The Pennsylvania State University

The Graduate School

College of the Liberal Arts

BEHAVIORAL AND CARDIOVASCULAR MARKERS OF EMOTION REACTIVITY DURING MIDDLE CHILDHOOD

A Thesis in

Psychology

by

Amy E. Dribin

Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Master of Science

August 2009

The thesis of Amy E. Dribin was reviewed and approved* by the following:

Kristin A. Buss
Associate Professor of Psychology
Thesis Advisor

Pamela M. Cole
Professor of Psychology
and Human Development and Family Studies

Ginger Moore
Assistant Professor of Psychology

Melvin M. Mark
Head of the Department of Psychology
Professor of Psychology

*Signatures are on file in the Graduate School.

ABSTRACT

Cumulating evidence has demonstrated that temperamentally based, individual differences in emotion reactivity, particularly in reactivity associated with fear and with high-intensity pleasure, are related to important developmental outcomes. Despite their importance, it is not well understood how two components of emotion reactivity—cardiovascular reactivity and behavioral displays of emotion—are related in middle childhood. The present study examined associations between cardiovascular reactivity and children's displays of fear and high-intensity pleasure in a typically developing sample (mean = 7.91, 47.6% female). RSA suppression and autonomic profiles characterized by RSA suppression were more common in the fear task than in the high-intensity pleasure task. Cardiovascular reactivity was not predictive of fear. Children who showed the autonomic profile of Reciprocal SNS activation displayed more pleasure than children with the profile of Reciprocal PNS activation. This is one of the first studies to document associations between cardiovascular reactivity and children's display of a positive emotion. Further, this study also demonstrated the utility of using autonomic profiles to understand links between behavioral and physiological markers of emotion reactivity.

TABLE OF CONTENTS

List of Tables

Introduction

Middle childhood is a developmental stage that places unique demands on children's developing emotion systems. The structure of the school environment requires greater attentional and behavioral control from children (Graziano, Keane, & Calkins, 2007). Additionally, middle childhood is a developmental stage during which many children first encounter challenging peer interactions, including peer rejection, relational aggression, and difficulty making friends (Ladd, 2006). For some children, successfully navigating these challenges is related to decreased risk for psychopathology and to better socioemotional adjustment. For other children, the challenges in middle childhood may exacerbate or create risk for psychopathology, as reflected in an increased number of referrals for internalizing and externalizing problems in middle childhood (Briggs-Gowan et al., 2000). In middle childhood, children's emotion reactivity is related to both behavior problems (Biederman, Hirshfeld-Becker, Rosenbaum, Herot, Friedman, & Snidman et al., 2001) and positive adjustment (Hastings et al., 2008). Behavioral markers of emotion reactivity, including fear and high-intensity pleasure, are associated with children's internalizing and externalizing difficulties (Stifter, Putnam, & Jahromi, 2008; Talge, Donzella, & Gunnar, 2008). Emerging evidence has suggested that physiological markers of emotion reactivity are also related to children's adjustment difficulties (Boyce, Quas, Alkon, Smider, Essex, Kupfer et al., 2001). Yet, concurrent relationships between behavioral and physiological markers of emotion reactivity are unclear (Quas et al., 2000). The current study addresses this question and examines the concordance between a physiological marker, cardiovascular reactivity, and children's concurrent behavioral displays of emotion during both a fear-eliciting task and a high-intensity pleasure eliciting task.

Individual Differences in Emotion Reactivity

This study utilized a temperament perspective to examine individual differences in the associations between physiological and behavioral markers of emotion because a temperament perspective is inherently concerned with individual differences in reactivity at the intersection of behavior and physiology. Temperament reflects biologically based, individual differences in experiencing and expressing primary emotions (Goldsmith & Campos, 1990; Goldsmith, Lemery, Aksan, & Buss, 2000). This conceptualization builds on the functionalist theories that emotions organize children's thoughts and behaviors, facilitating communication with the social world (Campos, Mumme, Kermoian, & Campos, 1994). Emerging in infancy, temperamental differences in emotion reactivity are present throughout development; however, the expressions of these temperamental characteristics change. For example, in infancy, social fear is characterized by facial and bodily signs of distress and freezing behaviors; yet in middle childhood, social fear is often characterized by more subtle behaviors, including wariness and fidgeting.

Temperament arises from complex interactions between children's behavioral and physiological reactivity. Many theoretical accounts of temperament acknowledge that the physiological substrates of emotion contribute to temperament (e.g., Goldsmith); however, these associations are best conceptualized within Rothbart's (1981) psychobiological definition of temperament. The physiological underpinnings of temperament are inherent in Rothbart's definition. This definition specifies that temperament reflects a constitutionally based set of individual differences in reactivity and self regulation, with *reactivity* defined as the excitability, responsibity, or arousability of the behavioral and physiological system, including the somatic, endocrine, and autonomic nervous system (Rothbart & Derryberry, 1981). Reactivity at any one level of temperament (e.g., behavioral, attentional, and physiological levels) both influences and is influenced by reactivity at another level of temperament. For example, a physiological response to a fear-eliciting task may precipitate behavioral displays of fear like freezing behaviors, while facial expressions of fear alter subsequent physiological responses (Levenson, 2003). Measuring markers of reactivity across multiple levels of temperament yields a more precise measurement of individual differences in emotion reactivity. The current study is concerned broadly with understanding interactions across the behavioral and physiological levels of temperament and is concerned specifically with understanding associations between cardiovascular reactivity and children's displays of fear and high-intensity pleasure.

Fear and high-intensity pleasure are the focus of the current study because these patterns of reactivity are linked to important developmental outcomes in middle childhood (Stifter et al., 2008; Talge et al., 2008). Extensive theoretical and empirical work has established that fear and high-intensity pleasure reflect relatively independent temperamental traits (Goldsmith & Campos, 1990; Goldsmith et al., 2000; Rothbart & Derryberry, 1984). Fear behaviors include avoidance, distress, wariness, and nervousness during situations perceived as threatening (Campos, Barrett, Lamb, Goldsmith, & Sternberg, 1983). High-intensity pleasure is characterized by the frequency and intensity of laughter, smiling, and approach behaviors expressed during situations that involve obtaining a goal (Rothbart & Derryberry, 1984). Positive emotions are not well understood, making it difficult for theoretical and empirical work to disentangle high-intensity pleasure, low-intensity pleasure, joy, and contentment. Recent work has demonstrated that physiological reactivity (EEG asymmetries) differentiates high- and low-intensity pleasure (Light, Coan, Frye, Goldsmith, & Davidson, 2009), thus lending support to Rothbart's distinction between the same. Given that the emotions of fear and high-intensity pleasure reflect separate aspects of temperament that are nevertheless considered risk factors for behavior problems in childhood, understanding the physiological underpinnings of these behaviors is especially important.

To summarize, the present study is concerned with temperamentally based, individual differences in the physiological and behavioral markers of emotion reactivity associated with fear and high-intensity pleasure. This conceptualization of temperament is informed largely by Goldsmith's perspective on temperament; the conceptualization also borrows from Rothbart's model because it more clearly articulates the theoretical associations between behavioral and physiological markers of reactivity than does Goldsmith's work. Yet, though Rothbart makes the theoretical argument that behavioral and physiological levels of emotion reactivity are related, in her model the specific relationships between physiological reactivity and behavioral displays of emotion are unclear. For example, does physiological reactivity precipitate behavioral displays of emotion? Do children's emotion expressions yield physiological changes? Do specific patterns of physiological reactivity differentiate emotions like fear and pleasure, or do patterns of physiological reactivity relate to general emotional arousal? The present study begins exploring these questions; yet, it is necessary to consider how relevant work within the field of psychophysiology informs these questions before turning to the specific aims addressed here.

Psychophysiology and Cardiovascular Reactivity

The field of psychophysiology offers specific predictions regarding the associations between cardiovascular and behavioral markers of emotion reactivity. Psychophysiological perspectives seek to identify ontological changes in the associations between psychological constructs and physiological measures by examining multiple physiological systems (Cacioppo, Tassinary, & Berntson, 2000). Psychological constructs may relate to physiological measures in a variety of ways. Physiological measures can be outcomes, markers, or concomitants with psychological constructs, or they may reflect invariant relationships with psychological constructs. Concomitant and invariant relationships are often assumed (Cacioppo, Tassinary et al., 2000), but these associations are rare. More probable is the idea that a physiological measure in a specific context is a marker of a psychological construct. For example, within a fear-eliciting context a pattern of physiological reactivity such as an increased heart rate may be a marker of fear, yet within a pleasure-eliciting context an increased heart rate may be a marker of high-intensity pleasure. In the present study, reactivity within one physiological system, the cardiovascular system, was examined as a possible marker of children's behavioral displays of fear and high-intensity pleasure.

Of interest in the present study are two measures of cardiovascular reactivity, *respiratory sinus arrhythmia* (RSA) and *preejection period* (PEP), measures that have emerged as the gold standards for capturing changes within the cardiovascular system (Berntson, Cacioppo, & Quigley, 1993a; Cacioppo, Uchino, & Berntson, 1994). Cardiovascular reactivity reflects changes within the Parasympathetic Nervous System (PNS) and the Sympathetic Nervous System (SNS). Many measures have been used to capture PNS and SNS reactivity, including heart rate (Valiente et al., 2004), mean arterial pressure (Quas et al., 2000), skin conductance

(Gilissen, Koolstra, van Ijzendoorn, Bakermans-Kranenburg, & van der Veer, 2007), and the ratio of high- to low-frequency heart rate variability (Kagan et al., 2007). Unlike these other measures, RSA and PEP are advantageous because empirical work has demonstrated that RSA and PEP capture independent changes within the PNS and SNS respectively (Berntson et al., 1993a). A measure of heart rate variability, RSA refers to changes in heart periods (r to r intervals) at the rate of respiration (Berntson, Cacioppo, & Quigley, 1993b). A decrease in the magnitude of RSA indicates PNS withdrawal and corresponds to increased heart rate. PEP is the time, in milliseconds, between the onset of ventricular depolarization and the opening of the semilunar valve in the heart, indicating the onset of the left ventricular ejection (Cacioppo et al., 1994). A faster, shorter PEP reflects activation of the SNS.

Cardiovascular Reactivity as a Marker of Discrete Emotions

Whether there are specific patterns of autonomic activity that differentiate expressions of emotion is one of the oldest questions in the field of psychophysiology (Cacioppo et al., 2000).One theoretical perspective contends that specific patterns of autonomic reactivity are related to specific emotion expressions because of direct connections between the ANS and behavioral expressions of emotion that serve evolutionary purposes related to survival and reproduction (Levenson, 2003; Levenson, Ekman, & Friesen, 1990). These specific patterns of ANS reactivity are theorized to provide physiological support for action associated with particular emotions (e.g., fleeing during a fear situation). In a seminal study, Levenson and colleagues (1990) demonstrated that specific patterns of autonomic reactivity (heart rate, finger temperature, and skin conductance) differentiated positive from negative emotions, and differentiated expressions of fear, anger, and sadness. They found that, on average, heat rate was lower when participants made expressions of disgust than when participants made expressions of anger, fear, or sadness. Additional research with adult samples has also demonstrated emotion-specific patterns of cardiovascular reactivity (Levenson, et al., 1990; Levenson, Ekman, Heider, & Friesen, 1992; Rainville, Bechara, Naqvi, & Damasio, 2006). Related developmental work has indicated that children's displays of fear are related to less suppression of RSA (Calkins & Dedmon, 2000; Talge et al., 2008) and a faster PEP (Buss, Davidson, Kalin, & Goldsmith, 2004; Buss, Goldsmith, & Davidson, 2005). Emerging work has suggested that positive emotions are related to more suppression of RSA (Field, Pickens, Fox, & Nawrocki, 1995; Stifter, Fox, & Porges, 1989) and in adults, a slower PEP (Neumann & Waldstein, 2001). There are no known studies examining associations between PEP change and positive emotion in childhood.

While there is evidence with children and adults that lends support to the idea that there are emotion-specific patterns of cardiovascular reactivity, these research findings are inconsistent, suggesting that the associations between cardiovascular reactivity and displayed emotion are not as specific as Levenson has suggested. A meta-analysis demonstrated that measures of cardiovascular reactivity did not reliably differentiate expressions of sadness, anger, or disgust within adult samples (Cacioppo, Berntson, Larsen, Poehlmann, & Ito, 2000). Similarly, two independent studies that used middle-childhood samples failed to find associations between cardiovascular reactivity and children's displays of emotion (Forbes, Fox, Cohn, Galles, & Kovacs, 2006; Quas et al., 2000). Additionally, no developmental study has demonstrated associations between both RSA change and PEP change with children's expression of a discrete emotion. One possible explanation is that these null findings reflect methodological difficulties. For example, Quas and colleagues examined cardiovascular reactivity and children's displays of emotion during cognitive, rather than emotional, stressors. The Forbes study examined cardiovascular reactivity and behavioral displays of general negative affect rather than considering children's expressions of specific negative emotions like fear, anger, or sadness. A second possible explanation is that the null findings occurred because associations between cardiovascular reactivity and displays of emotion are not as specific as Levenson predicted. Nevertheless, given research in support of emotion-specific patterns of cardiovascular reactivity and the methodological problems in some developmental work, the current study sought to rectify some of these methodological difficulties and examined the possibility that there are emotion-specific patterns of cardiovascular reactivity.

Autonomic Profiles

Examining the joint associations between multiple indices of cardiovascular reactivity may predict displays of emotion more reliably than a single measure of cardiovascular reactivity (Berntson, Cacioppo, Quigley, & Fabro, 1994; Berntson, Norman, Hawkley, & Cacioppo, 2008). One approach to understanding these joint associations is through the creation of *autonomic profiles,* or dichotomous measures that characterize physiologically meaningful patterns of RSA change and PEP change (Berntson et al., 1994). Classically, it was purported that there were only two types of autonomic profiles and that these profiles represented reciprocal relationships between the SNS and the PNS (e.g., increased RSA occurring jointly with decreased PEP). In addition to these reciprocal profiles (Reciprocal PNS activation, Reciprocal SNS activation), Berntson and colleagues (1991, 1994, 2008) identified autonomic profiles characterized by co-occurring changes in PNS and SNS activity (Coinhibition, Coactivation) as well as profiles representing independent changes (Uncoupled PNS, Uncoupled SNS). Coinhibition reflects decreased RSA and a slower PEP, while the profile of Coactivation reflects increased RSA and faster PEP. The profile of Reciprocal PNS activation is characterized by increased RSA and a slower PEP, while the profile of Reciprocal SNS activation indicates decreased RSA and a faster

PEP. Finally, Uncoupled PNS activation describes any change in RSA without changes in PEP, while Uncoupled SNS activation indicates any change in PEP without changes in RSA.

Autonomic profiles are rarely considered within developmental work; however, emerging work has demonstrated that children show the same six autonomic profiles as adults do and that there is variation in which profile children display (Alkon et al., 2003; Quigley & Stifter, 2006). The most common profiles in middle childhood reflect reciprocal activation and co-occuring activation, and it is rare for children to show profiles reflecting uncoupled activation (Salomon, Matthews, & Allen, 2000). Individual differences in the autonomic profile that children display during challenging activities are related to behavioral problems (Boyce et al., 2001) and family conflict (Matthews, Salomon & Allen, 2003). While researchers have examined autonomic profiles in relation to developmental outcomes in middle childhood, it is unknown how autonomic profiles relate to concurrent displays of children's emotion expressions. The present study began addressing this question and askexamined if there were associations between children's autonomic profiles and children's displays of emotion within a fear-eliciting task and a high-intensity pleasure-eliciting task.

Cardiovascular Reactivity as a Marker of Engagement with the Social Environment

A third prediction that has emerged from psychophysiological work posits that cardiovascular reactivity represents undifferentiated emotional arousal suggestive of a person's engagement with the social world (Porges, 1995, 2007). According to Porges (2007), cardiovascular reactivity reflects the "neurophysiolgoical substrates for emotional experiences and affective processes that are the major components of social behavior" (121). These "neurophysiolgoical substrates" reflect an individual's range of emotional expressions within a specific context, such that changes in cardiovascular reactivity are theorized to parallel individual and intra-individual differences in emotional behaviors (139). These predictions are embedded within Porges's Polyvagal Theory (1995, 2007), which contends that vagal suppression (decreases in RSA from task to baseline) facilitates flexible engagement with and disengagement from the social environment through the deployment of metabolic resources. The Polyvagal Theory also suggests that the SNS is activated only when there is compromised activity within the neural pathways (the myelinated vagus pathways) that facilitate the suppression of RSA during challenge. When RSA does not change during a challenging situation, the SNS mobilizes and deploys flight- or fight-type responses.

In contrast to predictions that there are emotion-specific patterns of cardiovascular reactivity (Levenson, et al., 1990), the Polyvagal theory predicts that cardiovascular reactivity is a marker of social engagement that facilitates the expression of developmentally typical emotional responses for a given context. Thus, the patterns of cardiovascular reactivity are expected to differ only when emotions vary in the intensity of emotional arousal. For example, in a study of adults, Frazier and colleagues (2004) found that cardiovascular reactivity (magnitude of RSA change) differed between tasks with different emotional intensities (a neutral task and emotion-eliciting tasks); however, it did not differ between tasks with separate emotional valences but similar emotional intensities (e.g., a fear task and a positive-affect task). The authors concluded that RSA change was related more closely to the intensity of an affective task (reflecting differences in the metabolic resources to engage in the task) than to the valence of the task. How are these findings reconciled with previous work demonstrating that less suppression of RSA and a faster PEP were characteristic of displayed fear? A possible explanation is that suppression of RSA reflects physiological engagement with the environment and the display of context-appropriate emotions. Thus, suppression of RSA during a fear task would relate to fewer displays of fear, while suppression of RSA during a positive-affect task would relate to higher-intensity pleasure. As Fraizer and colleagues (2004) did not include behavioral measures, it is unknown if, or in what way, suppression of RSA was related to participants' expressions of either fear or pleasure. Thus, it is possible that in Frazier's study, participants who showed less suppression of RSA displayed more fear; this would be consistent with previous research. In summary, it is necessary that future researchers extend Frazier's work by examining links between RSA change, PEP change, and concurrent displays of fear and high-intensity pleasure within a middle-childhood sample.

Behavioral Reactivity, Cardiovascular Reactivity, and Development

In middle childhood there is increased stability in children's temperamentally based patterns of behavioral and physiological reactivity; this suggests that associations between these two levels of temperament may be clearer in middle childhood than during earlier developmental stages that are characterized by more rapid changes in the emotion system and the cardiovascular system. The stability of temperament increases from infancy, through the toddler/preschool years, with temperament becoming relatively stable in middle childhood (Durbin, Hayden, Klein, & Olino, 2007; Lemery, Goldsmith, Klinnert, & Mrazek, 1999; Roberts & DelVecchio, 2000). Similarly, children's expression and regulation of emotions becomes increasingly organized across these same developmental periods (Denham, 1998). Changes in a child's cognitive capacity (e.g., language, executive functioning) during the toddler and preschool years allow a child to manage and modulate his/her emotional experience with greater independence from caretakers (Calkins & Hill, 2007; Cole, Martin, & Dennis, 2004). By the end of preschool, children are capable of using relatively sophisticated emotion regulation strategies (Grolnick, Bridges, & Connell, 1996; Gilliom, Shaw, Beck, Schonberg, & Lukon, 2002) and children's use of these strategies is more organized, consistent, and efficient by middle childhood (Calkins & Hill, 2007).

There are also rapid changes within the cardiovascular system during early childhood, with levels of RSA decreasing and levels of PEP increasing from infancy through middle childhood (Marshall & Stevenson-Hinde, 1998; Alkon et al., 2003; Alkon et al., 2006; Finley & Nugent, 1995; Finley & Nugent, 1995). This pattern of a higher RSA and a faster PEP in younger as compared to older children suggests a decrease in ANS activation across early childhood into middle childhood, perhaps reflecting increased efficiency of the cardiovascular system. It is less clear if there are age-related changes in measures of cardiovascular reactivity, as some research (Alkon et al., 2003) has shown that younger children (3–4 years) showed more cardiovascular reactivity than older children (7–8 years), while at least one other study did not find age-related differences in measures of cardiovascular reactivity (Allen & Matthews, 1997). This discrepancy may result from younger children perceiving challenging tasks as more threatening in cross-sectional studies than older children do.

Collectively, this work suggests that there are important developmental differences in children's emotion system and cardiovascular system. These differences highlight the need to understand associations between cardiovascular reactivity and displays of emotion within specific developmental stages. These relationships may be easier to detect and more straightforward during middle childhood because there is less change within the emotion system and the cardiovascular system during this developmental stage as compared to earlier stages of development. Further, understanding these associations during middle childhood may elucidate developmental processes during earlier stages of development.

The Present Study

Cumulating evidence has demonstrated that temperamentally based, individual differences in emotion reactivity, particularly in reactivity associated with fear and with high-intensity pleasure, are related to important developmental outcomes. Despite their importance, it is not well understood how two components of emotion reactivity—cardiovascular reactivity, and behavioral displays of emotion—are related in middle childhood. Psychophysiological perspectives offer several alternative predictions regarding these associations: (1) that cardiovascular reactivity differentially relates to displays of emotion (Levenson et al., 1990), (2) that the joint associations between RSA and PEP reflected in autonomic profiles more reliably differentiate displays of emotion (Berntson et al., 1994), and (3) that changes in RSA and PEP reflect undifferentiated emotional arousal and engagement with the environment (Porges, 2007).

To test these predictions, the purpose of this study was to examine associations between RSA change, PEP change, and behavioral displays of emotion within a fear task and a high-intensity pleasure task in an effort to disentangle how cardiovascular changes relate to children's displayed emotions. This goal was accomplished in two ways: by using continuous measures of RSA change and PEP change and by using dichotomous measures of autonomic profiles to examine the links between cardiovascular reactivity and displayed emotion during middle childhood.

Thus, a first aim of this project was to determine if patterns of RSA change and PEP changed differed between the fear and the high-intensity pleasure tasks. Task differences were expected in the continuous measures of RSA change, such that children would show greater decreases in RSA during the fear task than during the pleasure task, because the fear task was hypothesized to be more emotionally arousing than the pleasure task. Task differences in PEP change were not expected at the group level because neither task was hypothesized to elicit enough emotional arousal to necessitate activation of the SNS. Additionally, it was expected that autonomic profiles characterized by RSA suppression (Reciprocal PNS activation and Coactivation) would be more common in the fear-eliciting task, while autonomic profiles characterized by increases in RSA would be more common in the high-intensity pleasure task.

A second goal of this project was to determine if individual differences in cardiovascular reactivity corresponded to individual differences in children's behavioral displays of emotion. This question was examined using continuous measures of cardiovascular reactivity and by using autonomic profiles. The prediction that cardiovascular reactivity indicates general engagement with the environment (Porges, 1995, 2007) would be supported by findings that the same pattern of cardiovascular reactivity was associated with fear and high-intensity pleasure. The prediction that there are emotion-specific patterns of cardiovascular reactivity (Levenson et al., 1990) would be supported by findings that different patterns of cardiovascular reactivity are related to fear and high-intensity pleasure. In light of previous work that has demonstrated that cardiovascular reactivity does not reliably differentiate emotional expressions (Cacioppo, Berntson et al., 2000), it was expected that patterns of cardiovascular reactivity would reflect general engagement with the environment. Specifically, it was expected that less suppression of RSA and a faster PEP, patterns reflecting physiological disengagement with the environment, would be predictive of increased displays of fear during the fear-eliciting task and fewer displays of pleasure in the high-intensity pleasure task. It was also anticipated that more suppression of RSA and a slower PEP, cardiovascular changes thought to reflect physiological engagement with the environment, would be predictive of less fear in the fear task and more pleasure in the high-intensity pleasure task.

Finally, it was expected that autonomic profiles characteristic of physiological engagement with the environment, Reciprocal SNS activation and Coinhibition, would be related to less fear in the fear task and to more pleasure in the high-intensity pleasure task. Autonomic profiles reflecting physiological disengagement with the environment, Reciprocal PNS activation and Coactivation, were expected to relate to increased displays of fear during the fear-eliciting task and to less pleasure in the high-intensity pleasure-eliciting task.

Method

Participants

Participants included 180 (47.6% female) children between the ages of 6 and 10 (*M* = 7.91, *SD* = .98) who participated in a larger twin study examining temperament (Affect, Psychophysiology, and Heritability Encoded by the Conduct of Twins). Recruited through birth records, participating children were above the 10th percentile for twin-specific birth weight and showed no significant birth complications or congenital anomalies. One twin from each pair was randomly selected for inclusion in this study (each child included in these analyses had a twin who completed the same tasks; however data from each of the cotwins has not been analyzed and will not be presented here). Children were predominantly Caucasian (83.2%) and lived in middle class (Hollingshead Index score *M* =45.73, *SD* = 9.86), two-parent homes that mirrored the local population.

Procedure

As part of a larger study, families completed a 2.5 hour psychophysiology laboratory visit. After the families had given consent and assent, the children provided saliva and DNA samples. Sensors were placed on the children to record cardiovascular activity, brain electrical activity, and eye blink responses. Only cardiovascular data is included in this study. Except for one task, the children were either alone in the testing room or with an experimenter. The children participated in a series of five challenging tasks that ranged in length from one to eight minutes (modified from the LAB-TAB protocol). Only the two tasks described below are included in this study. Tasks were completed in a standard order, and cardiovascular data was collected during all tasks. After the last task, the sensors for physiological monitoring were removed, and the experimenter collected a final saliva sample. All episodes were videotaped through a two-way mirror.

Behavioral tasks

Fear-eliciting task. The *Stranger Conversation* task has been shown to elicit fear and social wariness during middle childhood (Talge et al., 2008). In this task, a stranger entered the room and engaged the child in a conversation about his/her hobbies and interests. If the child spoke, the stranger gave two additional prompts before thanking the child and starting the next part of the task. If the child did not speak, the stranger waited 90 seconds and repeated the initial prompt. If the child still remained silent, the stranger waited an additional 90 seconds before making a final prompt.

High-intensity pleasure task. The *Pop-Out Toy* task has been shown to elicit high-intensity pleasure during middle childhood (Pfeifer, Goldsmith, Davidson, & Rickman, 2002). In this task, children were first "surprised" or "tricked" and were then given the opportunity to "surprise" or "trick" their parents. An experimenter gave the child a can that appeared to contain nuts, but, in actuality, contained a slinky toy snake. The experimenter asked the child to help open the can, and then the experimenter opened the lid and allowed the slinky toy to burst out of the can. In a conspiratorial voice, the experimenter suggested that the child surprise his/her parents by pretending that the second can was also filled with nuts. The experimenter left the room, returned 30 seconds later, having given the child the opportunity to surprise his/her parent. This study used only data from the portion of the task in which the child surprised his/her parent.

Cardiovascular data collection.

Cardiovascular data was collected during the two tasks described above, during a four-minute *Pre-task baseline,* and during a four-minute *Post-task baseline*. Band sensors were placed on the child to collect impedance cardiography (ZCG) and electrocardiography (ECG). These bands were placed around the child's neck, below his/her arms, and around his/her torso at the base of the ribcage. Spot sensors were placed on the child's clavicle bones and on his/her torso just below the right underarm. After a *Pre-task baseline* in which the child was instructed to remain relaxed, not to talk, and to sit still, cardiovascular data was collected during the behavioral tasks described above. Finally, a *Post-task baseline* was collected at the end of the study.

A non-invasive, CIC-1000 Cardiac Output Monitor (SORBA Medical Systems, 1997) was used to collect impedance cardiography (ZCG) data. The ZCG signal measured volumetric changes in the heart and systolic time intervals including preejection time and left ventricular ejection time. A 500 uA, 40-kHz oscillating current (both harmless and undetectable) was passed through the two outer current electrodes. Separate channels recorded ECG, basal thoracic impedance (Zo), change in impedance (DZ), and the first derivative of the change in thoracic impedance during systole (dZdt) from the two inner recording band electrodes. An 8-input, 12-bit, 100-kHz analog-to-digital converter, with analog output and 7 bits of digital I/O, and a Toshiba 6400 computer were used to sample the ECG, Zo, DZ, and dZ-dt signals at a rate of 500 micro amps, 40 kHZ current uA, per channel. The raw, continuous ECG signal was extracted from the SORBA system and separately pushed through a bandpass filter at 30 HZ and 100 HZ, amplified 20 K, and sampled at 500 ms, following the methods of Buss and colleagues (2004, 2005).

Measures

Coding of displayed emotion.

For each task, behavioral scoring was completed by one of two coding teams that were comprised by undergraduate students that were reliable with a graduate-level master coder by achieving Kappas of .70 or higher for at least 10 participants. The master coder double coded approximately 20% of the sample. Kappas for all variables ranged from .69 to .89 (M = .77). All tasks were scored in 10-second epochs. The maximum intensity of facial fear was scored using the AFFEX definitions (Izard, Dougherty, & Hembree, 1983). Following this scheme, the reliable coders examined movement in three regions of the face: the brow region, the eye/nose/cheek region, and the mouth region. The intensity of emotions was rated as follows: 0 = no codable movement in facial regions, 1 = one facial region showed movement, 2 = two facial regions showed movement or definite expression in one region (e.g., eyes), and 3 = a change in all 3 facial regions or strong impression of the emotion. The intensity of bodily fear, avoidance, and vigor of enthusiasm were scored using the following intensity scale: 0 = no detectable bodily display of emotion/behavior, 1 = low bodily display of emotion/behavior, 2 = moderate bodily display of emotion/behavior and 3 = high bodily display of emotion/behavior. Definitions of these codes are provided within the task descriptions below.

Stranger Conversation. One team of reliable coders rated behaviors associated with fear and wariness. Facial fear was characterized by partially raised, straight brows that were drawn in; widened eyes showing more white than usual; a raised upper eyelid; and a slightly opened mouth with the corners pulled straight back. Bodily fear was coded when children showed decreased motor activity, bodily tension, startling, or freezing. Avoidance behaviors reflected children's efforts to maintain or increase distance from the stranger (e.g., turning body away, covering face, crossing arms, sinking in seat). Dichotomous codes (0 = absence of behavior, 1 = presence of behavior) were used to rate the following behaviors: number of stranger prompts, nervous fidgeting, whispered speech, and verbal disfluencies. The latencies (in seconds) from the start of the task until the child spoke, displayed a fear response, or displayed fidgeting behaviors were also recorded. The latency to show a fear response and the latency to show fidgeting were reversed so that longer latencies indicated that more of the behaviors had taken place. Additionally, coders rated the proportion of time that the child spoke.

Pop-Out Toy. A second team of reliable coders rated behaviors indicative of high-intensity pleasure. Using the intensity scale described above, intensity of smiling was characterized by raised cheeks, the corners of the mouth pulled back and up, and a furrow between the eyebrows. Vigor of enthusiasm reflected interest in the game, approach behaviors, animation, and positive motor activity (e.g., kicking legs excitedly). Dichotomous codes (0 = absence of behavior, 1 = presence) were used to rate laughter. The peak intensity of positive vocalizations was rated on a 4-point scale, such that 0 reflected a lack of positive vocalizations, and a score of 3 represented extremely positive vocalizations. Additionally, coders rated the children's baseline state at the beginning of the task, the degree to which the children showed a startle response when surprised by the snake, and the children's level of positivity after the game ended.

Cardiovascular scoring.

PEP. PEP was used to measure SNS-influenced cardiovascular activity. PEP was calculated as the time in milliseconds from the beginning of the electrical systole (corresponding to the Q wave of the ECG) to the beginning of the mechanical contraction (corresponding to the peak of the R spike on the ECG). PEP was calculated offline using CIC-1000 Impedance Cardiograph software, Version 7.2 (SORBA Medical Systems, 1997). For all tasks, PEP was calculated in 30-second epochs. Algorithms in the CIC-1000 software automatically marked the dZ/dt B point and the beginning of the QRS complex on the ECG waveform. The children's height, weight, and the distance (in inches) between the two inner band electrodes were entered to accurately calculate PEP. For each epoch, the software calculated a PEP score, or the time between the onset of the Q-wave in the ECG waveform and the B-point of the dZ/dt waveform. The software also flagged abnormalities in the data that were later examined, and when necessary, edited, and PEP was recalculated. The means and standard deviations of the task-level PEP scores are presented in Table 1.

RSA. RSA was used to measure PNS-influenced cardiovascular activity. To calculate RSA, the raw ECG wave was extracted from the SORBA system, filtered, and transformed into files containing interbeat intervals (IBIs), or the time between heart beats, using a program that had adjustable thresholds to detect R-waves. The IBI files were entered into MXedit software, and the data was cleaned to identify and edit artifacts. The IBIs were subjected to a moving polynomial filter. RSA, or the natural logarithm of the variance in the frequency bands between .24 and 1.04Hz, was generated in 30-second epochs. The means and standard deviations of the task-level RSA scores are also presented in Table 1.

Data Reduction

Behavioral data reduction.

Within each emotion-eliciting task, coded behaviors were averaged across epochs to create a mean score for each behavior. The raw means and standard deviations of the coded behaviors for the *Stranger Conversation* and the *Pop-Out Toy* tasks are presented in Table 1. Next, to examine the extent to which the *Stranger Conversation* and *Pop-Out Toy* tasks elicited fear and high-intensity pleasure respectively, the modes for each of the variables were examined to determine what the “typical” behavioral response was for each task. The modes are also presented in Table 1.

As seen in Table 1, in the *Stranger Conversation* task, on average children showed low-intensity fear behaviors; but some children showed higher-intensity fear behaviors. An examination of the modes indicates that the children showed nervous fidgeting when prompted by the stranger, that they talked to the stranger for approximately half of the task, and that they used speech characterized by verbal disfluencies. The children who did show fear, displayed fear quickly, showed more avoidance and bodily fear, and were prompted more often by the stranger. Patterns of correlations among the variables were examined to determine which variables should be included in a composite of fear behaviors (Table 3). Significantly correlated variables (*rs* ranging from .21 to .41) were standardized using a z-transformation that resulted in a distribution with a mean of zero and a standard deviation of 1. These standardized variables were then averaged to create a fear composite. This fear composite consisted of the following variables: average intensity of avoidance behaviors, average intensity of bodily fear, average intensity of nervous fidgeting, latency to show fear (reversed), and the number of prompts given by the stranger. Facial fear occurred infrequently ($n = 1$) and was excluded from these analyses.

As seen in Table 1, on average children were alert and calm when the *Pop-Out Toy* task began, showed a mild startle when the snake popped out of the can, showed positive emotionality within 10 seconds of starting the task, displayed moderate to high levels of positivity during the task with positivity characterized by enthusiasm, laughter, and moderate to high-intensity smiles. Further, the majority of children displayed positive emotion at the end of the task. To create the composite of high-intensity pleasure, patterns of correlations among the *Pop-Out Toy* variables were examined (Table 4). Significantly correlated variables (*rs* ranging from .18 to .61) were standardized using a z-score transformation and averaged to form a composite of high-intensity pleasure. This composite consisted of the following variables: average duration of smiling, average intensity of smiling, laughter, average enthusiasm, positive vocalizations, presence of post-game positivity, and the latency to first positivity (reversed so that larger scores reflect a shorter duration).

Finally, the distributions of the behavioral composites were examined, and values 1.5*SD* above or below the mean were removed and replaced with the next value in the distribution. In the *Stranger Conversation* task, four children had scores above this threshold and these scores were replaced. No children in the *Pop-Out Toy* task scored above or below this threshold. The resulting distributions were relatively normal (skewness < 2). The means and standard deviations of these finalized variables are presented in Table 5.

Cardiovascular data reduction.

Continuous measures of cardiovascular change. Task composites for PEP and RSA data were created by averaging the children's scores across the 30-second epochs (*Pre-baseline, Stranger Conversation,* and *Pop-Out Toy*). PEP change scores were created by subtracting the *Pre-baseline* PEP value from the task PEP values. Negative numbers represented a faster PEP (SNS activation), and positive numbers represented a slower PEP (SNS withdrawal). RSA change scores were created by subtracting baseline RSA values from task RSA values. Decreases in RSA represented RSA suppression (PNS withdrawal); increases in RSA represented RSA augmentation (PNS activation).

The distributions of all cardiovascular variables were examined, and outliers greater than 2 *SD* above or below the mean were removed and replaced with the next highest value in the distribution. The resulting distributions were relatively normal (skewness < 2). The means and standard deviations for the cardiovascular change scores are presented in Table 5.

Autonomic profiles. To examine task differences in the joint associations between RSA change and PEP change, autonomic profiles were created for the children who showed meaningful RSA and PEP change within each task. Following the work of Quigley and Stifter (2006), meaningful change was defined as a change in the cardiovascular measure that was equal to or greater than the standard error for that task. Thus, RSA change scores of .05 ln ms^2 or greater were considered meaningful, while PEP change scores of .55 *ms* or more were considered meaningful. Then, dummy codes were used to classify the children into one of four autonomic profiles: Coinhibition (decreased RSA, slower PEP), Coactivation (increased RSA, faster PEP), Reciprocal PNS activation (increased RSA, slower PEP), and Reciprocal SNS activation (decreased RSA, faster PEP). Following the work of Alkon and colleagues (2003), the profiles of Uncoupled PNS and Uncoupled SNS activation were not considered, as they are relatively rare in middle childhood. The frequencies of these profiles are presented in Table 7.

Results

Preliminary Analyses

Before the aims of this study were established, preliminary analyses were conducted to explore possible correlations between study variables. The preliminary analyses also determined which variables should be controlled in subsequent analyses as well as which types of autonomic profiles were typical within each task.

Effects of sex and age.

Bivariate correlations between child age, child sex, behavioral variables, and cardiovascular variables were examined (Table 6). Fear was not significantly correlated with child age or child sex. High-intensity pleasure was negatively correlated with child age, such that younger children were more likely to show pleasure during the *Pop-Out Toy* task, $r = -.18$, $p < .05$. Additionally, high-intensity pleasure was significantly correlated with child sex, such that girls showed more pleasure than boys during the task, $r = .23$, $p < .05$. Subsequent analyses using the pleasure composite controlled for child age and sex.

Startle responses during the Pop-Out Toy task.

To explore the possibility that the children's cardiovascular responses during the *Pop-Out Toy* task were influenced by the children's startle response and surprise when the pop-out toy emerged from the can, correlations between the *Pop-Out Toy* cardiovascular variables and children's startle responses during that task were examined (Table 6). The correlations suggested that children's startle response was not significantly related to children's cardiovascular reactivity.

Typical patterns of autonomic change.

To determine which patterns of cardiovascular change were typical in each task, the frequencies of each autonomic profile were examined. As seen in Table 7, the most frequent autonomic profile shown in the *Stranger Conversation* task was Coinhibition (47.2%), followed by Reciprocal SNS activation (31.1%), Coactivation (12.2%), and Reciprocal PNS activation (9.4%). In the *Pop-Out Toy* task, the profile that occurred most frequently was also Coinhibition (33.3%), followed by Coactivation (26.3%), Reciprocal PNS activation (21.2%), and Reciprocal SNS activation (19.2%). This suggests the most frequently occurring pattern of joint changes in cardiovascular reactivity was a decrease in RSA and a slower PEP. However, Table 7 shows that there were individual differences in regard to which pattern of ANS change children showed.

Aim 1: Between-Task-Differences in Patterns of Cardiovascular Reactivity.

Continuous measures of RSA and PEP change. Paired sample *t*-tests were used to determine if there were task-related differences of the continuous measures of RSA change and PEP change. Consistent with expectations, these analyses indicated that there was more suppression of RSA in the *Stranger Conversation* task ($M = -.44$, $SD = .63$) than in the *Pop-Out Toy* task ($M = -.09$, $SD = .63$), $t_{132} = -6.02$, $p < .05$. A second paired sample *t*-test used to compare task differences in PEP showed no significant task differences in PEP at the group level.

Autonomic Profiles. A chi-square analysis was conducted to determine if the proportion of children showing each autonomic profile differed between the *Stranger Conversation* and the *Pop-Out Toy*. This revealed that the autonomic profiles differed between the tasks, X^2 (3, N = 205) = 15.26, $p < .05$. To determine which autonomic profiles differed between the two groups, the adjusted standardized residuals were examined. These residuals follow the *z*-distribution, indicating that values greater than 1.96 correspond to an alpha significance of .05. An examination of the adjusted standardized residuals indicated that autonomic profiles characterized by decreases in RSA (Coactivation and Reciprocal SNS activation) were more common in the *Stranger Conversation* task than in the *Pop-Out Toy* task. Autonomic profiles characterized by increases in RSA (Coactivation and Reciprocal PNS activation) were more common in the *Pop-Out Toy* task than in the *Stranger Conversation* task.

Aim 2: Associations between patterns of RSA change, PEP change, and behavior.

Continuous measures of RSA and PEP change. Two hierarchical linear regressions were used to determine if RSA and PEP changes were predictive of children's displayed fear and high-intensity pleasure. The first model tested associations between RSA change from baseline to task and PEP change between the same intervals in predicting fear behaviors during the *Stranger Conversation* task. The second model tested if RSA change and PEP change were predictive of high-intensity pleasure in the *Pop-Out Toy* task. For both models, child age and sex were entered into the first step of the model to control for differences in the children related to maturation or sex. Next, cardiovascular variables of interest, changes in PEP and changes in RSA, were entered into the second step of the model to determine if RSA change and PEP made unique contributions to the children's behaviors. Contrary to expectations, these models were not predictive of either the children's fear behaviors or the children's displays of high-intensity pleasure.

Autonomic profiles. Within each task, ANCOVAs were used to determine if there were associations between autonomic profiles and the children's displays of emotion, after controlling for child sex and child age. Child age and child sex were entered as covariates in the model, and autonomic profile groups were entered as a fixed factor. The model for the *Stranger Conversation* task was non-significant.

However, the ANCOVA in the *Pop-Out Toy* task indicated that there was a significant relationship between *Pop-Out Toy* autonomic profiles and children's displays of high-intensity pleasure, $F(5, 98) = 3.27$, $p < .05$. Specifically, there was a main effect for child age that showed that younger children displayed more high-intensity pleasure than older children, $F(1, 98) = .5.64$, $p < .05$. Additionally, there was a moderately significant main effect for child sex, which demonstrated that girls showed more pleasure than boys, $F(1, 98) = 3.62$, $p = .06$. There was also a moderately significant main effect suggesting that children's display of high-intensity pleasure varied as a function of which autonomic profile they showed, $F(3, 92) = 2.32$, $p = .08$). Follow-up LSD comparisons indicated that children who showed the Reciprocal SNS autonomic profile displayed more high-intensity pleasure during the task than children with the Reciprocal PNS profile. So, children who showed physiological meaningful decreases in RSA and meaningful increases in PEP were rated as showing more high-intensity pleasure than children who showed physiological meaningful increases in RSA and a slower PEP.

Discussion

Grounded in a framework drawn from the temperament literature and influenced by predictions from psychophysiology, this study took as its purpose the examination of associations between two types of emotion reactivity—behavioral displays of emotion and cardiovascular reactivity—within tasks that differed in emotional valence. The first aim was to determine if there were task differences in children's pattern of cardiovascular reactivity. Supporting hypotheses, cardiovascular reactivity, particularly RSA change, differed between the tasks. The second aim was to determine if cardiovascular reactivity was related concurrently to children's displays of fear and high-intensity pleasure. The finding that autonomic profiles related to children's high-intensity pleasure supported these predictions. All other predictions were unsupported.

Task differences in RSA change and PEP change

Consistent with previous work, the present study found that children's patterns of cardiovascular reactivity differed between tasks that varied in emotional valence (Calkins & Dedmon, 2000) and that these differences were the result of RSA change. In both tasks, Coinhibition (suppression of RSA and a lengthened PEP) was the most frequent autonomic profile that children showed, a finding consistent with previous research in middle childhood (Alkon et al., 2003). However, the magnitude of RSA change (via the continuous change scores) was greater in the fear task than in the high-intensity pleasure task. Also, the autonomic profiles characterized by RSA suppression (Coactivation and Reciprocal SNS activation) were more likely to occur in the fear task than in the high-intensity pleasure task. In light of research that has demonstrated that fear behaviors were related to less suppression of RSA (Buss et al., 2005; Talge, et al., 2008), these findings are initially perplexing. But, if RSA suppression is, as predicted by Porges, indicative of general emotional arousal, then the current findings may indicate that the fear task evoked more intense emotional arousal than the high-intensity pleasure task did. If this was the case, then children would need a greater suppression of RSA during the fear task to mobilize the metabolic resources necessary to display developmentally typical behaviors (in the present study, moderate fear behaviors characterized by nervousness and fidgeting). This finding that children showed more RSA suppression during the fear task does not demonstrate a relationship between RSA suppression and children's expressions of fear, but rather indicates that there was more RSA suppression during a task designed to elicit fear. As Frazier (2004) cautioned, it is important not to interpret task-differences in cardiovascular reactivity that may relate to the intensity of arousal as evidence for emotion-specific patterns of cardiovascular reactivity. To demonstrate emotion-specific patterns of cardiovascular reactivity, it is also necessary to consider associations between children's behavioral displays of emotion and cardiovascular reactivity.

Associations between Cardiovascular Reactivity and High-intensity Pleasure

As a second aim, this study sought to determine if there was evidence for emotion-specific patterns of cardiovascular reactivity or if cardiovascular reactivity during emotion-evoking situations was indicative of general arousal and engagement with the environment. Consistent with the predictions of the Polyvagal Theory (1995, 2007), the present study found that children who showed the autonomic profile of Reciprocal SNS activation (RSA suppression and a faster PEP), a profile theorized to represent physiological engagement with the environment, displayed more high-intensity pleasure than children who showed the autonomic profile of Reciprocal PNS activation (increased RSA and a slower PEP), a profile theorized to represent physiological disengagement with the environment. Previous research linking cardiovascular reactivity to displays of positive emotion has been inconsistent. Some research has found that RSA suppression is related to more positive emotion (e.g., Frazier et al., 2004), while other work has found that less RSA suppression is related to positive emotionality (Field & Diego, 2008). One possibility accounting for these discrepancies is that physiological engagement is related to high-intensity, approach-oriented, positive emotions, while physiological disengagement is related to low-intensity, positive emotions (Frazier, Strauss, & Steinhauer, 2004). Supporting this idea is recent work showing the EEG asymmetry differentiated children who showed high-intensity pleasure from children who showed low-intensity pleasure. Further research seeking to understand how the intensity of positive emotion moderates associations between physiological reactivity and behavioral displays of emotion would be an exciting development.

In considering the associations between cardiovascular reactivity and high-intensity pleasure, it is important to note that these associations were found only when the autonomic profiles suggested by Berntson's (1994) work were used. Berntson and colleagues (1994) postulated that joint associations between SNS- and PNS-influenced cardiovascular reactivity are more likely to relate to displays of emotion than single, continuous measures of cardiovascular reactivity. Previous research has established that there are individual differences in which autonomic profiles children display during emotional stressors (Alkon et al., 2003; Quigley & Stifter, 2006). However, this is the first known study to examine this prediction in childhood. Consistent with Berntson's hypothesis, the present study found that the joint measures of cardiovascular reactivity, autonomic profiles, predicted children's display of high-intensity pleasure when continuous measures of RSA change and PEP change were unassociated with children's behaviors. Further, this finding lends support to recent work that contends that the best way to examine associations between physiology and behavior is through multi-measurement approaches (Bauer, Quas, & Boyce, 2002). It is, therefore, important for future work to continue examining the associations between autonomic profiles and children's displays of emotion.

Dissociations between Cardiovascular Reactivity and Fear

Consistent with previous research (Forbes et al., 2006; Quas et al., 2000), this study failed to demonstrate associations between cardiovascular reactivity and children's displays of fear. However, changes in RSA and PEP have been related to fear behaviors in younger children (Buss et al., 2004; Buss et al., 2005). The task used to elicit fear in the present study, talking to a stranger, did not elicit high-intensity fear, as reflected in the behavioral data showing that only one child displayed facial fear and that most children showed moderate fear characterized by nervousness and fidgeting. Further, recall that almost 50% of children showed autonomic profiles hypothesized to reflect physiological engagement with the environment (RSA suppression and lengthened PEP) during the fear task. Perhaps autonomic profiles hypothesized to reflect fear (less suppression of RSA and a faster PEP) occurred too infrequently for associations between reactivity and fear to be detected within this study. Collectively, because a greater concordance between cardiovascular reactivity and emotion is expected during situations characterized by high-intensity emotion (Cacioppo et al., 1992), it is important for future work to use tasks that elicit high-intensity fear to examine these associations.

It is also possible that cardiovascular reactivity was unrelated to fear because children regulated expressions of fear more than they regulated expressions of high-intensity pleasure, making it difficult to detect associations between cardiovascular reactivity and fear. Emotion regulation refers to changes in activated emotions, including physiology or other psychological phenomenon (Cole et al. 2004) and previous research has demonstrated associations between children's emotion regulation and the expression of temperamental traits (Blandon, Calkins, Keane, & O'Brien, 2008; Buss & Goldsmith, 1998). Within western cultures, positive emotions are considered to be more socially appropriate than negative emotions (Mesquita & Albert, 2007) and children understand these cultural norms from a young age (Banerjee, 1997). Given that young children can regulate the display of negative emotions (Cole, Zahn-Waxler, & Smith, 1994), perhaps children in the present study simply displayed more pleasure than fear, making it easier to detect associations between cardiovascular reactivity and displayed emotion (Cacioppo et al., 1992). As the present study only examined emotion behaviors theorized to reflect Rothbart's construct of reactivity, it is important that future work concerned with understanding the behavioral and physiological markers of temperament also consider associations between the regulatory components of emotion reactivity and cardiovascular reactivity.

It is often difficult to identify precise relationships between behavioral and physiological markers of temperament (Goldsmith & Campos, 1982). Thus, it is also important to consider the possibility that cardiovascular measures lack the specificity to detect changes in the behavioral displays of emotion because the time-course of changes in cardiovascular measures is slower than the time-course of changes in emotion (Cacioppo, Berntson et al., 2000). Future studies should consider utilizing physiological measures that have a shorter time-course, like electroencephalogram (EEG) approaches. For example, a recent study by Light and colleagues (2009) examined EEG changes during the *Pop-Out Toy* task and found that increases in children's displays of pleasure corresponded to increasing left-frontal EEG asymmetry and that increasing right-frontal EEG asymmetry was characteristic of children who showed low-intensity pleasure. Collectively, this work suggests that the inclusion of other physiological measures in research paradigms investigating the links between physiological and behavioral markers of emotion reactivity is a promising avenue of research.

Collectively, fear was not associated with cardiovascular reactivity; this, therefore, prohibits the drawing of any general conclusions regarding the associations between physiological and behavioral markers of temperamentally based patterns of emotion reactivity. If cardiovascular reactivity were differentially related to displays of emotion (Levenson et al., 1990), it would be expected that different patterns of reactivity would relate to behavioral displays of fear and high-intensity pleasure. If cardiovascular reactivity represented general arousal and engagement with the environment (Porges, 2007; Fraizer, 2004), it would be expected that the same pattern of cardiovascular reactivity would relate to the display of fear and high-intensity pleasure. As cardiovascular reactivity was unrelated to fear but was related to high-intensity pleasure, it is not possible for the present study to draw any conclusions regarding the veracity of the predictions described above. These issues should be addressed in subsequent work.

Limitations & Future Directions

A number of issues necessitate additional consideration. First, this study used a cross-sectional design, and the children who participated ranged in age from six to ten years of age. As research has demonstrated that the autonomic nervous system and the emotion system develop during middle childhood, it is important to examine associations between RSA change, PEP change, and emotions longitudinally. It is possible that the emotion-eliciting tasks used in this study may not have been arousing enough to fully capture individual differences in children's cardiovascular reactivity, particularly in regard to PEP. This is a common problem within the developmental literature (Cacioppo et al., 1992; Quas et al., 2000) that should be addressed in future work. Collectively, research is needed to determine a battery of emotion-eliciting stressors that are stressful enough to produce RSA and PEP changes.

While patterns of reactivity both influence and are influenced by a child's experiences with the world (Kagan & Fox, 2006) this study did not test ways that environmental factors influenced reactivity. Some of these influences include maternal supportiveness (Calkins, Dedmon, Gill, Lomax, & Johnson, 2002), marital conflict (Gottman & Katz, 2002), peers (Fantuzzo, Bulotsky-Sheare, Fusco, & McWayne, 2005), siblings (Volling, McElwain, & Miller, 2002), and culture (Mesquita & Albert, 2007b). Beyond the scope of this study, examining potential mediating and moderating influences of these environmental factors on the associations between reactivity and children's displays of fear and high-intensity pleasure is a much-needed area of research.

Finally, following conventions within the literature (Fox, Schmidt, Henderson, & Marshall, 2007), this study used difference scores to measure RSA and PEP reactivity. This approach assumes linear relationships among the variables, and information regarding the timing of cardiovascular changes is lost. For example, recent work demonstrated that toddlers who showed patterns of RSA change characterized by later decreases in RSA were at more risk for anxiety problems as compared to toddlers who showed early decreases in RSA (Brooker & Buss, in press). Thus the timing, in addition to the amount of cardiovascular reactivity, merits additional consideration. The cardiovascular change scores used in this study were created by examining change from an affectively neutral baseline task. However, the tasks examined in this study were not sequential, and cardiovascular changes that occurred between the fear task and the high-intensity pleasure task were not considered. It is possible that the association between autonomic profiles and high-intensity pleasure resulted from cardiovascular changes that occurred in the preceding task. This possibility is unlikely given that supplemental analyses demonstrated that task RSA values were higher in the high-intensity pleasure task than in the preceding task, suggesting that the patterns of cardiovascular reactivity resulted from the high-intensity pleasure task rather than from the preceding task. Nevertheless, it is still important that future work consider dynamic measures of cardiovascular changes in conjunction with behavioral displays of emotion.

Conclusions

This study used temperament and psychophysiological perspectives to examine the associations between cardiovascular reactivity and children's displays of emotion within a fear-eliciting task and a high-intensity pleasure-eliciting task. Consistent with the hypothesis that fear would elicit more intense arousal and necessitate greater metabolic resources to promote engagement with the environment, children showed more suppression of RSA in the fear task than in the high-intensity pleasure task. Similarly, children were more likely to show autonomic profiles characterized by RSA suppression in the fear task and were more likely to show autonomic profiles characterized by increased RSA in the high-intensity pleasure task. However, the only evidence that this study found in support of associations between cardiovascular reactivity and emotion was that children's autonomic profiles contributed to children's displays of high-intensity pleasure. As there were no associations between cardiovascular reactivity and fear behaviors, it was not possible for this study to conclude if it is best to conceptualize cardiovascular reactivity as being differentially related to specific emotions or to conceptualize cardiovascular reactivity as representing general emotional arousal related to physiological engagement with the environment. The present study is one of the first studies to document associations between cardiovascular reactivity and children's display of a positive emotion. Additional research on children's positive emotions is needed within the psychophysiological literature. Moreover, this study also demonstrates the utility of considering joint associations between RSA change and PEP change via the creation of autonomic profiles in order to understand associations between cardiovascular reactivity and children's displayed emotion in middle childhood.

.

Refrences

Alkon, A., Goldstein, L. H., Smider, N., Essex, M. J., Kupfer, D. J., & Boyce, W. T. (2003). Developmental and contextual influences on autonomic reactivity in young children. *Developmental Psychobiology, 42*(1), 64–78.

Alkon, A., Lippert, S., Vujan, N., Rodriquez, M. E., Boyce, W. T., & Eskenazi, B. (2006). The ontogeny of autonomic measures in 6- and 12-month-old infants. *Developmental psychobiology, 48*(3), 197–208.

Allen, M. T., & Matthews, K. A. (1997). Hemodynamic responses to laboratory stressors in children and adolescents: The influences of age, race, and gender. *Psychophysiology, 34*(3), 329–339.

Banerjee, M. (1997). Hidden emotions: Preschoolers' knowledge of appearance-reality and emotion display rules. *Social Cognition, 15*(2), 107–132.

Bauer, A. M., Quas, J. A., & Boyce, W. T. (2002). Associations between physiological reactivity and children's behavior: Advantages of a multisystem approach. *Journal of Developmental & Behavioral Pediatrics, 23*(2), 102–113.

Berntson, G. G., Cacioppo, J. T., & Quigley, K. S. (1993a). Cardiac psychophysiology and autonomic space in humans: Empirical perspectives and conceptual implications. *Psychological Bulletin, 114*(2), 296–322.

Berntson, G. G., Cacioppo, J. T., & Quigley, K. S. (1993b). Respiratory sinus arrhythmia: Autonomic origins, physiological mechanisms, and psychophysiological implications. *Psychophysiology, 30*(2), 183–196.

Berntson, G. G., Cacioppo, J. T., Quigley, K. S., & Fabro, V. T. (1994). Autonomic space and psychophysiological response. *Psychophysiology, 31*(1), 44–61.

Berntson, G. G., Norman, G. J., Hawkley, L. C., & Cacioppo, J. T. (2008). Cardiac autonomic balance versus cardiac regulatory capacity. *Psychophysiology, 45*(4), 643–652.

Biederman, J., Hirshfeld-Becker, D. R., Rosenbaum, J. F., Herot, C,, Friedman, D., Snidman N., Kagan, J., & Farone, S. V. (2001). Further evidence of association between behavioral inhibition and social anxiety in children. *American Journal of Psychiatry, 158*(10), 1673–1679.

Blair, C. (2002). School readiness: Integrating cognition and emotion in a neurobiological conceptualization of children's functioning at school entry. *American Psychologist, 57*(2), 111–127.

Blandon, A. Y., Calkins, S. D., Keane, S. P., & O'Brien, M. (2008). Individual differences in trajectories of emotion regulation processes: The effects of maternal depressive symptomatology and children's physiological regulation. *Developmental Psychology, 44*(4), 1110–1123.

Boyce, W. T., Quas, J. A., Alkon, A., Smider, N. A., Essex, M. J., Kupfer, D. J., et al. (2001). Autonomic reactivity and psychopathology in middle childhood. *British Journal of Psychiatry, 179,* 144–150.

Briggs-Gowan, M. J., Horwitz, S. M., Schwab-Stone, M. E., Leventhal, J. M., & Leaf, P. J. (2000). Mental health in pediatric settings: Distribution of disorders and factors related to service use. *Journal of the American Academy of Child & Adolescent Psychiatry, 39,* 841–849.

Brooker, R. J., & Buss, K. A. (in press). *Dynamic measures of RSA predict distress and regulation in toddlers*. Manuscript submitted for publication.

Buss, K. A., Davidson, R. J., Kalin, N. H., & Goldsmith, H. H. (2004). Context-specific freezing and associated physiological reactivity as a dysregulated fear response. *Developmental Psychology, 40*(4), 583–594.

Buss, K. A., & Goldsmith, H. H. (1998). Fear and anger regulation in infancy: Effects on the temporal dynamics of affective expression. *Child Development, 69*(2), 359–374.

Buss, K. A., Goldsmith, H. H., & Davidson, R. J. (2005). Cardiac reactivity is associated with changes in negative emotion in 24-month-olds. *Developmental Psychobiology, 46*(2), 118–132.

Cacioppo, J. T., Berntson, G. G., Larsen, J. T., Poehlmann, K. M., & Ito, T. A. (2000). The psychophysiology of emotion. In M. Lewis & R. J. M. Haviland-Jones (Eds.), *The handbook of emotions* (2nd ed., pp. 172–191). New York: Guilford Press.

Cacioppo, J. T., Tassinary, L. G., & Berntson, G. G. (2000). Psychophysiological science. In J. T. Cacioppo, L. G. Tassinary, & G. G. Berntson (Eds.), *Handbook of psychophysiology* (pp. 3–23). Cambridge, UK: Cambridge University Press.

Cacioppo, J. T., Uchino, B. N., & Berntson, G. G. (1994). Individual differences in the autonomic origins of heart rate reactivity: The psychometrics of respiratory sinus arrhythmia and preejection period. *Psychophysiology, 31*(4), 412–419.

Cacioppo, J. T., Uchino, B. N., Crites, S. L., Snydersmith, M. A., Smith, G., Berntson, G. G., et al. (1992). Relationship between facial expressiveness and sympathetic activation in emotion: A critical review, with emphasis on modeling underlying mechanisms and individual differences. *Journal of Personality and Social Psychology, 62*(1), 110–128.

Calkins, S. D., & Dedmon, S. E. (2000). Physiological and behavioral regulation in two-year-old children with aggressive/destructive behavior problems. *Journal of Abnormal Child Psychology, 28*(2), 103–118.

Calkins, S. D., Dedmon, S. E., Gill, K. L., Lomax, L. E., & Johnson, L. M. (2002). Frustration in infancy: Implications for emotion regulation, physiological processes, and temperament. *Infancy, 3*(2), 175–197.

Calkins, S. D., & Hill, A. (2007). Caregiver influences on emerging emotion regulation: Biological and environmental transactions in early development. In J. J. Gross (Ed.), *Handbook of emotion regulation* (pp. 229–248). New York, NY, Guilford Press.

Campos, J. J., Barrett, K. C., Lamb, M. E., Goldsmith, H. H., & Sternberg, C. (1983). Socioemotional development. In P. H. Mussen (Ed.), *Handbook of Child Psychology* (pp. 783–916). New York: Wiley.

Campos, J. J., Mumme, D. L., Kermoian, R., & Campos, R. G. (1994). A functionalist perspective on the nature of emotion. *Monographs of the Society for Research in Child Development,* 59, 284–303.

Cole, P. M., Zahn-Waxler, C., & Smith, K. D. (1994). Expressive control during a disappointment: Variations related to preschoolers' behavior problems. *Developmental Psychology, 30*(6), 835–846.

Denham, S. A. (1998). Emotional Development in Young Children. *The Guildford Series on Social and Emotional Development*, *2,* 19–57.

Durbin, C. E., Hayden, E. P., Klein, D. N., & Olino, T. M. (2007). Stability of laboratory-assessed temperamental emotionality traits from ages 3 to 7. *Emotion, 7,* 388–399.

Fantuzzo, J. W., Bulotsky-Sheare, R., Fusco, R. A., & McWayne, C. (2005). An investigation of preschool classroom behavioral adjustment problems and social-emotional school readiness competencies. *Early Childhood Research Quarterly, 20*(3), 259–275.

Field, T., & Diego, M. (2008). Vagal activity, early growth and emotional development. *Infant Behavior & Development, 31*(3), 361–373.

Field, T., Pickens, J., Fox, N. A., & Nawrocki, T. (1995). Vagal tone in infants of depressed mothers. *Development and Psychopathology, 7*(2), 227–231.

Finley, J. P., & Nugent, S. T. (1995). Heart rate variability in infants, children and young adults *Journal of the Autonomic Nervous System, 51*(2), 103–108.

Forbes, E. E., Fox, N. A., Cohn, J. F., Galles, S. F., & Kovacs, M. (2006). Children's affect regulation during a disappointment: Psychophysiological responses and relation to parent history of depression. *Biological Psychology, 71*(3), 264–277.

Fox, N. A., Hane, A. A., & Perez-Edgar, K. E. (2006). Psychophysiological methods for the study of developmental psychopathology. In D. Cicchetti & D. Cohen (Eds.), *Developmental psychopathology, developmental neuroscience* (2nd ed., Vol. 2, pp. 381–426). Hoboken: John Wiley & Sons.

Fox, N. A., Schmidt, L., Henderson, H. A., & Marshall, P. J. (2007). Developmental psychophysiology: Conceptual and methodological issues. In J. T. Cacioppo, L. G. Tassinary, & G. G. Berntson (Eds.), *Handbook of physiology* (Vol. 3, pp. 2453–2481). New York: Cambridge University Press.

Frazier, T. W., Strauss, M. E., & Steinhauer, S. R. (2004). Respiratory sinus arrhythmia as an index of emotional response in young adults. *Psychophysiology, 41*(1), 75–83.

Gilissen, R., Koolstra, C. M., van Ijzendoorn, M. H., Bakermans-Kranenburg, M. J., & van der Veer, R. (2007). Physiological reactions of preschoolers to fear-inducing film clips: Effects of temperamental fearfulness and quality of the parent-child relationship. *Developmental Psychobiology, 49*(2), 187–195.

Gillom, M., Shaw, D. S., Beck, J. E., Schonberg, M. A., & Lukon, L. L. (2002). Anger regulation in disadvantaged preschool boys: Strategies, antecedents, and the development of self-control. *Developmental Psychology,* 38, 222–235.

Goldsmith, H. H., Buss, A. H., Plomin, R., Rothbart, M. K., et al. (1987). What is temperament? Four approaches. *Child Development, 58*(2), 505–529.

Goldsmith, H. H., & Campos, J. J. (1982). Toward a theory of infant temperament. In R. Emde & R. Harmon (Eds.), *Attachment and affiliative systems* (pp. 161–193). New York: Plenum Press.

Goldsmith, H. H., & Campos, J. J. (1990). The structure of temperamental fear and pleasure in infants: A psychometric perspective. *Child Development, 61*(6), 1944–1964.

Goldsmith, H. H., Lemery, K. S., Aksan, N., & Buss, K. A. (2000). Temperamental substrates of personality. In D. Molfesse & V. Molfesse (Eds.), *Temperament and personality development across the lifespan* (pp. 1–32). Hillside, NJ: Erlbaum.

Gottman, J. M., & Katz, L. F. (2002). Children's emotional reactions to stressful parent–child interactions: The link between emotion regulation and vagal tone. *Marriage & Family Review, 34*(3–4), 265–283.

Graziano, P. A., Keane, S. P., & Calkins, S. D. (2007). Cardiac vagal regulation and early peer status. *Child Development, 78(1),* 264–278.

Grolnick, W. S., Bridges, L. J., & Connell, J. P. (1996). Emotion regulation in two-year-olds: Strategies and emotional expression in four contexts. *Child Development, 67*(3), 928–941.

Hastings, P. D., Sullivan, C., McShane, K. E., Coplan, R. J., Utendale, W. T., & Vyncke, J. D. (2008). Parental socialization, vagal regulation, and preschoolers' anxious difficulties: Direct mothers and moderated fathers. *Child Development, 79*(1), 45–64.

Izard, C. E., Dougherty, L. M., & Hembree, E. A. (1983). A system for identifying affect expressions by holistic judgments (Affex). University of Delaware.

Kagan, J., & Fox, N. A. (2006). Biology, culture, and temperamental biases. In W. Damon & R. M. Lerner (Eds.), *Handbook of child psychology, social, emotional, and personality development* (6th ed., pp. 167–225).

Kagan, J., Snidman, N., Kahn, V., & Towsley, S. (2007). The preservation of two infant temperaments into adolescence. *Monographs of the Society for Research in Child Development, 72*(2), 1–75.

Ladd, G. W. (2006). Peer rejection, aggressive or withdrawn behavior, and psychological maladjustment from ages 5 to 12: An examination of four predictive models. *Child Development, 77,* 822–846.

Lemery, K. S., Goldsmith, H. H., Klinnert, M. D., & Mrazek, D. A. (1999). Developmental models of infant and childhood temperament. *Developmental Psychology, 35,* 189–204.

Levenson, R. W. (2003). Blood, sweat, and fears: The autonomic architecture of emotion. In P. Ekman, J. J. Campos, R. J. Davidson, & F. B. M. de Waal (Eds.), *Emotions inside out* (pp. 348–366). New York: The New York Academy of Sciences.

Levenson, R. W., Ekman, P., & Friesen, W. V. (1990). Voluntary facial action generates emotion-specific autonomic nervous system activity. *Psychophysiology, 27*(4), 363–384.

Levenson, R. W., Ekman, P., Heider, K., & Friesen, W. V. (1992). Emotion and autonomic nervous system activity in the Minangkabau of West Sumatra. *Journal of Personality and Social Psychology, 62*(6), 972–988.

Light, S. N., Coan, J. A., Frye, C., Goldsmith, H. H., & Davidson, R. J. (2009). Dynamic variation in pleasure in children predicts nonlinear change in lateral frontal brain electrical activity. *Developmental Psychology, 45*(2), 525–533.

McEwen, B. S. (2000). The neurobiology of stress: From serendipity to clinical relevance. *Brain Research, 886*(1–2), 172–189.

Marshall, P. J., & Stevenson-Hinde, J. (1998). Behavioral inhibition, heart period, and respiratory sinus arrhythmia in young children. *Developmental Psychobiology, 33,* 283–292.

Matthews, K. A., Salomon, K., Brady, S. S., & Allen, M. T. (2003). Cardiovascular reactivity to stress predicts blood pressure rise in adolescence. *Psychosomatic Medicine, 65,* 410–415.

Mesquita, B., & Albert, D. (2007). The cultural regulation of emotions. In J. J. Gross (Ed.), *Handbook of emotion regulation* (pp. 2486–2503). New York: Guilford Press.

Neumann, S. A., & Waldstein, S. R. (2001). Similar patterns of cardiovascular response during emotional activation as a function of affective valence and arousal and gender. *Journal of Psychosomatic Research, 50,* 245–253.

Pfeifer, M., Goldsmith, H. H., Davidson, R. J., & Rickman, M. (2002). Continuity and change in inhibited and uninhibited children. *Child Development, 73*(5), 1474–1485.

Porges, S. W. (2007). The polyvagal perspective. *Biological Psychology, 74*(2), 116–143.

Quas, J. A., Hong, M., Alkon, A., & Boyce, W. T. (2000). Dissociations between psychobiologic reactivity and emotional expression in children. *Developmental Psychobiology, 37*(3), 153–175.

Quigley, K. S., & Stifter, C. A. (2006). A comparative validation of sympathetic reactivity in children and adults. *Psychophysiology, 43*(4), 357–365.

Rainville, P., Bechara, A., Naqvi, N., & Damasio, A. R. (2006). Basic emotions are associated with distinct patterns of cardiorespiratory activity. *International Journal of Psychophysiology, 61*(1), 5–18.

Roberts, B. W., & DelVecchio, W. F. (2000). The rank-order consistency of personality traits from childhood to old age: A quantitative review of longitudinal studies. *Psychological Bulletin, 126,* 3–25.

Rothbart, M. K. (1981). Measurement of temperament in infancy. *Child Development, 52,* 569–578.

Rothbart, M. K., & Derryberry, D. (1981). Development of individual differences in temperament. *Advances in developmental psychology, 1,* 37–86.

Rothbart, M. K., & Derryberry, D. (1984). Development of individual differences in temperament. In M. E. Lamb & A. L. Brown (Eds.), *Advances in developmental psychology* (Vol. 1, pp. 37–86). Hillside, NJ: Erlbaum.

Salomon, K., Matthews, K. A., & Allen, M. T. (2000). Patterns of sympathetic and parasympathetic reactivity in a sample of children and adolescents. *Psychophysiology, 37*(6), 842–849.

Stifter, C. A., Fox, N. A., & Porges, S. W. (1989). Facial expressivity and vagal tone in 5- and 10-month-old infants. *Infant Behavior & Development, 12*(2), 127–137.

Stifter, C. A., Putnam, S. P., & Jahromi, L. B. (2008). Exuberant and inhibited toddlers: Stability of temperament and risk for problem behavior. *Development and psychopathology, 20,* 401–421.

Talge, N. M., Donzella, B., & Gunnar, M. R. (2008). Fearful temperament and stress reactivity among preschool-aged children. *Infant and Child Development, 17,* 427–445.

Valiente, C., Eisenberg, N., Shepard, S. A., Fabes, R. A., Cumberland, A. J., Losoya, S. H., et al. (2004). The relation of mothers' negative expressivity to children's experience and expression of negative emotion. *Journal of Applied Developmental Psychology, 25*(2), 215–235.

Volling, B. L., McElwain, N. L., & Miller, A. L. (2002). Emotion regulation in context: The jealousy complex between young siblings and its relations with child and family characteristics. *Child development, 73*(2), 581–600.

Appendix: Tables

Table 1.

Raw PEP and RSA Variables

	N	*M*	SD	Sample Max.	Sample Min.	Skew	Kurtosis
PEP Pre baseline	155	95.78	8.59	72.63	117.60	-.32	.044
PEP *Stranger Conversation*	140	95.16	10.13	56.67	122.50	-.76	1.87
PEP *Pop Out Toy*	133	96.77	11.14	66.67	129.00	-.26	.58
RSA Pre baseline	152	6.91	1.04	4.31	9.44	-.21	-.32
RSA *Stranger Conversation*	140	6.45	1.11	3.68	9.28	-.08	.32
RSA *Pop-Out Toy*	142	6.79	.05	4.24	9.53	-.48	.40

Table 2.

Raw Means and Standard Deviations for Stranger Conversation and Pop-Out Toy Variables

	N	*M*	SD	Sample Min.	Sample Max.	Possible Min.	Possible Max.	Mode	Skew	Kurtosis
SC: Latency to Show Fear (Rev) (seconds)	144	44.24	65.68	0.00	372.00	0	444	0	2.08	5.50
SC: Avg. Avoidance	151	0.14	0.30	0.00	2.00	0	3	0	3.27	13.25
SC: Avg. Bodily Fear	149	0.29	0.57	0.00	2.54	0	3	0	2.37	4.79
SC: Avg. Nervous Fidgeting	144	0.53	0.39	0.00	1.00	0	1	1	-0.18	-1.58
SC: # Stranger Prompts	151	1.42	0.67	0.00	4.00	0	n/a	1	0.92	1.12
SC: Prop. Child Talking	151	0.10	0.10	0.01	0.57	0	1	.08	2.57	8.03
SC: Verbal Disfluencies	150	0.71	0.48	0.00	2.50	0	n/a	1	0.49	0.51
POT: Baseline State	163	1.20	0.57	1.00	4.00	1.00	5.00	1	2.86	7.38
POT: Startled	159	1.07	0.47	0.00	2.00	0.00	2.00	1	0.24	1.55
POT: Avg. Duration of Smiling	161	18.94	9.73	3.33	30.00	0.00	90.00	30	-0.08	-1.66
POT: Avg. Intensity of Smiling	163	2.50	0.54	0.67	3.00	0.00	3.00	3	-1.23	1.29
POT: Avg. Enthusiasm	163	2.16	0.50	1.00	3.00	0.00	3.00	2	-0.27	-0.01
POT: Avg. Laughter	162	0.51	0.36	0.00	1.00	0.00	1.00	0.33	0.04	-1.26
POT: Avg. Positive Vocalizations	161	0.35	0.47	0.00	2.50	0.00	3.00	0	1.30	1.68
POT: Post-game Positivity	163	2.10	0.77	0.00	3.00	0.00	3.00	2	-0.59	-0.02

SC = Stranger Conversation, *POT* = Pop-Out Toy

Table 3.

Bivariate Correlations among Stranger Conversation Variables

	Latency to Show Fear (reversed)	Avg. Avoidance	Avg. Bodily Fear	Avg. Nervous Fidgeting	# Stranger Prompts	Prop. Child Talking
Avg. Avoidance	**.41**					
Avg. Bodily Fear	**.38**	**.22**				
Avg. Nervous Fidgeting	**.21**	**.23**	.11			
# Stranger Prompts	**.29**	**.19**	-.02	.07		
Prop. Child Talking	**.19**	.12	-.09	**.19**	-.08	
Verbal Disfluencies	.02	.05	-.08	.01	-.11	**.33**

*Bolded values = *p* < .05.

Table 4.

Bivariate Correlations among Pop-Out Toy Variables

	Baseline State	Startled	Avg. Duration Smiling	Avg. Intensity Smiling	Avg. Enthusiasm	Avg. Laughter	Avg. Positive Voc
Startled	-0.03						
Avg. Duration Smiling	-0.08	0.07					
Avg. Intensity Smiling	0.00	0.13	**0.40**				
Avg. Enthusiasm	0.06	-0.02	0.02	0.10			
Avg. Laughter	0.03	0.14	**0.21**	**0.61**	**0.26**		
Avg. Positive Vocalizations	0.00	0.15	0.07	**0.27**	**0.20**	**0.30**	
Post-game Positivity	-0.05	0.13	**0.25**	**0.45**	**0.38**	**0.51**	**0.20**

*Bolded values = *p* < .05.

Table 5.

Means and Standard Deviations for Key Variables.

	N	Sample Max.	Sample Min.	Mean	*SD*	Skew	Kurtosis
Child Sex	164	0.00	1.00	0.48	0.50	0.10	-2.02
Child Age	164	6.00	10.00	7.91	0.97	-0.11	-0.26
Stranger Conversation PEP Change (*ms*)	138	-27.29	18.75	-0.05	0.59	-1.02	5.93
Stranger Conversation RSA Change (ln ms^2)	140	-2.32	1.37	-0.45	0.63	-0.33	0.44
Stranger Conversation Fear Composite (standardized score)	151	-0.73	1.48	-0.02	0.56	0.76	0.04
Pop-Out Toy PEP change (ms)	128	-12.50	22.50	0.32	6.44	0.67	0.84
Pop-Out Toy RSA change (ln ms^2)	141	-1.94	1.46	-0.09	0.63	-0.31	0.33
Pop-Out Toy Positive Affect Composite (standardized score)	163	-1.56	1.36	0.00	0.63	-0.13	-0.52

Table 6.

Correlations among Key Variables

	Child's Sex	Age	SC PEP Δ	SC RSA Δ	SC ANS Profiles	SC Fear	POT PEP Δ	POT RSA Δ	POT ANS Profile	POT Pleasure
Child's Age	-.08									
SC PEPΔ	-.06	.05								
SCRSA Δ	.02	.03	**.18**							
SC ANS Profile	-0.08	0.08	**0.65**	**0.47**						
SC Fear	.02	-.12	-.10	.02	0.05					
POT PEP Δ	.03	-.03	**.41**	.08	**0.22**	-.20				
POT RSA Δ	-.01	-.02	**.28**	**.45**	**0.32**	.04	**.22**			
POT ANS Profile	.05	-.02	0.35	0.2	0.31	-.03	**0.79**	**0.48**		
POT Pleasure	**.23**	**-.18**	-.14	-.14	**-0.28**	**.17**	.20	-.20		
POT Startle	-.16	.02	-.15	.02	.14	.14	.10	-.02	-.07	**.16**

* Bolded values = $p < .05$.

SC = Stranger Conversation, *POT* = Pop-Out Toy, *ANS Profiles* = Autonomic Nervous System Profiles of cardiovascular change.

Table 7.

Percentage of Children Showing Each Type of Autonomic Profile in the Stranger Conversation and in the Pop-Out Toy tasks.

	Coinhibition (Decreased RSA, Slower PEP)	Reciprocal PNS Activation (Increased RSA, Slower PEP)	Reciprocal SNS Activation (Decreased RSA, Faster PEP)	Coactivation (Increased RSA, Faster PEP)
Stranger Conversation	47.2% (*n* = 50)	9.4% (*n* = 10)	31.1% (*n* = 33)	12.2% (*n* = 13)
Pop-Out Toy	33.3% (*n* = 33)	21.2% (*n* = 21)	19.2% (*n* = 19)	26.3% (*n* = 26)