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EARLY AGGRESSION, SOCIAL COMPETENCE, AND PEER REJECTION: ASSOCIATIONS WITH PHYSIOLOGICAL INDICES OF EMOTIONAL FUNCTIONING

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ABSTRACT

While recent research has supported the role of emotional functioning in the development of childhood aggression, little work has investigated the role of physiological indicators of emotional functioning in the manifestation of aggression and peer relations in young children. The present study examined associations among physiological measures of emotional functioning, aggression, social competence, and peer rejection in children with early-starting aggressive behaviors. Participants included 207 children with elevated aggression at kindergarten entry (73% African American, 19% Latino, 8% Caucasian; 66% male; average age 5.62 years at kindergarten entry). Aggressive behavior and social competence was assessed via teacher ratings and peer sociometric nominations, and peer preference was assessed via peer sociometric nominations. Two physiological indicators of emotional functioning were collected: heart rate reactivity in response to emotionally evocative movie scenes (used as an index of emotional reactivity), and the P300 component of the event-related potential in response to unfavorable reward conditions during an attention task (used as an index of emotion regulation). Heightened heart rate reactivity and reduced P300 were associated with elevated aggression and reduced social competence. While linear regression models revealed no direct effects between the physiological indicators of emotional functioning and peer preference, elevated aggression and reduced social competence were associated with peer rejection. The results of the study support the contribution of physiological indices of emotional reactivity and emotion regulation to aggression and socially adaptive behavior, as well as the role of aggression and social competence in peer rejection. Results suggest that exploration of the associations among emotional functioning, social behavior and peer rejection over time warrants future research.

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Introduction

Aggression constitutes one of the most challenging behavioral patterns in childhood. Manifestations of disruptive behavior often begin as early as the preschool years and tend to show significant stability over time. Early-onset aggression, in particular, is associated with high levels of symptom continuity as well as heightened risk for engagement in violence and delinquency later in adolescence (Broidy et al., 2003; Loeber, 1991).

One of the most problematic consequences of aggressive behavior involves its impact on children's social-emotional development and peer relations. Beginning in elementary school, children who display disruptive and aggressive behaviors often show corresponding delays in the development of social competence with elevated risk for peer rejection (Coie & Dodge, 1998). In turn, peer rejection deprives aggressive children of interactions with more prosocial peers, and thereby reduces opportunities for them to learn more adaptive behaviors (Dishion, Spracklen, Andrews, & Patterson, 1996). In addition, isolation from the mainstream peer group often propels aggressive children into mutual friendships, which reinforce and amplify their aggressive and disruptive behaviors. In these ways, poor social competence and peer rejection place aggressive youth at heightened risk for trajectories involving continued aggression, violence and deviant activities (Dishion, Patterson, Stoolmiller, & Skinner, 1991).

Interestingly, not all aggressive children struggle socially; some are able to avoid peer rejection and may even gain positions of dominance and perceived popularity in the peer group (Bierman, Smoot, & Aumiller, 1993; Estell, Cairns, Farmer, & Cairns, 2002). In early elementary school, aggressive children who avoid rejection are more likely to show reduced aggression over time relative to those who are rejected by their peers (Bierman & Powers, 2009; Bierman & Wargo, 1995; Kupersmidt & Coie, 1990; Miller-Johnson, Coie, Maumary-Gremaud,

Bierman, & Conduct Problems Prevention Research Group [CPPRG], 2002). For this reason, understanding the factors associated with early childhood aggression that may increase a child's risk for peer rejection is a priority.

Over the past several decades, accumulating evidence has supported the central role of social-emotional functioning in the peer relations of aggressive children. In particular, developmental research has suggested that aggressive children with higher levels of emotional reactivity and emotion dysregulation are at particular risk for peer rejection (Calkins, Gill, Johnson, & Smith, 1999; Rubin, Coplan, Fox, & Calkins, 1995). A major limitation of this research, however, is that measures of emotional functioning in developmental studies are typically based on observations of behavior in emotionally challenging situations or on teacher or parent reports of children's emotional functioning. These measures, which assess emotional functioning based on behavior resulting from the combination and interaction of multiple emotional processes, may conflate the assessment of these separate processes and their unique contributions to emotional expression. In this way, the exclusive use of behavioral indices may preclude a more precise assessment of emotional functioning, its various underpinnings, and its associations with aggression, social competence, and peer rejection.

The purpose of this study is to contribute to research examining links between the emotional functioning, aggression, social competence, and peer rejection of children with early-starting aggressive behaviors, using physiological measures of emotional functioning. To do so, this study used data from a larger study of a preventive intervention for aggressive kindergarten children. Two physiological indicators of emotional functioning were collected, each examining the impact of an emotionally challenging event: 1) heart rate reactivity in response to emotionally evocative movie scenes, and 2) the P300 component of the event-related potential

(ERP) in response to an unfavorable change in reward conditions during an attention task. These indicators of emotional functioning were compared with aggressive behavior (teacher ratings and peer sociometric nominations), social competence (teacher ratings and peer sociometric nominations), and peer preference (peer nominations of "most liked" and "least liked" classmates). Two hypotheses were tested: 1) that the two physiological indicators of emotional functioning (heart rate reactivity and the P300) would each show significant associations with elevated aggressive behaviors and poor social competence at school, and 2) that the two physiological indicators of emotional functioning would be significantly associated with peer preference, either directly or indirectly, through their effects on child aggression and social competence.

The Emotional Functioning of Aggressive Children

When exhibited at high rates, aggressive behaviors, including interpersonally hostile, destructive, and rule-breaking activities, are the key symptoms representing conduct disorder in the DSM-IV and DSM-V. In early childhood, high rates of these aggressive behaviors are particularly likely to be accompanied by irritable, angry, and emotionally volatile behaviors, which represent the key symptoms of oppositional defiant disorder, evident in both peer and adult interactions (Burke, Loeber, & Birmaher, 2002; Lahey, McBurnett, & Loeber, 2000).

The development of these two patterns of disruptive behavior has been typically conceptualized within a social learning framework. In this framework, disruptive behaviors emerge at problematic levels when stressed parents (e.g., single parents, elevated depression) living in adverse circumstances (e.g., poverty, crowded living quarters, high violence neighborhoods) become enmeshed in frequent parent-child conflicts and resort to harsh discipline strategies, which they use inconsistently with limited effectiveness. These parent-

child interactions both model aggression and reinforce child aggression, either by giving in when faced with child aggression or giving up on commands or requests (Patterson, Debaryshe, & Ramsey, 1989). In addition, children in high-risk contexts frequently face further exposure to disruptive behaviors through their interactions with peers. Often compounded by a lack of adequate parental monitoring, these children encounter increased exposure to deviant peers, who also model and reinforce antisocial activities (Dishion & Tipsord, 2011; Synder et al., 2008). Considerable empirical evidence exists to support this conceptualization of the behavioral learning and associated developmental processes that support chronic aggressive behaviors and emerging antisocial activity (Dodge, Greenberg, Malone, & Conduct Problems Prevention Research Group [CPPRG], 2008).

Although the role of emotional functioning in the developmental course of aggression is less well-established, this topic has attracted increasing attention in recent years (Beauchaine, Gatzke-Kopp, & Mead, 2007). Research has documented that oppositional defiant disorder, which is characterized as much by dysfunctional emotionality as it is by problem behavior, often serves as a developmental precursor of conduct disorder (Burke et al., 2002; Lahey et al., 2000). In addition, social learning theory models of aggression often note that temperamental factors such as negative emotionality may increase the likelihood of the emergence and escalation of coercive parent child conflict (Dodge et al., 2008; Lynam et al., 2000).

Models of Temperament and Aggression

Research on the role of emotional functioning in the manifestation of aggression has largely been based on the study of temperament, which is broadly conceptualized as constitutionally based, individual differences that are relatively enduring (Rothbart, Ahadi, & Hershey, 1994). Such research has typically focused on patterns consistent with “difficult”

temperament, characterized by negative mood, intense reactions to novel stimuli, slow adaptability to change, withdrawal from new stimuli, and irregularity of biological functions (Thomas & Chess, 1977). Work in this domain has often supported a link between "difficult" temperament and externalizing behaviors, both concurrently (Blackson, Tarter, Martin, & Moss, 1994; Giancola, Mezzich, & Tarter, 1998) and prospectively (Bates, Maslin, & Frankel, 1985; Henry, Caspi, Moffitt, & Silva, 1996; Sanson, Smart, Prior, & Oberklaid, 1993). For example, in a large longitudinal study conducted by Prior and colleagues, children with stable aggressive behavior across early and middle childhood were more likely to be classified as having a difficult temperament than those with patterns of transient aggression or nonaggressive behavior (Kingston & Prior, 1995). Similarly, Moffitt and Caspi (2001) have demonstrated that difficult temperament in early childhood increases the risk for life-course-persistent delinquency.

In addition to being conceptualized as a measure of individual differences, temperament has been further defined as constitutionally based individual differences in reactivity and regulation (Rothbart, Ahadi, et al., 1994). Emotional reactivity here refers to individual differences in the intensity and threshold of the experience of emotion, reflecting variations in the biological processes and corresponding physiological arousal that occur in response to environmental stimuli (Rothbart & Derryberry, 1981). From this view, emotional reactivity broadly represents the process of arousal associated with emotional experience. Emotion regulation, on the other hand, refers to the initiation, maintenance, modification and/or modulation of emotional arousal that is often necessary to accomplish one's goals in emotionally arousing circumstances (Eisenberg et al., 2000). In this way, emotion regulation reflects the capacity to flexibly respond to stressful situations and emotional experiences in an adaptive and socially appropriate manner (Cole, Michel, & Teti, 1994; Eisenberg & Morris, 2003). It is

important to note that, while reactivity and regulation refer to components of emotional response in a specific situation or context, within this framework, they are conceptualized as processes that are consistent with more global emotional patterns and thus indicative of more trait-like, stable dispositions (Rothbart, Ahadi, & Evans, 2000). The current study is based from this perspective.

Given this understanding of emotional reactivity and emotion regulation, it follows that, when children have temperamental styles characterized by maladaptive patterns of reactivity and regulation, they are at heightened risk for psychological maladjustment. In fact, research has demonstrated that children who have reactivity and regulation patterns consistent with a difficult temperamental disposition, or a general distress-proneness, are more likely to demonstrate externalizing, as well as internalizing, problems (Caspi, Henry, McGee, Moffitt, & Silva, 1995; Cole et al., 1994; Eisenberg et al., 2001, 2009; Frick & Morris, 2004). Given the varied nature of problematic emotional patterns, it appears that the divergence in pathways to externalizing and internalizing symptoms may be influenced by differences in the nature of the child's temperament and emotional difficulties. Specifically, theory asserts that the distress-proneness characteristic of children with difficult temperament includes two distinct types of distress-proneness: distress to new or challenging stimuli (often characterized as fear), and distress to restraint or the blocking of goals (typically characterized as irritability or anger/frustration) (Rothbart, Derryberry, & Posner, 1994; Rothbart, et al. 2000). In general, research has linked the former type of distress-proneness to internalizing problems and the second type of distress-proneness to externalizing problems (Rothbart, Ahadi, et al., 1994; Eisenberg et al., 2001, 2009).

Behavior-based Assessments of Emotional Reactivity

Research on emotional functioning has consistently supported a link between behavioral measures of heightened emotional reactivity and the manifestation of aggression and other externalizing problems in childhood (Calkins et al., 1999; Eisenberg, Fabes, Nyman, Bernzweig, & Pinuelas, 1994, Eisenberg et al., 2000; Shields & Cicchetti, 1998). For example, in a study conducted by Eisenberg and colleagues, preschool children rated high in emotional intensity, a defining feature of reactivity (Rothbart & Derryberry, 1981), displayed more aggressive reactions to anger-inducing situations than children rated lower in emotional intensity (Eisenberg et al., 1994). In addition to demonstrating concurrent associations between emotional functioning and externalizing behavior, research has also provided support for a predictive relationship between behavior-based assessments of emotionality and aggression across childhood (Eisenberg et al., 2000). For instance, following children longitudinally, Vitaro, Brendgen and Tremblay (2002) found that maternal ratings of emotional reactivity at age six predicted teacher ratings of reactive aggression in later childhood.

Behavior-based Assessments of Emotion Regulation

In addition to the potential role that emotional reactivity plays as a risk factor for aggressive behavior, emotion regulation has also been implicated in developmental models of aggression and social dysfunction. The development of emotion regulation skills, which begins in preschool and continues throughout the early elementary years, is crucial to adaptive social behavior. During preschool, the emergence of certain skills, such as those associated with language, attention, and inhibitory control, fosters children's capacities to modulate their emotional arousal and regulate their behavior to accommodate to social expectations (Cole et al., 1994; Eisenberg & Morris, 2003; Frick & Morris 2004). For example, when faced with an

emotionally frustrating situation (e.g., losing at a competitive game with a peer), children who can maintain focus on a superordinate social goal (e.g., finishing the game peacefully) will be better able to modulate their frustration and continue the game in a calm manner. In contrast, children who are unable to maintain focus on the superordinate goal will be less likely to effectively modulate their frustration and more likely to act in a socially undesirable way (e.g., yelling at the peer). In this way, emotion regulation skills are necessary for adaptive social behavior, and deficits in these skills can lead to problematic outcomes, such as aggression and other forms of externalizing behaviors (Frick & Morris 2004; Martin et al., 1994).

Parallel to research using behavior-based measures of emotional reactivity, studies incorporating behavior-based measures of emotional regulation have shown strong associations with externalizing behaviors, such as aggression. In particular, work in this area has widely supported an inverse relationship between emotion regulation and aggression, with researchers such as Eisenberg and colleagues demonstrating an association between poor emotion regulation assessed by teacher ratings, parent ratings, or behavioral observations, and aggressive behaviors (Calkins et al., 1999; Eisenberg et al., 1994, 2000, 2001; Rothbart, Ahadi, et al., 1994). For example, in her study of emotion coping in preschool children, Eisenberg found that children who were rated by teachers and parents as having poorer regulatory abilities were more likely to show less constructive and more aggressive reactions to anger-inducing situations than children with better regulatory abilities (Eisenberg et al., 1994). These findings are consistent with research demonstrating that young children with reduced emotion regulation capacity engage in more externalizing and problematic behaviors with peers than children with greater emotion regulation capacity (Calkins et al., 1999; Rubin et al., 1995). Associations between regulation and problem behaviors have also been demonstrated for older children (Eisenberg, et al., 2000,

2001) and, furthermore, have indicated that early problems with emotion regulation often serve as a risk factor for the development of later externalizing problems (Caspi et al., 1995; Newman, Caspi, Moffitt, & Silva, 1997).

In addition to their associations with aggression, heightened emotional reactivity and poor emotion regulation assessed on the basis of behavior have also been linked with poor social functioning. Indeed, a number of studies have revealed strong associations between behavior-based measures of emotional reactivity, low social competence, and elevated rates of peer rejection. In a study conducted by Calkins and colleagues (1999), for example, toddlers who exhibited more emotional reactivity during a stress-inducing task were less likely to engage in cooperative social behaviors than toddlers who exhibited less reactivity during the same task. Likewise, in Eisenberg's study of emotional intensity in preschool children, children rated high in emotional intensity were more likely to show reduced social competence as well as reduced peer status than children rated low in emotional intensity (Eisenberg et al., 1993).

Similarly, research has also demonstrated that poor emotion regulation assessed behaviorally places children at risk for compromised social functioning. Such work has generally centered on the idea that adequate emotion regulation is necessary to support the modulation of emotion needed to behave in accordance with social demands and/or expectations, and that this competent social behavior elicits positive responses from peers and enables children to avoid peer rejection (Cole et al., 1994; Denham et al., 2003; Frick & Morris, 2004). In accordance with this general notion, research has consistently shown that children who display emotionally dysregulated behavior also show reduced social competence (Denham et al., 2003; Eisenberg et al., 1993, 1995, 1997; Fabes et al., 1999). Additionally, research has revealed that emotionally dysregulated behavior increases risk for a variety of problematic social outcomes,

including low peer acceptance and elevated peer rejection (Eisenberg et al., 1993, 1995; Fabes & Eisenberg, 1992). Pope and Bierman (1999), for example, found that boys who displayed greater levels of dysregulated behavior in elementary school showed a wide range of peer problems, including difficulty gaining acceptance, higher levels of peer dislike, and greater levels of ostracism and victimization, during both elementary school and adolescence. Such findings are consistent with literature indicating that deficiencies in emotion regulation, and not necessarily aggressive behavior per se, contribute to problematic peer outcomes in childhood (Bierman et al., 1993; Pope, Bierman, & Mumma, 1991), as well as literature supporting the predictive relationship between childhood regulatory deficits and interpersonal problems in adulthood (Caspi, 2000; Newman et al., 1997).

Physiological Assessments of Emotional Functioning

Taken together, this line of research supports the idea that both heightened emotional reactivity and poor emotion regulation confer risk for aggression and peer rejection. However, research on the processes of emotional functioning comes with many challenges. Most notably, the processes of reactivity and regulation are often very difficult to disentangle from one another, as both processes contribute to the expression of an observable emotional response (Cole, Martin, & Dennis, 2004; Frick & Morris, 2004). For example, a child with moderate levels of reactivity and very poor regulatory skills may appear equally aggressive to a child with average regulatory skills and very high levels of reactivity. For this reason, exclusive reliance on behavioral measures in this context is likely to lead to imprecise measures of emotional functioning and its component processes. The prior review was based upon studies that used behavioral measures (teacher ratings, parent ratings, or observations) to assess emotional reactivity and regulation. While a more nuanced assessment of emotional functioning can be

obtained by using physiological indicators, which allow for more temporally discrete and fine-grained measurement of these component processes, very few studies are available that use such physiological indices of emotional functioning and examine associations with aggression, social competence, and peer relations in young children. Given that multiple theoretical models concerning emotionality and aggression have been suggested (Beauchaine et al., 2007; Bierman & Sasser, in press) and that this area of research is still in its infancy, studies that assess emotional processes via physiological measures are needed in order to better understand the specific mechanisms linking emotional functioning to aggression, social competence, and peer rejection.

Physiological Reactivity, Aggressive Behavior, and Social Competence

A small set of research studies have linked physiological measures of emotional reactivity with aggression and social competence. Parallel to research using behavioral measures to assess emotional reactivity, a central focus of this work has been on the processes of hyper-arousal and/or elevated stress responding and their associations with externalizing behaviors including aggression. Such work has centered on the hypothesis that certain children have a predisposition towards neurobiological hyper-arousal when confronted with a threat, and that this predisposition serves as a risk factor for aggressive responding (El-Sheikh et al., 2009).

Relatedly, research on aggression and processes of the autonomic nervous system has largely been based on the tenets of polyvagal theory. Broadly, polyvagal theory, articulated by Porges (2001), accounts for the way in which the body, and specifically the parasympathetic nervous system (PNS), reacts to threat in different contexts. In particular, polyvagal theory asserts that there are two branches of the vagal nerve: the dorsal motor nucleus, which suppresses the metabolic processes of the PNS during conditions of threat, and the nucleus ambiguus, which

modulates the cardiac functions of the sympathetic nervous system (SNS) during conditions of threat. In stress-inducing situations where social affiliation is adaptive, the nucleus ambiguus inhibits input to the SNS that would result in a fight or flight response, and instead, prompts a deceleration in heart rate. In contrast, in stress-inducing situations in which a fight or flight response is adaptive, the nucleus ambiguus withdraws its inhibitory input to the SNS to allow for increased cardiac output (vagal withdrawal) (Beauchaine et al., 2007). According to this theory, the nucleus ambiguus, which is a phylogenetically newer structure than the dorsal motor nucleus, evolved to meet the needs of socially affiliative behavior in the context of increasingly complex human interaction (Porges, 1995). From this perspective, individuals who have heightened threat responses, and who are more likely to exhibit vagal withdrawal and a fight or flight response when social affiliation would be more adaptive, may be more likely to exhibit elevated levels of aggression. It is important to note that, based on this framework of physiological reactivity, assessments of resting state or baseline autonomic functioning may be less valid indices of the physiological processes associated with aggression than assessments conducted in the face of threatening or emotionally evocative stimuli.

In line with polyvagal theory, many researchers have asserted that processes of the vagal system represent an important index of stress responsivity and adaptive social functioning and that disruptions in this system serve as indicators of impaired social functioning (Beauchaine et al., 2007; Fox & Field, 1989; Huffman et al., 1998). Research on the functioning of the vagal system in youth has supported this framework, specifically by demonstrating a relationship between low vagal tone and externalizing or problem behaviors (Eisenberg et al., 1995; El-Sheikh et al., 2009; Beauchaine, Katkin, Strassberg, & Snarr, 2001). For example, in a set of studies conducted by Beauchaine and colleagues, children and adolescents with oppositional

defiant disorder and/or conduct disorder displayed lower baseline respiratory sinus arrhythmia (a measure of vagal tone) than controls (Beauchaine et al., 2007). Similarly, in a study on adolescent males, low baseline vagal tone was associated with elevated levels of antisocial behavior (Mezzacappa et al., 1997). Such findings support the role of attenuated parasympathetic control of cardiac responsivity and corresponding reactivity in the manifestation of aggressive and antisocial behaviors.

Research on the sympathetic branch of the autonomic nervous system has also demonstrated a link between the manifestation of externalizing behavior and processes of hyper-arousal. For example, elevated levels of sympathetic functioning have been shown to moderate the relation between contextual risk factors such as harsh parenting and externalizing behavior, with heightened baseline sympathetic functioning associated with elevated externalizing behavior (Bubier, Drabick, & Breiner, 2009).

In addition to research on the association between baseline indices of autonomic functioning and aggression, several studies have also explored the link between autonomic functioning under stressful or emotionally evocative conditions and aggressive responding. For example, in a study by Hubbard and colleagues, children who exhibited greater skin conductance reactivity when faced with a cheating play partner were found to be more reactively aggressive by teacher report and more likely to express angry nonverbal behaviors than children without this pattern of reactivity (Hubbard et al., 2002, 2004). Similarly, other research has demonstrated a positive association between heart rate (which reflects both sympathetic and parasympathetic functioning) in response to provocation by peers and elevated externalizing behaviors such as aggression (Waschbusch et al., 2002; Williams, Lochman, Phillips, & Barry, 2003). Moreover, in a meta-analysis conducted by Lorber (2004), both elevated skin conductance reactivity and heart

rate reactivity were found to be associated with aggression, and heart rate reactivity was found to be specifically associated with conduct problems in children.

Taken together, these studies, consistent with prior work using behavioral measures to assess emotional reactivity, suggest that physiological indicators of heightened emotional reactivity may be associated with elevated levels of aggressive behavior and problematic social functioning. In particular, this research indicates that emotional reactivity in response to conditions of emotional threat or distress is likely to be particularly linked with elevated aggression and impaired social competence.

Attention Control under Emotionally Challenging Conditions

A related, but separate, line of research examining emotional functioning and aggression has focused on the role of attention, considered a key component of emotion regulation (Cole et al., 2004; Eisenberg, Spinrad, & Eggum, 2010; Rothbart et al., 2000). More specifically, research on the association between attention and externalizing behaviors has commonly focused on how emotional challenges affect attention regulation in goal-oriented situations. One index that has commonly been used in the measurement of attention regulation and its association with externalizing behaviors is the P300 component of the event-related potential (ERP), a positive deflection of the EEG that occurs following a task-relevant event. Research on the P300 has indicated that it reflects the ability to direct controlled attention to a salient stimulus and that it is implicated in attention regulation (Segalowitz & Davies, 2004). In addition, the P300 component has demonstrated sensitivity to the amount of attention resources engaged during dual task performance (Polich, 2012), and for this reason, has been used to assess the impact of emotionally challenging circumstances on attention control in attention-performance tasks. For example, the P300 has been used as an index of attention control in much of the research on the

impact of negatively valenced stimuli and changes in reward contingencies on performance during attention regulation tasks (Lewis, Granic, & Lamm, 2006; Lewis, Lamm, Segalowitz, Stieben, & Zelazo, 2006; Lewis, Todd, & Honsberger, 2007; Pérez-Edgar & Fox, 2005; Rich et. al, 2005). In these studies, which used emotionally evocative visual stimuli or unfavorable manipulation of rewards to elicit emotional arousal, children were required to regulate their emotions as well as continue to focus attention on a task. Within such paradigms, reduced capacity to attend to the task has been interpreted as the result of interference induced by emotional arousal. Taken together, such studies support the use of the P300 as an index of children's ability to recruit and focus attention in the context of affective or emotionally challenging cognitive tasks, and in this way, support the use of the P300 as an index of emotion regulation.

Research using the P300 to more specifically explore the link between attention regulation and aggression has generally revealed an association between reduced P300 amplitude (reflective of low attention control) and externalizing behaviors. Work in this area, which has predominately focused on late adolescence and early adulthood, indicates that individuals with reduced P300 amplitudes are more likely to have externalizing problems such as alcohol and drug dependence, conduct disorder and antisocial behaviors (Patrick et al., 2006). Reduced P300 amplitudes in adolescence have also been linked to the early manifestation of problem behaviors (such as police contact and sexual intercourse) which often precede the onset of more serious externalizing problems, and have been shown to predict the development of substance use disorder in early adulthood (Iacono, Carlson, Malone, & McGue, 2002; Iacono & McGue, 2006). Such findings support the idea that reduced attention control, as indexed by the P300, serves as a risk factor for the development of externalizing problems in youth.

Developmental research suggests that the association between the P300 and externalizing problems in childhood may be particularly pronounced when children are performing an attention control task under emotionally challenging conditions. Work in this area has generally centered on the idea that emotionally challenging circumstances present cognitive demands that are typically met with increased allocation of cognitive resources. For example, several studies have demonstrated that, when moving from a neutral task to a more emotionally evocative task, most children respond by exhibiting increased attention control (Lewis et al., 2007; Pérez-Edgar & Fox, 2005; Todd, Lewis, Meusel, & Zelazo, 2008). Similarly, on tasks of response inhibition and attention regulation, children typically respond to changes in reward contingencies designed to elicit frustration (i.e., rigged negative feedback), with increased attention control (Lewis, Lamm, et al., 2006; Rich et al., 2005). This pattern of marshaling additional attention control in response to conditions designed to evoke frustration or negative affect is believed to result from the need to put forth more cognitive effort in order to perform tasks that demand attention control in the presence of negative emotions (Lewis, Lamm, et al., 2006; Todd et al., 2008). More specifically, it has been hypothesized that the tendency to recruit additional attention control in response to emotionally challenging circumstances reflects the increased cognitive effort needed to regulate anxiety induced by negative contexts (Lewis et al., 2007).

Interestingly, researchers have found that children with externalizing problems do not show this same pattern of increased attention control in the presence of emotionally challenging conditions (Lewis, Granic, et al., 2006), and, in fact, exhibit decreased attention control in response to frustration-inducing conditions on cognitive control tasks (Rich et al., 2005). These findings, which have been demonstrated in preadolescents with elevated externalizing behaviors (Lewis, Granic, et al., 2006) and in children and adolescents with pediatric bipolar disorder (Rich

et al., 2005), indicate that children with externalizing problems may not only have trouble recruiting additional cognitive effort to perform tasks that demand attention control during emotionally challenging situations, but that they may actually allocate less cognitive effort for attention to the task in such circumstances. Rich and colleagues (2005) suggest that this pattern of difficulty focusing attention during affectively challenging tasks in children with externalizing problems may be the result of their tendency to inappropriately direct attention to their emotional experience of frustration instead of to the task.

Despite the existence of literature on externalizing problems and patterns of diminished attention control under emotionally challenging conditions, to our knowledge, no studies using physiological indices of cognitive functioning have explored the relation between attention control under affective arousal and aspects of social functioning, including aggression, social competence, and peer rejection, in young elementary school children.

The Present Study

Based on research concerning the role of physiological processes of autonomic reactivity and attention control in social functioning, the present study examines aspects of emotional functioning associated with each of these physiological systems. Specifically, two physiological measures, corresponding to each of these systems, are used in this study to assess children's emotional responding when presented with emotionally challenging situations: 1) heart rate reactivity when exposed to emotionally evocative movie clips, and 2) the P300 component of the ERP, measured in the context of unfavorable reward contingencies. The first index, which assesses the intensity of children's emotional response to distressing stimuli, corresponds to the processing of affect and taps an aspect of emotional reactivity; the second index, which assesses

the impact of affective arousal on goal-oriented behavior (Polich, 2012), corresponds to attention control in the context of emotional challenge and taps an aspect of emotion regulation.

This study marks a very important progression in the investigation of the associations among emotional functioning, aggressive behavior, social competence and peer rejection. Specifically, it extends research by using physiological indices of emotional functioning to allow for more temporally precise measurement of the component processes involved in emotional reactivity and emotion regulation. Prior research suggests that physiological variations in children's reactions to emotionally evocative stimuli and situations, particularly a tendency to react with greater intensity to emotionally distressing stimuli, may be associated with elevated aggression, impaired social competence, and peer rejection. In addition, the inability to increase attention control in the context of an emotionally evocative task (e.g., a reduced schedule of reward) may be associated with poor emotion regulation and difficulties with emotional and anger control. However, given the dearth of studies that utilize physiological indices of emotional functioning, especially with children, more research in this area is greatly needed.

The present study aims to explore the relations among physiological indicators of emotional functioning, aggression, social competence, and peer rejection. Specifically, the study will explore the concurrent relationships between physiological markers of emotional functioning, aggression (as reported by teachers and peers), social competence (as reported by teachers and peers) and peer preference (as reported by peers) in a group of kindergarten children over-sampled for aggression. Based on prior research, heart rate reactivity during exposure to distressing movie scenes and the P300 during exposure to unfavorable reward contingencies will be used as indices of emotional functioning, with the former corresponding to the processing of affect and the broader domain of emotional reactivity, and the latter corresponding to attention

control in the context of emotional challenge and the broader domain of emotion regulation. From this framework, heightened heart rate reactivity and reduced P300 (believed to reflect the overwhelming of regulatory capacity resulting from affective arousal) will serve as indices of problematic emotional functioning. Following this logic, two hypotheses are generated. First, it is hypothesized that heightened heart rate reactivity and reduced P300 in emotionally challenging contexts will be positively associated with aggression and negatively associated with social competence. The second hypothesis is that heightened heart rate reactivity and reduced P300 will be linked with peer rejection (low liking, elevated disliking), either directly or indirectly, through their associations with aggression and social competence.

Method

Data for the present study were drawn from the initial baseline assessments for a multi-component prevention program aimed at kindergarten children with early-onset aggression. The present study focuses on data collected prior to the initiation of any intervention activities.

Participants

Ten elementary schools in the Harrisburg School District participated in this study. During October of 2008 (Cohort 1) and again in October of 2009 (Cohort II), kindergarten teachers screened all children in their classrooms on a 10-item measure of aggressive behavior, the Authority Acceptance Scale of the Teacher Observation of Child Adaptation-Revised (TOCA-R; Werthamer-Larsson, Kellam, & Wheeler, 1991). Items focused on physical aggression and rule violations, such as such as “fights,” and “yells at others,” and were rated on a 6-point Likert scale. Based on their scores, children in each cohort were ranked ordered within classroom, and those in the upper quartile of aggression were identified for recruitment. Of the 1,192 children who were screened over the two years, 297 children were identified with elevated

aggression. The families of these children were contacted by project research assistants, and 207 agreed to a home visit, providing informed consent for study participation, and completed initial measures for the project. Three months later, when the assessments for the current study were conducted, some of these children had settled into the school routine, such that 20% scored in the "almost never" to "rarely" range on teacher ratings of aggression. The others still showed elevated aggressive-disruptive behaviors. Overall, the sample represented children at high-risk for early aggression, with variability in the severity and stability of their early behavior problems. Sample demographics were as follows: 73% African American, 19% Latino, 8% Caucasian; 66% male. The average age at screening was 5.62 years (*SD* = .36).

Procedures and Measures

Pre-intervention assessments were administered three months after screening and included physiological measures of emotion reactivity and regulation collected in a mobile laboratory, as well as measures of aggression and social competence, and measures of peer preference (e.g., peer liking, peer disliking). Classroom teachers provided behavioral ratings, and sociometric peer nominations were completed by the students in each class. As compensation for their time, teachers were provided a $15 gift card for each set of child ratings.

Teacher ratings. Teachers rated children's aggression using an abbreviated version of the TOCA–R (Werthamer-Larsson et al., 1991) that included seven items describing overt aggression (e.g., "yells at others"). Research using this abbreviated scale has shown high levels of internal consistency (α = .88) and adequate inter-rater agreement (r = .74).

Teachers also completed the Social Competence Scale (Conduct Problems Prevention Research Group [CPPRG], 1995). This study focused on the emotion regulation subscale of this measure, which targets social competence under conditions of emotional challenge with six

items (e.g., “copes well with disappointment or frustration” and “stops and calms down when frustrated or upset”), each rated on a 6-point Likert scale ranging from “never” to “almost always.” Teacher ratings on this scale demonstrated high internal consistency in this study (α = .94) and have shown adequate inter-rater agreement in prior research (r = .70) (Bierman et al., 2008).

Sociometric Nominations. To assess social functioning, sociometric nominations were collected in each classroom. The majority of children (89%) were given parental consent to participate in the sociometric interviews. The interviews were conducted individually with each child by members of the research team. For each interview, a research assistant took the child from the classroom and showed him or her photographs of every child in the class for whom consent had been obtained. Children were asked to nominate classmates who fit different behavioral descriptions. Peer nominations of aggression and cooperation were assessed using two different behavioral descriptions. Aggression was measured by children’s nominations of classmates who “start fights and hurt others.” Cooperation was measured by children’s nominations of classmates who “share and help a lot.” During the interview, children were also asked to nominate the classmates whom they “liked the most” and the classmates whom they “liked the least.” In all cases, children could nominate girls or boys in the classroom, and unlimited nominations were accepted. The total number of nominations each child received was divided by the number of classmate raters.

Child psychophysiological assessment. All psychophysiological assessments were conducted inside a RV outfitted with the necessary equipment that was driven to each elementary school. In order to minimize children’s apprehension of the psychophysiological assessments, the RV was decorated with an outer-space motif, including a picture of a familiar cartoon

character dressed in an astronaut suit. In addition, at the beginning of the school year, each kindergarten class was a given tour of the RV, so that when children were later enrolled and ready for the pre-intervention assessment, they were familiar with the vehicle.

For every psychophysiological assessment, research assistants (RAs) met children in their classroom and escorted them to the RV. The RAs then explained the assessment procedure to the children and asked them to provide verbal assent. Children who did not want to participate were taken back to their classrooms but were approached on another day and were offered the chance to participate again. Of the full sample of children recruited for the study, only three refused to participate in the psychophysiological assessment.

Before the assessment began, children were given a drawing activity to assess for handedness. Once handedness had been established, the RA applied physiological electrodes on the non-dominant hand. Children were seated while the RA applied the physiological electrodes for the cardiac and electroencephalographic (EEG) measures described below.

To begin the assessment, children were seated at a table with a computer monitor in front of them. The RA then explained to the child that he or she was going to "travel through space." The child was told to sit very still while "traveling," during which time he or she watched a moving star-field video on the computer. During this "travel" period, which lasted for two minutes, a baseline recording of the child's cardiac and EEG measures was conducted.

Emotion induction paradigm. During the emotion induction protocol, children were shown a series of video clips depicting different emotions. The video clips were all taken from the movie, *The Lion King*, due to its age appropriateness and its emotionally-charged story line. The movie was also selected on account of the nonhuman nature the protagonist, an animal

cartoon character, so that the video-based emotion induction would not differ in terms of racial saliency for children of different racial backgrounds.

The video clips included three emotionally evocative scenes, one designed to evoke fear during which Simba, the main character, is being chased by the bad hyenas, one designed to evoke anger, during which Simba is fighting the evil Scar, and one designed to evoke sadness, during which Simba's father is dying. The video clips also included a non-distressing scene, during which the characters are singing a joyous song. Each emotion induction video clip lasted for two to three minutes. Following a standard protocol used in prior research, a 30 second neutral clip was presented at the end of each scene to facilitate children's return to baseline between emotionally evocative clips. These neutral clips displayed no specific emotional content, and if relevant, showed the resolution of conflict depicted in the previous clip. In addition, following the neutral clip, a 30 second baseline was recorded in order to index the pre-clip baseline for that specific clip and control for any potential order effects of the clips.

Cardiac data processing. During the emotion induction task, cardiac measures were collected continuously at 500 Hz via the Biolab 2.4 acquisition system (Mindware, Westerville, OH). One disposable, pre-gelled cardiac electrode was placed in each of the following places: over the distal right collar bone, over lower left rib, and over lower right rib. A trained research assistant visually inspected and corrected the ECG data as necessary. Heart rate, in beats per minute, was calculated in 30 seconds epochs across the task. Since each emotion induction condition was comprised of multiple 30 second epochs (seven epochs for the fear condition, five epochs for the anger condition, and four epochs for the sad condition), mean heart rate was averaged across all epochs for each emotion induction condition.

In addition, for each emotion induction condition, the difference between the mean heart rate during the condition and the mean heart rate averaged across the four baseline clips was calculated. For each of these difference scores, increased heart rate in the emotion induction condition relative to baseline clip served as our index of increased heart rate reactivity.

Go/No-go task. During the "travel through space," children were also shown how to play a go/no-go game, a task modified from a program created by J. Stieben (Stieben et al., 2007). During this task, a series of cartoon characters ("alien critters") appear on the computer screen and children are instructed to "zap" the characters as they pop up by pressing a corresponding button. Children are further instructed not to zap a character when it appears twice in a row (so that they must resist pressing the button if the character who had just popped up, pops up again). Children are also told that a big red square will appear around the character when they make a mistake (during both errors of commission and errors of omission).

After providing children with both verbal and visual instructions, which included a page of pictures depicting sample images from the game, the RA asked the children to practice the game before starting it. During this practice period, the RA observed and recorded the children's error rate on the no-go trials. If children made errors more than 60% of the time, the game instructions were reviewed and children were given additional practice time, in order to make sure all children understood the game before the formal testing started.

Before beginning the game, children were told that they would be earning points for their performance during the game and, that if they "got enough points," they would receive a prize at the end. In order to motivate children to maximize their accumulation of points, no specific value of points needed to earn a prize was identified. Prizes, which consisted of goody bags filled with small toys and stickers, were shown to children ahead of time. Children were informed that

approximately every five trials a thermometer displaying their total number of points would appear, and that this thermometer would be accompanied by a cartoon face that would display a "thumbs-up" or a "thumbs-down" based on whether or not the child had earned points since the last feedback.

Each game was administered in three blocks. Consistent with standard go/no-go procedures, 20% of the trials consisted of no-go stimuli. During the first block (Block A), the algorithm for point accumulation strongly favored correct responses and weakly punished incorrect responses and thus lead to a rapid accumulation of points. During the second block (Block B), the algorithm was reversed and thus led to a loss of points despite maintained level of performance. During the last block (Block C), the algorithm from Block A was reinstated so that all children finished the game with enough points to win a prize. The game lasted for approximately 12 minutes.

After the go/no-go task, children were given a break and offered a small snack or some juice. Then they were told that they would be "traveling through space" again, and another baseline was recorded in order to account for any drift since the last baseline.

During this task, EEG was assessed with a 32-channel elastic stretch BioSemi headcap with the Active Two BioSemi system (BioSemi, Amsterdam, Netherlands). Head circumference was measured to identify cap size. Placement of the Cz electrode was centered at the point of intersection between the line from the nasion to inion and from one temporal mandibular joint to the other. Once the cap was placed, gel was inserted into each electrode receptacle. Two additional electrodes were placed on the left and right mastoids, and four additional facial electrodes were used to measure eye movement. Vertical eye movements were measured from electrodes placed on the infra-orbital ridges centered under the pupils of both eyes and

corresponding supra-orbital electrodes embedded within the cap. Horizontal eye movement was measured from electrodes placed approximately 1 cm outside the participants' right and left outer canthi. Data were recorded at 512 Hz with Actiview Software, v8.0.

Data were post-processed using Brain Vision Analyzer 2.0 and re-referenced to the average of all sites. EEG data were strongly affected by slow frequency power in the delta band, considered typical of young children and conceptualized as a marker of developmental immaturity (Somsen, van Klooster, van der Molen, van Leeuwen, & Licht, 1997; Yordanova & Kolev, 2008). In order to reduce the impact of sub- and very low delta frequency noise and maximize the ability to detect individual differences in P3b amplitude in response to the experimental paradigm, we employed a 1 to 30 Hz Butterworth Zero Phase filter (see, e.g., Lewis, Lamm, et al., 2006). The high-pass filter at 1 Hz also served to remove very slow wave drift that was present in the data.

Correct responses on go trials, defined as those in which the child responded to the stimulus between 100 and 1,000 ms after stimulus onset, were segmented from -200 to 1,000 ms relative to stimulus onset. Trials were baseline-corrected to the mean amplitude across the 200 ms prior to stimulus onset and corrections were made for eye blink artifacts using the Gratton and Coles algorithm, as implemented by Brain Vision Analyzer 2.0 (Gratton, Coles, & Donchin, 1983). Any trials with a voltage step of more than 100 μV between sampling points or a voltage reading outside the range of -75 μV to 75 μV was marked as artifactual and removed from the analysis.

The mean number of artifact-free correct go trials ranged from 22 to 199 trials, with an average of 119 (*SD* = 38.4) trials across the three task blocks. Research indicates that average amplitude measures are less sensitive to noise than peak amplitude measures (Luck, 2005), and

thus P300 amplitude was defined as the mean voltage at the Pz electrode in a 500 to 700 ms post-stimulus time window. Visual inspection of the grand average waveform confirms a broad positive peak in this window, and is generally consistent with previous studies in children (Pfueller et al., 2011; Thomas & Nelson, 1996).

In order to index average P300 amplitude per block, P300 mean amplitude was calculated separately within each task block. Difference in P300 mean amplitude between Block A and Block B was then calculated to measure the change in P300 in response to the shift from favorable to unfavorable reward contingencies as the child moved from Block A to Block B. For this measure, decreased P300 in Block B relative to Block A served as our index of reduced P300, reflecting reduced attention control in the context of emotional challenge.

Results

Data analysis occurred in two stages. First, descriptive analyses were conducted, including an examination of gender differences and simple correlations among the study variables. Second, regression analyses were conducted in order to examine the associations of the physiological indices of emotion reactivity and regulation (heart rate reactivity, P300) with the measures of aggression (teacher-rated aggression, peer-nominated aggression) and social competence (teacher-rated social competence, peer-nominated cooperation). Lastly, a final set of regressions examined associations with peer preference (liking, disliking) and tested direct and possible indirect associations with the physiological ratings of emotion reactivity and regulation, and aggression and social competence.

Descriptive Analyses and Correlations

The means, standard deviations, and ranges for all study variables are shown in Table 1. Tests for sex differences demonstrated that boys had significantly higher levels than girls of

teacher-rated and peer-nominated aggression and lower levels of teacher-rated social competence.

Correlations among the physiological measures of emotion reactivity and regulation are shown in Table 2. Heart rate reactivity in response to the film clips selected to evoke fear, anger, and sadness were mildly to moderately intercorrelated, *rs* = .25 - .51, suggesting that some children were more reactive physiologically to the emotion clips than others, but that there was also variability in individual responding across clips designed to evoke different emotions. The P300, used to assess emotion regulation, was not significantly correlated with heart rate reactivity to any of the emotion clips. In this case, the P300 reflected the extent to which children increased their attention allocation as reward contingencies became less favorable and they began to lose points in the game. This aspect of emotion regulation appears independent of heart rate reactivity to emotional experiences, at least as measured here, supporting the use of these physiological indices as distinct measures of specific aspects of emotional functioning. Correlations among the teacher ratings and peer nominations are shown in Table 3. Teacher ratings and peer nominations of aggression were moderately inter-correlated, $r = .41$, and each of them was significantly correlated with teacher ratings of social competence, $r = -.68$ for teacher-rated aggression and $r = -.26$ for peer-nominated aggression. Interestingly, neither teacher nor peer assessments of aggression were significantly associated with peer-nominated cooperation, nor was teacher-rated social competence significantly correlated with peer-nominated cooperation. This may be due to a difference in the context of assessment (e.g., teachers perhaps focused on classroom behavior and peers perhaps focused on playground behavior), and it could also reflect differences in the measure emphasis, as the teacher-rated social competence items

Table 1. *Descriptive Statistics for all Study Variables*

		Full Sample		Male	Female
Variables	N	*M* (*SD*)	Range	*M* (*SD*)	*M* (*SD*)
Heart Rate Reactivity					
Fear	166	-0.64 (3.52)	-12.92 – 7.75	-0.76 (3.45)	-0.41 (3.69)
Anger	156	0.82 (3.62)	-6.62 – 13.53	0.96 (3.49)	0.56 (3.87)
Sadness	166	-0.69 (3.38)	-16.26 – 9.82	-0.66 (3.52)	-0.76 (3.10)
Attention Regulation					
P300 Regulation	167	-0.28 (2.56)	-6.71 – 8.54	-0.45 (2.40)	0.04 (2.81)
Aggression and Social Competence					
Aggression (T)	179	3.05 (1.07)	1.00 – 5.71	3.21 (1.06)	2.77 (1.04)
Aggression (P)	205	0.15 (0.17)	0.00 – 1.00	0.18 (0.17)	0.09 (0.15)
Social Competence (T)	179	3.14 (0.99)	1.00 – 6.00	2.98 (0.97)	3.43 (0.96)
Cooperation (P)	205	0.10 (0.09)	0.00 – 0.40	0.10 (0.09)	0.11 (0.09)
Peer Preference					
Liking (P)	205	0.15 (0.13)	0.00 – 0.90	0.16 (0.14)	0.13 (0.10)
Disliking (P)	205	0.16 (0.13)	0.00 – 0.71	0.17 (0.14)	0.14 (0.12)

Note: T = Teacher rating, P = Peer nomination. Sex differences were significant for teacher-rated aggression, F (1, 177) = 6.98, peer-nominated aggression, F (1, 203) = 14.64, and teacher-rated social competence, F (1, 177) = 8.62.

focused on positive social behavior under conditions of emotional arousal whereas the peer measure focused simply on being helpful and cooperative. All four measures of social behavior (teacher-rated aggression, peer-nominated aggression, teacher-rated social competence, and peer-

Table 2. *Correlations among the Physiological Measures of Emotional Reactivity and Regulation*

	Heart Rate Reactivity			P300 Regulation
	Fear	Anger	Sadness	
Heart Rate Reactivity (Fear)	--	.25**	.51**	-.04
Heart Rate Reactivity (Anger)		--	.25**	.09
Heart Rate Reactivity (Sadness)			--	-.02
P300 Regulation				--

* $p < .05$. ** $p < .01$.

Table 3. *Correlations among the Teacher and Peer Ratings of Child Social Functioning*

	Aggression (P)	Social Competence (T)	Cooperation (P)	Liking (P)	Disliking (P)
Aggression and Social Competence					
Aggression (T)	.41**	-.68**	-.12	-.09	.29**
Aggression (P)	--	-.26**	.04	.06	.39**
Social Competence (T)		--	.14	.08	-.21**
Cooperation (P)			--	.52**	-.15*
Peer Preference					
Liking (P)				--	-.16*
Disliking (P)					--

Note: T = Teacher rating, P = Peer nomination. * $p < .05$. ** $p < .01$.

nominated cooperation) were significantly associated with peer rejection (disliking nominations) in the expected direction, with a range of $r = -.15$ to $r = .39$. However, only peer-nominated cooperation was significantly correlated with peer liking nominations, $r = .52$. The nominations reflecting peer liking and peer disliking were only mildly inversely correlated ($r = -.16$).

Of direct relevance to the hypotheses tested in this study, the correlations presented in Table 4 represent the associations between the physiological measures of emotional functioning (heart rate reactivity, P300) and aggression (teacher-rated aggression, peer-nominated aggression) social competence (teacher-rated social competence, peer-nominated cooperation), and peer preference (liking, disliking). Heart rate reactivity in the fear condition was significantly associated with teacher ratings of aggression, r = .24, teacher ratings of social competence, r = -.27, and with peer nominations of cooperation, r = -.27. Heart rate reactivity in the sadness condition was significantly associated with peer nominations of aggression, r = .16, teacher ratings of social competence, r = -.24, and peer nominations of cooperation, r = -.21. However, heart rate reactivity in the anger condition was not associated with any of the social behavior variables. Change in P300, which was not associated with any of the heart rate reactivity measures, showed small but significant correlations with teacher ratings of aggression, r = -.17, and teacher ratings of social competence, r = .18. None of the physiological measures correlated significantly with peer nominations of liking or disliking.

Overall, these correlations revealed the hypothesized associations of heightened heart rate reactivity in the fear and sadness conditions with elevated aggression and reduced social competence. They also revealed the hypothesized associations of increased P300 in response to the frustration condition with enhanced social competence and reduced aggression. No direct associations emerged between these physiological responses and being liked or disliked by peers. However, social behavior marked by higher levels of aggression and lower levels of social competence was associated with peer dislike.

Table 4. *Correlations between the Teacher and Peer Ratings of Child Social Functioning and the Physiological Measures of Emotional Reactivity and Regulation*

Child Functioning	Heart Rate Reactivity			P300 Regulation
	Fear	Anger	Sadness	
Aggression and Social Competence				
Aggression (T)	.24**	-.10	.13	-.17*
Aggression (P)	.03	.06	.16*	.04
Social Competence (T)	-.27**	-.05	-.24**	.18*
Cooperation (P)	-.27**	-.11	-.21**	.11
Peer Preference				
Liking (P)	-.08	.04	-.08	.02
Disliking (P)	.03	.02	.15	.06

Note: T = Teacher rating, P = Peer nomination. * $p < .05$. ** $p < .01$.

Linear Regression Models

In order to test the first hypothesis and evaluate the unique and cumulative effects of the physiological indices of heart rate reactivity and the P300 on social behavior, four sets of linear regression models were conducted to predict each of the dependent variables (teacher-rated aggression, peer-nominated aggression, teacher-rated social competence, and peer-nominated cooperation). These regressions are presented in Table 5. For each of the models, age and sex were entered as covariates in step one, and the physiological indices of emotional functioning were added at step two. Since heart rate reactivity in the anger condition was not significantly associated with any of the dependent variables, it was excluded from these analyses. Thus, the predictors in step two included heart rate reactivity in the fear condition, heart rate reactivity in the sad condition, and the P300. These regressions revealed that heart rate reactivity in the fear and sad conditions and the P300 together accounted for a significant proportion of the variance in all four measures of social behavior. In particular, heart rate reactivity and the P300 accounted

Table 5. *Regressions Predicting Teacher and Peer Ratings of Aggression and Social Competence*

	Aggression (T)			Aggression (P)			Social Competence (T)			Cooperation (P)		
Variable	R^2	β	ΔF	R^2	β	ΔF	R^2	β	ΔF	R^2	β	ΔF
Step 1	.02		2.45	.07		6.39*	.05		3.86*	.01		1.83
Covariates												
Step 2	.09		4.13**	.10		2.61*	.16		6.24**	.09		4.69**
Heart Rate Reactivity (Fear)		.24*			-.03			-.19			-.20*	
Heart Rate Reactivity (Sadness)		.04			.23*			-.18			-.11	
P300 Regulation		-.15			.06			.16			.12	

Note. Standard partial betas control for child age and sex. For Aggression (T) and Social Competence (T), in step 1, df = 2, 120; in step 2, df = 5, 117. For Aggression (P) and Cooperation (P), in step 1, df = 2, 136; in step 2, df = 5, 133. T = Teacher rating, P = Peer nomination. * $p < .05$, ** $p < .01$.

for 9% of the variance in teacher-rated aggression, $p < .01$, with heart rate reactivity in the fear condition showing a unique association with teacher-rated aggression, $\beta = .24$, $p < .05$. Similarly, heart rate reactivity and the P300 together accounted for 5% of the variance in peer-nominated aggression, $p = .05$. In this regression, heart rate reactivity in the sad condition showed a unique association with peer-nominated aggression, $\beta = .23$, $p < .05$. When teacher-rated social competence was considered, heart rate reactivity and the P300 together accounted for 13% of the variance, $p < .01$; none of the physiological indices made unique

contributions. Finally, the physiological variables accounted for 9% of the variance in peer-nominated cooperation, $p < .01$, and heart rate reactivity in the fear condition showed a unique association, $\beta = -.20$, $p < .05$. Overall, the results of these regressions support the first hypothesis and indicate that increased heart rate reactivity in the emotionally evocative conditions and reductions in P300 in response to the frustration condition were associated with teacher and peer assessments of social behavior.

The second hypothesis was that the physiological measures would predict peer preference (liking and disliking) either directly or indirectly, via their associations with aggression and social competence. To test this hypothesis, two step-wise regressions were conducted to predict peer liking and peer disliking. In these, the demographic covariates were entered in step one, the physiological measures were added in step two, and the measures of social behavior were added in step three. These regressions are presented in Table 6.

These regressions revealed that heart rate reactivity in the fear and sad conditions and the P300 did not account for a significant proportion of the variance in either measure of peer preference. However, the social behavior variables accounted for 27% of the variance in peer nominations of liking, $p < .01$, and for 16% of the variance in peer nominations of disliking, $p < .01$. Given the demonstrated associations between the physiological measures of emotional functioning and the measures of social behavior, this pattern of results suggests that there might be a possible cascade effect, whereby the physiological indices of emotional functioning impact social behavior, which, in turn, impacts peer preference. Thus, while no direct associations between the physiological indices of emotional functioning and peer rejection were found, it may be that these associations develop over time as patterns of emotional functioning and

Table 6. *Regressions Predicting Peer Preference*

	Liking (P)			Disliking (P)		
Variable	R^2	β	ΔF	R^2	β	ΔF
Step 1	.06		4.64*	.04		3.24*
Covariates						
Step 2	.04		.38	.04		1.21
Heart Rate Reactivity (Fear)		-.02			-.03	
Heart Rate Reactivity (Sadness)		-.07			.18	
P300 Regulation		.05			.03	
Step 3	.30		11.58**	.18		5.97**
Aggression (T)		-.09			.15	
Aggression (P)		.07			.34**	
Social Competence (T)		.06			.02	
Cooperation (P)		.54**			-.10	

Note. Standard partial betas control for child age and sex. In step 1, df = 2, 119; in step 2, df = 5, 116; in step 3, df = 9, 112. T = Teacher rating, P = Peer nomination. * $p < .05$, ** $p < .01$.

corresponding social behavior become more solidified, and subsequently exert an influence on peer relations.

Discussion

The purpose of the present study was to explore the relations between physiological indicators of emotional functioning and behavior-based assessments of aggression, social competence, and peer rejection. To achieve this, two physiological indicators of emotional functioning were assessed (heart rate reactivity and the P300) and compared with teacher ratings

and peer sociometric nominations. In particular, heart rate reactivity in response to emotionally evocative movie scenes was used as an index of affective processing and the broader domain of emotional reactivity; change in the P300 in response to an unfavorable shift in reward contingencies during an attention task was used as an index of attention control in the context of emotional challenge and the broader domain of emotion regulation. In this vein, heightened heart rate reactivity and reduced P300 were conceptualized as indices of problematic emotional functioning.

Given prior research on emotional reactivity and emotion regulation, it was hypothesized that heart rate reactivity and the P300 would show significant associations with aggression and social competence. It was further hypothesized that heart rate reactivity and the P300 would be significantly associated with peer rejection, either directly or indirectly, through associations with aggression and social competence.

Results of the analyses demonstrated support for the first hypothesis. Both heightened heart rate reactivity in response to film scenes designed to evoke fear and sadness, and decreased P300 in response to the frustrating reward contingencies, were associated with elevated aggression, both individually and cumulatively. Similarly, heightened heart rate reactivity and reduced P300 were also individually and cumulatively associated with reduced social competence. The demonstrated associations between heart rate reactivity and aggression and social competence indicate that children who experienced increased autonomic arousal in response to the fear-inducing and sad stimuli were found by teachers and peers to be more aggressive and less likely to behave in a socially competent manner. In general, these results are consistent with prior research indicating that children who are more reactive to distressing or negative stimuli are more likely to engage in aggressive behaviors (Cole et al., 1994; Eisenberg

et al., 2009; Frick & Morris, 2004). Further, the positive association between heart rate reactivity, used here as an index of emotional reactivity, and aggression is consistent with literature demonstrating an association between behavioral manifestations of emotional reactivity and aggression (Eisenberg et al., 2000; Vitaro et al., 2002), as well as literature demonstrating an association between physiological indices of stress reactivity and aggression (Beauchaine et al., 2007; Donzella, Gunnar, Krueger, & Alwin, 2000). In particular, the link between increased heart rate reactivity and aggression is consonant with research showing a relation between heightened autonomic functioning under stressful or emotionally evocative conditions and aggressive responding (Hubbard et al., 2002; Waschbusch et al., 2002). Together, such research supports the notion that heightened autonomic arousal implicated in the fight or flight response is likely to contribute to manifestations of the "fight" response in the form of aggressive behavior (Beauchaine et al., 2007).

The finding that heart rate reactivity was negatively associated with social competence is also consistent with previous research on emotional reactivity and socially adaptive behaviors. In particular, this finding fits well with prior studies demonstrating that children with high levels of emotional reactivity show less social competence and fewer cooperative social behaviors (Calkins et. al., 1999; Eisenberg et al., 1993). This finding also fits well with research on the role of autonomic indices of emotional reactivity in socially adaptive behavior (Eisenberg et al., 1995; Fox & Field, 1989). Polyvagal theory in particular, which asserts that the modulation of the sympathetic fight or flight response is necessary for social affiliation and adaptive social functioning, provides a theoretical basis of support for the current findings (Porges, 1995, 2001). Specifically, the study's findings regarding heart rate reactivity are generally consistent with the notion that children who are prone to elevated levels of emotional reactivity are less able to

modulate their arousal in a manner that allows them to both refrain from engaging in aggressive behavior and also engage in more adaptive and socially competent forms of behavior.

Despite the significant findings with heart rate reactivity in response to the fear-inducing and sad film scenes, heart rate reactivity in response to the anger-inducing film scene was not associated with any of the indices of social behavior. This is surprising given the conceptual link between reactivity to threat and anger and aggressive behavior. However, in general, children in this sample showed reactivity to the anger-inducing film clip such that heart rate reactivity in the anger condition was on average much higher than heart rate reactivity in the fear and sad conditions. Hence, it is plausible that the anger condition provided a stimulus that was unambiguously threatening, thereby reducing variability in responding and masking individual differences in reactivity.

While the present findings with heart rate reactivity are consistent with research supporting the role of elevated stress responding (hyper-reactivity) in aggression and maladaptive social functioning, it is important to note that other research has supported an opposite association between reactivity and social behavior. Specifically, some prior researchers have documented a link between very low levels of reactivity, or hypo-arousal, and externalizing problems. In general, the link between low reactivity, or arousal, and externalizing behaviors has been accounted for by two main theoretical explanations. The first explanation posits that low levels of reactivity reflect low levels of fear and that individuals with less fear are more likely to engage in aggressive behaviors because they are not concerned about the negative consequences that result from such behaviors (Raine, 1993). The second explanation is based on the idea that low levels of arousal are associated with an unpleasant physiological state and that individuals with low arousal seek out stimulation in order to increase their arousal to a more desirable level.

From this perspective, the inclination to seek out stimulating activities propels children with low arousal to initiate aggressive and/or antisocial behaviors (Raine, 2002; Zuckerman, 1994). Associations between low levels of arousal and externalizing behaviors have been supported by a wide range of studies (McBurnett, Lahey, Rathouz, & Loeber, 2000; Oosterland, Geurts, Knol, & Sergeant, 2005; Ortiz & Raine, 2004; van Goozen, Matthys, Cohen-Kettenis, Buitelaar, & van Engeland, 2000).

Given the heterogeneous nature of externalizing problems, it is likely that these distinct patterns of reactivity (i.e., hyper-reactivity and hypo-reactivity) are associated with varying types of aggressive behavior. In particular, theorists have posited that patterns of hypo-arousal are more consistent with aggression characterized by profiles of callous-unemotional traits and proactive forms of aggressive behavior, whereas hyper-reactivity may be more strongly linked to impulsive-reactive forms of aggression common in young aggressive children (Frick & Morris, 2004; Raine, 2002; Stieben et al., 2007; Vitaro & Brengden, 2005). There is also some evidence suggesting that the link between reactivity and externalizing behaviors is influenced by context, whereby elevated arousal in response to stressful situations, and low arousal in non-stressful situations (baseline arousal), may both contribute to the manifestation of aggressive behavior (Lorber, 2004). Either way, such explanations for the differing patterns of reactivity associated with aggression are consistent with the general notion that multiple physiological processes, such as those guiding approach/appetitive behavior and those guiding the autonomic regulation of emotion, are implicated in the manifestation of aggressive behavior (Beauchaine, 2001). Thus, in light of the present findings, it may be that the children identified as aggressive in this study more closely fit a reactive aggressive profile than a proactive aggressive profile; or it may be that

that the emotionally charged paradigm used in this study specifically captured the pattern of stress-induced hyper-reactivity that seems to be particularly associated with aggression.

The findings with the P300 during the attention control task, namely the negative association between change in P300 and aggression and the positive association between change in P300 and social competence, suggest that children who showed decreased P300 in response to the frustrating reward contingencies were considered more aggressive and less able to behave competently in emotionally challenging social situations than children who did not show this pattern. These results with the P300, used here as an index of attention control implicated in the process of emotion regulation, is consistent with work demonstrating the role of regulatory processes in social behavior. For example, the negative association between the P300 and aggression is consonant with research demonstrating that poor emotion regulation is associated with and contributes to the manifestation of aggression (Calkins et al., 1999; Caspi et al., 1995). More specifically, the link between the P300 index of impaired attention regulation and aggression is strongly supported by research on executive functioning, which has consistently demonstrated that deficits in executive function, such the ability to sustain and/or shift attention, are linked with aggressive behavior both concurrently (Hughes, White, Sharpen, & Dunn, 2000; Olson, Sameroff, Kerr, Lopez, & Wellman, 2005) and longitudinally (Belsky, Pasco Fearon, & Bell, 2007; Eisenberg et al., 2005; Nigg, Quamma, Greenberg, & Kusche, 1999). Similarly, the association between the P300 and social competence is consistent with research indicating that executive functions such as attention control are central to the capacity to adaptively regulate one's emotional response and engage in socially competent behavior (Blair, Zelazo, & Greenberg, 2005; Riggs, Jahromi, Razza, Dillworth-Bart, & Mueller, 2006). Moreover, unlike research utilizing behavioral indices of regulatory processes, the present study's use of the P300

as a physiological index of regulatory capacity provides further support for the conceptual link between regulatory ability and aggression, as it suggests that there are discrete, fine-grained attention processes that are implicated in aggression and other social behaviors.

The association between the P300 and aggression also fits well with research demonstrating that, on affectively-challenging cognitive control tasks, children with externalizing problems do not show normative patterns of increased attention control (Lewis, Granic, et al., 2006) and instead show decreased attention control (Rich et al., 2005). Together, these results support the idea that children with externalizing problems may have difficulty recruiting additional cognitive resources to engage in tasks that demand attention during emotionally challenging situations, and that they may actually recruit less attention effort under such circumstances (Rich et al., 2005). From this view, it may be that children who are less able to marshal cognitive control during the experience of emotional arousal are less able to recruit the attention processes required for adequate emotion regulation, and thereby are more likely to engage in aggressive responding.

However, the findings linking the P300 to aggression and social competence were weakened by the fact that the P300 was not associated with either of the peer nominations of aggression or cooperation. It is not clear why this difference emerged in terms of the different associations between the P300 and teacher versus peer assessments, and we can only speculate about the possible reasons. One possibility is that teacher and peer assessments reflect experiences in somewhat different contexts, and differences in the regulatory demands associated with these contexts account for the different pattern of correlates. Teachers likely base their assessments primarily on observations of child behavior and peer interactions observed in more structured group contexts, such as the classroom, hallways, and lunchroom, where they spend

time with the children. In contrast, peers likely base their assessments primarily on their social experiences with each other, particularly play interactions in less structured settings such as the playground. The regulatory functioning assessed by the P300 may be particularly important in contexts that require more regulatory control, including structured group settings such as the classroom, when children must follow directions, complete tasks, inhibit impulses, and cooperate effectively with peers. In contrast, more unstructured peer settings such as the playground are characterized by fewer behavioral demands for inhibition and fewer behavioral constraints. For this reason, regulatory functioning as indexed by the P300 may play a less central role in facilitating playground adjustment than classroom social functioning, at least in kindergarten when peer play is less rule-based. It is possible that, as peer interactions become more structured and rule-based in the older grades, regulatory functioning as indexed by the P300 plays a greater role in facilitating social functioning in unstructured peer settings, as well as in the classroom.

Overall, the findings regarding the cumulative effects of heart rate reactivity and the P300 on social behavior suggest that increased autonomic reactivity and decreased regulatory capacity in response to emotionally evocative stimuli, in combination, are linked to higher levels of aggressive behavior and lower levels of socially adaptive behavior. However, it is also noteworthy that the results of the analyses revealed some unique associations. In particular, it was found that increased heart rate reactivity to fear-inducing stimuli was uniquely linked to increased teacher-rated aggression and reduced peer-nominated social competence, and that increased heart rate reactivity to sadness-inducing stimuli was uniquely linked to increased peer-nominated aggression. This indicates that autonomic reactivity has an effect on aggression and social competence beyond that of its shared effect with the P300 index of regulatory capacity,

suggesting that, in emotionally evocative contexts, autonomic reactivity might have a stronger effect on these social behaviors than that of regulatory capacity.

Additionally, the different patterns of unique associations found for heart rate reactivity in the fear condition and heart rate reactivity in the sad condition support the idea that even within the domain of emotional reactivity, reactivity to different forms of emotional distress may have different ramifications for social behavior. This idea is generally consistent with research indicating that differential patterns of response to different emotional experiences are associated with distinct behavior profiles (Rothbart et al., 2000). Yet, the study's specific findings regarding the distinct types of heart rate reactivity should be interpreted with caution, as explanations for a stronger link between fear-reactivity and teacher-rated aggression, and a stronger link between sadness-reactivity and peer-nominated aggression, are not necessarily clear. Still, the general pattern of unique associations between the study's physiological indices of emotional reactivity and emotion regulation suggests that these separate processes of emotional functioning likely differentially influence distinct aspects of social functioning.

The study's second hypothesis, that heart rate reactivity and the P300 physiological measures would be linked to peer rejection, either directly or indirectly, through associations with social behavior, was not supported. In particular, there were no direct effects of heart rate reactivity and the P300 to either measure of peer preference, indicating that these physiological indices of emotional functioning did not directly impact peer rejection in this sample of children. However, the finding that aggression and social competence, which were each associated with heart rate reactivity and the P300, were also associated with peer liking and disliking, lends support for a potential cascade model. Specifically, this pattern of results suggests that the physiological indices corresponding to heightened emotional reactivity and poor emotion

regulation may negatively impact social behavior, which may subsequently lead to peer dislike and rejection. This hypothesized cascade would be consistent with research indicating that heightened emotional reactivity and poor emotion regulation confer risk for the development of aggression and poor social competence (Caspi et al., 1995; Eisenberg et al., 1994, 2000) and research demonstrating that such maladaptive social behaviors lead to rejection by peers (Coie & Dodge, 1998).

It is possible that direct associations between the physiological indices of emotional functioning and peer outcomes will emerge at a later point developmentally, as a result of cascade effects. That is, it is possible that as children progress through school, the impact of emotional functioning on social behavior and peer relations may become more solidified, thus making the negative cascade between problematic emotional functioning and peer rejection more likely to emerge**.** Future research is needed to determine whether this happens.

Study Limitations

Several limitations to the current study exist. First, only one physiological measure was used to index each form of emotional functioning. Given the complexity of human physiology and the many simultaneous physiological processes that underlie both emotional reactivity and emotion regulation, it is likely that assessing only one of these processes in isolation does not adequately capture the biological nature of these phenomena. For example, it may be that in order to better assess autonomic emotional reactivity, various measures of sympathetic functioning, such as skin conductance, as well as those corresponding to parasympathetic functioning, such as respiratory sinus arrhythmia, are needed. In this way, including other physiological indices of emotional reactivity and emotion regulation in the present study would

have allowed for a more comprehensive index of the biological processes underlying these components of emotional functioning.

Second, the cross-sectional nature of the study precludes any causal conclusions regarding the associations among emotional functioning, social behavior and peer outcomes. While prior research has demonstrated that heightened emotional reactivity and poor emotion regulation are predictive of later aggression and social problems (Caspi et al., 1995; Eisenberg et al., 2000), the present study cannot speak to such predictive findings. For example, the association between aggression and peer dislike found in the present study could reflect the tendency for children engaging in aggressive behavior to elicit dislike from peers; however it could also reflect the tendency for children who are rejected by peers to respond to rejection with aggressive behavior. In addition, the cross-sectional nature of the present study precludes exploration of the role of physiological processes of emotional functioning in the development of social behavior and peer relationships across time and, more specifically, the study of any potential cascade effects, as hypothesized.

Third, the use of the movie clip emotion induction paradigm to elicit feelings of emotional distress, although commonly used, relies on the assumption that the specified clip is successfully inducing the corresponding emotion. This is problematic because it assumes that the child watching the film clip is identifying, or at least empathizing, with the protagonist to whom the depicted events are happening. In the present study, a child who does not identify with Simba is unlikely to have the intended emotional experience while watching the film clips. Similarly, it may be that, for certain children, the situation depicted in the film clip does not adequately elicit the intended emotion, or that it does so to varying extents. For example, it may be that children who are chronically exposed to stressful situations are more likely to respond to the emotionally

evocative film clips with less (or more) emotional intensity than those who are not exposed to chronic stress.

Lastly, the current sample of children, identified as high-risk for early aggression, is not representative of children with normative levels of aggressive behavior. Although the over-representation of aggressive children in the present sample is helpful for studying processes associated with the development of aggression and problematic social functioning, findings from the current study may not be generalizable to more normative populations.

Future Directions and Clinical Implications

The findings from the present study indicate that more research needs to be conducted on the relationships among emotional functioning, social behavior and peer outcomes in early to middle childhood. In particular, research should focus on understanding how the different components of emotional functioning, such as emotional reactivity and emotion regulation, are linked to problematic social behavior such as aggression and impaired social competence, and peer relationships. To this end, the use of physiological indices of emotional functioning, as exemplified in the present study, provide a very helpful tool, as they can help disentangle separate emotional processes and thereby further our understanding of how these processes are implicated in social functioning.

Given that the study of physiological indices of emotional functioning is still a relatively recent area of work and is largely characterized by inconsistent findings, more attention should be dedicated to this area in order to better understand how these discrete emotional processes contribute to problematic emotional and social functioning. Prior research has suggested that inconsistencies in the literature, especially concerning the link between autonomic reactivity and aggression, may be a result of the utilization of different methodologies for assessing

physiological processes (Lorber, 2004). In light of this potential explanation, work in this area should explore how different measures of physiological indices of emotional functioning may be linked to different forms of social behavior. Specifically, research should not only compare how different physiological processes are associated with social behavior, but also how different indices of these processes (e.g., measures at baseline versus in reaction to different types of stimuli) are associated with social functioning.

Similarly, research should also further investigate how different profiles of problematic social functioning are linked to various patterns of physiological emotional functioning. For example, based on research indicating that hyper-reactivity may be specifically implicated in impulsive-reactive forms of aggression (Stieben et al., 2007; Vitaro & Brengden, 2005), continued exploration of the associations between different forms of aggression, such as reactive and proactive aggression, and different patterns of physiological emotional reactivity is warranted.

Lastly, research on physiological indices of emotional functioning and associations with social behavior such as aggression, and peer relationships should be approached longitudinally in order to best understand how emotional functioning contributes to the development of social behavior and peer relationships over time.

A more thorough understanding of the different processes of emotional functioning and their implications for social behavior will also greatly contribute to the development of intervention programs aimed at promoting social competence and preventing the development of social-emotional problems such as aggression. In particular, knowledge of how different aspects of emotional functioning are linked to problems such as aggression and peer rejection will allow for the design of interventions that can specifically target the problematic patterns of emotional

functioning implicated in the outcomes of interest. Such work is likely to result in the development of interventions that more accurately address the specific processes underlying complex patterns of problematic social functioning, and thus, in the development of interventions that are ultimately more effective.

The present study represents an important progression in the exploration of emotional functioning and social behavior, as it is the first to our knowledge to investigate the relationships among physiological indices of emotional reactivity and emotion regulation, social behavior, and peer relationships in kindergarten children. While such relationships have often been explored using behavioral measures of emotional functioning, the use of physiological indices in the present study allowed for more discrete measures of these individual emotional processes and their combined and unique associations with social behavior. The results of the study support the cumulative contribution of emotional reactivity and emotion regulation to aggression and socially adaptive behavior, and also provide support for unique contributions of emotional reactivity. The results also lend support for a potential negative cascade effect, whereby heightened emotional reactivity and poor emotion regulation may negatively impact social behavior, which, in turn, may lead to peer rejection. In this way, the study highlights the complexity of young children's emotional functioning and the important role of the distinctive processes of emotional reactivity and emotion regulation in children's social adjustment, as well the likely contribution of these emotional processes to the formation of early peer relationships.

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