

BOSTON UNIVERSITY
GRADUATE SCHOOL OF ARTS AND SCIENCES

Dissertation

**PARASYMPATHETIC REACTIVITY AND DISRUPTIVE BEHAVIOR
PROBLEMS IN YOUNG CHILDREN DURING INTERACTIONS WITH
MOTHERS AND OTHER ADULTS**

by

CHRISTINE ELIZABETH COOPER-VINCE

B.A., Connecticut College, 2007
M.A., Boston University, 2010

Submitted in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

2015

ProQuest Number: 3734019

All rights reserved

INFORMATION TO ALL USERS

The quality of this reproduction is dependent upon the quality of the copy submitted.

In the unlikely event that the author did not send a complete manuscript and there are missing pages, these will be noted. Also, if material had to be removed, a note will indicate the deletion.



ProQuest 3734019

Published by ProQuest LLC (2015). Copyright of the Dissertation is held by the Author.

All rights reserved.

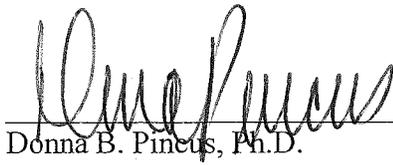
This work is protected against unauthorized copying under Title 17, United States Code
Microform Edition © ProQuest LLC.

ProQuest LLC.
789 East Eisenhower Parkway
P.O. Box 1346
Ann Arbor, MI 48106 - 1346

© Copyright by
CHRISTINE ELIZABETH COOPER-VINCE
2015

Approved by

First Reader



Donna B. Pincus, Ph.D.

Associate Professor of Psychological and Brain Sciences

Second Reader



Jonathan S. Comer, Ph.D.

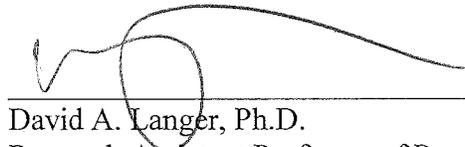
Associate Professor of Psychology and Psychiatry

Florida International University, School of Integrated Science and
Humanity

Adjunct Associate Professor of Psychological and Brain Sciences

Boston University, College of Arts and Sciences

Third Reader



David A. Langer, Ph.D.

Research Assistant Professor of Psychological and Brain Sciences

DEDICATION

To my parents, thank you for teaching me to think critically and investigate passionately.

ACKNOWLEDGEMENTS

First and foremost I would like to thank my mentors, Dr. Jonathan Comer and Dr. Donna Pincus, for their unparalleled mentorship over the past six years. The countless hours of lab meetings, paper revisions, and lab family dinners have shaped me into the clinical researcher that I am today. Thank you both for helping me build a strong foundation in clinical science and encouraging me to pursue clinically and personally meaningful questions through my work. I would also like to thank you for your creativity, enthusiasm and friendship, all of which have been invaluable aspects of my graduate experience.

I would also like to thank Dr. Kate McLaughlin for sharing her expertise in psychophysiological assessment methods, and Dr. David Langer for his valuable guidance on this project. I would also like to express my gratitude to Dr. Erica Musser for the training and support she provided in psychophysiological assessment procedures, and to Dr. Jami Furr for the countless hours of clinical supervision on the assessment treatment of early childhood disruptive behavior disorders that has been central to shaping my research questions.

The project would not have been possible without the devoted support of the Florida International University Mental Health Interventions and Technology Program. I would like to specially recognize the exceptional efforts of Mariah DeSerisy, Alejandra Golik, Elizabeth Miguel, Danielle Cornacchio, and Amanda Sanchez. I could not have

asked for a harder working and more fun research team with whom to spend my nights and weekends in the lab!

I would also like to acknowledge the Boston University Clara Mayo Memorial Fellowship for providing the funding to make this project possible, and thank all of the families who donated their time to participate in this research.

I am also grateful to my lab mates, Aubrey Carpenter, Tommy Chou, Danielle Cornacchio, Kathleen Crum, Meredith Elkins, and Caroline Kerns, for their phenomenal support as collaborators and friends over the years. Additionally, I would like to thank my classmates Teresa Au and Ben Emmert-Aronson for their friendship and support.

Last, but not least, I would like to thank my family for their love, support, and encouragement of my academic development since my earliest memory. I am especially grateful to my husband Raphael for his tremendous support and gourmet home-cooked meals that have fueled me on many levels to make this all possible.

**PARASYMPATHETIC REACTIVITY AND DISRUPTIVE BEHAVIOR
PROBLEMS IN YOUNG CHILDREN DURING INTERACTIONS WITH
MOTHERS AND OTHER ADULTS**

(Order No.)

CHRISTINE COOPER-VINCE

Boston University Graduate School of Arts and Sciences, 2015

Major Professor: Donna B. Pincus, Ph.D., Associate Professor of Psychological and
Brain Sciences

ABSTRACT

Disruptive behavior problems are among the most commonly occurring forms of childhood psychopathology and show considerable stability beginning in early childhood. Investigations of the biological underpinnings of behavior problems have revealed that the influences of the parasympathetic branch of the autonomic nervous system on cardiac functions are central to self-regulation. Parasympathetic regulation of heart rate is indexed via respiratory sinus arrhythmia (RSA). Suppression of RSA during challenging emotional and cognitive tasks is associated with better emotional and behavioral functioning in preschoolers. However, the relationship between RSA suppression and preschool social functioning is still unclear. Further, direct relationships between behavior problems and RSA reactivity within command-based play tasks (i.e., child instructed to build 3 towers) with parents and other adults have yet to be examined. The present study experimentally evaluated the relationship between child RSA reactivity and adult (mother vs. staff) commands requiring child compliance during command-based

play tasks in children ages 3-8 with and without disruptive behavior disorders (N=43). Child RSA suppression in response to commands was examined as a predictor of child command compliance during experimental play tasks and of general child behavior problems, and was compared across command-based interactions with mothers versus staff. Less RSA suppression in the context of mothers' play-based commands was associated with more severe behavioral problems ($p=.046$). In the context of staff play-based commands, more RSA suppression was associated with more severe behavior problems ($p=.009$), an effect that was significant only among boys ($p<.000$). Further, greater child RSA suppression predicted greater compliance with mother-given commands ($p=.017$), but was unrelated to compliance with staff-given commands. The relationship between child RSA suppression and compliance with mother-given commands was moderated by child age, such that the effect of RSA suppression on child compliance was stronger for younger children than older children. Findings suggest that RSA reactivity to social demands, and the functional association between RSA suppression and behavioral compliance, vary by social context (i.e., mother vs. other adult command-givers) and identify child factors (i.e., age, gender) that influence these associations. This work may inform efforts to identify a biomarker of early childhood behavior problems.

TABLE OF CONTENTS

Introduction.....	1
Disruptive Behavior Disorders	1
Autonomic Nervous System	2
Resting RSA and Self-Regulation	4
RSA Reactivity and Self-Regulation	6
RSA Reactivity and Parenting Interventions	13
Hypotheses	16
Method	17
Participants.....	17
Procedures.....	17
Measures	19
Physiological Measures Derived.....	23
Data Analysis	24
Results.....	25
Preliminary Analyses	25
Manipulation Check.....	26
Parasympathetic Influences and Diagnostic Status.....	27
Parasympathetic Influences and Child Behavior Problems	27
Examining the Moderating Roles of Child Age and Sex.....	28
Discussion.....	29

Tables.....	40
Figures.....	50
Bibliography	53
Curriculum Vitae	72

LIST OF TABLES

Table 1.	Demographic characteristics of sample.....	40
Table 2.	Study assessment procedures.....	41
Table 3.	Descriptive statistics for respiratory sinus arrhythmia (RSA) and child behavior problems.....	43
Table 4.	Command frequency across play conditions.....	44
Table 5.	Respiratory sinus arrhythmia (RSA) across diagnostic groups.....	45
Table 6.	Associations across study variables.....	46
Table 7.	Details of tests of child age and sex as moderators of associations between parasympathetic reactivity and mother-rated child behavior problems....	47
Table 8.	Details of tests of child age and sex as moderators of associations between parasympathetic reactivity and clinician-rated child behavior problem severity.....	48
Table 9.	Details of tests of child age and sex as moderators of associations between parasympathetic reactivity and in-task child compliance.....	49

LIST OF FIGURES

- Figure 1.** ECG and ICG electrode configuration.....50
- Figure 2.** Child behavior problems as a function of RSA suppression during staff ADI and child sex, controlling for RSA during staff CDI.....51
- Figure 3.** Child compliance as a function of RSA suppression during mother ADI and child age, controlling for RSA during mother CDI.....52

LIST OF ABBREVIATIONS

ADI	Adult-Directed Interaction
ANS	Autonomic Nervous System
CD	Conduct Disorder
CDI	Child-Directed Interaction
CGI-S	Clinical Global Impressions-Severity
DBD	Disruptive Behavior Disorder
DISC	Diagnostic Interview Schedule for Children
DPICS	Dyadic Parent-Child Interaction Coding System
ECG	Electrocardiogram
ECBI	Eyberg Child Behavior Inventory
ICG	Impedance Cardiography
KDBDS	Kiddie-Disruptive Behavior Disorder Interview Schedule
ODD	Oppositional Defiant Disorder
PCIT	Parent-Child Interaction Therapy
PNS	Parasympathetic Nervous System
RSA	Respiratory Sinus Arrhythmia
SNS	Sympathetic Nervous System

Introduction

Disruptive Behavior Disorders

Disruptive behavior disorders (DBD) are among the most commonly occurring disorders in childhood, affecting approximately 1 in 5 children by adolescence (Costello, Mustillo, Erkanli, Keeler, & Angold, 2003; Merikangas et al., 2010). DBDs include diagnoses of Oppositional Defiant Disorder (ODD) and Conduct Disorder (CD) which are characterized by difficulties with emotional and behavioral self-control resulting in oppositional and rule-breaking behavior (APA, 2013). Disruptive behavior disorders can be reliably assessed as early as 3 years of age and affect up to 7% of preschool children (Egger & Angold, 2006; Ezpeleta, Granero, de la Osa, Penelo, & Domenech, 2012). Although commonly found to occur more often in boys (See Loeber, Burke, Lahey, Winters, & Zera, 2000 for a review), evidence has emerged suggesting more even distribution of disruptive behavior problems between males and females across the lifespan (Nock, Kazdin, Hiripi, & Kessler, 2007; Rowe, Maughan, Pickles, Costello, & Angold, 2002).

Early-onset problems of oppositionality and non-compliance show considerable stability and do not simply constitute normative transient behavioral difficulties (Briggs-Gowan, Carter, Bosson-Heenan, Guyer, & Horwitz, 2006; Keenan, Shaw, Delliquadri, Guivannelli, & Walsh 1998; Keenan et al., 2011; Lavigne, Arend, Rosenbaum, Binns, Christoffel, & Gibbons, 1998; Shaw, Gilliom, Ingoldsby, & Nagin, 2003; Tremblay et al., 2004). Further, childhood DBDs confer significant risk for depressive, anxiety, and substance abuse disorders, and often precede the onset of mood and substance use

disorders (Boylan, Georgiades, & Szatmari, 2010; Boylan, Vaillancourt, Boyle, & Szatmari, 2007; Nock et al., 2007). Children affected by DBDs experience impairment in academic, social and family functioning, and are at higher risk for later life criminality (Copeland, Miller-Johnson, Keeler, Angold, & Costello, 2007; Ezpeleta, Keeler, Erkanli, Costello, & Angold, 2001; Gau et al., 2007; Kim-Cohen et al., 2003; Lahey, Loeber, Burke, & Applegate, 2005). Given the significant prevalence, stability, and impairment associated with these disorders, early identification and intervention to mitigate the deleterious course of these problems are essential.

Early childhood temperamental traits have been identified that are associated with later diagnosis of a DBD. Temperamental traits—including negative emotionality, intense and reactive responding, low persistence, and inflexibility—have been associated with later development of DBDs (Kim et al., 2010; Paterson & Sanson, 1999; Stringaris, Maughan, & Goodman, 2010). Evidence suggests that autonomic nervous system (ANS) functioning may underlie such early temperamental difficulties and interact with other environmental risks, such as parenting environment, to further contribute to the development of DBDs early in childhood (Blandon, Calkins, Keane, & O'Brien, 2010; Morales, Beekman, Blandon, Stifter, & Buss, 2015). Before considering how ANS functioning may meaningfully relate to child behavior problems, it is first critical to more fully consider basic ANS functioning and its component systems.

Autonomic Nervous System

The ANS is comprised of the sympathetic (SNS) and parasympathetic nervous systems (PNS), which regulate an individual's response to internal and external

environmental changes and demands. Broadly speaking, the SNS allocates the body's metabolic energy to respond to challenges and threats (i.e., “fight or flight” response), whereas the PNS redistributes metabolic energy towards restoration and maintenance of homeostasis after threat has passed. The ANS exerts these regulatory functions upon multiple organ systems, including the heart. Cardiac activity is regulated by the dynamic interplay of the SNS and PNS. Both parasympathetic motor neurons of the X cranial nerve (i.e., the vagal nerve) and sympathetic motor neurons act on the sinoatrial node of the heart—the heart's “pacemaker” (Berntson, Cacioppo, & Quigley, 1993). Acceleration of heart rate is achieved by the excitatory impulse of the SNS, while deceleration in heart rate and return to homeostasis is achieved through PNS inhibition of sympathetic activation. Importantly, these influences do not always act opposite one another, and have been found to covary reciprocally, independently, and nonreciprocally (Berntson, Cacioppo, & Quigley, 1991).

As both sympathetic and parasympathetic influences contribute to changes in heart rate, examination of overall heart rate variability does not provide insight into the unique regulatory contributions of sympathetic and parasympathetic influences. The unique contributions of the PNS and SNS can be better understood by examining changes in heart rate associated with respiration. During the breath cycle, the influences of the PNS and SNS vary as a function of respiration phase. During inspiration, the vagal nerve is inhibited and sympathetic cardiomotor neurons are activated, leading to increases in heart rate. During expiration the vagal nerve is activated, restoring the inhibitory effect of the vagal nerve and decreasing heart rate. Importantly, the parasympathetic influences on

heart rate occur quickly (i.e., 500 milliseconds) and decay rapidly (i.e., 1 second). Sympathetic effects occur more slowly (i.e., 1,200-2,000 milliseconds) and are longer lasting (i.e., 15 seconds). Due to the slower and more prolonged impact of sympathetic cardiac influences, high frequency changes in heart rate within a respiration cycle (i.e., modulations >0.12 Hz) are attributed primarily to parasympathetic control via the vagal nerve. Thus, high frequency (>0.12 Hz) rhythmic variation in heart rate that occurs within a respiration cycle is termed Respiratory Sinus Arrhythmia (RSA). RSA is considered to be a non-invasive index of parasympathetic cardiac influence (Appelhans & Luecken, 2006; Berntson et al., 1993; Berntson et al., 1997).

There is currently no gold standard methodology for assessing RSA. However, frequency-based methods, including spectral analysis, are widely used to calculate RSA (Allen, Chambers, & Towers, 2006; Mendes, 2013). Through spectral analysis, the total variance of an electrocardiogram (ECG) data series is broken down into its frequency components, and then expressed as a spectral density function—i.e., spectral power as a function of frequency (Berntson et al., 1997). Such a process allows for the evaluation of data within the specified high frequency band. Autoregressive techniques and the fast Fourier transformation are both widely used approaches to spectral analysis, which yield similar results (Allen et al., 2007).

Resting RSA and Self-Regulation

Organisms at rest conserve energy through slowing heart rate via parasympathetic inhibition. Therefore, organisms with strong parasympathetic cardiac control in a resting state (i.e., high resting RSA) are thought to have greater reserve energy. This reserve can

then be drawn upon when transitioning to an activated state to most flexibly respond to demands (Beauchaine, 2001; Grossman & Taylor, 2007; Thayer & Lane, 2000). As resting RSA has been conceptualized as an index of coping resources, resting RSA has been investigated as a biomarker of youth psychopathology.

The current literature, however, yields mixed findings regarding resting RSA as a biomarker of youth externalizing psychopathology. Lower resting RSA has been linked to the presence of externalizing and aggressive behaviors (Beauchaine, 2001; Calkins & Keane, 2004; Musser, Galloway-Long, Frick, & Nigg, 2013), but other work does not find such a relationship (Crowell, et al., 2006; Hinnant & El-Sheikh, 2009). Given varied results regarding resting RSA and child behavior problems, low resting RSA may be most usefully conceptualized as a vulnerability factor that can enhance the impact of stressors and psychosocial influences, such as parenting (Hastings & De, 2008; Hinnant, Erath, & El-Sheikh, 2015; McLaughlin, Alves, & Sheridan, 2014). Beginning in preschool, the emotional adjustment of children with low resting RSA is more highly influenced by their parents' socialization behaviors, with higher resting RSA even buffering against the effects of parental psychopathology (Bandon et al., 2008; Hastings & De, 2008). Later in childhood, low resting RSA has been shown to contribute to the development of delinquent behavior under the influences of harsh parenting (Hinnant et al., 2015). Given the higher rates of harsh and inconsistent parenting observed in parents of children with disruptive behavior problems (Harvey, Metcalfe, Herbert, & Fanton, 2011; Piffner, McBurnett, Rathouz, & Judice, 2005; Rowe et al., 2002), the identification of underlying biological vulnerabilities that enhance the influence of

parenting practices—positive or negative—has important clinical implications for early intervention with at-risk youth.

RSA Reactivity and Self-Regulation

RSA reactivity to challenge has been identified as a marker of self-regulation processes (Beauchaine, 2001; Porges, 2007; Thayer & Lane, 2000). Prominent theoretical perspectives conceptualize the suppression of RSA in response to challenges or threats as the allocation of metabolic resources away from maintenance of internal homeostasis and towards mobilization of resources for active coping to meet environmental demands (Porges, 2007; Grossman & Taylor, 2007; Thayer & Lane, 2000). In the instance of RSA suppression, the inhibitory influence of the vagal nerve is decreased, allowing for more activation from SNS influences.

Lower RSA suppression in response to a variety of stressor tasks has been linked to poor self-regulation in childhood and adolescence, as well as the broad presence of externalizing psychopathology (Blair, 2003; Boyce et al., 2001; Calkins, 1997; Calkins & Keane, 2004; Calkins, Smith, Gill, & Johnson, 1998; El-Sheikh, Harger, and Whitson, 2001; Gentzler, Santucci, Kovacs, & Fox, 2009). However, such patterns are not consistently found when characterizing behavior problems by diagnostic status or when investigating these patterns within clinical samples of preschoolers (Beauchaine et al., 2013; Crowell et al., 2006). Overall, recent meta-analytic findings do indicate that greater RSA suppression is linked with lower levels of externalizing problems, although the main effect of this relationship is small (Graziano & Derefinko, 2013). Importantly, the relationship between RSA reactivity and externalizing psychopathology can be

influenced by variations in assessment procedures including type of challenge task, social context of assessment, and the child's broader social environment.

The role of task type. RSA reactivity in early childhood has been assessed as change in RSA from resting baseline to engagement in a challenging task, including emotional, physical, and cognitive challenges (Blair, 2003; Boyce et al., 2001; Calkins, 1997; Calkins & Keane, 2004; Calkins et al., 1998; El-Sheikh et al., 2001; Gentzler et al., 2009). Emotionally challenging tasks are assessed with the induction of emotional states via audio and/or video clips (Calkins & Keane, 2004; Gatzke-Kopp, Greenberg, & Bierman, 2015), as well as the elicitation of frustration by delaying or eliminating access to a pleasurable toy or food (e.g., Calkins & Keane, 2004; Calkins et al., 1998). Cognitive challenges are typically presented in tasks requiring sustained attention (e.g., sorting of beads by color) or inhibitory control (Calkins & Keane, 2004; Utendale et al., 2014). Challenging play tasks have also been utilized (e.g., block-building, puzzle solving, origami folding, and toy cleanup), and present cognitive and emotional challenges within an interpersonal interaction (Beauchaine et al., 2013; Calkins & Keane, 2004; Graziano, Bagner, Sheinkopf, Vohr, & Lester, 2012).

During frustration-inducing and cognitively demanding tasks, greater RSA suppression among young children has often been linked to better child compliance, fewer behavior problems, and active engagement in emotion regulation strategies (Calkins, 1997; Calkins & Dedmon, 2000; Calkins, Graziano, & Keane, 2007; Calkins & Keane, 2004; Calkins et al., 1998; Perry, Calkins, Nelson, Leerkes, & Marcovitch, 2012). Meta-analytic findings also indicate that the extent of suppression elicited varies by type

of task, with frustrating and negative mood inducing tasks eliciting greater suppression than cognitively demanding tasks (Graziano & Derefinko, 2013). However, it is important to note that greater, and potentially excessive, suppression of RSA in response to anger induction and inhibitory control tasks has been linked to more severe externalizing psychopathology and diminished inhibitory control in samples including clinical and at-risk youth (Beauchaine et al., 2013; Gatzke-Kopp et al., 2015; Utendale et al., 2014).

These findings provide important insight into patterns of autonomic self-regulation associated with discrete stressors that predict adaptive outcomes in early childhood. However, the majority of these tasks offer limited ecological validity relative to the settings in which disruptive behavior problems typically occur (i.e., interpersonal interactions with parents and peers). Evaluations of RSA reactivity that have utilized dyadic play-based tasks (i.e., block building, puzzle building and cleanup) yield somewhat conflicting findings. In this work both greater RSA suppression and less RSA suppression have been linked to behavioral and social problems (Beauchaine et al., 2013; Calkins & Keane, 2004; Calkins et al., 2008; Graziano et al., 2012). As such, it remains unclear what signature of RSA reactivity is indicative of adaptive interpersonal behavioral functioning in young children. Further, the relationship between RSA suppression during a most ecologically valid task specifically requiring child compliance with adult commands has yet to be evaluated in regard to the child's behavioral compliance during the task, limiting our understanding of the function of RSA suppression during challenging interpersonal interactions and its influence on subsequent

child behavior. Further, inconsistencies in the relationship between RSA reactivity and behavioral outcomes across tasks requiring varied levels of interpersonal interaction point to the importance of considering interpersonal context when evaluating functional relationships between RSA reactivity and child behavior.

The role of social context. Theoretical underpinnings of the influence of RSA on social functioning are grounded in Polyvagal Theory (Porges, 2007). This theory posits that regulation of vagal output and behaviors necessary for social engagement are linked via the social engagement system. Porges asserts that the social engagement system is comprised of several cranial nerves connected to the myelinated vagus nerve (i.e., cranial nerve X) that regulate the muscle movements of the face and head, and control social functions including eye contact and listening. Within this system, maintenance or increase of the vagal inhibition on heart rate—which results in maintained or slowed heart rate—is necessary to support social engagement behaviors such as eye contact and smiling (Porges, 2007). Therefore, successful engagement in social tasks should theoretically be promoted by the maintenance of or increases in RSA from a resting baseline.

When assessing RSA reactivity in young children, most tasks are delivered in an interpersonal context to provide developmentally appropriate supervision. Greater child RSA suppression has been linked to fewer behavior problems during challenging tasks, completed with assessors as well as parents (Blair, 2003; Calkins et al., 1997; Calkins, Graziano, & Keane, 2007; Graziano, Keane, & Calkins, 2007). However, effects in the opposite direction have also been observed (Beauchaine et al., 2013; Utendale et al.,

2014). When child RSA is compared across tasks with different types of adults, it is found that children tend to engage in greater RSA suppression when completing a task with their mother versus with an assessor or independently (Calkins & Keane, 2004; Calkins Graziano, Berdan, Keane, & Degnan, 2008). This finding holds true among higher stress parent-child dyads but not among maltreating dyads, suggesting that the presence of a parent may not facilitate autonomic self-regulation in the most severely dysfunctional families (Calkins et al., 2008; Skowron, Cipriano-Essel, Gatzke-Kopp, Teti, & Ammerman, 2014). These findings have important implications for children with disruptive behavior problems. As these children are more likely to experience inconsistent and harsh parenting, their potential to autonomically benefit from parental presence when responding to a challenge could be impacted, and in turn differentially influence the expression of behavior problems in parent-child interactions relative to interactions with other adults (Harvey et al., 2011; Piffner et al., 2005; Rowe et al., 2002).

Evidence also suggests that children who engage in RSA suppression in the presence of an assessor not only utilize emotion regulation strategies (e.g., distracting one's self and orienting towards the assessor to cope with a frustrating stimuli), but are also better able to utilize social support provided by the assessor (Calkins, 1997; Perry et al., 2012; Wolff, Wadsworth, Wilhelm, & Mauss, 2012). These findings suggest that RSA suppression in the presence of a non-parental adult is associated with better behavioral functioning as well as use of socially based coping. However, it should be noted that the assessment methods used in these studies employed a range of various

tasks, including cognitive, frustration, interpersonal, and physical challenges.

Importantly, an opposite pattern emerges when RSA reactivity is examined in more ecologically valid social interaction paradigms and in regard to the child's social functioning. During play activities with parents and peers, less suppression of RSA has been linked to fewer externalizing behavior problems (Beauchaine et al., 2013; Hastings, Nuselovici et al., 2008). Similarly, lower RSA suppression is linked to elicitation of empathy and better social competence in clinical and at-risk children (Blair & Peters, 2003; Calkins & Keane, 2004; Graziano & Derefinko, 2013).

Though these findings support Polyvagal Theory's proposed need for maintained RSA to promote social awareness and engagement, they are at odds with work linking limited RSA suppression to externalizing behavior problems, which typically occur within interpersonal contexts. Additionally, in community samples, *more* RSA suppression is linked to better social skills and social status (Graziano et al., 2007; Graziano & Derefinko, 2013). These findings highlight the complexities of RSA reactivity in response to environmental challenges that occur within a social context. Though greater RSA suppression in many cases is associated with better behavioral regulation, social engagement during a child's everyday activities (e.g., play) may be best supported via maintenance of RSA. Consequently, it remains unclear what pattern of autonomic self-regulation in response to social interaction challenges is most adaptive. Optimal autonomic regulation may vary across interpersonal tasks characterized by play versus interpersonal tasks requiring behavioral compliance from the child.

Importantly, RSA reactivity has yet to be experimentally evaluated across

interpersonal contexts (e.g., parent versus other adult) within an ecologically valid paradigm. Therefore, it has not been possible to determine whether variability in the direction and magnitude to the relationship between RSA reactivity and behavior problems are a result of varying task demands or social context.

Taken together, these findings suggest that RSA suppression serves as a biological marker for behavioral self-regulation in response to environmental challenge. However, several important questions central to understanding the self-regulatory challenges of behavior problems in young children remain. First, the majority of assessment tasks used are lab-bound procedures lacking a social emphasis and administered by an evaluator. Consequently, they have limited ecological validity with regard to the contexts in which a large proportion of behavioral problems occur (i.e., following commands from parents or teachers). Second, the few evaluations that utilized more ecologically valid assessment procedures (e.g., toy cleanup and peer play; Calkins et al., 1998; Hastings, Nuselovici et al, 2008), have not evaluated child compliance with commands, preventing a direct examination of links between parasympathetic self-regulation and actual child compliance, a core feature of disruptive behavior disorder pathology (Keenan & Wakschlag, 2004).

Further, RSA suppression has consistently been measured from a resting baseline to task, confounding suppression scores with the effects of attentional deployment and increased motor demands of engaging in the social experimental task (Bush, Alkon, Obradovic, Stamperdahl, & Boyce, 2011). Therefore, the extent of RSA change uniquely associated with the stimuli in question—relative to co-occurring attentional and motor

demands—is obscured. When seeking to clarify the autonomic underpinnings of early childhood oppositionality and non-compliance, it is essential to specifically evaluate parasympathetic responses to adult commands to better understand how noncompliant children experience commands and the factors that drive their responses to commands. To most accurately assess these processes, commands must be delivered in ecologically valid paradigms (e.g., interactive play-task) that also control for the attentional and motor demands of the task.

Lastly, as no studies to date have systematically varied the social context of an assessment task, it remains unknown whether the function of RSA reactivity (suppression or maintenance) varies based on the adult with which children are interacting. To inform the autonomic underpinnings of behavior problems across contexts (with parents, teachers, and childcare providers) experimental manipulation of adult-type across a single interpersonal task is needed. Specifically, research is needed to assess RSA reactivity to adult-given commands, in which the effect of the adult command-giver can be isolated and evaluated in relation to child behavioral compliance to clarify factors driving behavioral inconsistencies across settings in behavior-disordered youth.

RSA Reactivity and Parenting Interventions

Autonomic self-regulation in young children is also influenced by the characteristics of the child’s social context, including parenting environment. In early childhood, children receiving non-supportive parenting experience delays in development of RSA suppression abilities and are more vulnerable to the effects of non-supportive parenting when they are only capable of engaging in low levels of RSA suppression

(Perry et al., 2012; Perry et al., 2013). Longitudinal investigations also reveal reciprocal relationships between parenting environment and RSA reactivity. Early hostile and high stress parent-child relationships predict decreases in children's RSA suppression across childhood (Calkins et al., 2008; Hinnant et al., 2015). These findings suggest that lower RSA suppression can increase child vulnerability to the influences of negative parenting, and parenting environment can in turn impact the child's parasympathetic regulatory capabilities.

Given the role of RSA suppression in emotional and behavioral regulation in early childhood and the developmental influences of parenting environment, parasympathetic regulation may also play an important role in outcomes of interventions designed to address child behavioral problems through the modification of parent behavior.

Behavioral parent training programs have shown considerable efficacy in the treatment of child behavior problems (Comer, Chow, Chan, Cooper-Vince, & Wilson, 2013), and one such well-supported treatment protocol is Parent-Child Interaction Therapy (PCIT).

PCIT is an evidenced-based treatment for disruptive behavior problems in preschool aged children that aims to modify child behavior through coaching parents in the use of positive attending and effective parenting skills in order to reinforce appropriate child behavior and apply consistent discipline strategies for noncompliance (Eyberg et al., 2001; Hood & Eyberg, 2003; Schuhmann, Foote, Eyberg, Boggs, & Algina, 1998).

Although originally developed for use with preschool children with oppositional behavior, PCIT has been successfully adapted for use with a variety of new populations including premature children with behavioral problems (Bagner, Sheinkopf, Vohr, &

Lester, 2010).

In the treatment of preschool behavioral problems, a small body of recent work has yielded inconsistent findings regarding the utility of resting RSA and RSA reactivity as predictors of treatment outcome (Bagner et al., 2012; Beauchaine et al., 2013; Graziano et al., 2012). Among prematurely born children with behavior problems, lower resting RSA at baseline predicted a longer length of treatment that resulted in greater reductions in child behavior problems (Bagner et al., 2012). In this trial, child RSA suppression increases across treatment were associated with mother's use of positive attention, suggesting that physiological processes underlying child behavioral dysregulation are sensitive to behavioral intervention (Graziano et al., 2012). However, in a behavioral parent training intervention (Incredible Years) targeting preschool ADHD, child resting RSA and RSA reactivity did not predict behavioral outcomes despite improvements in behavior and emotion regulation (Beuachaine et al., 2013).

Though this work provides important insight into the roles of child RSA and parenting in the development of externalizing psychopathology, it remains unclear how child behavior problems relate to RSA reactivity in the specific context of command-based interactions with adults. Indeed, child oppositionality and non-compliance following adult-given commands are central features of child disruptive behavior problems. Understanding children's parasympathetic self-regulatory processes in the specific context of adult-given commands and expectations of compliance, and linking those processes with observed child compliance, is critical for elucidating biological mechanisms that may underlie early disruptive behavior problems to enhance targeting of

treatment methods. Moreover, given that patterns of oppositionality and noncompliance among youth with behavior problems vary considerably across settings (i.e., school vs. home), research examining the influence of interpersonal context on child autonomic self-regulation and behavioral compliance will clarify biological underpinnings of behavioral inconsistencies across settings and inform intervention design to enhance generalization of treatment effects across settings. The present study is an experimental evaluation examining associations between child parasympathetic self-regulation (resting RSA and RSA reactivity), child behavior problems, and patterns of child behavioral non-compliance in the context of command-based interactions with children's mothers and with non-parental adults.

Hypotheses

1. Children with disruptive behavior problems will demonstrate lower resting RSA. Disruptive behavior problems will be measured in two ways: dichotomously via diagnostic status and continuously.
2. Children with disruptive behavior problems will show less RSA suppression during adult-led play tasks. Disruptive behavior problems will be measured in two ways: dichotomously via diagnostic status and continuously.
3. Child compliance will be positively associated with child RSA suppression during adult-led play in all children.
4. The relationships between child RSA suppression during adult-led play and child compliance will vary as a function of adult type (i.e., mother vs. staff).

Method

Participants

The sample ($N_{\text{Total}}=43$) was comprised of children between the ages of 3-8 years ($M_{\text{Age}}=4.60$; $SD=1.47$) with and without disruptive behavior disorders ($N_{\text{DBD}}=21$; $N_{\text{Control}}=22$). The DBD group included children (ages 3-8), with a diagnosis of ODD, CD, and/or DBD NOS, and their mothers. These children were recruited from a university-based child clinic specializing in the treatment of externalizing disorders in Miami, Florida. Control children were recruited from community ads placed in the Greater Miami area and did not meet criteria for ODD, CD, and ADHD, or have a history of mental disorder. Children were excluded from study participation if they had a history of pervasive developmental disorder, a history of cardiac illness (because of the psychophysiological data collection), if they could not speak and understand English (because the interaction tasks were conducted in English), or if their mother was the under the age of 18 or could not read and speak English. The sample was predominantly male, Caucasian, and Hispanic. See Table 1 for demographic characteristics broken down by diagnostic group.

Procedures

Diagnostic assessment. All mothers first completed the structured diagnostic parent interview. Children who met criteria for a diagnosis of ODD, CD or DBD NOS were included in the DBD group; children who did not meet diagnostic criteria for these disorders and had no history of mental disorder were included in the community control group. Mothers were also sent questionnaires to complete at home.

Physiological assessment. Table 2 presents the sequence of assessment procedures completed by all participants during the lab visit. After applying the ECG and ICG electrodes the child was seated in a booster seat at the play table, the assessor left the room and conducted the assessment from a mirrored observation room, while the child, mother, and a female staff member remained in the assessment room throughout the entire assessment. Throughout the assessment the assessor unobtrusively provided instructions to both the mother and staff via bug-in-the-ear devices. The order in which the mother and staff participated in the child interaction tasks was counterbalanced to protect against order effects. When the mother or staff member were not actively participating in the current child-interaction task, she was instructed to remain seated at the other end of the room completing paperwork, but was allowed to respond naturally if the child addressed her directly, to limit the potential influence of child stress responses associated with active ignoring.

The physiological assessment began with an assessment of *resting RSA* while the child watched a 3-minute cartoon (Spot the Dog) seated at the table with Adult 1 (i.e., mother or staff, depending on counterbalance ordering). Children next completed 5 minutes of *child-directed interaction (CDI)*, during which the child remained seated at the table and was provided with markers and paper, building blocks, and a pair of Mr. Potato Heads. Adult 1 was instructed to follow the child's lead in playing a game of the child's choosing. Following this, children watched a second 3-minute cartoon (Spot the Dog) to serve as a physiological washout period to prevent carry over effects into the next play task. Then, children remained seated at the table and completed the *adult-*

directed interaction (ADI) task with Adult 1. During this task all of the toys (i.e., markers and paper, building blocks, and a pair of Mr. Potato Heads) were put back on the table, and Adult 1 was instructed to tell the child that it was the adult's turn to choose the game and then lead the child in a building activity to achieve a specified goal. Goals were matched to child age to be challenging yet developmentally appropriate. Adults interacting with 3-5 year-olds instructed children to build 3 different color towers and adults interacting with 6-8 year-olds were told to build a four-walled structure with color-patterned walls.

Following the completion of *Adult 1-directed play*, Adult 1 was seated away from the play table, while the child was joined at the play table by Adult 2 (i.e., mother or staff, depending on counterbalance ordering). Adult 2 then repeated the same assessment steps completed by Adult 1, with modified goals for the *adult-led play* task (See Table 2, Steps 6-9). To protect against practice effects, Adult 2 was instructed to lead the child in achieving a drawing goal. Three to five year olds were instructed to draw a house, a yellow sun, and a green tree. Six to eight year olds were instructed to draw 4 houses, a yellow sun and 3 green trees.

Upon completion of all adult-child play tasks, electrodes were removed from the child. The child was allowed to select a small toy to take home and the mother was given a \$50 gift card for participation.

Measures

Child diagnostic status was assessed via a structured diagnostic interview with the child's mother. For developmental compatibility, the structured diagnostic interview used

was matched to child age. Children ages 3-5 were assessed with the Kiddie-Disruptive Behavior Disorders Schedule (K-DBDS; Keenan et al., 2007), a structured parent interview that evaluates the presence of ODD, CD, and ADHD in preschool-aged children. The K-DBDS has been shown to be a reliable tool for the assessment of disruptive behavior disorders in preschool aged children (Bunte, Schoemaker, Hessen, Heijden, & Matthys, 2013). Children ages 6-8 were assessed with the ODD, CD, and ADHD modules of the Diagnostic Interview Schedule for Children (DISC-IV), parent interview. The DISC-IV has shown strong reliability and validity in the assessment of externalizing disorders in children 6-17 (Shaffer, Fisher, Lucas, Dulcan, & Schwab-Stone, 2000).

Child behavior problems were assessed via mother-report on the Eyberg Child Behavior Inventory (ECBI; Eyberg & Pincus, 1990). The ECBI is a well-supported 36-item parent-report questionnaire measuring the frequency of child behavior problems in young children. Internal consistency of the ECBI was strong in the present sample (Cronbach $\alpha=.978$). Clinician-rated severity of child behavior problems was also measured via the Clinical Global Impression Scale-Severity (CGI-S; Guy, 1976), based on information obtained in the diagnostic interview. The CGI-S is a widely used generic measure of global clinical severity that reflects the clinician's global impression of subject severity. Clinician's rate global severity on a 7 point Likert scale ranging from 1, normal, not at all ill to 7, among the most extremely ill.

Adult commands were coded during adult-child play tasks using the Dyadic Parent-child Interaction Coding System-4th Ed (DPICS-IV; Eyberg, Nelson, Ginn,

Bhuiyan, & Boggs, 2013). The DPICS-IV is a structured behavioral observation coding system, with strong psychometric properties, that is used to assess adult behaviors during parent-child interactions (i.e., commands, questions, and negative talk; labeled praise, reflections, and behavior descriptions) as well as child compliance in response to adult-given commands. Adult commands are “statements directing the child to preform vocal or motor behaviors, as well as internal, unobservable actions (e.g., think, decide)” (Eyberg et al., 2013, p. 43). Commands were coded as direct (i.e., a declarative statement containing an order or direction that indicates the child is to preform the behavior) or indirect (i.e., a suggestion for a behavior to be preforms that is unclear if the child must preform the behavior). Three trained coders completed the DPICS-IV coding. Inter-rater reliability was established in the present sample on 20% of cases, indicating acceptable inter-rater agreement (71% agreement).

Child behavioral compliance during the adult-child play tasks was also assessed via the DPICS-IV (Eyberg et al., 2013). As per the DPICS-IV guidelines, child compliance with each command was coded as comply (i.e., child performed, or reasonably attempted to perform, the prompted behavior within 5 seconds of the stated command), non-comply (i.e., child did not perform, or reasonably attempt to perform, the prompted behavior within 5 seconds), or no opportunity to comply (the child did not have the opportunity to comply with the command because another interfering command was given immediately following the command). To afford a standardized measure of compliance across youth that accounted for differences in commands given during various interactions, a compliance ratio was generated by dividing the number of given

commands with which the child complied by the total number of given commands with which the child had an opportunity to comply. In accordance with gold standard child compliance rates within the behavioral parent training literature that require child compliance with 75% of parental commands for treatment graduation, children were rated within each adult-led interaction dichotomously as either compliant ($\geq 75\%$ compliance) or non-compliant ($\leq 75\%$ compliance).

Parasympathetic influences were measured with Mindware Technologies psychophysiological recording equipment (Mindware Technologies, Ltd., Gahanna OH). Electrocardiogram (ECG) and impedance cardiography (ICG) were recorded continuously throughout the adult-child interaction procedures (See Table 2) and the R-R series was sampled at a rate of 1,000 Hz. ECG electrodes were placed on the child in a modified *Lead II* configuration (i.e., right clavicle, left lower torso, right lower torso). For impedance cardiography (ICG), the two voltage electrodes were placed on the child's chest one below and to the right of the suprasternal notch and one below the xiphoid process, while the current electrodes were placed on the child's back approximately 1 inch outside of the voltage electrodes (see Figure 1). This electrode configuration allows the child to move all limbs during play, while also minimizing artifacts due to muscle movement and speech. A respiration signal was derived from ICG.

RSA was calculated from the high frequency component ($>0.15\text{Hz}$) of the R-R time series in 60-second epochs using spectral analysis implemented in Mindware Heart Rate Variability Software V.3.1.0F (Mindware Technologies, 2014). Using the HRV software, ECG signals were visually inspected and artifacts were removed. Based on

evidence suggesting that controlling for respiration rate is necessary in order for RSA to represent a measure of purely parasympathetic cardiac control (Grossman, Karemaker, & Wieling, 1991; Grossman & Taylor, 2007), the high frequency band was set over the respiration band of 0.24 to 1.040Hz to account for respiration in young children (Calkins et al., 2008; Musser al., 2013).

Physiological Measures Derived

PNS cardiac influences were indexed via children's resting baseline RSA, and by RSA reactivity during command-based interactions with mothers and staff. Resting RSA [RSA_R] was measured twice: once while watching a neutral 3-minute video with their mother [RSA_{R(M)}] and once while watching a neutral 3-minute video with the female staff member [RSA_{R(S)}]. Although the attentional deployment required to attend to a video does impact RSA values, resting RSA in early childhood is typically assessed while the child is sitting quietly watching a calm movie or listening to a story, as such methods are necessary to limit stress, movement, and speech for a several minute period in young children (Bagner et al., 2012; Blair & Peters, 2003; Calkins & Keane, 2004). Active RSA baselines [RSA_B] were measured twice: once during the 5-minute period of child-directed play completed with the child's mother [RSA_{B(M)}], and once with the female staff member [RSA_{B(S)}]. Lastly, RSA was also measured across two 5 minute periods of command-based play: one in which mothers directed the child in play [RSA_{C(M)}] and one in which a female staff member directed the child in play [RSA_{C(S)}]. During resting, play baselines, and command-based tasks, RSA values were calculated for 60-second epochs, and values were average across epochs to obtain mean RSA scores for the task.

RSA suppression can be calculated by either subtracting the child's baseline RSA from RSA obtained during a challenge task, or by statistically controlling for baseline RSA. Although resting RSA values often serve as baseline values in such analyses, recent recommendations point to the use of active baselines that are matched to experimental task for motor and cognitive demands, to more effectively isolate vagal regulatory actions linked to the stimulus of investigation (Bush et al., 2011).

For the present study, RSA reactivity scores were obtained by co-varying RSA_B in the prediction of RSA_C in analyses. As such, RSA reactivity [$RSA_{\text{Reactivity}}$] scores represent mean RSA during command-based tasks controlling for mean RSA during child-led play tasks (RSA_B). RSA_B scores were used as the baseline measures of RSA, rather than RSA_R , to control for physical and attentional demands of adult-child play that can influence RSA scores, affording a more conservative measure of RSA reactivity specific to command-based interactions and not simply adult-child play in general (Bush et al., 2011).

Data Analysis

First DBD and community youth were compared on demographic group differences using Chi Square and T-tests. Prior to beginning parametric analyses, all continuous variables were also examined for normality of residuals. Those violating the assumptions of normality were log10-transformed. Next repeated measures ANOVA was used to test the change in command frequency from CDI to ADI to confirm experimental manipulation of command frequency during adult-directed play. Additionally, the counterbalancing of the order of adult-type in play (i.e., mother vs. staff) was examined

in relation to child diagnostic status and sex using Chi Square tests. Differences in RSA_R and RSA_C associated with diagnostic status were then evaluated using ANCOVA controlling for child age.

Following diagnostic group comparisons, both groups were pooled into one sample to examine relationships when considering disruptive behavior problems dimensionally across youth. Specifically, relationships between RSA_R and continuous measures of disruptive behavior problems and child behavioral compliance were evaluated, as well as partial correlations between RSA_C and continuous measures of disruptive behavior problems and child behavioral compliance that controlled for RSA_B in order to assess links with $RSA_{Reactivity}$. Child age and sex were also evaluated as potential moderators of relationships via multiple regression. Bias-corrected bootstrapped 95% confidence intervals with 1,000 bootstrapped samples were generated to assess significance of interaction effects. Significant interactions with child sex were followed up by comparing simple slope conditional effects between boys and girls. Significant interactions with child age were followed up by comparing simple slope conditional effects between youth 1 SD above the sample mean age (i.e., youth age 6) and youth 1 SD below the sample mean age (i.e., youth age 3).

Results

Preliminary Analyses

All continuous measures to be used in parametric analyses were first evaluated for outliers and normality. All RSA data fell within the expected range and were found to have normal distributions of residuals (Bar-Haim, Marshall & Fox, 2000; Byrne, Fleg,

Vaitkevicius, Wright, & Porges, 1996; see Table 3). Both continuous measures of child behavior problems, ECBI and CGI-S, were found to have non-normal distributions of residuals and were therefore log₁₀ transformed. Parametric analyses including the ECBI and CGI-S were conducted once with log-transformed values and again with the original values. As all tests yielded identical findings in regard to significance, analyses using non-transformed values are reported to enhance interpretability.

Overall, the sample was predominantly male. Regarding ethnicity most youth were Hispanic, and regarding race most youth were Caucasian (see Table 1). Chi Square and T-tests were used to evaluate diagnostic group differences in categorical and continuous variables, respectively. There were no differences between diagnostic groups in child race, ethnicity, sex, or family financial means (i.e., annual income/number of dependents). Children with DBDs were on average slightly younger (1.09 years) than control children. Accordingly, all analyses comparing diagnostic groups included child age as a covariate. Additionally, the order of adult-type in play (i.e., mother vs. staff) was successfully counterbalanced within diagnostic groups ($\chi^2=.020, p=.887$). The order in which adults completed play with children was found to vary in relation to child sex, such that, 63% of boys vs. 27% of girls completed play tasks with a staff member first ($\chi^2=4.083, p=.043$).

Manipulation Check

Changes in command frequency from child-directed (CDI) to adult-directed (ADI) interactions were evaluated to confirm that adult command use significantly increased from CDI to ADI (see Table 4 for means and standard deviations). Across the

full sample, repeated measures ANOVA revealed a significant increase in maternal commands from CDI to ADI ($F(1,37)=56.94, p<.000$), with an average increase of 10.8 maternal commands during mother ADI. Repeated measures ANOVA also revealed a significant increase in staff-given commands from CDI to ADI ($F(1,37)=52.24, p<.000$), with an average increase of 10.3 staff-given commands during staff ADI. Findings indicate a successful experimental manipulation, with ADI indeed showing significantly greater numbers of adult commands given to children.

Parasympathetic Influences and Diagnostic Status

Diagnostic group differences in RSA_R were evaluated with ANCOVA, controlling for child age. Children diagnosed with a DBD did not significantly differ from control children with regard to their resting RSA in the presence of their mother ($RSA_{R(M)}$) or the staff member ($RSA_{R(S)}$; see Table 5). $RSA_{Reactivity(M)}$ and $RSA_{Reactivity(S)}$ also did not differ as a function of child diagnostic status (see Table 5).

As dichotomous diagnostic conceptualization failed to capture the continuum of severity within which behavioral problems naturally occur, all further analyses evaluated relationships between continuous measures of child behavioral problems and parasympathetic influences across the full sample ($N=43$).

Parasympathetic Influences and Child Behavior Problems

Bivariate correlations between study variables and RSA_R were used to evaluate relationships between severity of child behavior problems and resting RSA. $RSA_{R(M)}$ was not correlated with child behavior problems (ECBI or CGI-S) or child compliance with mother-given commands (see Table 6). $RSA_{R(S)}$ was not correlated with child behavior

problems (ECBI or CGI-S) or child compliance with staff-given commands (see Table 6).

Partial correlations between study variables and RSA_C , controlling for RSA_B were used to evaluate relationships between severity of child behavior problems and RSA reactivity to command-based play ($RSA_{Reactivity}$). When interpreting correlation effects, lower $RSA_{Reactivity}$ values represent greater suppression of RSA in response to command-based play and higher ECBI values representing greater behavior problems.

$RSA_{Reactivity(M)}$ was positively correlated with ECBI score, while $RSA_{Reactivity(S)}$ was negatively correlated with ECBI score. That is, more severe behavioral problems were associated with less RSA suppression in the context of maternal commands, but with greater RSA suppression in the context of staff commands. Both associations reflected medium-sized effects (see Table 6). In contrast, clinician-rated severity of behavior problems (as measured via the CGI-S) was not significantly correlated with RSA_C during mother- or staff-led play after controlling for RSA_B .

Greater child $RSA_{Reactivity(M)}$ was positively correlated with observed child compliance with mother's commands. This association reflected a medium-sized effect (see Table 6). Child $RSA_{Reactivity(S)}$ was not correlated with staff command compliance (see Table 6).

Examining the Moderating Roles of Child Age and Sex

Further analyses examined the extent to which child age and sex moderated relationships between $RSA_{Reactivity}$ and behavior problems (RSA_C values were entered as the independent variable, with RSA_B variables entered as covariates). All variables were mean centered before generating interaction terms. The relationship between child

RSA_{Reactivity(M)} and behavior problems (i.e., ECBI) was not moderated by child age or sex. In contrast, the relationship between RSA_{Reactivity(S)} and behavior problems was moderated by child sex, but not child age (see Table 7). An evaluation of simple slope conditional effects revealed that in the context of staff commands, the association between RSA_{Reactivity} and behavior problems was significant among boys ($\beta=-62.554$, $t=-3.866$, $p<.000$) but not girls ($\beta=-24.314$, $t=-1.447$, $p=.156$; see Figure 2). Neither child age nor child sex moderated associations between RSA_{Reactivity} and clinician-rated symptom severity (i.e., CGI-S) (see Table 8).

Child age moderated the link between RSA_{Reactivity(M)} and child compliance with mother-given commands (see Table 9). Specifically, the effect of RSA_{Reactivity(M)} on child compliance was significant among younger children ($\beta=-5.005$, $z=-2.922$, $p=.004$), but not older children ($\beta=-1.020$, $z=-.705$, $p=.481$; see Figure 3). In contrast, child age and sex did not moderate an association between RSA_{Reactivity(S)} and compliance with staff-given commands.

Discussion

The present findings add to a growing body of research examining parasympathetic influences that may underlie child behavioral self-regulation and maladaptation (Beauchaine, 2001; Graziano, & Derefinko, 2013; Calkins & Keane, 2004; Miller et al., 2013; Musser et al., 2013) by clarifying the role of interpersonal context in determining key relationships between child RSA reactivity, behavior problems, and noncompliance in response to adult commands. Children participated in an experimental paradigm in which the specific adult giving them commands was systematically varied

from their mother to a female staff member while cardiac data were collected. Findings revealed that the relationship between RSA reactivity and child behavior problems indeed varies by interpersonal context. Specifically, less child RSA suppression in the context of *mothers'* commands was associated with more severe child behavioral problems and poorer in-task compliance. In contrast, greater child RSA suppression in the context of female *staff-members'* commands was associated with more severe behavior problems, particularly among boys.

These findings underscore the importance of interpersonal context in determining the relationship between child autonomic self-regulation and behavioral functioning. The present finding that less RSA suppression specifically in response to maternal commands is associated with more severe child behavior problems is consistent with previous work linking less RSA suppression during challenging tasks to higher levels of externalizing child psychopathology (Blair, 2003; Calkins, Graziano, & Keane, 2007; Graziano & Derefinko, 2013; Perry et al., 2012). Whereas these previous studies examined child RSA suppression in the context of frustrating and challenging tasks, the present study was novel in its specific manipulation of mother commands during play as the challenge task—while also controlling for the cognitive and motor demands of play—and thus speaks directly to problems of family-based oppositionality and non-compliance that are commonly at the center of clinical presentations among children with behavior problems referred for treatment (Keenan & Wakschlag, 2004). Accordingly, the present study was able to go beyond previous work in the area by directly linking parasympathetic self-regulation during maternal commands with actual child compliance with those very same

commands and found that less RSA suppression during mother-given commands was associated with reduced in-task compliance. This finding suggests that RSA suppression specifically in response to mother-given commands may be a biomarker of adaptive behavioral regulation. Further, RSA suppression in response to maternal commands also demonstrated a small but non-significant correlation with child compliance to staff-given commands. Indeed, RSA suppression in response to maternal commands could potentially be indicative of better behavioral regulation across other contexts as well, but this hypothesis warrants further investigation in a larger sample.

When the interpersonal context of the command-based task was manipulated such that staff members gave commands to children rather than mothers, the relationship between RSA suppression and child behavior problems reversed, particularly for boys. Importantly, these divergent patterns of RSA suppression were not simply due to ordering effects within the experimental procedure, as the ordering of mother-led vs. staff-led play was counter balanced across participants. This finding diverges from previous work demonstrating that RSA suppression during challenging assessor-administered tasks negatively correlates with externalizing symptom severity (Blair, 2003; Calkins, 1997; Calkins et al., 1998; Calkins et al., 2007; Perry et al., 2012), although the challenge tasks in these studies (e.g., cognitive challenges, frustration challenges) did not specifically entail assessors giving ongoing commands with which children were expected to comply, and these tasks did not require as much social engagement with the assessor from the child. Interestingly, the present finding that greater child RSA suppression in response to staff-given commands was associated with

more severe behavior problems (particularly among boys) is consistent with patterns of RSA suppression that predict adaptive social functioning in clinical and at-risk children (Beauchaine et al., 2013; Graziano & Derefinko, 2013).

This finding is also consistent with the adaptive RSA response to social demands described in Polyvagal Theory (Porges, 2007). Porges asserts that the social engagement system links activity of the myelinated vagus nerve to regulation of muscle movements in the face and head (e.g., eye contact, smiling) that facilitate social communication.

Therefore, the promotion of social engagement behaviors occurs during a calmer visceral state resulting from maintenance of the vagal break (i.e., less RSA suppression). It is possible that receiving commands from a non-parental adult increases the social salience of a task, which in turn results in less RSA suppression in order to support adaptive basic social functions. However, as interacting with one's parent similarly demands engagement in eye-contact and active listening, it remains unclear why demands on of the "social engagement system" would vary when interacting with parents versus other adults.

Another possible interpretation of this finding is that receiving commands from a non-parental adult does increase the social salience of a task, and in turn influences how children experience the task based on their behavioral history. Given the interpersonal context in which oppositional behavior occurs and social impairments experienced by behavior disordered youth (Keenan & Wakschlag, 2004; Ezpeleta et al., 2001), children with behavior problems may experience command-based play with a new adult as a serious challenge, whereas children without a history of behavior problems may experience such play as an opportunity for social engagement. Therefore, greater RSA

suppression when receiving commands from another adult may represent an over activation of the “fight or flight” response that results from interpretation of command-based play with staff as more challenging among children with more severe behavioral problems. Such an *over* suppression of RSA is consistent with RSA reactivity observed in aggressive children in response to anger and challenging play (Beauchaine et al., 2013; Gatzke-Kopp et al., 2015).

As the first study to experimentally manipulate adult type across an adult-child interaction task, findings reveal how the interpersonal context in which adult commands are given impacts how different children experience and respond to those commands and what patterns of autonomic self-regulation underlie adaptive child functioning. Further, although other studies have evaluated RSA reactivity during adult-child problem-solving and cleanup tasks (Beauchaine et al., 2013; Calkins & Dedmon, 2000; Calkins & Keane, 2004; Graziano et al., 2012), RSA reactivity in these studies has been measured as change in RSA from a resting baseline to the adult-child problem-solving or cleanup task. Given that RSA suppression also results from increased attention and motor demands (Byrne et al., 1996; Graziano & Derefinko, 2013), past work utilizing resting baselines for computing RSA suppression is unable to distinguish the extent to which RSA suppression is associated specifically with receiving adult commands versus with the increased attention and motor demands that accompany those tasks. By evaluating RSA reactivity as change in RSA from an activity-matched baseline (i.e., child-led play), the effects of the motor and attentional demands of play were controlled for, allowing for RSA changes to be attributed solely to the influence of adult-given commands.

Child sex and age were also explored as moderators of behavioral outcomes to better clarify for whom parasympathetic self-regulatory processes most strongly influence functional outcomes. In the context of staff-given commands, child sex emerged as a moderator of the association between RSA suppression and behavior problem severity. Specifically, the relationship between RSA suppression in response to staff-given commands and child behavior problems was significant among boys, such that boys show more severe behavior problems with greater RSA suppression. While this effect was not significant for girls, it is important to note that the effect for girls was smaller and in the same direction. This suggests a similar yet smaller effect that may have reached significance in a larger sample. Consistent with this finding, previous work has found that sex moderates the relationship between resting RSA, RSA reactivity, and vulnerability to adversity (Beauchaine, Hong, & Marsh, 2008; El-Sheikh, 2005; Hinnant et al., 2015; McLaughlin, Rith-Najarian, Dirks, & Sheridan, 2015). While meta-analytic findings have not found sex to moderate links between RSA reactivity and functional outcomes in early childhood (Graziano & Derefinko, 2013), the present findings suggest that boys' behavior may be particularly vulnerable to parasympathetic self-regulatory processes in the specific context of non-parental adult commands. As RSA reactivity is susceptible to behavioral intervention (Graziano et al., 2012; Hinnant et al., 2015), the observed moderation effect for sex could potentially be due to gender-based socialization of girls towards more compliant behavior relative to boys (Chaplin, Cole, & Zahn-Waxler, 2005). However, the sex differences observed must be interpreted with caution, due to the relationship between male status and more severe behavior problems observed

in this sample. Additionally, as boys completed play with a staff member first more often than girls, it is possible that this stronger effect could be due to order effects of adult-type.

Child age also emerged as a moderator of the relationship between child RSA suppression and compliance with mother-given commands, such that this relationship was stronger for younger children, and non-significant for the oldest children. Younger children's (4 and younger) in-task compliance was associated with greater RSA suppression, whereas this was not true for the oldest children (6 and older). It should be noted that the effect for older children was in the same direction, but smaller in magnitude and non-significant. While decreases in RSA suppression with child age have been found in one longitudinal evaluation (Calkins & Keane, 2004), this is not found consistently (El-Sheikh, 2005). Further, age was not correlated with RSA suppression in the present sample. These findings speak to the enhanced utility of RSA suppression as a biomarker of non-compliance early in the preschool years.

These findings have important implications for the use of RSA suppression as a biomarker of early childhood oppositionality. First, these findings support the use of assessment methods that evaluate child RSA reactivity in ecologically valid tasks with parents. Using such a method may allow for the identification of young children whose autonomic self-regulatory processes place them at heightened risk to engage in more severe forms of oppositional behavior and noncompliance, while also controlling for the influence of other emotional states (e.g., anxiety in response to an unfamiliar adult), that could obscure the RSA signature in children at-risk for problems.

The use of RSA reactivity to parental commands as a biomarker may also enable early identification of children who are biologically engaging in ineffective emotion regulation in interactions with their own parents, and could therefore benefit from interventions targeting those ineffective parent-child interactions (e.g., PCIT; Eyberg et al., 2001). Additionally, current treatments for early childhood disruptive behavior could potentially be enhanced by the inclusion or expansion of components that target underlying parasympathetic dysregulation. Treatments built upon behavioral reinforcement principals (e.g., PCIT, Incredible Years, Helping the Noncompliant Child, and the Triple-Positive Parenting Program; see Comer et al., 2013; Eyberg et al., 2001; Forehand & McMahon, 2005; Sanders, Kirby, Tellegen, & Day, 2014; Webster Stratton, 2005), target parental reinforcement of compliance with parental commands, and may reinforce successful self-regulation at a parasympathetic level. However, parent training programs could be enhanced by the inclusion of emotional regulatory skills training for young children with disruptive behavior disorders who show limited RSA suppression in response to parental commands, to prime children for use of self-regulatory skills and create opportunities for behavioral reinforcement of skill use (e.g., Carpenter, Puliatico, Kurtz, Pincus, & Comer, 2014; Chronis-Tuscano et al., 2014; Luby, Lenze, & Tillman, 2012). Additionally, biofeedback targeting RSA has shown promise as an adjunctive treatment for psychopathology in adulthood, and could potentially be a useful therapeutic adjunct, when developmentally adapted for young children (Patron et al., 2013; Zucker, Samuelson, Muench, Greenberg, & Gevirtz, 2009).

The non-significant findings of the present study may also have important

implications for the assessment and classification of disruptive behavior in early childhood. Two metrics of behavior problems that were found to be unrelated to child resting RSA and RSA reactivity were clinician-rated symptom severity and child diagnostic status. In this study, global severity ratings were made after diagnostic interviews, and were thus filtered through parent-report of disruptive behavior symptoms and associated interference. As such, parental perception and report of behavioral symptoms could have potentially been influenced by stressors external to the child's behavior, such as parent psychopathology (Chi and Hinshaw, 2002; Briggs-Gowan, Carter, Schwab-Stone, 1996). Consequently, parent report, or omission, of symptoms during the interview may have resulted in potentially inflated or underestimated CGI ratings. This may be particularly relevant in a sample including both community and treatment-seeking families. Frequency ratings of objective behaviors and observational measurement of compliance are less vulnerable to this bias, and in this study those measures were in fact linked to child RSA.

Diagnostic classification (i.e., clinical vs. control) was also found to be unrelated to all child RSA measures, while continuous ratings of problematic behavior were significantly linked with underlying biological processes. This discrepancy provides further support for the use of continuous measurement when assessing biological mechanisms that may underlie psychopathology. The use of dichotomous categorical classification is a widely debated topic, due to the abundance of empirical support for the dimensional classification of psychopathology and the utility of such an approach when seeking to identify biological markers of emotional processes (Brown & Barlow, 2009;

Carragher, Krueger, Eaton, & Slade, 2015; Insel, 2014; Witkiewitz, et al., 2013). As clinical diagnoses were unrelated to child RSA, the findings of this study provide further support for the utility of a dimensional classification approach to psychopathology and its underlying biological influences beginning in early childhood.

When considering the implications of these findings, one must also remain aware of several important study limitations. The present sample size limited the analytic plan. Although the sample was sufficiently powered to detect moderately sized relationships, small effects did not reach significance. Further, a sample of this size did not allow for more complex and nonlinear modeling of parasympathetic processes. Additionally, despite 70% of the children in the sample being Hispanic, there was limited variability with regard to child race. Though findings provide insight into early childhood behavioral regulation in a traditionally understudied ethnic group, the generalizability of the present findings to other racial and ethnic groups is limited. Lastly, the analytic approach to RSA reactivity applied in this study captures only overall changes in RSA from baseline to task, without taking into account the rate and shape of RSA change during command-based play. Non-linear trajectories of RSA change during anger and fear eliciting tasks have been found to differentially inform links to externalizing and internalizing problems (Brooker & Buss, 2010; Miller et al., 2013). Consequently, the shape of RSA change may be particularly relevant to fully understanding adaptive patterns of RSA reactivity enabling both management of frustration and anxiety in interpersonal command-based interactions with non-parent adults. Future work would also do well to longitudinally evaluate RSA reactivity and externalizing symptom trajectories across childhood, with

specific regard to the identification of biomarkers for the maintenance of externalizing problems and the development of depressive problems found among oppositional youth (Drabick & Gadow, 2012; Rowe, Costello, Angold, Copeland, & Maughan, 2010; Stringaris & Goodman, 2009).

Taken together, these findings advance the understanding of the autonomic self-regulatory deficits associated with child disruptive behavior problems by demonstrating a moderate link between child RSA suppression and non-compliance with parental commands, a core difficulty among children with behavior problems referred for treatment. Further, this work advances the field by demonstrating that the functional association between RSA suppression and behavioral compliance is socially influenced. This work informs the use of preschool RSA reactivity as a biomarker for the early identification of disruptive behavior problems, and clarifies the biological underpinnings of behavioral deregulation across contexts to inform treatment.

Table 1.

Demographic characteristics across participants

Demographic variable	Total Sample <i>M</i> (<i>SD</i>)	Diagnostic Group		<i>t</i>
		DBD <i>M</i> (<i>SD</i>)	Community Control <i>M</i> (<i>SD</i>)	
Age	4.60 (1.47)	4.05 (1.32)	5.14(1.42)	2.595*
Financial means ^a , \$	23,369 (15,162)	18,610 (11,102)	27,448 (17,151)	1.874
	%	N (%)	N (%)	χ^2
Sex				2.751
Male	74	86	64	
Female	26	14	36	
Race				1.339
Caucasian	81	86	77	
African-American	7	5	9	
Asian-American	2	0	5	
Other	9	10	9	
Ethnicity				2.434
Hispanic	70	81	59	
Non-Hispanic	30	19	41	

Note: DBD= Disruptive behavior disorders

^a Annual household income, divided by number of dependents

*= $p < .05$

Table 2.

Study assessment procedures

Step	Procedures Completed
1 Equipment Set-up	<ul style="list-style-type: none"> • Children equipped with Mindware physiological recording equipment: <ul style="list-style-type: none"> ○ 3 ECG chest electrodes ○ 4 ICG chest and back electrodes • Child's mother remained in room
2 Resting RSA with Adult 1 (Cartoon)	<ul style="list-style-type: none"> • Physiological acquisition begins • Child sat with Adult 1 and watched 3-minute cartoon of "Spot the Dog"
3 Child-directed play with Adult 1 (Adult 1 CDI)	<ul style="list-style-type: none"> • Child completed 5-minute child-led play task with Adult 1 while seated at a table. • Child given 3 toys for play: markers & paper, blocks, and Mr. Potato Head • The play task was video recorded and later coded in accordance with the DPCIS-IV coding system
4 Washout (Cartoon)	<ul style="list-style-type: none"> • Child sat with Adult 1 and watched new 3-minute cartoon of "Spot the Dog"
5 Adult 1 ADI (Adult-directed play with child)	<ul style="list-style-type: none"> • Child remained seated at table with markers & paper, blocks, and Mr. Potato Head • Child completed a 5-minute tower building task with Adult 1 while seated at a table. <ul style="list-style-type: none"> ○ Ages 3-5: build 3 towers each with a different color of blocks ○ Ages 6-8: Build a structure with 4 walls, with each wall containing a pattern of alternating colors • The play task was video recorded and later coded in accordance with the DPCIS-IV coding system.
6 Resting RSA with Adult 2 (Cartoon)	<ul style="list-style-type: none"> • Child sat with Adult 2 and watched new 3-minute cartoon of "Spot the Dog"
7 Adult 2 CDI (Child-directed play with Adult 2)	<ul style="list-style-type: none"> • Child completed 5-minute child-led play task with Adult 2 while seated at a table. • Child given 3 toys for play: markers & paper, blocks, and Mr. Potato Head • The play task was video recorded and later coded in accordance with the DPCIS-IV coding system

8	Washout (Cartoon)	<ul style="list-style-type: none"> • Child sat with Adult 2 and watched new 3-minute cartoon of “Spot the Dog”
9	Adult 2 ADI (Adult-directed play with Adult 2)	<ul style="list-style-type: none"> • Child remained seated at table with markers & paper, blocks, and Mr. Potato Head • Child completed a 5-minute drawing task with Adult 2 while seated at a table. <ul style="list-style-type: none"> ○ Ages 3-5: Draw a house, yellow sun and green tree ○ Ages 6-8: Draw 4 houses, a yellow sun, and 3 green trees • The play task was video recorded and later coded in accordance with the DPCIS-IV coding system. • Physiological acquisition ended after play complete
10	Equipment Removal	<ul style="list-style-type: none"> • All electrodes were removed from child.
11	Prize Selection	<ul style="list-style-type: none"> • Child selected a small prize • Mother was given gift card

Note: The order of play tasks completed with the mother and staff were counterbalanced.

Table 3.

Descriptive statistics for respiratory sinus arrhythmia (RSA) and child behavior problems

Variable	%	M	SD	Range		Kolmogorov-Smirnov test of normality
				Min	Max	
Mother Present						
RSA _{R(M)}	-	6.931	1.092	3.68	8.76	.100
RSA _{B(M)}	-	6.206	1.030	3.64	8.21	.057
RSA _{C(M)}	-	6.203	.911	3.93	7.98	.096
75% Compliance	50	-	-	-	-	-
Staff Present						
RSA _{R(S)}	-	7.030	1.142	3.49	9.13	.086
RSA _{B(S)}	-	6.168	1.117	3.19	8.56	.072
RSA _{C(S)}	-	6.205	1.067	3.98	8.21	.080
75% Compliance	35	-	-	-	-	-
ECBI	-	105.634	55.110	39.00	234.00	.160*
CGI-S	-	3.209	1.753	1.00	6.00	.220***

Note: RSA_{R(M)}= Resting RSA with mother; RSA_{B(M)}= RSA during active baseline of child-directed interactions with mother; RSA_{C(M)}= RSA during command-based interactions with mother; RSA_{R(S)}= Resting RSA with staff; RSA_{B(S)}= RSA during active baseline of child-directed interactions with staff; RSA_{C(S)}= RSA during command-based interactions with staff; ECBI = Eyberg Child Behavior Inventory; CGI-S= Clinical Global Impressions -Severity

*= $p < .05$, **= $p < .01$, ***= $p < .001$

Table 4.

Command frequency across play conditions

	CDI M(<i>SD</i>)	ADI M(<i>SD</i>)
DBD		
Mother	9.55(1.22)	23.75(2.69)
Staff	6.50(1.10)	19.60(2.26)
Non-Clinical		
Mother	6.11(1.26)	13.32(2.76)
Staff	4.68(1.13)	11.79(2.32)
Total Sample		
Mother	7.87(5.68)	18.63(12.81)
Staff	5.46(4.87)	15.79(10.73)

Note: DBD=Disruptive Behavior Disorder, CDI=Child-directed interaction, ADI=Adult-directed interaction

Table 5.

Respiratory sinus arrhythmia (RSA) across diagnostic groups

Variable	DBD M(SE)	Control M(SE)	df	F	<i>p</i>
RSA Resting					
RSA _{R(M)}	7.007(.242) ^a	6.858(.236)	1,40	.180	.673
RSA _{R(S)}	7.030(.260) ^a	7.030(.253)	1,40	.000	1.00
RSA Reactivity					
RSA _{Reactivity(M)}	6.322(.093) ^b	6.084(.093)	1,38	3.071	.088
RSA _{Reactivity(S)}	6.136(.103) ^c	6.272(.100)	1,39	.836	.366

Note: ^a Mean value controlling for child age, ^b Mean value controlling for RSA_{B(M)} and child age, ^c Mean value controlling for RSA_{B(S)} and child age

Table 6.

Associations across study variables

	1	2	3	4	5	6	7	8	9
1. RSA _{Reactivity(M)}	-								
2. RSA _{Reactivity(S)}	.038	-							
3. RSA _{R(M)}	.239	.390*	-						
4. RSA _{R(S)}	.401**	.252	.858***	-					
5. ECBI	.321*	-.408**	-.181	-.275	-				
6. CGI-S	.211	-.274	-.027	-.124	.868***	-			
7. Compliance with mother commands	-.410*	.145	.077	-.103	-.370*	-.319	-		
8. Compliance with staff commands	-.193	.097	.378*	.270	-.131	-.128	.141	-	
9. Age	.171	.371*	.297	.218	-.350*	-.375*	.091	-.027	-
10. Sex	-.068	-.056	.031	.121	-.342*	-.317*	.058	.189	-.134

Note: RSA_{Reactivity(M)} values were obtained by controlling RSA_{B(M)} and RSA_{Reactivity(S)} values were obtained by controlling for RSA_{B(S)}. Compliance refers to compliance with 75% of commands given during a 5-minute adult-directed interaction

*= $p < .05$, **= $p < .01$, ***= $p < .001$

Table 7.

Details of tests of child age and sex as moderators of associations between parasympathetic reactivity and mother-rated child behavior problems

Predictor	Proposed Moderator	Coefficient	SE	95% Confidence Interval ^a	
				Lower Limit	Upper Limit
RSA _{Reactivity(M)} ^b	Age	-4.252	7.220	-18.909	10.405
	Sex	19.569	19.467	-19.951	59.090
RSA _{Reactivity(S)} ^c	Age	-3.431	6.198	-16.002	9.141
	Sex	38.239**	13.184	11.502	64.977

Note: ^a Bias corrected bootstrapped confidence interval with 1,000 bootstrapped samples,

^b RSA_{Reactivity(M)} controls for RSA_{B(M)}

^c RSA_{Reactivity(S)} controls for RSA_{B(S)}

*= $p < .05$, **= $p < .01$, ***= $p < .001$

Table 8.

Details of tests of child age and sex as moderators of associations between parasympathetic reactivity and clinician-rated child behavior problem severity

Predictor	Proposed Moderator	Coefficient	SE	95% Confidence Interval ^a	
				Lower Limit	Upper Limit
RSA _{Reactivity(M)} ^b	Age	-.106	.189	-.488	.277
	Sex	.775	.756	-.757	2.306
RSA _{Reactivity(S)} ^c	Age	.015	.209	-.408	.438
	Sex	.930	.560	-.202	2.063

Note: ^a Bias corrected bootstrapped confidence interval with 1,000 bootstrapped samples,

^b RSA_{Reactivity(M)} controls for RSA_{B(M)}

^c RSA_{Reactivity(S)} controls for RSA_{B(S)}

*= $p < .05$, **= $p < .01$, ***= $p < .001$

Table 9.

Details of tests of child age and sex as moderators of associations between parasympathetic reactivity and in-task child compliance

Predictor	Proposed Moderator	Coefficient	SE	95% Confidence Interval ^a	
				Lower Limit	Upper Limit
RSA _{Reactivity (M)} ^b	Age	1.343*	.586	.195	2.492
	Sex	-.283	.898	-2.042	1.477
RSA _{Reactivity (S)} ^c	Age	.594	.410	-.209	1.398
	Sex	-.416	.854	-2.089	1.258

Note: ^a Bias corrected bootstrapped confidence interval with 1,000 bootstrapped samples,

^b RSA_{Reactivity(M)} controls for RSA_{B(M)}

^c RSA_{Reactivity(S)} controls for RSA_{B(S)}

*= $p < .05$, **= $p < .01$, ***= $p < .001$

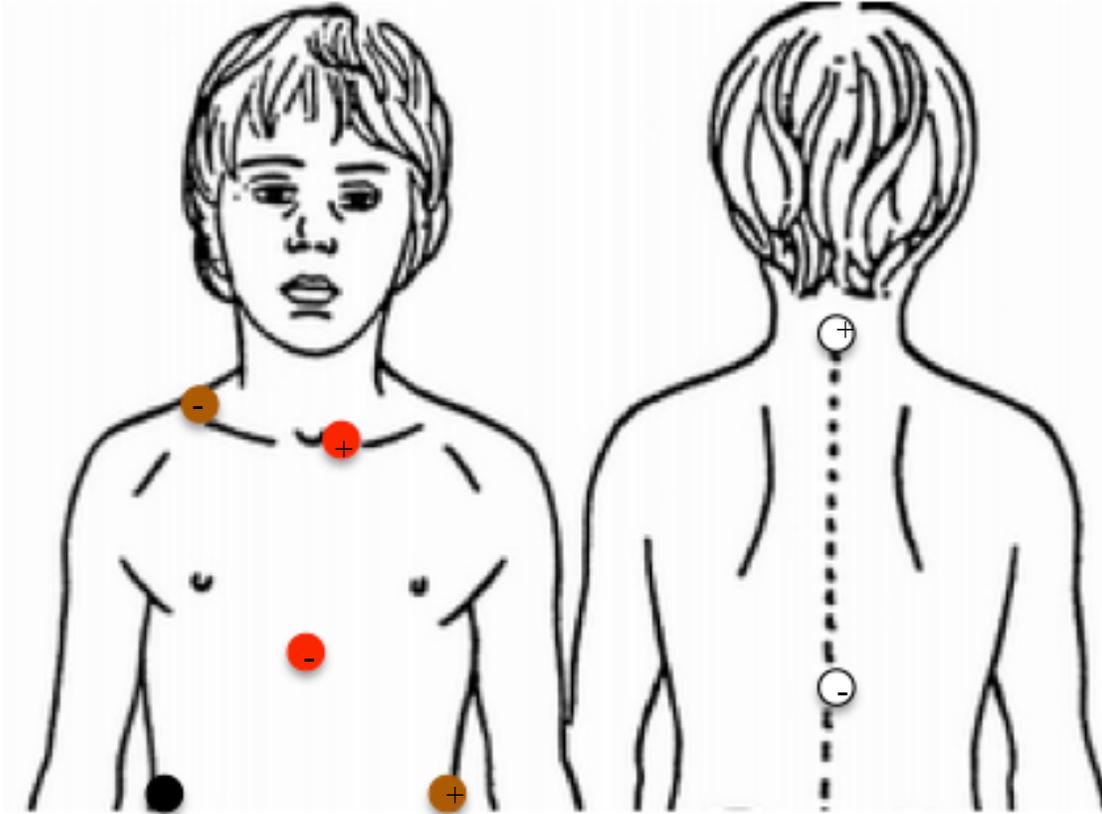


Figure 1. ECG and ICG electrode configuration.

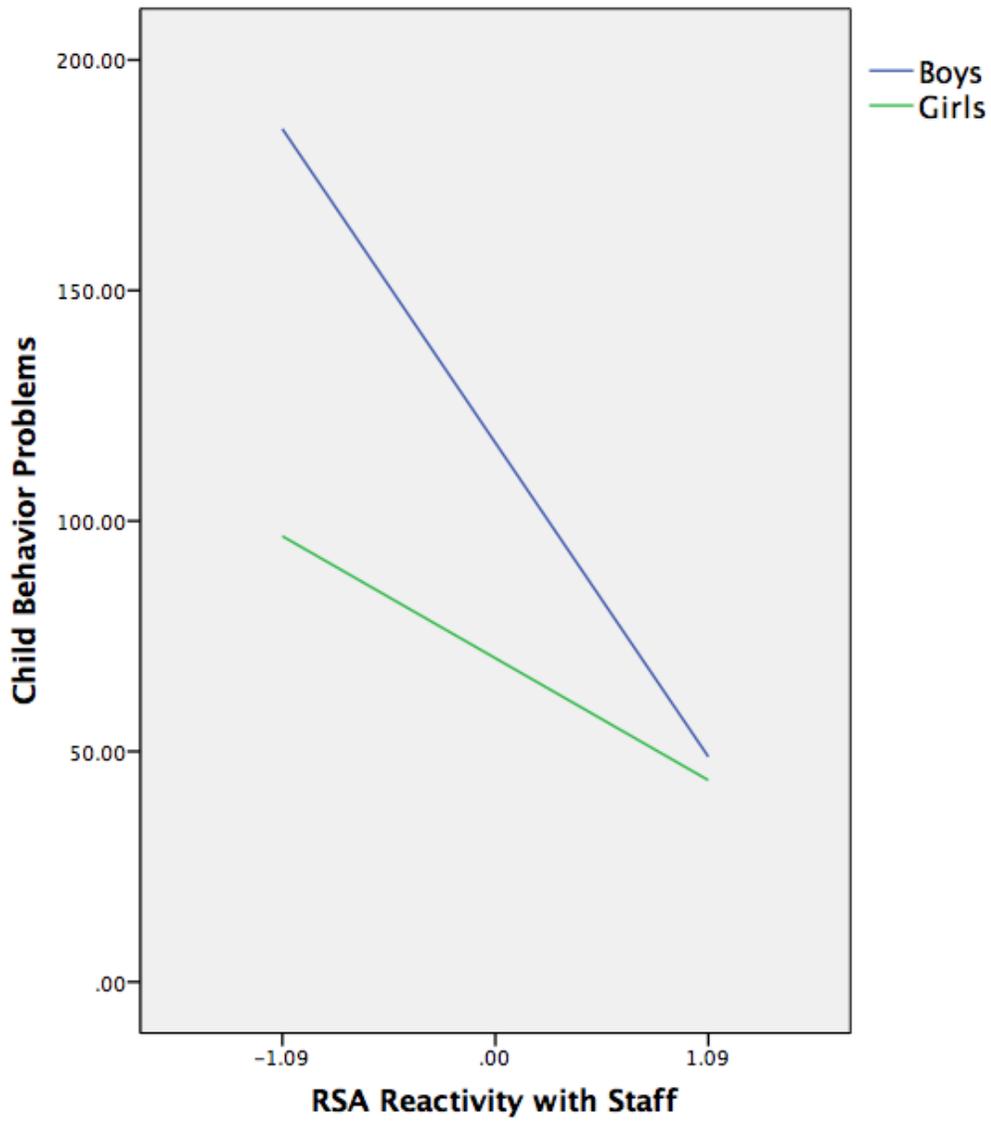


Figure 2. Child behavior problems as a function of RSA suppression during Staff ADI and child sex, controlling for RSA during Staff CDI.

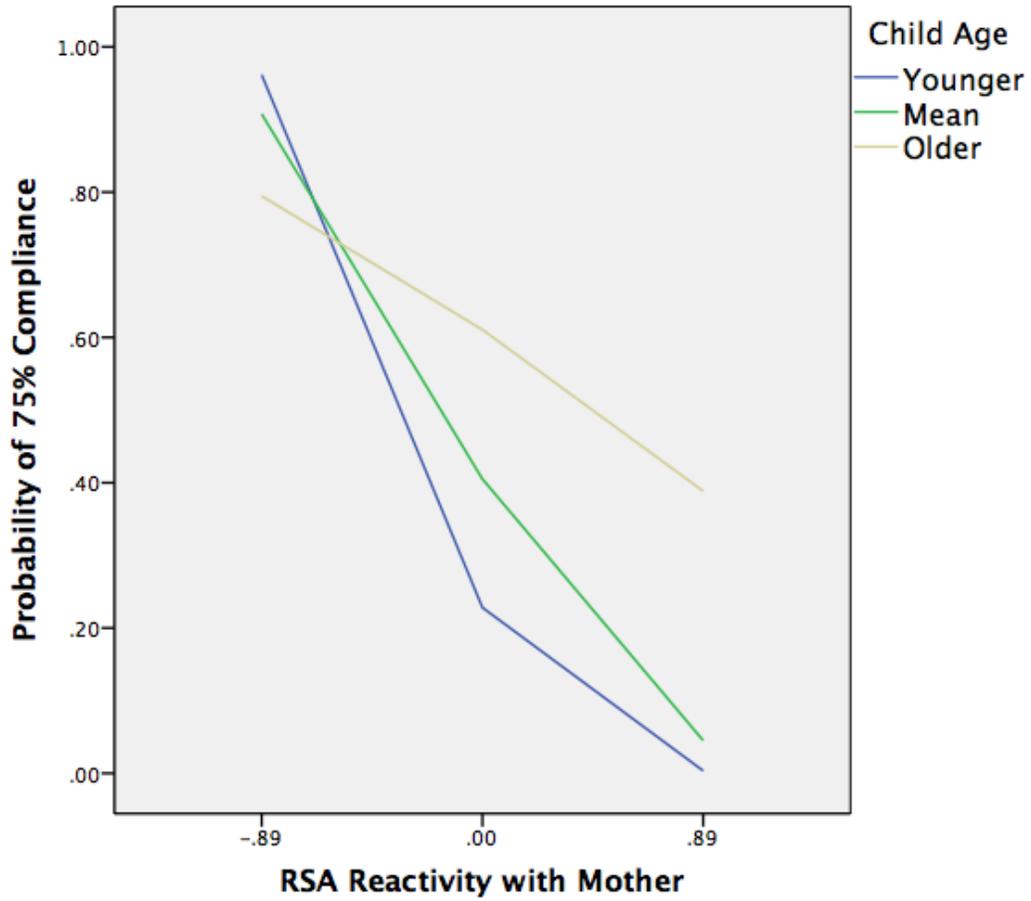


Figure 3. Child compliance as a function of RSA suppression during Mother ADI and child age, controlling for RSA during Mother CDI.

Bibliography

- Allen, J. J. B., Chambers, A. S., & Towers, D. N. (2007). The many metrics of cardiac chronotropy: A pragmatic primer and a brief comparison of metrics. *Biological Psychology*, 74(2), 243–262. doi:10.1016/j.biopsycho.2006.08.005
- American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders, Fifth Edition*. Arlington, VA: American Psychiatric Association.
- Appelhans, B. M., & Luecken, L. J. (2006). Heart rate variability as an index of regulated emotional responding. *Review of General Psychology*, 10, 229–240. doi:10.1037/1089-2680.10.3.229
- Bagner, D. M., Graziano, P. A., Jaccard, J., Sheinkopf, S. J., Vohr, B. R., & Lester, B. M. (2012). An initial investigation of baseline respiratory sinus arrhythmia as a moderator of treatment outcome for young children born premature with externalizing behavior problems. *Behaviour Therapy*, 43, 652-665. doi:10.1016/j.beth.2011.12.002
- Bagner, D. M., Sheinkopf, S. J., Vohr, B. R., & Lester, B. M. (2010). Parenting intervention for externalizing behavior problems in children born premature: An initial examination. *Journal of Developmental and Behavioral Pediatrics*, 31, 209-216. doi:10.1097/DBP.0b013e3181d5a294
- Bar-Haim, Y., Marshall, P., & Fox, N. (2000). Developmental changes in heart period and high-frequency heart period variability from 4 months to 4 years of age. *Developmental Psychobiology*, 37, 44–56. doi: 10.1002/1098-2302(200007)37:1<44::AID-DEV6>3.0.CO;2-7

- Beauchaine, T. (2001). Vagal tone, development, and Gray's motivational theory: Toward an integrated model of autonomic nervous system functioning in psychopathology. *Development and Psychopathology, 13*, 183-214. doi:10.1017/S0954579401002012
- Beauchaine, T. P., Gatzke-Kopp, L., Neuhaus, E., Chipman, J., Reid, M. J., & Webster-Stratton, C. (2013). Sympathetic- and parasympathetic-linked cardiac function and prediction of externalizing behavior, emotion regulation, and prosocial behavior among preschoolers treated for ADHD. *Journal Of Consulting And Clinical Psychology, 81*, 481-493. doi:10.1037/a0032302
- Beauchaine, T. P., Hong, J., & Marsh, P. (2008). Sex differences in autonomic correlates of conduct problems and aggression. *Journal of the American Academy of Child & Adolescent Psychiatry, 47*, 788-796. doi:10.1097/CHI.0b013e318172ef4b
- Berntson, G. G., Bigger, T., Eckberg, D. L., Grossman, P., Kaufmann, P. G.,... Van der Molen, M. W. (1997). Heart rate variability: Origins, methods, and interpretive caveats. *Psychophysiology, 34*, 623-48. doi:10.1111/j.1469-8986.1997.tb02140.x
- Berntson, G. G., Cacioppo, J. T., Quigley, K. (1991). Autonomic determinism: The models of autonomic control, the doctrine of autonomic space, and the laws of autonomic constraint. *Psychological Review, 98*, 459-487. doi:10.1037/0033-295X.98.4.459
- Berntson, G. G., Cacioppo, J. T., Quigley, K. (1993). Respiratory sinus arrhythmia: Autonomic origins, physiological mechanisms, and psychophysiological

implications. *Psychophysiology*, 30, 183-196. doi:10.1111/j.1469-8986.1993.tb01731.x

Blair, C. (2003). Behavioral inhibition and behavioral activation in young children: relations with self-regulation and adaptation to preschool in children attending Head Start. *Developmental Psychobiology*, 42, 301-311. doi:10.1002/dev.10103

Blair, C., & Peters, R. (2003). Physiological and neurocognitive correlates of adaptive behavior in preschool among children in Head Start. *Developmental Neuropsychology*, 24, 479–497. doi:10.1207/S15326942DN2401_04

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, 1110–1123. doi:10.1037/0012-1649.44.4.1110

Boyce, W. T., Quas, J., Alkon, A., Smider, N. A., Essex, M. J., Kupfer, D. J., ...

Steinberg, L. (2001). Autonomic reactivity and psychopathology in middle childhood. *British Journal of Psychiatry*, 179, 144–150. doi:10.1192/bjp.179.2.144

Boylan, K., Georgiades, K., & Szatmari, P. (2010). The Longitudinal Association Between Oppositional and Depressive Symptoms Across Childhood. *Journal of the American Academy of Child & Adolescent Psychiatry*, 49, 10. doi:10.1097/00004583-201002000-00009

- Boylan, K., Vaillancourt, T., Boyle, M., & Szatmari, P. (2007). Comorbidity of internalizing disorders in children with oppositional defiant disorder. *European Child and Adolescent Psychiatry, 16*, 484-494. doi: 10.1007/s00787-007-0624-1
- Briggs-Gowan, M.J., Carter, A.S., Bosson-Heenan, J., Guyer, A.E., & Horwitz, S.M. (2006). Are infant-toddler social-emotional and behavioral problems transient? *Journal of the American Academy of Child and Adolescent Psychiatry, 45*, 849-858. doi:10.1097/01.chi.0000220849.48650.59
- Briggs-Gowan, M. J., Carter, S., & Schwab-Stone, M. (1996). Discrepancies among mother, child, and teacher reports: examining the contributions of maternal depression and anxiety. *Journal of Abnormal Child Psychology, 24*, 749–765. doi:10.1007/BF01664738
- Brooker, R. J., & Buss, K. A. (2010). Dynamic measures of RSA predict distress and regulation in toddlers. *Developmental Psychobiology, 52*, 372–382. doi:10.1002/dev.20432
- Brown, T. A., & Barlow, D. H. (2009). A proposal for a dimensional classification system based on the shared features of the DSM-IV anxiety and mood disorders: implications for assessment and treatment. *Psychological Assessment, 21*, 256–271. doi:10.1037/a0016608
- Bunte, T. L., Schoemaker, K., Hessen, D. J., Heijden, P. G. M., & Matthys, W. (2013). Clinical usefulness of the kiddie-disruptive behavior disorder schedule in the diagnosis of DBD and ADHD in preschool children. *Journal of Abnormal Child Psychology* doi:10.1007/s10802-013-9732-1

- Bush, N. R., Alkon, A., Obradovic, J., Stamperdahl, J., & Boyce, W. T. (2011). Differentiating challenge reactivity from psychomotor activity in studies of children's psychophysiology: considerations for theory and measurement. *Journal of Experimental Child Psychology, 110*, 62-79. doi:10.1016/j.jecp.2011.03.004
- Byrne, E. A., Fleg, J. L., Vaitkevicius, P. V, Wright, J., & Porges, S. W. (1996). Role of aerobic capacity and body mass index in the age-associated decline in heart rate variability. *Journal of Applied Physiology, 81*, 743–750.
- Calkins, S. D. (1997). Cardiac vagal tone indices of temperamental reactivity and behavioral regulation in young children. *Developmental Psychobiology, 31*, 125-135. doi:10.1002/(SICI)1098-2302(199709)31:2<125::AID-DEV5>3.0.CO;2-M
- Calkins, S. D., & Dedmon, S. E. (2000). Physiological and Behavioral Regulation in Two-Year-Old Children with Aggressive/Destructive Behavior Problems, *28*, 103–118. doi:10.1023/A:1005112912906
- Calkins, S. D., Graziano, P. A., Berdan, L. E., Keane, S. P., & Degnan, K. A. (2008). Predicting cardiac vagal regulation in early childhood from maternal-child relationship quality during toddlerhood. *Developmental Psychobiology, 50*, 751-766. doi:10.1002/dev.20344
- Calkins, S. D., Graziano, P. A., & Keane, S. P. (2007). Cardiac vagal regulation differentiates among children at risk for behavior problems. *Biological Psychology, 74*, 144-153. doi:10.1016/j.biopsycho.2006.09.005

- Calkins, S. D., & Keane, S. P. (2004). Cardiac vagal regulation across the preschool period: stability, continuity, and implications for childhood adjustment. *Developmental Psychobiology*, 45, 101-112. doi:10.1002/dev.20020
- Calkins, S. D., Smith, C. L., Gill, K. L., & Johnson, M. C. (1998). Maternal Interactive Style Across Contexts: Relations to Emotional, Behavioral and Physiological Regulation During Toddlerhood. *Social Development*, 7(3), 350-369. doi:10.1111/1467-9507.00072
- Carpenter, A. L., Puliafico, A. C., Kurtz, S. M. S., Pincus, D. B., & Comer, J. S. (2014). Extending Parent-Child Interaction Therapy for early childhood internalizing problems: New advances for an overlooked population. *Clinical Child and Family Psychology Review*, 17, 340-356. doi:10.1007/s10567-014-0172-4
- Carragher, N., Krueger, R. F., Eaton, N. R., & Slade, T. (2015). Disorders without borders: current and future directions in the meta-structure of mental disorders. *Social Psychiatry and Psychiatric Epidemiology*, 50(3), 339–350. doi:10.1007/s00127-014-1004-z
- Chi, T. C., & Hinshaw, S. P. (2002). Mother-child relationships of children with ADHD: The role of maternal depressive symptoms and depression-related distortions. *Journal of Abnormal Child Psychology*, 30, 387–400. doi:10.1023/A:1015770025043
- Chaplin, T. M., Cole, P. M., & Zahn-Waxler, C. (2005). Parental socialization of emotion expression: gender differences and relations to child adjustment. *Emotion*, 5, 80–88. doi:10.1037/1528-3542.5.1.80

- Chronis-Tuscano, A., Lewis-Morrarty, E., Woods, K. E., O'Brien, K. A., Mazursky-Horowitz, H., & Thomas, S. R. (2014). Parent-child interaction therapy with emotion coaching for preschoolers with attention-deficit/hyperactivity disorder. *Cognitive and Behavioral Practice*. doi:10.1016/j.cbpra.2014.11.001
- Comer, J. S., Chow, C., Chan, P., Cooper-Vince, C., & Wilson, L. A. S. (2013). Psychosocial treatment efficacy for disruptive behavior problems in young children: A meta-analytic examination. *Journal of the American Academy of Child and Adolescent Psychiatry*, 52, 26-36. doi:10.1016/j.jaac.2012.10.001
- Copeland, W. E., Miller-Johnson, S., Keeler, G., Angold, A., & Costello, E. J. (2007). Childhood psychiatric disorders and young adult crime: A prospective, population-based study. *American Journal of Psychiatry*, 164, 1668-1675. doi:10.1176/appi.ajp.2007.06122026
- Costello, E. J., Mustillo, S., Erkanli, A., Keeler, G., & Angold, A. (2003). Prevalence and development of psychiatric disorders in childhood and adolescence. *Archives of General Psychiatry*, 60, 837-844. doi:10.1001/archpsyc.60.8.837
- Crowell, S. E., Beauchaine, T. P., Gatzke-Kopp, L., Sylvers, P., Mead, H., & Chipman-Chacon, J. (2006). Autonomic correlates of attention-deficit/hyperactivity disorder and oppositional defiant disorder in preschool children. *Journal of Abnormal Psychology*, 115, 174-178. doi:10.1037/0021-843x.115.1.174
- Drabick, D. A., & Gadow, K. D. (2012). Deconstructing oppositional defiant disorder: clinic-based evidence for an anger/irritability phenotype. *Journal of the American*

Academy of Child and Adolescent Psychiatry, 51, 384-393.

doi:10.1016/j.jaac.2012.01.010

Egger, H. L., & Angold, A. (2006). Common emotional and behavioral disorders in preschool children: presentation, nosology, and epidemiology. *Journal of Child Psychology and Psychiatry, 47, 313-337.* doi:10.1111/j.1469-7610.2006.01618.x

El-Sheikh, M. (2005). Stability of respiratory sinus arrhythmia in children and young adolescents: A longitudinal examination. *Developmental Psychobiology, 46, 66-74.* doi:10.1002/dev.20036

El-Sheikh, M., Harger, J., & Whitson, S. M. (2001). Exposure to interparental conflict and children's adjustment and physical health: the moderating role of vagal tone. *Child Development, 72, 1617-1636.* doi: 10.1111/1467-8624.00369

Eyberg, S., & Pincus, D. (1990). *Eyberg Child Behavior Inventory & Sutter-Eyberg Student Behavior Inventory-Revised: Professional Manual.* Odessa, FL: Psychological Assessment Resources.

Eyberg, S. M., Funderburk, B. W., Hembree-Kigin, T. L., McNeil, C. B., Querido, J. G., & Hood, K. K. (2001). Parent-child interaction therapy with behavior problem children: One and two year maintenance of treatment effects in the family. *Child & Family Behavior Therapy, 23, 1-20.* doi:10.1300/J019v23n04_01

Eyberg, S. M., Nelson, M. M., Ginn, N. C., Bhuiyan, N., & Boggs, S. R. (2013). *Dyadic Parent-Child Interaction Coding System-Fourth Ed.* PCIT International, Inc.

- Ezpeleta, L., Granero, R., de la Osa, N., Penelo, E., & Domenech, J. M. (2012). Dimensions of oppositional defiant disorder in 3-year-old preschoolers. *Journal of Child Psychology and Psychiatry*. doi:10.1111/j.1469-7610.2012.02545.x
- Ezpeleta, L., Keeler, G., Erkanli, A., Costello, E. J., & Angold, A. (2001). Epidemiology of psychiatric disability in childhood and adolescence. *Journal of Child Psychology and Psychiatry*, 42, 901-914. doi:10.1111/1469-7610.00786
- Forehand, R. J., & McMahon, R. (2005). Helping the noncompliant child: Family-based treatment for oppositional behavior, Second Edition. New York, New York: The Guildford Press.
- Gatzke-Kopp, L. M., Greenberg, M., & Bierman, K. (2015). Children's parasympathetic reactivity to specific emotions moderates response to intervention for early-onset aggression. *Journal of Clinical Child and Adolescent Psychology*, 44, 291-304. doi:10.1080/15374416.2013.862801
- Gau, S. S. F., Chong, M. Y., Yang, P., Yen, C. F., Liang, K. Y., & Cheng, A. T. A. (2007). Psychiatric and psychosocial predictors of substance use disorders among adolescents: Longitudinal study. *British Journal of Psychiatry*, 190, 42-48. doi:10.1192/bjp.bp.106.022871
- Gentzler, A. L., Santucci, A. K., Kovacs, M., & Fox, N. A. (2009). Respiratory sinus arrhythmia reactivity predicts emotion regulation and depressive symptoms in at-risk and control children. *Biological Psychology*, 82, 156-163. doi:10.1016/j.biopsycho.2009.07.002

- Graziano, P. A., Bagner, D. M., Sheinkopf, S. J., Voehr, B. R., & Lester, B. M. (2012). Evidence-based intervention for young children born premature: preliminary evidence for associated changes in physiological regulation. *Infant Behavior and Development, 35*, 417-428. doi:10.1016/j.infbeh.2012.04.001
- Graziano, P., & Derefinko, K. (2013). Cardiac vagal control and children's adaptive functioning: A meta-analysis. *Biological Psychology, 94*, 22–37. doi:10.1016/j.biopsycho.2013.04.011
- Graziano, P. A., Keane, S. P., & Calkins, S. D. (2007). Cardiac Vagal Regulation and Early Peer Status. *Child Development, 78*, 264-278. doi:10.1111/j.1467-8624.2007.00996.x
- Grossman, P., & Taylor, E. W. (2007). Toward understanding respiratory sinus arrhythmia: Relations to cardiac vagal tone, evolution and biobehavioral functions. *Biological Psychology, 74*, 263–285. doi:10.1016/j.biopsycho.2005.11.014
- Guy, W. (1976) ECDEU Assessment Manual for Psychopharmacology – Revised. Rockville, MD: U.S. Department of Health, Education, and Welfare, Public Health Service, Alcohol, Drug Abuse, and Mental Health Administration, NIMH Psychopharmacology Research Branch, Division of Extramural Research Programs.
- Harvey, E. A., Metcalfe, L. A., Herbert, S. D., & Fanton, J. H. (2011). The role of family experiences and ADHD in the early development of oppositional defiant disorder. *Journal of Consulting and Clinical Psychology, 79*, 784–795. doi:10.1037/a0025672

- Hastings, P. D., & De, I. (2008). Parasympathetic Regulation and Parental Socialization of Emotion: Biopsychosocial Processes of Adjustment in Preschoolers. *Social Development, 17*, 211-238. doi:10.1111/j.1467-9507.2007.00422.x
- Hastings, P. D., Nuselovici, J. N., Utendale, W. T., Coutya, J., McShane, K. E., & Sullivan, C. (2008). Applying the polyvagal theory to children's emotion regulation: Social context, socialization, and adjustment. *Biological Psychology, 79*, 299–306. doi:10.1016/j.biopsycho.2008.07.005
- Hinnant, J. B., & El-Sheikh, M. (2009). Children's externalizing and internalizing symptoms over time: The role of individual differences in patterns of RSA responding. *Journal of Abnormal Child Psychology, 37*, 1049–1061. doi:10.1007/s10802-009-9341-1
- Hinnant, J. B., Erath, S. A., & El-Sheikh, M. (2015). Harsh Parenting, Parasympathetic Activity, and Development of Delinquency and Substance Use. *Journal of Abnormal Psychology, 124*, 137–151. doi:10.1037/abn0000026
- Hood, K. K., & Eyberg, S. M. (2003). Outcomes of Parent-Child Interaction Therapy: Mothers' reports of maintenance three to six years after treatment. *Journal of Clinical Child and Adolescent Psychology, 32*, 419-429. doi:10.1207/s15374424jccp3203_10
- Insel, T. R. (2014). The NIHM Research Domain Criteria (RDoC) Project: Precision medicine for psychiatry. *The American Journal of Psychiatry, 171*, 395-397. doi:10.1176/appi.ajp.2014.14020138

- Keenan, K., Boeldt, D., Chen, D., Coyne, C., Donald, R., Duax, J., ... Humphries, M. (2011). Predictive validity of DSM-IV oppositional defiant and conduct disorders in clinically referred preschoolers. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, 52, 47–55. doi:10.1111/j.1469-7610.2010.02290.x
- Keenan, K., Shaw, D., Delliquadri, E., Guivannelli, J., & Walsh, B.T. (1998). Evidence for the continuity of early problem behaviors: Application of a developmental model. *Journal of Abnormal Child Psychology*, 26, 441-452. doi:10.1023/A:1022647717926
- Keenan, K., & Wakschlag, L. S. (2004). Are oppositional defiant and conduct disorder symptoms normative behaviors in preschoolers? A comparison of referred and nonreferred children. *American Journal of Psychiatry*, 161, 356-358. doi:10.1176/appi.ajp.161.2.356
- Keenan, K., Wakschlag, L. S., Danis, B., Hill, C., Humphries, M., Duax, J., & Donald, R. (2007). Further evidence of the reliability and validity of DSM-IV ODD and CD in preschool children. *Journal of the American Academy of Child & Adolescent Psychiatry*, 46, 457-468. doi:10.1097/CHI.0b013e31803062d3
- Kim, H. W., Cho, S. C., Kim, B. N., Kim, J. W., Shin, M. S., & Yeo, J. Y. (2010). Does oppositional defiant disorder have temperament and psychopathological profiles independent of attention deficit/hyperactivity disorder? *Comprehensive Psychiatry*, 51, 412-418. doi:10.1016/j.comppsy.2009.09.002
- Kim-Cohen, J., Caspi, A., Moffitt, T. E., Harrington, H., Milne, B. J., & Poulton, R. (2003). Prior juvenile diagnoses in adults with mental disorder: Developmental

- follow-back of a prospective-longitudinal cohort. *Archives of General Psychiatry*, 60, 709-717. doi:10.1001/archpsyc.60.7.709
- Lahey, B. B., Loeber, R., Burke, J. D., & Applegate, B. (2005). Predicting future antisocial personality disorder in males from a clinical assessment in childhood. *Journal of Consulting and Clinical Psychology*, 73, 389-399. doi:10.1037/0022-006X.73.3.389
- Lavigne, J. V., Arend, R., Rosenbaum, D., Binns, H. J., Christoffel, K. K., & Gibbons, R. D. (1998). Psychiatric disorders with onset in the preschool years: I. Stability of diagnoses. *Journal of the American Academy of Child and Adolescent Psychiatry*, 37, 1246-1254. doi:10.1097/00004583-199812000-00007
- Loeber, R., Burke, J. D., Lahey, B. B., Winters, A., & Zera, M. (2000). Oppositional defiant and conduct disorder: a review of the past 10 years, part I. *Journal of the American Academy of Child Adolescent Psychiatry*, 39, 1468-1484. doi:10.1097/00004583-200012000-00007
- Luby, J., Lenze, S., & Tillman, R. (2012). A novel early intervention for preschool depression: Findings from a pilot randomized controlled trial. *Journal of Child Psychology and Psychiatry*, 53, 313-322. doi:10.1111/j.1469-7610.2011.02483.x
- McLaughlin, K.A., Alves, S., & Sheridan, M. A. (2014). Vagal regulation and internalizing psychopathology among adolescents exposed to childhood adversity. *Developmental Psychobiology*, 56, 1036–1051. doi:10.1002/dev.21187
- McLaughlin, K. A., Rith-Najarian, L., Dirks, M. A., & Sheridan, M. A. (2013). Low Vagal Tone Magnifies the Association Between Psychosocial Stress Exposure

- and Internalizing Psychopathology in Adolescents. *Journal of Clinical Child and Adolescent Psychology*, 44, 37–41. doi:10.1080/15374416.2013.843464
- Mendes, W. B. (2013). Autonomic Nervous System. In E. Harmon-Jones & J. Beer (Eds.), *Methods in the Neurobiology of Social and Personality Psychology*. Guilford Press.
- Merikangas, K. R., He, J. P., Burstein, M., Swanson, S. A., Avenevoli, S., Cui, L., ... Swendsen, J. (2010). Lifetime prevalence of mental disorders in U.S. adolescents: results from the National Comorbidity Survey Replication--Adolescent Supplement (NCS-A). *Journal of the American Academy of Child and Adolescent Psychiatry*, 49, 980–989. doi:10.1016/j.jaac.2010.05.017
- Miller, J. G., Choccol, C., Nuselovici, J. N., Utendale, W. T., Simard, M., & Hastings, P. D. (2013). Children's dynamic RSA change during anger and its relations with parenting, temperament, and control of aggression. *Biological Psychology*, 92, 417–425. doi:10.1016/j.biopsycho.2012.12.005
- Mindware Technologies (2014). Mindware Heart Rate Variability Software. V.3.1.0F. Gahanna, OH: Mindware.
- Morales, S., Beekman, C., Bandon, A. Y., Stifter, C. A., & Buss, K. (2015). Longitudinal associations between temperament and socioemotional outcomes in young children: The moderating role of RSA and gender. *Developmental Psychobiology*, 57, 105–119. doi:10.1002/dev.21267
- Musser, E. D., Galloway-Long, H. S., Frick, P. J., & Nigg, J. T. (2013). Emotion regulation and heterogeneity in attention-deficit/hyperactivity disorder. *Journal of*

the American Academy of Child and Adolescent Psychiatry, 52, 163–171.e2.

doi:10.1016/j.jaac.2012.11.009

Nock, M. K., Kazdin, A. E., Hiripi, E., & Kessler, R. C. (2007). Lifetime prevalence, correlates, and persistence of oppositional defiant disorder: results from the National Comorbidity Survey Replication. *Journal of Child Psychology*

Psychiatry, 48, 703-713. doi:10.1111/j.1469-7610.2007.01733.x

Paterson, G., & Sanson, A. (1999). The association of behavioural adjustment to temperament, parenting and family characteristics among 5-year-old children.

Social Development, 8, 293-309. doi:10.1111/1467-9507.00097

Perry, N. B., Calkins, S. D., Nelson, J. A., Leerkes, E. M., & Marcovitch, S. (2012).

Mothers' responses to children's negative emotions and child emotion regulation: the moderating role of vagal suppression. *Developmental Psychobiology*, 54, 503-

513. doi:10.1002/dev.20608

Perry, N. B., Nelson, J. A., Swingler, M. M., Leerkes, E. M., Calkins, S. D., Marcovitch,

S., & O'Brien, M. (2013). The relation between maternal emotional support and child physiological regulation across the preschool years. *Developmental*

Psychobiology, 55, 382-94. doi:10.1002/dev.21042.

Pfiffner, L. J., McBurnett, K., Rathouz, P. J., & Judice, S. (2005). Family correlates of oppositional and conduct disorders in children with attention deficit/hyperactivity

disorder. *Journal of Abnormal Child Psychology*, 33, 551–563.

doi:10.1007/s10802-005-6737-4

- Patron, E., Messerotti Benvenuti, S., Favretto, G., Valfrè, C., Bonfà, C., Gasparotto, R., & Palomba, D. (2012). Biofeedback assisted Control of respiratory sinus arrhythmia as a biobehavioral intervention for depressive symptoms in patients after cardiac surgery: A preliminary study. *Applied Psychophysiology and Biofeedback*, 1–9. doi:10.1007/s10484-012-9202-5
- Porges, S. W. (2007). The polyvagal perspective. *Biological Psychology*, 74, 116-143. doi:10.1016/j.biopsycho.2006.06.009
- Rowe, R., Costello, E. J., Angold, A., Copeland, W. E., & Maughan, B. (2010). Developmental pathways in oppositional defiant disorder and conduct disorder. *Journal of Abnormal Psychology*, 119, 726-738. doi:10.1037/a0020798
- Rowe, R., Maughan, B., Pickles, A., Costello, E. J., & Angold, A. (2002). The relationship between DSM-IV oppositional defiant disorder and conduct disorder: findings from the Great Smoky Mountains Study. *Journal of Child Psychology Psychiatry*, 43, 365-373. doi:10.1111/1469-7610.00027
- Sanders, M. R., Kirby, J. N., Tellegen, C. L., & Day, J. J. (2014). The Triple P-Positive Parenting Program: A systematic review and meta-analysis of a multi-level system of parenting support. *Clinical Psychology Review*, 34, 337-357. doi:10.1016/j.cpr.2014.04.003
- Schuhmann, E. M., Foote, R. C., Eyberg, S. M., Boggs, S. R., & Algina, J. (1998). Efficacy of parent-child interaction therapy: Interim report of a randomized trial with short-term maintenance. *Journal of Clinical Child Psychology*, 27, 34-45. doi:10.1207/s15374424jccp2701_4

- Shaffer, D., Fisher, P., Lucas, C. P., Dulcan, M. K., & Schwab-Stone, M. E. (2000). NIMH Diagnostic Interview Schedule for Children Version IV (NIMH DISC-IV): description, differences from previous versions, and reliability of some common diagnoses. *Journal of the American Academy of Child and Adolescent Psychiatry*, 39, 28–38. doi:10.1097/00004583-200001000-00014
- Shaw, D., Gilliom, M., Ingoldsby, E., & Nagin, D. (2003). Trajectories leading to school-age conduct problems. *Developmental Psychology*, 39, 189-200. doi:10.1037/0012-1649.39.2.189
- Skowron, E. A., Cipriano-Essel, E., Gatzke-Kopp, L. M., Teti, D. M., Ammerman, R. T. (2014). Early adversity, RSA, and inhibitory control: evidence of children's neurobiological sensitivity to social context. *Developmental Psychobiology*, 56, 964-78. doi:10.1002/dev.21175.
- Stringaris, A., & Goodman, R. (2009). Longitudinal outcome of youth oppositionality: irritable, headstrong, and hurtful behaviors have distinctive predictions. *Journal of the American Academy of Child and Adolescent Psychiatry*, 48, 404-412. doi:10.1097/CHI.0b013e3181984f30
- Stringaris, A., Maughan, B., & Goodman, R. (2010). What's in a disruptive disorder? Temperamental antecedents of oppositional defiant disorder: findings from the Avon longitudinal study. *Journal of the American Academy of Child Adolescent Psychiatry*, 49, 474-483. doi:10.1097/00004583-201005000-00008

- Thayer, J. F., & Lane, R. D. (2000). A model of neurovisceral integration in ER and dysregulation. *Journal of Affective Disorders*, *61*, 201–216. doi:10.1016/S0165-0327(00)00338-4
- Tremblay, R., Nagin, D., Seguin, J., Zoccolillo, M., Zelazo, P., Boivin, M.,...Japel, C. (2004). Physical aggression during early childhood: Trajectories and predictors. *Pediatrics*, *114*, 43-50. doi: 10.1542/peds.114.1.e43
- Utendale, W. T., Nuselovici, J., Saint-Pierre, A. B., Hubert, M., Chochol, C., & Hastings, P. D. (2014). Associations between inhibitory control, respiratory sinus arrhythmia, and externalizing problems in early childhood. *Developmental Psychobiology* *56*, 686–699. doi:10.1002/dev.21136
- Webster-Stratton, C. (2005). The Incredible Years: A Training Series for the Prevention and Treatment of Conduct Problems in Young Children. In E. D. Hibbs, P. S. Jensen, E. D. Hibbs, P. S. Jensen (Eds.), *Psychosocial treatments for child and adolescent disorders: Empirically based strategies for clinical practice (2nd ed.)* (pp. 507-555). Washington, DC, US: American Psychological Association.
- Witkiewitz, K., King, K., McMahon, R. J., Wu, J., Luk, J., Bierman, K. L., ... Pinderhughes, E. E. (2013). Evidence for a multi-dimensional latent structural model of externalizing disorders. *Journal of Abnormal Child Psychology*, *41*, 223–237. doi:10.1007/s10802-012-9674-z
- Wolff, B. C., Wadsworth, M. E., Wilhelm, F. H., & Mauss, I. B. (2012). Children's vagal regulatory capacity predicts attenuated sympathetic stress reactivity in a socially supportive context: Evidence for a protective effect of the vagal system.

Development and Psychopathology, 24, 677–689.

doi:10.1017/S0954579412000247

Zucker, T. L., Samuelson, K. W., Muench, F., Greenberg, M. A., & Gevirtz, R. N. (2009). The effects of respiratory sinus arrhythmia biofeedback on heart rate variability and posttraumatic stress disorder symptoms: a pilot study. *Applied Psychophysiology and Biofeedback*, 34, 135–143. doi:10.1007/s10484-009-9085-2

Curriculum Vitae

Christine E. Cooper-Vince, M.A.

Massachusetts General Hospital
15 Parkman St, WACC-815
Boston, MA 02114

EDUCATION

2014-2015	Predoctoral Internship	Massachusetts General Hospital/ Harvard Medical School	Clinical Psychology
		Training Track: <i>Cognitive Behavioral Scientist</i>	
Expected 2015	Ph.D.	Boston University	Clinical Psychology
2010	M.A.	Boston University	Psychology
2007	B.A.	Connecticut College	Major: Psychology
2005		School for International Training	Semester Abroad
		Melbourne, Australia	

ACADEMIC APPOINTMENTS

2013-2014	Visiting Scholar, Center for Children and Families, Florida International University, Miami, FL
-----------	--

PEER-REVIEWED PUBLICATIONS

-
1. Chou, T., Cornacchio, D., **Cooper-Vince, C.E.**, Crum, K., & Comer, J.S. (2015). DSM-5 and the assessment of childhood anxiety disorders: Meaningful progress, new problems, or persistent quagmires? *Psychopathology Review*, 2, 30-51.
 2. Comer, J.S., Furr, J.M., **Cooper-Vince, C.E.**, Madigan, R.M., Chow, C.W., Chan, P.T., Idrobo, F., Chase, R.M., McNeil, C.B., & Eyberg, S.M. (In Press). Rationale and considerations for the Internet-based delivery of Parent-Child Interaction Therapy. *Cognitive and Behavioral Practice*.
 3. **Cooper-Vince, C.E.**, Chan, P.T., Pincus, D., & Comer, J.S. (2014). Paternal autonomy restriction, neighborhood safety, and child anxiety across time in a large multiphase sample of community youth. *Journal of Applied Developmental Psychology*, 35, 265-272.
 4. **Cooper-Vince, C.E.**, Pincus, D., & Comer, J.S. (2014). Maternal intrusiveness, family financial means, and anxiety across childhood in a large multiphase sample of community youth. *Journal of Abnormal Child Psychology*, 42, 429-438. doi: 10.1007/s10802-013-9790-4
 5. **Cooper-Vince, C.E.**, Emmert-Aaronson, B., Pincus, D., & Comer, J.S. (2013). The diagnostic utility of DSM-IV separation anxiety disorder symptoms: An item response theory analysis. *Journal of Abnormal Child Psychology*, 42, 417-428.
 6. Comer, J.S., Furr, J.M., **Cooper-Vince, C.E.**, Kerns, C.E., Chan, P.T., Edson,

- A.L., Khanna, M., Franklin, M.E., Garcia, A.M., & Freeman, J.B. (2013). Internet-delivered, family-based treatment for early-onset OCD: A preliminary case series. *Journal of Clinical Child and Adolescent Psychology*.
7. Gallo, K.P., **Cooper-Vince, C.E.**, Hardway, C.L., Pincus, D.B., & Comer, J.S. (2013). Trajectories of change across outcomes in intensive treatment for adolescent panic disorder and agoraphobia. *Journal of Clinical Child and Adolescent Psychology*. Advance online publication. doi: 10.1080/15374416.2013.794701
 8. Leyfer, O., Gallo, K.P., **Cooper-Vince, C.E.**, & Pincus, D. (2013). Comorbidity of DSM-IV anxiety disorders in a clinical sample of children and adolescents. *Journal of Anxiety Disorders, 27*, 306-311. doi: 10.1016/j.janxdis.2013.01.010
 9. Comer, J.S., Chow, C., Chan, P.T., **Cooper-Vince, C.E.**, & Wilson, L.A. (2013). Psychosocial treatment efficacy for disruptive behavior problems in very young children: A meta-analytic examination. *Journal of the American Academy of Child and Adolescent Psychiatry, 52*, 26-36. doi: 10.1016/j.jaac.2012.10.001
 10. Safren, S.A., Sprich, S.E., **Cooper-Vince, C.E.**, Knouse, L.E., & Lerner, J.A. (2010). Life impairments in adults with medication-treated ADHD. *Journal of Attention Disorders, 13*, 524-531. doi: 10.1177/1087054709332460
 11. Sprich, S.E., Knouse, L.E., **Cooper-Vince, C.E.**, Burbridge, J., & Safren, S.A. (2010). Description and demonstration of CBT for ADHD in adults. *Cognitive and Behavioral Practice, 17*, 9-15. doi: 10.1016/j.cbpra.2009.09.002
 12. Knouse, L.E., Sprich, S.E., **Cooper-Vince, C.E.**, & Safren, S.A. (2009). ADHD symptom profiles in medication-treated adults entering a psychosocial treatment program. *Journal of ADHD and Related Disorders, 1*, 34-48.
 13. Knouse, L.E., **Cooper-Vince, C.E.**, Sprich, S.E., & Safren, S.A. (2008). Recent developments in the psychosocial treatment of adult ADHD. *Expert Review of Neurotherapeutics, 8*, 1537-1548. doi: 10.1586/14737175.8.10.1537

PRESENTATIONS (Selected from over 20)

1. **Cooper-Vince, C.E.**, Comer, J.S., Furr, J.M., Franklin, M.E., Khanna, M., Marrs Garcia, A., & Freeman, J. (2014, November). Paper presented at the meeting of the Association for Behavioral and Cognitive Therapies, Philadelphia, PA.
2. **Cooper-Vince, C.E.**, McLaughlin, K.A., Cornacchio, D. & Comer, J.S. (2014, November). Psychophysiological Correlates of Oppositionality and Noncompliance in Very Young Children During Interactions with Parents and Other Adults. Paper presented at the meeting of the Association for Behavioral and Cognitive Therapies, Philadelphia, PA.
3. **Cooper-Vince, C.E.**, Emmert-Aaronson, B., Pincus, D., & Langer, D.A. (2014, May). The Classification of Specific Phobias in Childhood. Paper presented at the meeting of the Association for Psychological Science, San Francisco, CA.
4. **Cooper-Vince, C.E.**, Comer, J.S., Furr, J.M., Franklin, M.E., Khanna, M., Marrs Garcia, A., & Freeman, J. (2013, November). *Internet-delivered treatment for early-onset OCD: A pilot feasibility trial*. Paper presented at the meeting of the Association for Behavioral and Cognitive Therapies, Nashville, TN.

5. **Cooper-Vince, C.E.**, Kerns, C.E., Cheron, D.M., Whitton, S., Pincus, D., & Comer, J.S. (2013, November). *The psychometric properties of the Parental Behavioral Control Scale in a sample of anxious youth*. Poster session presented at the meeting of the Association for Behavioral and Cognitive Therapies, Nashville, TN.
6. Comer, J.S., & **Cooper-Vince, C.E.**, Chan, P.T., Edson, A.L., Elkins, M.E., Furr, J.M., Kerns, C., & Madigan, R. (2013, September). *Internet-based Parent-Child Interaction Therapy Delivered to the home: Clinical considerations and preliminary findings*. Paper presented at the meeting of PCIT International, Boston, MA.
7. **Cooper-Vince, C.E.**, Puliafico, A.C., & Comer, J.S. (2013, June). *Adapting Parent-Child Interaction Therapy for Early Childhood Anxiety: The PCIT CALM Program*. Paper presented at the meeting of the International Society for Research in Child and Adolescent Psychopathology, Leuven, Brussels.
8. Boisseau, C.L., **Cooper-Vince, C.E.**, Graham, J.R., Kelly, S., Polo, A., Roemer, L., & Woodward, E. (2012, November). In K.P. Gallo (Chair), *A Commitment to Diversity: Diversity initiatives in clinical psychology training programs*. Panel discussion conducted at the meeting of the Association for Behavioral and Cognitive Therapies, National Harbor, MD
9. ***Cooper-Vince, C.E.**, Pincus, D., & Comer, J.S. (2012, November). *The interaction of neighborhood safety and paternal autonomy restriction in the prediction of child anxiety*. Poster session presented at the meeting of the Association for Behavioral and Cognitive Therapies, National Harbor, MD.
*Awarded Association of Behavioral and Cognitive Therapies Child Anxiety Special Interest Group 2012 Poster Award.
10. Comer, J.S., Furr, J.M., **Cooper-Vince, C.E.**, McNeil, C.B., & Eyberg, S.M. (2012, November). *Development of an internet-delivered protocol for Parent-Child Interaction Therapy: Implications of real-time feedback in technology-assisted intervention*. Paper presented at the meeting of the Association for Behavioral and Cognitive Therapies, National Harbor, MD.
11. **Cooper-Vince, C.E.**, Chow, C.W., Pincus, D.B., & Comer, J.S. (2012, August). *Income level and the relationship between parental intrusiveness and the developmental trajectory of anxiety in childhood*. Paper presented at the meeting of the European Association for Behavioral and Cognitive Therapies, Geneva, Switzerland.
12. **Cooper-Vince, C.E.**, Emmert-Aaronson, B., Pincus, D., & Comer, J.S. (2012, May). *The diagnostic utility of DSM-IV separation anxiety disorder symptoms: An item response theory analysis*. Paper presented at the meeting of the Association for Psychological Science, Chicago, IL.
13. **Cooper-Vince, C.E.**, Emmert-Aaronson, B., Pincus, D., & Comer, J.S. (2011, November). *The diagnostic utility of DSM-IV separation anxiety disorder symptoms: An item response theory analysis*. Poster session presented at the meeting of the Association for Behavioral and Cognitive Therapies, Toronto, ON, Canada.

14. Gallo, K.P., **Cooper-Vince, C.E.**, Marker, C.D., Pincus, D.B., & Comer, J.S. (2011, November). *Shape of change in an intensive treatment for adolescent panic disorder and agoraphobia*. Paper presented at the meeting of the Association for Behavioral and Cognitive Therapies, Toronto, ON, Canada.
15. Chou, T., Gallo, K., **Cooper-Vince, C.E.**, Pincus, D. & Comer, J.S. (2011, November). *Differences in clinical presentation between high and low SES families seeking specialty care for childhood anxiety disorders*. Poster session presented at the meeting of the Association for Behavioral and Cognitive Therapies, Toronto, ON, Canada.
16. **Cooper-Vince, C.E.**, & Pincus, D. (2010, November). *Effects of modified PCIT for separation anxiety disorder on collateral changes in family functioning*. Poster session presented at the meeting of the Association for Behavioral and Cognitive Therapies, San Francisco, CA.
17. **Cooper-Vince, C.E.**, & Pincus, D. (2010, November). *The relationship between experiential avoidance and parental behavioral control in mothers of anxious children*. Poster session presented at the meeting of the Association for Behavioral and Cognitive Therapies, San Francisco, CA.
18. Pincus, D., Chase, R., Chow, C., Weiner, C., **Cooper-Vince, C.E.**, & Eyberg, S. (2010, November). *Efficacy of modified parent-child interaction therapy for young children with separation anxiety disorder*. Paper presented at the meeting of the Association for Behavioral and Cognitive Therapies, San Francisco, CA.
19. Gallo, K., **Cooper-Vince, C.E.**, Leyfer, O., & Pincus, D. (2010, June). *Comorbid diagnoses in youth with anxiety disorders*. Poster session presented at the meeting of the World Congress of Behavioral and Cognitive Therapies, Boston, MA.

HONORS AND AWARDS

2013	Clara Mayo Memorial Fellowship, Boston University
2012	Association of Behavioral and Cognitive Therapies Child Anxiety Special Interest Group 2012 Poster Award
2007	Graduated Magna Cum Laude from Connecticut College
2007	Graduated with Honors in Psychology from Connecticut College
2005-2007	Member of Psi Chi National Psychology Honor Society
2003-2007	Dean's List, all semesters

FELLOWSHIP AND GRANT SUPPORT

2013-2015	Clara Mayo Memorial Fellowship Boston University Psychology Department "Psychophysiological Correlates of Oppositionality and Noncompliance in Preschool Children during Interactions with Parents and Other Adults", \$5,475
-----------	---