. Therefore it is also possible that associations between social information procession and behavioral reactions may not yet be evident in early childhood. On the other hand, the potential cognitive limitations noted above in the measurement of hostile intent attributions and physical aggression would also apply to the measurement of intent attributions and relational aggression and could have influenced the lack of association. Future studies, particularly those employing less cognitively-intensive methods for assessing hostile attribution biases, may further clarify this association. In particular, tasks that do not require hypothetical reasoning and abstract thought would allow for clearer conclusions to be drawn.

An important aspect of this study focused on the role of physiology in predicting future physical and relational aggression. Support for this hypothesis was strongest for physical aggression, where baseline measures of heart rate, RSA, and diastolic blood pressure predicted spring levels of physical aggression among preschoolers with poor self-regulation skills. Additionally, exaggerated fight/flight responses, as indexed by greater heart rate increases to stories of peer provocation measured in the fall, also predicted spring physical aggression. One physiological measure predicted spring levels of relational aggression; among preschoolers with less advanced self-regulation skills, higher diastolic blood pressure was associated with increased spring relational aggression. Whether the paucity of physiological predictors of spring relational aggression is a result of the measurement strategies used for physiological recording or the more transient nature of relational aggression in early childhood will require future studies. Additionally, larger sample sizes that allow for the examination of three-way interactions involving sex may help to further clarify the lack of longitudinal findings reported here.

Limitations

Although this study provides interesting preliminary information regarding physiological arousal and reactivity and aggression in early childhood, several limitations should be noted. First, small sample sizes may have precluded the identification of smaller effects and limited power to examine interactions. This is particularly relevant given the extent of the moderation effects hypothesized. Although the effortful control moderation analyses were significant, the age moderation effects with respect to physiological reactivity reached only trend level significance.

Furthermore, no sex moderation effects emerged. Findings regarding sex differences in relational aggression have been mixed in the preschool age group; therefore a larger sample with adequate power to examine two- and three-way interactions would clarify whether the lack of findings noted here was due to low power or a true lack of association.

Secondly, the sample in this study was comprised of middle to upper-middle class families and was relatively low-risk. As such, levels of aggression in these preschool classrooms may be considerably lower than levels of aggression in preschools serving higher risk populations, and aggression levels of nearly all of the preschoolers in this sample would be considered below clinical levels of aggressive behavior. As a result, these findings may not be generalizable to the wider population. Furthermore, teacher reports of physical aggression demonstrated clear floor effects, particularly among older preschoolers. This reduced variance likely hindered the ability to detect associations between study variables and physical aggression. Replication with a sample that is more diverse both racially and socioeconomically, as well as in level of aggressive behavior, is warranted.

Beauchaine (2001) and others have noted the need to measure both sympathetic and parasympathetic influences of the same organ (e.g., pre-ejection period and RSA as sympathetic and parasympathetic influences on cardiac activity, respectively). Understanding the differential ways in which sympathetic and parasympathetic nervous system activity interact and influence behavior problems may further clarify early developmental trajectories of these behaviors. Furthermore, some evidence suggests different patterns of SNS and PNS reactivity may characterize internalizing compared to externalizing problems, due to differential associations with behavioral activation and behavioral inhibition systems. In the current study, neither behavioral activation nor pure sympathetic measures of physiology were included. The inclusion of these measures in future research would allow for clearer tests of these hypotheses.

Finally, the procedure used to measure physiological reactivity may have been too subtle of a manipulation for the preschool age group. This may be particularly relevant to measures of RSA reactivity, which are thought to index both attention and emotion regulation. Without clear manipulation of only attention or the induction of sufficient emotion to require regulation, there are some challenges in interpreting these findings, particularly given that the associations found here are in the opposite direction of those found with more emotionally distressing procedures. Similarly, the use of a story to encourage children to sit quietly during the baseline RSA recording and the vignettes used as a baseline for reactivity calculations result in measures of RSA that cannot be considered true baseline or resting measures. These findings should be interpreted with caution. Nevertheless, the results of this study provide preliminary evidence of the role of baseline physiological arousal in the development of relational and physical aggression and point to utility of measuring physiological reactivity to peer conflict in studying physical aggression in early childhood.

Implications

These findings have implications for intervention efforts with the preschool age group. Given that ANS underarousal was particularly predictive of both physical and relational aggression in the context of low effortful control, intervention efforts focused on improving self-regulation in low ANS arousal/low effortful control children may be warranted. If sensation seeking is a key driver of physical and relational aggression among children with low ANS arousal, then attempts to provide stimulating activities to these children, as well as teaching children to select stimulating activities that are more appropriate than physical or relational aggression may help to reduce engagement in aggression.

Physiological reactivity was predictive of engagement in physical aggression, primarily among younger preschoolers. The fact that physically aggressive preschoolers demonstrated physiological reactivity to both relational and instrumental provocations suggests that these children may be particularly aware of threat or hostility in a range of settings. Attempts to foster more benign attributions and better regulation in the face of provocation in early childhood may be warranted. In sum, the addition of psychophysiological information to existing knowledge of correlates of aggression, such as social-information processing patterns and peer group functioning, may improve efforts to intervene with early physical and relational aggression.

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Appendix A

Table 1

Descriptive Statistics for Primary Study Variables

Variable	*M*	*SD*	*n*
Age	49.64	7.16	96
Baseline Heart Period (ms)	589.34	58.00	67
Baseline RSA	6.08	1.26	67
Systolic Blood Pressure	102.24	7.66	70
Diastolic Blood Pressure	51.62	6.48	70
ΔHR to Instrumental	6.44	16.54	59
ΔRSA to Instrumental	-.13	.47	59
ΔHR to Relational	9.34	21.70	61
ΔRSA to Relational	-.07	.52	61
HAB-Instrumental	.86	.73	78
HAB-Relational	.68	.68	78
Relational Agg Fall	1.57	.62	96
Relational Agg Spring	1.66	.72	94
Physical Agg Fall	1.17	.43	96
Physical Agg Spring	1.15	.37	94
Effortful Control	.00	2.17	80

Table 2

Correlations between Baseline Physiological Measures and Aggression

	1	2	3	4	5	6	7	8
1. Baseline Heart Period								
2. Baseline RSA	.76*							
3. Systolic BP	.06	.04						
4. Diastolic BP	-.21^t	-.12	.26*					
5. Effortful Control	-.03	-.01	-.06	.07				
6. Relational Agg Fall	.33*	.24*	-.16	.01	-.08			
7. Relational Agg Spr	.25*	.13	.01	-.11	-.28*	.61*		
8. Physical Agg Fall	.48*	.44*	-.08	-.09	-.40*	.39*	.22*	
9. Physical Agg Spr	.32*	.27*	-.01	-.32*	-.39*	.23*	.46*	.67*

Note. *$p < .05$; $^t p < .10$.

Table 3

Correlations Between Physiological Reactivity, Intent Attributions, and Aggression

	1	2	3	4	5	6	7	8	9
1. ΔHR Instrumental									
2. ΔRSA Instrumental	-.56*								
3. ΔHR Relational	.58*	-.23^{t}							
4. ΔRSA Relational	-.31*	.46*	-.38*						
5. Relational Agg Fall	-.04	.04	.03	.02					
6. Relational Agg Spr	.09	.05	.14	.02	.61*				
7. Physical Agg Fall	.16	-.02	.30*	-.09	.39*	.22*			
8. Physical Agg Spr	.33*	-.07	.39*	-.24^{t}	.23*	.46*	.67*		
9. HAB Relational	.05	.06	-.05	.00	.14	.10	-.17	-.10	
10. HAB Instrumental	.03	.20	.03	.05	.03	.03	-.06	-.08	.72*

Note. *p < .05; ^{t}p < .10.

Appendix B

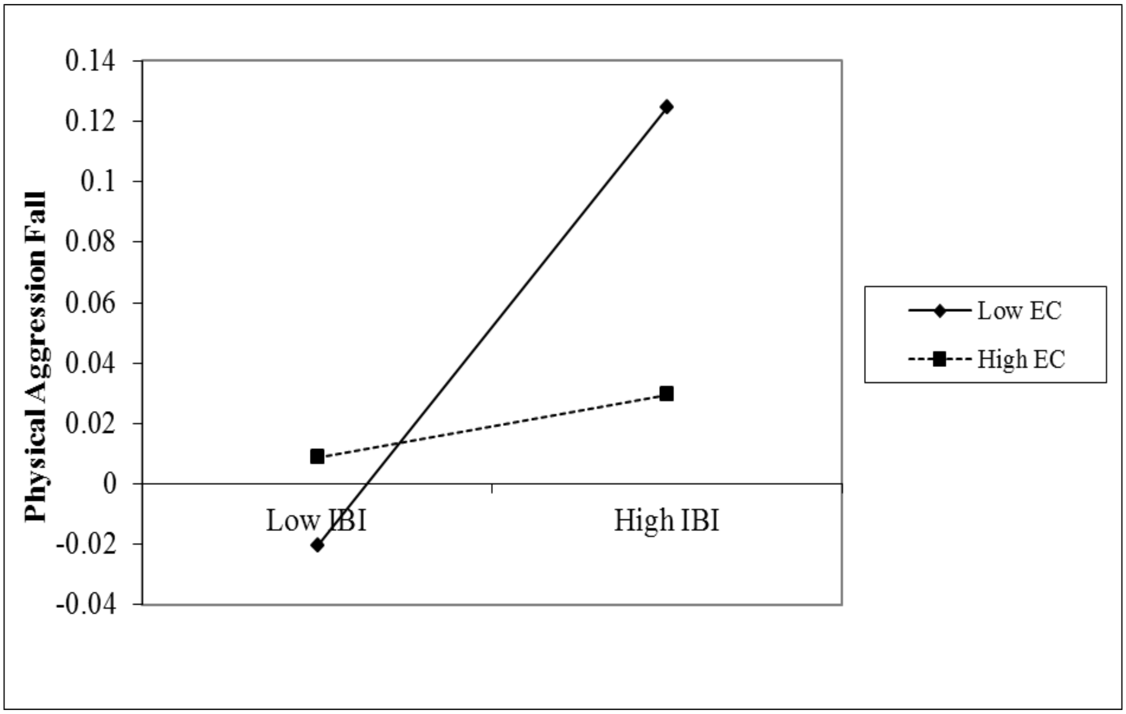

Figure 1. Illustration of effortful control as a moderator of the baseline heart period – fall physical aggression association. IBI represents interbeat interval, or heart period. Line slopes calculated at one standard deviation above and below the mean for effortful control (EC).

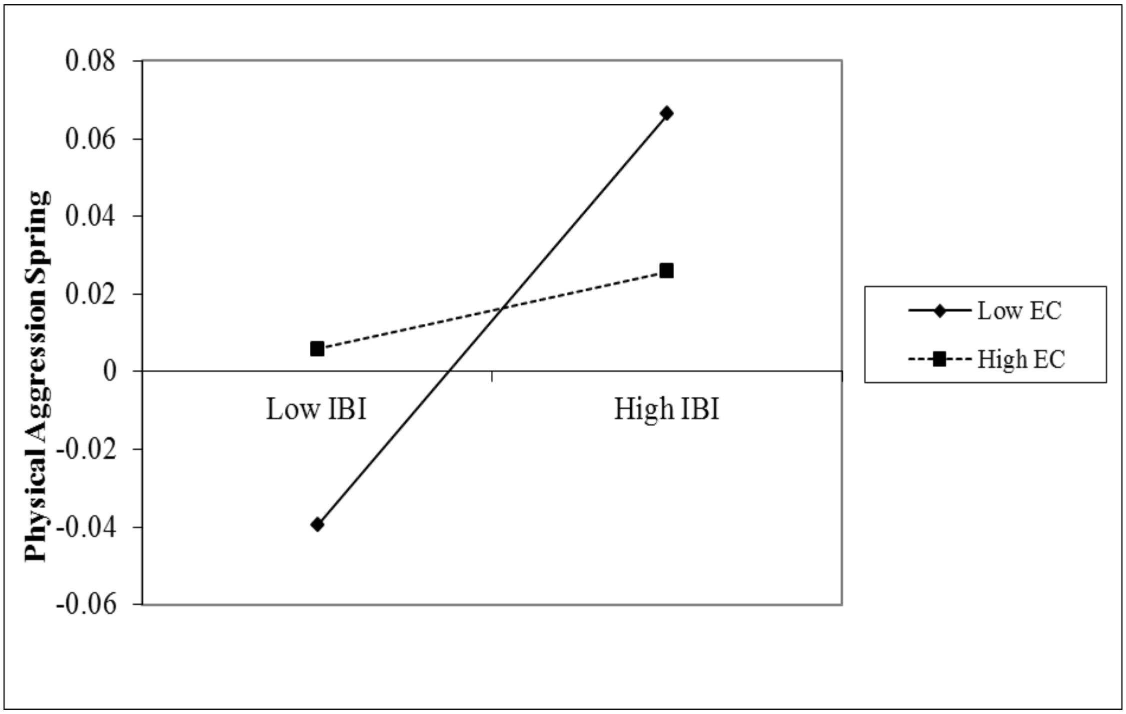

Figure 2. Illustration of effortful control as a moderator of the baseline heart period – spring physical aggression association. IBI represents interbeat interval, or heart period. Line slopes calculated at one standard deviation above and below the mean for effortful control (EC).

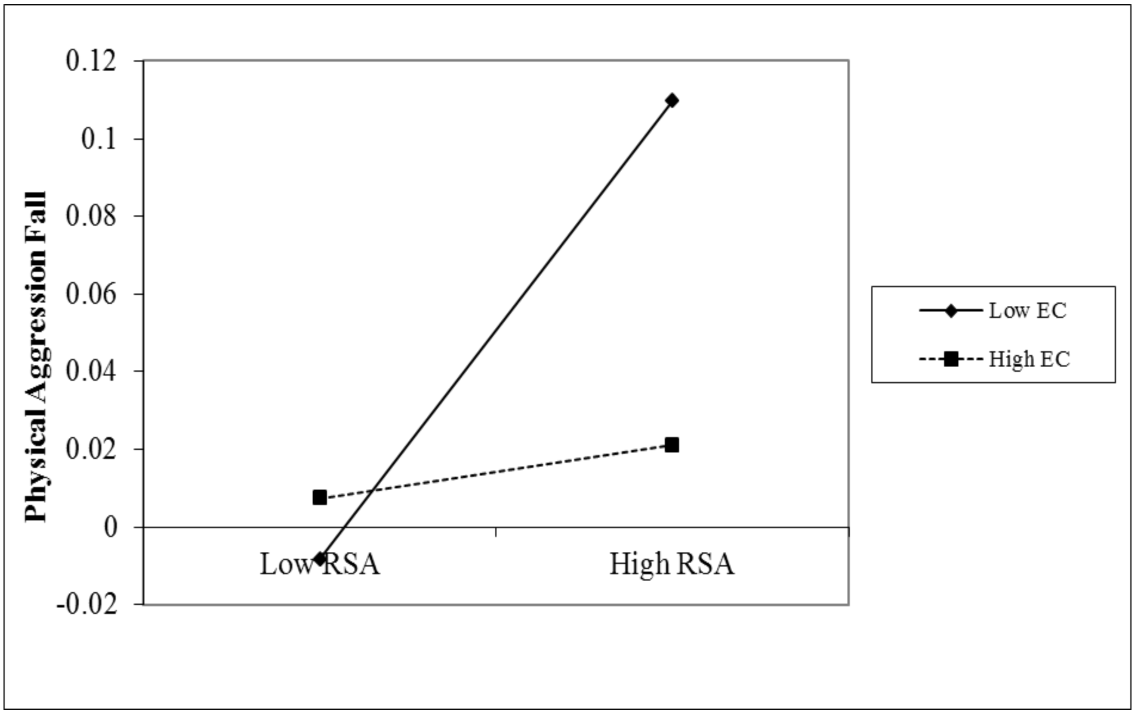

Figure 3. Illustration of effortful control as a moderator of the baseline RSA – fall physical aggression association. Line slopes calculated at one standard deviation above and below the mean for effortful control (EC).

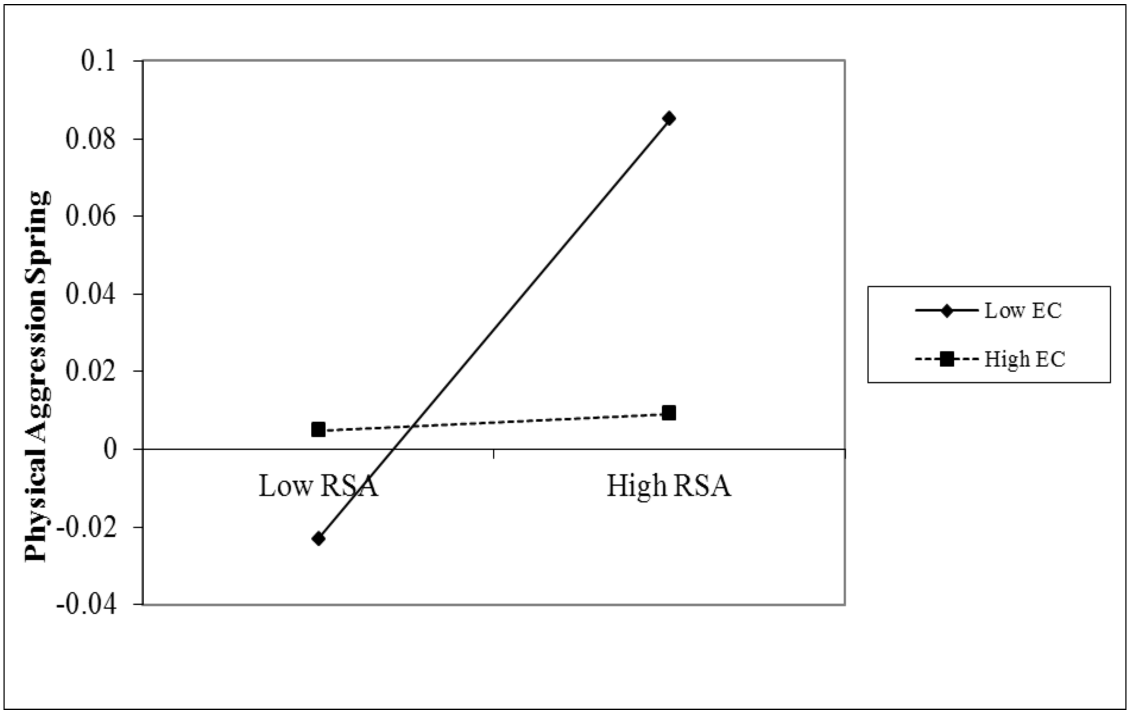

Figure 4. Illustration of effortful control as a moderator of the baseline RSA – spring physical aggression association. Line slopes calculated at one standard deviation above and below the mean for effortful control (EC).

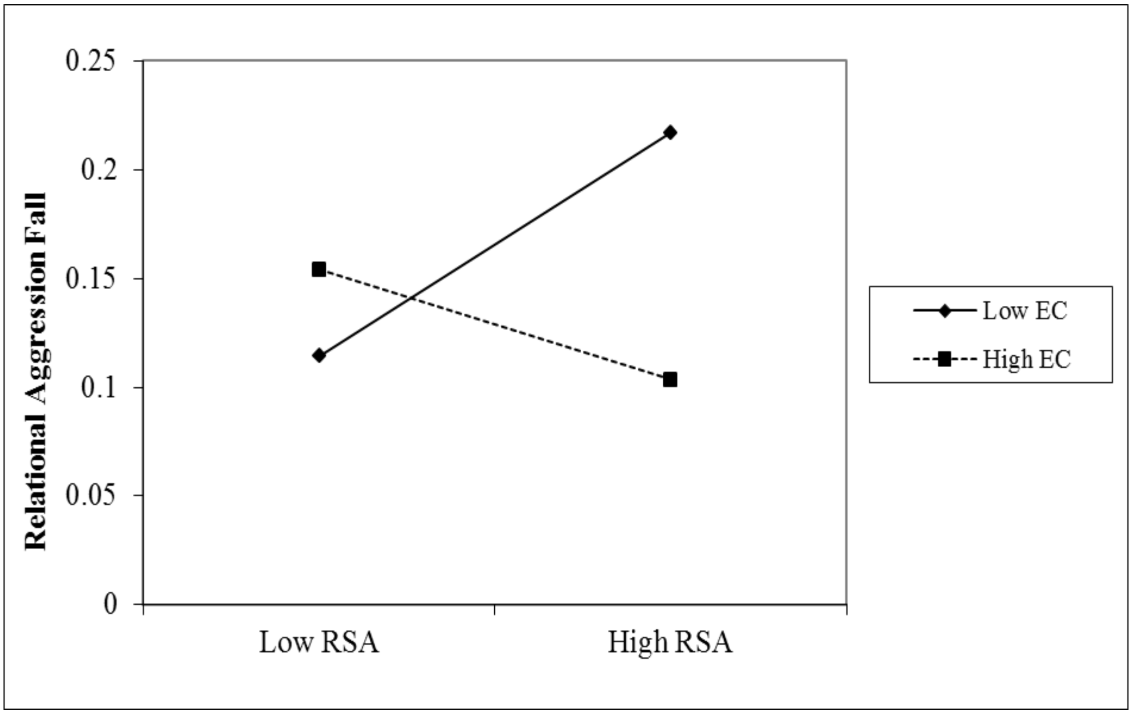

Figure 5. Illustration of effortful control as a moderator of the baseline RSA – fall relational aggression association. Line slopes calculated at one standard deviation above and below the mean for effortful control (EC).

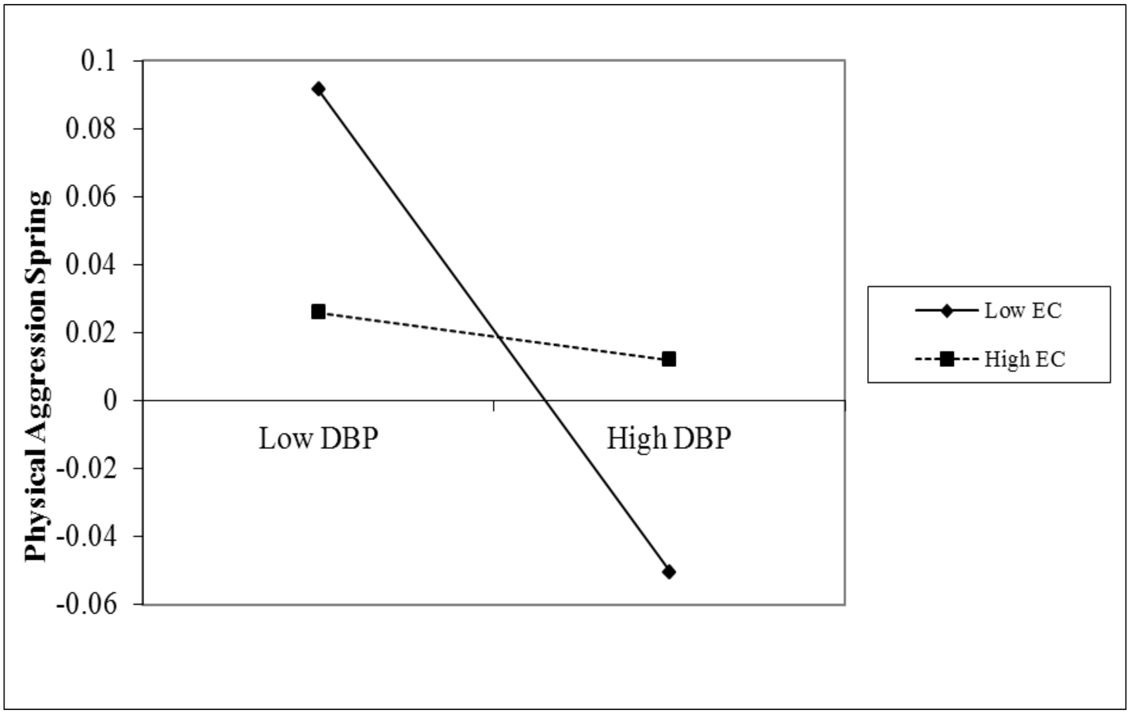

Figure 6. Illustration of effortful control as a moderator of the baseline diastolic blood pressure (DBP) – spring physical aggression association. Line slopes calculated at one standard deviation above and below the mean for effortful control (EC).

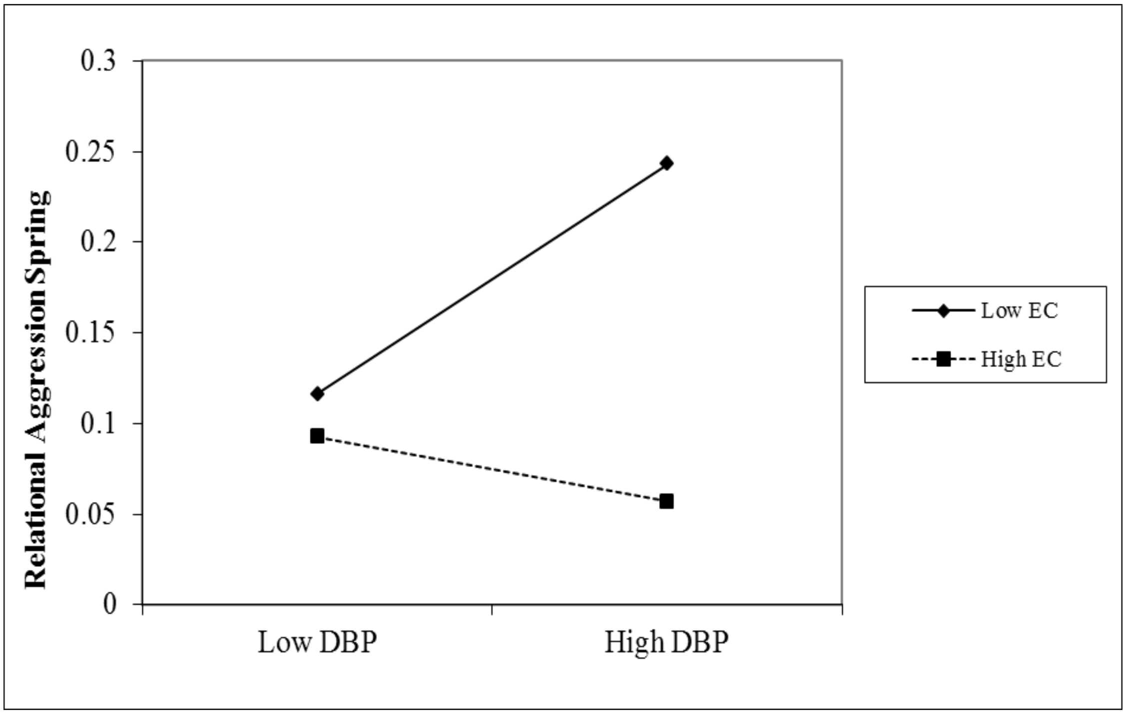

Figure 7. Illustration of effortful control as a moderator of the baseline DBP – spring relational aggression association. Line slopes calculated at one standard deviation above and below the mean for effortful control (EC)

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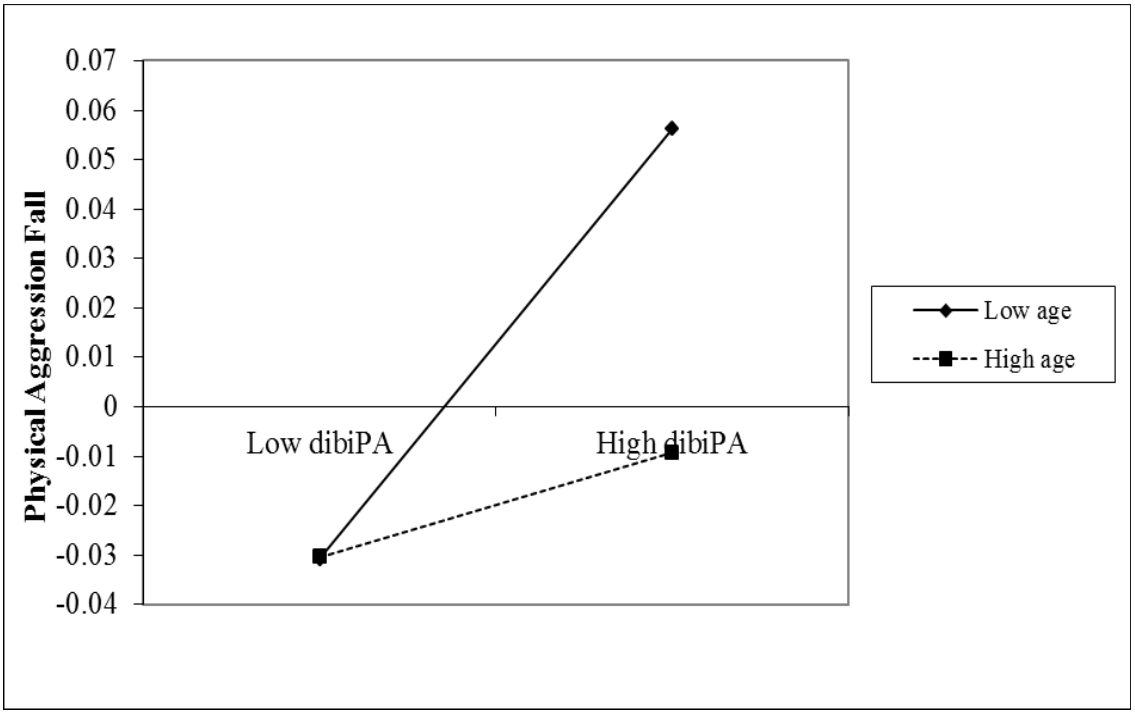

Figure 8. Illustration of age as a moderator of the heart rate change to instrumental conflict – fall physical aggression association. Scores are calculated such that larger change in IBI reflects increases in heart rate. Line slopes calculated at one standard deviation above and below the mean for age.

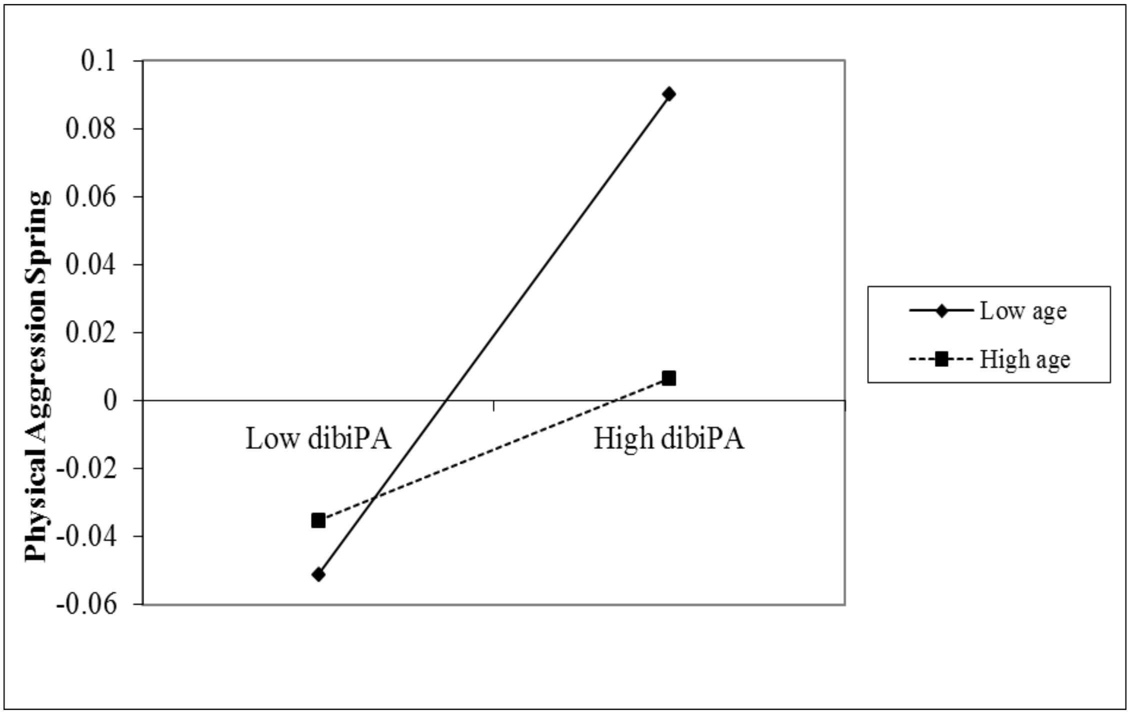

Figure 9. Illustration of age as a moderator of the heart rate change to instrumental conflict – spring physical aggression association. Scores are calculated such that larger change in IBI reflects increases in heart rate. Line slopes calculated at one standard deviation above and below the mean for age.

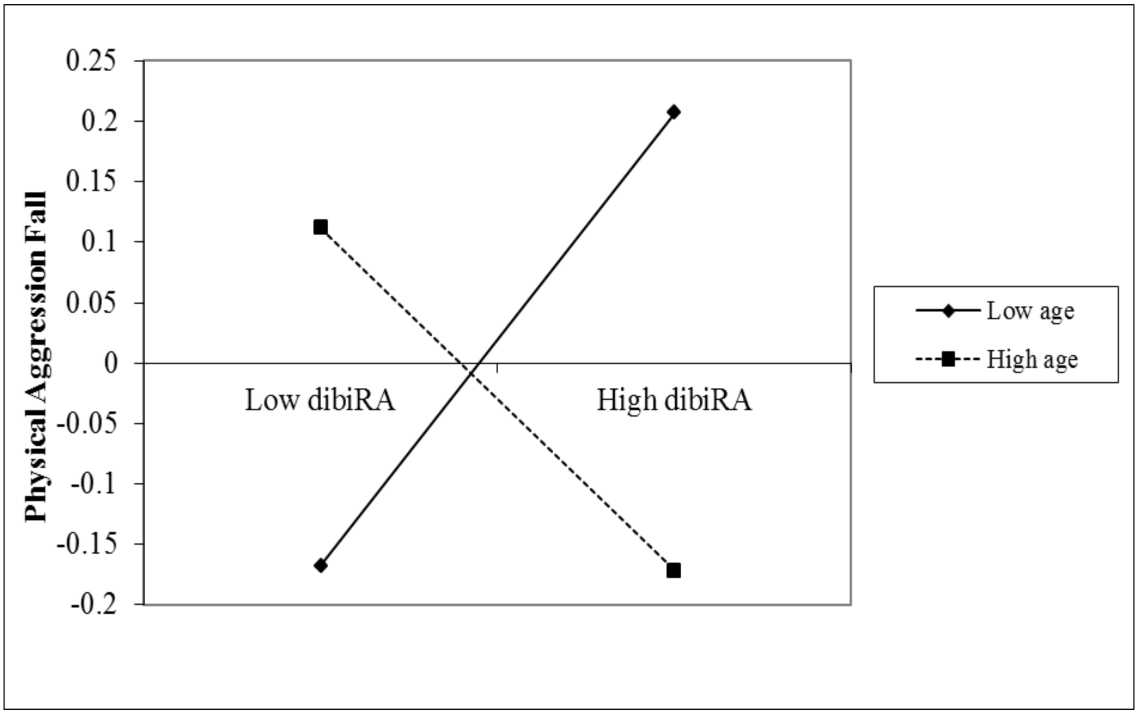

Figure 10. Illustration of age as a moderator of the heart rate change to relational conflict – fall physical aggression association. Scores are calculated such that larger change in IBI reflects increases in heart rate. Line slopes calculated at one standard deviation above and below the mean for age.

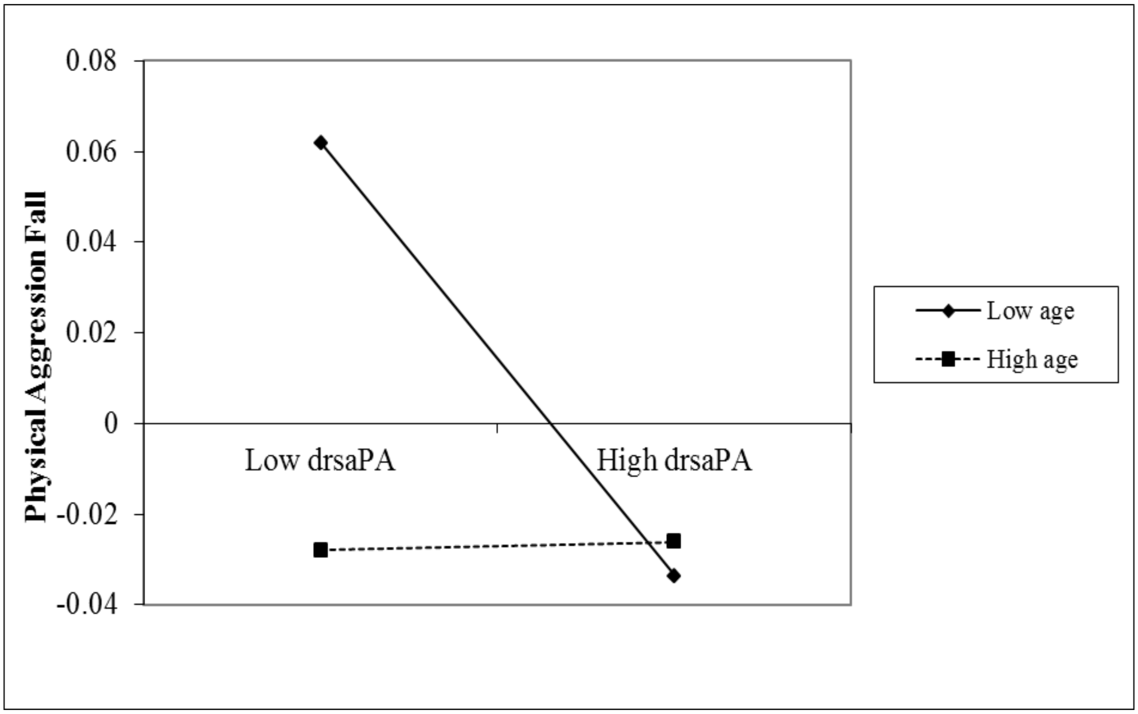

Figure 11. Illustration of age as a moderator of the RSA change to instrumental conflict – fall physical aggression association. Scores are calculated such that larger change in RSA reflects increases in RSA in response to conflict. Line slopes calculated at one standard deviation above and below the mean for age.

Appendix A

Block Neutral

"Let's pretend you're painting a picture on an easel. You're wearing a bright red smock, and you're painting with a lot of different colors: red, blue, yellow, and purple. You're painting a picture of a blue house with a bright yellow sun and a purple mailbox. Another kid in your class is painting a picture on an easel nearby. This kid is singing a really loud song while painting."

"Let's pretend you're reading a book in the book area. You are sitting on the couch, and you have the book on your lap. It's really comfortable. The story you're reading is about some fish who are swimming around in the ocean. In the story, when the fish swim around, they see lots of fish and plants under the water. While you're reading, another kid in your class sits down near you and starts to read a book out loud in a very loud voice."

"Let's pretend you're outside on the playground. You are swinging on the swing, and you're pumping your feet so hard that you're swinging really high! You can see the whole playground because you're so high up. The kid on the swing next to you is trying to pump, but this kid doesn't know how to pump yet, so this kid is not swinging very high. The kid gets upset and goes to play somewhere else."

"Let's pretend you're sitting at a table putting beads on a string. You have a long string and you filled it up to the end with really colorful beads. A kid sitting next to you is also working on a bead project. This kid is having a hard time getting the beads on the string. After a while, the kid puts the beads down on the table and leaves."

Block Relational

"Let's pretend that you are sitting at a table with other kids in your class playing with some play-doh. You're all sharing the play-doh and toys in the middle of the table. While you are playing you see that the two kids sitting by you are looking at you and whispering to each other. A few seconds later they both start laughing."

"Let's pretend that it is group time. All of the carpet squares are laid out in a circle, and kids are starting to find spots to sit. Everyone is talking to the friends next to them. You look for one of your friends to sit down next to, and you sit down next to them. After a minute your friend gets up and walks away from you."

"Let's pretend that a kid in your class is having a birthday party. This kid is really excited about this birthday, and has been talking about the party for a long time. There are going to be a lot of games at the party, and a big cake. On the day the invitations went out, you didn't get an invitation."

“Let’s pretend that some kids in your class are playing dress up. Everyone is putting on fancy clothes and shoes, and they’re pretending to go on a trip. They’re having fun and laughing together. You think it would be fun to play too, so you ask if you can dress up with them and go on the trip. The kids don’t answer you.”

Block Instrumental

“Let’s pretend that you are playing with some blocks and that you made a really neat house with them. You worked so hard and used so many blocks! It’s so neat that a kid in your class comes over to look at it. While the kid is looking at it, you go to the bathroom. When you come back, you realize the kid has knocked down your house of blocks.”

“Let’s pretend that you are waiting to go outside with your class. You are at the front of the line of all the kids in your class. While you are standing there waiting, you get bumped from behind and fall down. When you turn around, you see that it was someone in your class who bumped into you.”

“Let’s pretend you are playing in the sandbox. You’re concentrating really hard on the castle that you’re building. It’s so tall that it is tricky to build it higher, but you’re doing a great job! All of a sudden, you get hit by a bouncing ball. You look up and see that it was a kid in your class who hit you with it.”

“Let’s pretend you’re working on an art project. You’ve been working really hard, and your picture is almost done. You used red and blue paint, and you even glued on some beads. A kid next to you is working on a painting too, and knocks over the blue paint. The blue paint spills all over your project, and it is ruined.”