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BRIEF REPORT

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Parasympathetic reactivity and disruptive behavior problems in young children during interactions with their mothers and other adults: A preliminary investigation

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Abstract

Parasympathetic nervous system influences on cardiac functions—commonly indexed via respiratory sinus arrhythmia (RSA)—are central to self-regulation. RSA suppression during challenging emotional and cognitive tasks is often associated with better emotional and behavioral functioning in preschoolers. However, the links between RSA suppression and child behavior across various challenging interpersonal contexts remains unclear. The present study experimentally evaluated the relationship between child RSA reactivity to adult (mother vs. study staff) direction and disruptive behavior problems in children ages 3–8 with varying levels of disruptive behavior problems ($N = 43$). Reduced RSA suppression in the context of mothers' play-based direction was associated with more severe child behavior problems. In contrast, RSA suppression in the context of staff play-based direction was not associated with behavior problems. Findings suggest that the association between RSA suppression and child behavior problems may vary by social context (i.e., mother vs. other adult direction-givers). Findings are discussed in regard to RSA as an indicator of autonomic self-regulation that has relevance to child disruptive behavior problems.

KEYWORDS
disruptive behavior, noncompliance, parent–child interaction, psychophysiology, RSA

1 | INTRODUCTION

Disruptive behavior problems are common in children (Costello, Mustillo, Erkanli, Keeler, & Angold, 2003; Merikangas et al., 2010), and show considerable stability over time (Briggs-Gowan, Carter, Bosson-Heenan, Guyer, & Horwitz, 2006; Keenan et al., 2011; Lavigne et al., 1998). Functioning of the autonomic nervous system (ANS) —comprised of the sympathetic (SNS) and parasympathetic nervous systems (PNS)—may underlie early temperamental difficulties and interact with the parenting environment to contribute to disruptive behavior in early childhood (Blandon, Calkins, Keane, & O'Brien, 2010; Morales, Beekman, Blandon, Stifter, & Buss, 2015). High frequency rhythmic variation in heart rate that occurs within a respiration cycle—Respiratory Sinus Arrhythmia (RSA)—is used as a non-invasive index of parasympathetic cardiac influence (Appelhans & Luecken, 2006; Berntson, Cacioppo, & Quigley, 1993; Berntson et al., 1997).

1.1 | RSA reactivity and self-regulation

RSA reactivity refers RSA change in response to environmental changes. RSA suppression in response to challenge or threat is thought to represent allocation of metabolic resources away from maintenance of homeostasis and toward mobilization of resources to meet environmental demands (Porges, 2007; Grossman & Taylor, 2007; Thayer & Lane, 2000). RSA suppression during challenging tasks has been identified as a marker of self-regulatory processes (Beauchaine, 2001; Porges, 2007; Thayer & Lane, 2000). Lower RSA suppression in response to emotionally and cognitively challenging tasks is often linked with poorer child emotion regulation, attentional control, and externalizing problems (Blair, 2003; Boyce et al., 2001; Calkins & Keane, 2004; Calkins, Smith, Gill, & Johnson, 1998; El-Sheikh, Harger, & Whitson, 2001; Gentzler, Santucci, Kovacs, & Fox, 2009). However, these associations are not consistently found among more severely symptomatic preschoolers—in fact, greater (and potentially excessive) RSA suppression has been associated with early behavior problems in some studies (Beauchaine et al., 2013; Crowell et al., 2006; Gatzke-Kopp, Greenberg, & Bierman, 2015; Utendale et al., 2014).

Some heterogeneity in the relationship between RSA reactivity and child externalizing psychopathology may also be due to variations in the social context of tasks in which cardiac influences are evaluated. Polyvagal Theory (Porges, 2007) asserts that the PNS is involved in regulation of muscle movements in the face and head (e.g., eye contact, smiling) necessary for social communication. As such, maintenance of the vagal break to achieve a calmer visceral state (i.e., less RSA suppression), promotes social engagement. In fact, in dyadic play-based tasks (e.g., block/puzzle building, cleanup, and peer play) behavioral and social problems have been linked to both greater RSA suppression (Beauchaine et al., 2013; Hastings et al., 2008) and less RSA suppression (Calkins & Keane, 2004; Calkins et al., 2008). Thus, it remains unclear if divergent RSA reactivity patterns drive compliance with direction and reciprocal social engagement, both of which are needed for successful behavioral interactions with caregivers. Furthermore, the type of adult with whom interaction tasks are completed may impact the function of RSA reactivity as children tend to exhibit greater RSA suppression when interacting with a parent versus a non-parental adult (Calkins & Keane, 2004; Calkins et al., 2008). This may be attributed, in part, to the social demands of interacting with a new adult.

Though RSA suppression may serve as a biological marker of behavioral self-regulation, important questions central to understanding self-regulatory processes driving early childhood behavior problems remain. First, most evaluations have not examined RSA suppression in the context of observed noncompliance, a core feature of disruptive behavior disorders (Keenan & Wakschlag, 2004). Second, RSA suppression has been measured from resting baseline to challenge task, potentially confounding suppression scores with effects of attentional deployment and increased motor demands of task engagement (Bush, Alkon, Obradovic, Stamperdahl, & Boyce, 2011). Third, no study evaluating RSA suppression has systematically varied the social context of an assessment task.

The present study experimentally evaluated associations between child RSA reactivity, child behavior problems, and child behavioral noncompliance in the context of direction-based interactions with children's mothers and non-parental adults. We hypothesized that children with greater disruptive behavior will demonstrate less RSA suppression during adult-led play tasks, and that child compliance would be positively associated with RSA suppression during adult-led play. Furthermore, we hypothesized that relationships between child RSA suppression during adult-led play and child in-task compliance will be particularly strong during play tasks with mothers and somewhat weak during play tasks with other adults, due to the increased social salience of completing a direction-based task with an unfamiliar adult that may attenuate RSA suppression.

2 | METHOD

2.1 | Participants

The sample ($N = 43$) was comprised of Miami-area children between the ages of 3 and 8 years ($M_{Age} = 4.60$; SD = 1.47) with varied levels of disruptive behavior problems, and their mothers. As behavioral interventions for early childhood disruptive behavioral problems are supported for use with children from ages 3 to 8 (Comer et al., 2013), children across this age range were included in the present study to facilitate the application of findings to early childhood interventions. Children were excluded if they had a history of pervasive developmental disorder or cardiac illness, could not speak/understand English, or their mother was <18 years or could not read/speak English. The sample was predominantly male (74%) and Hispanic/Latino (70%). Regarding race, most participants were Caucasian (81%); 7% were African-American, 2% were Asian-American, and 9% of mothers identified their child's race as "other." Mean annual household income divided by number of in-home dependents was $23,369 (SD = 15,162).

2.2 | Procedures

To ensure variability with regard to child behavior problems, a behavior problem-enhanced community sample was recruited via broad school-based and flyer-based recruitment and strategic outreach at a university-based clinic for child behavior problems ($n = 18$ families seeking care through a Parent–Child Interaction Therapy treatment trial). Following phone screening, eligible families were scheduled for a lab visit, prior to which, mother-report questionnaires were completed online. Informed consent was obtained prior to study participation.

At the lab visit, electrocardiogram (ECG) and impedance cardiography (ICG) electrodes were applied to the child, after which he/she was seated in a booster seat at the table. The assessor conducted the assessment and unobtrusively provided direction to the mother via a bug-in-the-ear device from behind a one-way mirror. The child, mother, and a female staff member remained in the playroom throughout the entire assessment. The mother and staff member each completed two adult–child interaction tasks, child-led play and adult-led play, during which child RSA and behavioral compliance were measured (see Table 1 for details). The ordering of mother versus staff interaction tasks was counterbalanced. When the mother or staff member were not actively participating in the interaction task, she was instructed to sit at the other end of the room completing paperwork. Upon participation completion, the child selected a small toy and the mother received a $50 giftcard.

2.3 | Measures

2.3.1 | General child behavior problems

General child behavior problems were assessed via mother-report on the Eyberg Child Behavior Inventory (ECBI; Eyberg & Pincus, 1990), a 36-item questionnaire measuring the frequency of behavior problems in young children, including oppositional behaviors (e.g.,

TABLE 1 Psychophysiological assessment protocol

Adult participant	Activity	Activity details	Direction given to adult participant
1	Resting RSA (RSA_R)	3-min cartoon (Spot the Dog) while seated at the table with adult	NA
1	Child-directed interaction (CDI)	5-min of child led play seated at table with markers and paper, building blocks, and a pair of Mr. Potato Heads	Follow the child's lead in playing a game of the child's choosing.
1	Physiological washout	3-min cartoon (Spot the Dog) while seated at the table with adult	NA
1	Adult-directed interaction (ADI)	5-min of adult led play seated at table with markers and paper, building blocks, and a pair of Mr. Potato Heads	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. Children ages 3–5: *use the blocks to* build 3 different color towers. Children age 6–8: *use the blocks to* build a four-walled structure with color-patterned walls.
1 & 2	Adult transition	Adult 1 leaves table and Adult 2 joins child at the table (1+ min duration)	
2	Resting RSA (RSA_R)	3-min cartoon (Spot the Dog) while seated at the table with adult	NA
2	Child-directed interaction (CDI)	5-min of child led play seated at table with markers and paper, building blocks, and a pair of Mr. Potato Heads	Follow the child's lead in playing a game of the child's choosing.
2	Physiological washout	3-min cartoon (Spot the Dog) while seated at the table with adult	NA
2	Adult-directed interaction (ADI)	5-min of adult led play seated at table with markers and paper, building blocks, and a pair of Mr. Potato Heads	Tell the child that it was the adult's turn to choose the game and then lead the child in a drawing activity to achieve a specified goal. Children ages 3–5: draw a house, a yellow sun, and a green tree. Children age 6–8: draw 4 houses, a yellow sun and 3 green trees.

"refuses to go to bed on time," and "does not obey house rules"). ECBI internal consistency was strong in the present sample ($\alpha = 0.978$).

2.3.2 | Adult direction

Adult direction was coded during CDI and ADI play tasks using the Dyadic Parent–Child Interaction Coding System-4th Ed (DPICS-IV; Eyberg, Nelson, Ginn, Bhuilyan, & Boggs, 2013). The DPICS-IV is a structured behavioral observation coding system showing strong psychometric properties that assesses parent and child behaviors during structured dyadic interactions. Adult directions are coded as "statements directing the child to perform vocal or motor behaviors, as well as internal, unobservable actions (e.g., think, decide)" (Eyberg et al., 2013, p. 43). Three trained clinical psychology doctoral students completed DPICS-IV coding and showed acceptable inter-rater reliability (71% agreement on a 20% subset of interactions).

2.3.3 | Observed child behavioral compliance

Observed child behavioral compliance during ADI tasks was also assessed via the DPICS-IV (Eyberg et al., 2013). As per DPICS-IV guidelines, child compliance with each direction was coded as *comply* (i.e., child performed the prompted behavior within 5 s of stated direction), *non-comply* (i.e., child did not perform the prompted behavior within 5 s), or *no opportunity to comply* (i.e., another interfering direction was given immediately following the direction or the direction was not clear or developmentally attainable). To afford a standardized measure of compliance across youth, a compliance ratio was generated (% compliance = # comply/# of opportunities to comply). In accordance with established criteria for child compliance within the well-supported behavioral parent training literature and for the proper use of the DPICS (Eyberg & Funderburk, 2011) that (a) define a compliant child as one who is compliant to 75% of adult commands and (b) require child compliance with 75% of parental direction for treatment graduation, children were rated within each ADI dichotomously as either compliant (>75% compliance) or non-compliant (<75% compliance) for analyses.

2.3.4 | RSA

RSA was measured with Mindware Technologies psychophysiological recording equipment (Mindware Technologies, Ltd., Gahanna OH). ECG and ICG were recorded continuously throughout interaction procedures, each sampled at a rate of 1,000 Hz. ECG electrodes were placed on the child in a modified *Lead II* configuration to allow for limb movement and minimize muscle movement and speech artifacts. For ICG, the 2 V electrodes were placed on the child's chest (below and to the right of the suprasternal notch and below the xiphoid process) while current electrodes were placed on the child's back approximately 1 inch outside of the voltage electrodes. A respiration signal was derived from z0 signal. RSA was calculated from the high frequency component (0.24–1.040 Hz) of the R-R time series in 60-s epochs using spectral analysis implemented in Mindware Heart Rate Variability Software V.3.1.0F (Mindware Technologies, 2014), following visual inspection of ECG signals and removal of artifacts. The high frequency band was set over the respiration band of 0.24–1.040 Hz to account for respiration in young children (Calkins et al., 2008; Grossman, Karemaker, & Wieling, 1991; Grossman & Taylor, 2007; Musser et al., 2013).

PNS cardiac influences were indexed via resting baseline RSA (RSA_R) and by RSA reactivity during direction-based interactions with mothers and staff. RSA_R was measured while watching a neutral 3-min video with the staff member, consistent with previous work (Bagner et al., 2012; Blair & Peters, 2003; Calkins & Keane, 2004). RSA suppression (RSA_S) analyses examined decrease in mean RSA from child-led play tasks (RSA_{CDI}) to RSA during direction-based tasks (RSA_{ADI}), calculated using the formula $RSA_S = RSA_{ADI} - RSA_{CDI}$. Accordingly, more negative RSA_S scores represent greater suppression of RSA from CDI to ADI. RSA_{CDI} scores (rather than RSA_R) were used as the baseline RSA value from which RSA_S was measured. This was done to partially account for the influence of the physical and attentional demands of adult–child play that can influence RSA scores, beyond the effects of receiving adult directions. This affords a more conservative measure of RSA reactivity specific to direction-based interactions and not simply adult–child play in general (Bush et al., 2011). RSA was calculated for 60-s epochs, and averaged across epochs to obtain mean RSA scores for each task.

2.4 | Data analysis

Continuous measures were first evaluated for outliers and normality. As a manipulation check, repeated measures ANOVA tested changes in direction frequency from CDI to ADI. Multiple regression assessed links between RSA_S, controlling for child age, sex, and RSA_{CDI}, and disruptive behavior problems and between RSA_S and child behavioral compliance. Missing data was minimal (e.g., parent-reports [$n = 2$], ECG electrode loss during play interactions with mother [$n = 1$], observed compliance with mother's play-based direction [$n = 5$] and with staff play-based direction [$n = 6$] due to video recording distortion), and was deemed missing at random as missingness was not associated with any study variables.

3 | RESULTS

3.1 | Preliminary analyses

RSA data (i.e., RSA_R: $M = 7.030$, SD = 1.142; $RSA_{CDI(M)}$: $M = 6.206$, SD = 1.030; $RSA_{ADI(M)}$: $M = 6.203$, SD = 0.911; $RSA_{CDI(S)}$: $M = 6.168$, SD = 1.117; $RSA_{ADI(S)}$: $M = 6.205$, SD = 1.067) fell within expected ranges (min 3.19, max 9.13) and showed normal distributions of residuals using the Kolmogorov–Smirnov test of normality (all $p > .05$). ECBI scores showed a non-normal distribution of residuals and were therefore log10 transformed. Parametric analyses with the ECBI were conducted with log-transformed values. On average, ECBI scores fell within the higher end of the normative range ($M = 105.634$, SD = 55.110), with 34% reporting scores in the clinical range (i.e., ≥132). Repeated measures ANOVA revealed a significant increase in maternal direction from mother CDI to mother ADI ($F(1,37) = 56.94$, $p < .001$ $M_{Change} = 10.8$), and in staff-given direction from staff CDI to staff ADI ($F(1,37) = 52.24$, $p < .001$; $M_{Change} = 10.3$).

3.2 | RSA and child behavior problems

Table 2 presents correlations between study variables. Children's RSA_S was significantly related to study variables, controlling for child age, sex, and RSA_{CDI}. Specifically, greater decreases in child RSA in the context of maternal direction (i.e., more RSA suppression) significantly predicted *fewer* child behavioral problems, whereas greater decreases in child RSA in the context of non-maternal/staff direction (i.e., more RSA suppression) was not significantly associated with child behavioral problems, but trended toward predicting *more* behavior problems (Table 3). Greater child RSA_S (i.e., more RSA suppression) in the context of maternal direction, but not in the context of non-maternal direction, also predicted observed child compliance with mother's direction (see Table 3). However, this finding should be interpreted with caution, as the overall regression model was non-significant.

4 | DISCUSSION

The present findings advance the literature on the role of RSA suppression in child behavioral self-regulation (Beauchaine, 2001; Calkins & Keane, 2004; Graziano & Derefinko, 2013; Miller et al., 2013; Musser, Galloway-Long, Frick, & Nigg, 2013) by highlighting that the relationship between RSA suppression and child behavior problems may vary by the interpersonal context in which direction are given. Reduced RSA suppression in the context of *mothers*' direction was associated with more severe general child behavioral problems. In contrast, reduced child RSA suppression in the context of *non-maternal* adult direction was not significantly related to behavior problems.

The present finding that less RSA suppression specifically in response to maternal direction is associated with more severe child behavior problems is consistent with previous work linking less RSA suppression during challenging tasks to greater 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 direction during parent–child interactions as the challenge task, while also controlling for the motor demands of those interactions. Thus, the current study speaks directly to problems of interpersonal non-compliance that are commonly at the center of clinical presentations among children with behavior

TABLE 2 Zeroorder correlations across study variables

	1	2	3	4	5	6	7	8	9
1. $RSA_{R(S)}$	–								
2. $RSA_{CDI(M)}$	0.754***	–							
3. $RSA_{CDI(S)}$	0.794***	0.929***	–						
4. $RSA_{ADI(M)}$	0.791***	0.890***	0.852***	–					
5. $RSA_{ADI(S)}$	0.780***	0.873***	0.896***	0.800***	–				
6. ECBI	−0.257	−0.204	−0.088	−0.038	−0.259	–			
7. Compliance with mother direction[a]	−0.103	0.046	0.051	−0.146	0.110	−0.370*	–		
8. Compliance with staff direction[a]	0.270	0.448**	0.394*	0.320	0.393*	−0.131	0.141	–	
9. Age	0.218	0.150	0.131	0.210	0.280	−0.350*	0.091	−0.027	–
10. Sex	0.121	0.151	0.102	0.104	0.066	−0.342*	0.058	0.189	−0.134

Note: RSA_R, resting RSA; $RSA_{CDI(M)}$, RSA during child-directed interaction with mother; $RSA_{CDI(S)}$, RSA during child-directed interaction with staff; $RSA_{ADI(M)}$, RSA during adult-directed interactions with mother; $RSA_{ADI(S)}$, RSA during adult-directed interaction with staff; ECBI, Eyberg Child Behavior Inventory; Sex is coded as 1, male; 2, female.
*$p < .05$, **$p < .01$, ***$p < .001$
[a]Compliance = 75% compliance with direction given (see Method section).

problems referred for treatment (Keenan & Wakschlag, 2004). Furthermore, the present study made an initial step toward extending previous work by demonstrating a link between reduced RSA suppression during maternal direction with actual child non-compliance with those very directions. However, this finding should be interpreted with caution, as the overall regression model did not account for a significant amount of variance in the prediction of observed child compliance. It is possible that RSA suppression specifically in response to mother-given direction may be a biomarker of adaptive behavioral regulation.

When the interpersonal context of the direction-based interaction was manipulated such that non-maternal adults gave children direction rather than mothers, the relationship between RSA suppression and child behavior problems was not significant, and in fact showed a trend in the reverse direction (i.e., greater RSA suppression predicting more behavior problems). This diverges from some prior work demonstrating that RSA suppression during challenging assessor-administered tasks is negatively associated with externalizing symptoms (Blair, 2003; Calkins et al., 1998; Calkins, Graziano, & Keane, 2007; Perry et al., 2012). However, 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, nor did these tasks require the extensive social engagement with the assessor presently required.

The lack of support for a significant relationship between RSA suppression with non-parental adults and child behavior problems could potentially be explained by attenuation of RSA in response to social demands described in the Polyvagal Theory (Porges, 2007). Porges asserts that the social engagement system links activity of the PNS to regulation of muscle movements in the face and head (e.g., eye contact, smiling) that facilitate social communication. Therefore, 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 direction from a non-parental adult increases the social salience of a task, as higher levels of social engagement behaviors (i.e., active listening, eye-contact, orientation of gaze) are needed to attend to direction given by an adult whose phrasing and presentation of direction is not familiar to the child. This may result initially in less RSA suppression to support adaptive basic social functions, followed by RSA suppression later in the task to support compliance with direction, thereby obscuring a significant relationship between RSA reactivity and child behavior problem. Similarly, previous meta-analytic work has shown that RSA suppression is unrelated to social functioning in pooled samples of clinical and community children (Graziano & Derefinko, 2013).

As the first study to experimentally manipulate adult type across an adult–child interaction task, findings reveal how the interpersonal context in which adult direction is given impacts patterns of autonomic self-regulation that underlie adaptive child functioning. Furthermore, although other studies have evaluated RSA reactivity during adult–child problem-solving and clean-up tasks (Beauchaine et al., 2013; Calkins & Dedmon, 2000; Calkins & Keane, 2004; Graziano et al., 2012), RSA reactivity in these studies has been measured as RSA change from a resting baseline to the task. Given that RSA suppression also results from increased cognitive and motor demands (Byrne, Fleg, Vaitkevicius, Wright, & Porges, 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 direction 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 approximate effects of the motor and attentional demands of play on RSA suppression were limited. Though attention and motor movement were not measured across play conditions, qualitative observations revealed that all children did engage in and complete both play tasks, which required attending to and physically manipulating the play materials.

TABLE 3 Multiple regression analysis of RSA suppression predicting child behavior problems and compliance

Variable entered	B	SE (B)	β	T
Predicting child behavior problems on ECBI				
Play direction given by mother				
Child age	−0.077	0.020	−0.497	−3.876^
Child sex	−0.202	0.064	−0.401	−3.158**
$RSA_{CDI(M)}$	0.024	0.031	0.113	0.784
$RSA_{S(M)}$	0.199	0.067	0.419	2.955**
R^2 = 0.470, $F(4,35)$ = 7.773, p = .000				
Play direction given by staff				
Child age	−0.053	0.023	−0.345	−2.335*
Child sex	−0.212	0.067	−0.420	−3.140**
$RSA_{CDI(S)}$	−0.019	0.029	−0.097	−0.677
$RSA_{S(S)}$	−0.124	0.068	−0.277	−1.827^
R^2 = 0.384, $F(4,36)$ = 5.608, p = .001				
Predicting child compliance with adult direction				
Play direction given by mother				
Child age	0.060	0.056	0.176	1.073
Child sex	0.069	0.181	0.063	0.383
$RSA_{CDI(M)}$	−0.101	0.094	−0.201	−1.083
$RSA_{S(M)}$	−0.513	0.197	−0.481	−2.612*
R^2 = 0.188, $F(4,32)$ = 1.854, p = 0.143				
Play direction given by staff				
Child age	−0.045	0.059	−0.132	−0.763
Child sex	0.146	0.173	0.136	0.844
$RSA_{CDI(S)}$	0.193	0.076	0.441	2.554*
$RSA_{S(S)}$	0.148	0.171	0.153	0.867
R^2 = 0.199, $F(4,32)$ = 1.990, p = 0.120				

Note: $RSA_{S(M)}$, RSA suppression from child-directed to adult-directed interaction with mother; $RSA_{S(S)}$, RSA suppression from child-directed to adult-directed interaction with staff; Child sex is coded as 1, male; 2, female.
*$p < .05$, **$p < .01$, ^$p < .10$

Several study limitations merit comment. First, although the sample was sufficiently powered to detect moderately sized relationships, small effects that did not reach significance may have been found to be significant in a larger sample. Furthermore, the present sample size precluded more complex, nonlinear modeling of parasympathetic processes that take into account the rate and shape of change during direction-based play tasks (Brooker & Buss, 2010; Miller et al., 2013). Additionally, although the play-tasks were differentially tailored to the developmental level of the child (ages 3–5 and 6–8), it is possible that the tasks did not present the same level of difficulty across age groups, potentially confounding results. Moreover, although child compliance was coded dichotomously for direct consistency with the parent training literature (Eyberg & Funderburk, 2011) at a criterion cutpoint of 75% compliance with adult commands, other cutpoints for compliance could have been considered and might have yielded different outcomes. For example, when examining compliance as a simple continuous variable, $RSA_{CDI(S)}$ was no longer significantly associated with child compliance with parent directions. Finally, although parallel tasks were used to account for potential influences of attentional and motor demands, it is nonetheless possible that differences across mother and staff play tasks were confounded by differences in child compliance across the tasks. Indeed, when child compliance is treated as a continuous covariate rather than as a dependent variable, the relationship between $RSA_{S(M)}$ and child ECBI score is no longer significant. However, as there was no significant difference in child compliance in response to mother versus staff direction, divergent relationships between RSA reactivity and behavioral problems across types of adult-directed tasks is unlikely to be due to differences in the level of within-task conflict across mother versus staff interactions.

The present findings have key implications for the links between RSA suppression and early childhood oppositionality. First, findings support the use of assessment methods that evaluate child RSA reactivity in ecologically valid tasks with parents. Such methods may aid the identification of young children whose autonomic self-regulatory processes place them at heightened risk for non-compliant behavior, before persistent and impairing patterns of non-compliant behavior are established. The consideration of RSA reactivity to parental direction may also help identify children 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, supported behavioral parent management training programs for early childhood disruptive behavior (see Comer et al., 2013; Eyberg et al., 2001; Forehand & McMahon, 2005; Sanders, Kirby, Tellegen, & Day, 2014; Webster-Stratton, 2005), could potentially be enhanced by inclusion or expansion of emotion-regulatory skills training for young children with disruptive behavior disorders who show limited RSA suppression in response to parental direction, to prime children for use of self-regulatory skills and create opportunities for behavioral reinforcement of skill use (e.g., Carpenter, Puliafico, Kurtz, Pincus, & Comer, 2014; Chronis-Tuscano et al., 2014; Luby, Lenze, & Tillman, 2012).

Taken together, these findings advance our understanding of autonomic self-regulatory deficits associated with child disruptive behavior problems, and suggest functional associations between RSA suppression and behavioral compliance may vary across interpersonal contexts and adult–child interaction types. Findings may also help explain within-child variations in early child disruptive behaviors observed across settings, such as at home versus childcare or school settings (Campbell, 2002; De Los Reyes, Henry, Tolan, & Wakschlag, 2009).

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