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Parent-Child Coregulation of Parasympathetic Processes Varies by Social Context and Risk for Psychopathology

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Abstract

The parasympathetic nervous system supports social interaction and varies in relation to psychopathology. However, we know little about parasympathetic processes from a dyadic framework, nor in early childhood when parent-child social interactions become more complex and child psychopathology first emerges. We hypothesized that higher risk for psychopathology (maternal psychopathology symptoms and child problem behavior) would be related to weaker concordance of respiratory sinus arrhythmia (RSA) between mothers and children ($M = 3\frac{1}{2}$ years old; $N = 47$) and that these relations could vary by social contextual demands, comparing unstructured free play, semi-structured clean-up, and structured teaching tasks. Multilevel coupled autoregressive models of RSA during parent-child interactions showed overall dynamic, positive concordance in mother-child RSA over time, but this concordance was weaker during the more structured teaching task. In contrast, higher maternal psychological aggression and child externalizing and internalizing problems were associated with weaker dyadic RSA concordance, which was weakest during unstructured free play. Higher maternal depressive symptoms were related to disrupted individual mother and child RSA but not to RSA concordance. Thus, risk for psychopathology was generally related to weaker dyadic mother-child RSA concordance in contexts with less complex structure or demands (free play, cleanup), as compared to the structured teaching task that showed weaker RSA concordance for all dyads. Implications for the meaning and utility of the construct of parent-child physiological coregulation are discussed.

Keywords

infants/children; autonomic; psychopathology; heart rate variability; social factors

According to Polyvagal theory (Porges, 2007), the parasympathetic nervous system is a primary physiological substrate of emotional and behavioral self-regulation. A common index of parasympathetic processes is respiratory sinus arrhythmia (RSA), an index of the degree of variability in heart rate associated with the respiration rate, determined by output from the vagal nerve (Berntson, Cacioppo, & Quigley, 1993). Parasympathetic processes maintain essential bodily functions while at rest via this vagal regulation of the heart, but are also thought to help facilitate regulatory processes in social interactions, such as engagement, sustained attention, and self-soothing (Porges, 2001). In early infancy when infants' emotional and behavioral regulatory skills are limited and parents must act as external regulators of infants' needs, parasympathetic physiology may play a crucial role. Parents and infants show synchrony in parasympathetic physiology (Moore & Calkins, 2004), which is believed to support the child's developing stress regulation systems (Champagne, 2008). For example, mothers and infants show time-sensitive positive concordance in heart rate that increases around episodes of positive, synchronous behavior (Feldman, Magori-Cohen, Galili, Singer, & Louzoun, 2011).

We know less, however, about parent-child coregulation of parasympathetic physiology during the preschool years. This period is salient because it is critical for the internalization of self-regulation skills (Calkins, 2007). In contrast to infants' limited self-regulatory abilities, preschoolers actively internalize regulatory skills from interactions with their parents and show greater agency in driving interactions than do infants. They are more likely to test parental limits as they exercise their burgeoning autonomy, which can lead to challenging moments. These challenging moments may influence physiological arousal as parent or child becomes stressed by the emotions or behavior of the other, which could in turn influence physiological concordance.

Preliminary evidence demonstrates that physiological concordance does continue into the preschool years. Mothers and preschoolers show dynamic positive concordance in RSA over time (Lunkenheimer et al., 2015), and correlated adrenocortical responses during stressful tasks (Sethre-Hofstad, Stansbury, & Rice, 2002). However, given the complexity of factors particular to social interactions between parents and preschoolers, more research is needed. First, as preschoolers navigate different situations with varying regulatory demands such as beginning to be more responsible for themselves (e.g., clean up after themselves) or trying new tasks (e.g., attempting a challenging puzzle), their physiological arousal may vary, which in turn may influence dyadic physiological concordance. Second, developmental psychopathology emerges during early childhood in the form of dysregulated behavior problems, which are often correlated with parent mental health symptoms such as depressive symptoms or aggression (Hoffman, Crnic, & Baker, 2006). These psychopathology risk factors are associated with parasympathetic processes in adults and children (Calkins, Graziano, & Keane, 2007). Accordingly, in the present study we reanalyzed data from prior research (Lunkenheimer et al., 2015) with the purpose of completing a significantly broader,

more integrated examination of the effects of contextual factors and risk factors within both mother and child on parent-child coregulation of parasympathetic processes in early childhood.

Parasympathetic Regulation in Social Context

Parasympathetic processes are regulatory, thus most prior research has assessed these processes in laboratory paradigms designed to elicit a regulatory response, usually by prompting challenge or distress. Most studies have utilized individual child tasks (e.g., Calkins, Graziano, & Keane, 2007; El-Sheikh, 2004; Hastings et al., 2008; Hinnant & El-Sheikh, 2009) as opposed to dyadic parent-child tasks. Dyadic parasympathetic processes have been examined primarily between mothers and infants during stressful laboratory conditions (Conradt & Ablow, 2010; Moore & Calkins, 2004). For instance, the stressful or recovery phase of the Still Face Paradigm has been associated with RSA divergence (mother RSA augmentation, infant RSA withdrawal; Moore et al., 2009; Ostlund, Measelle, Laurent, Conradt, & Ablow, 2016). But few studies have conducted explicit and systematic tests of how tasks with varying levels of challenge or structure are associated with varying patterns of parasympathetic regulation, whether individual or dyadic.

If the parasympathetic nervous system supports social interaction (Porges, 2001) and there are differences in the degree to which different social contexts elicit arousal, then different types of parent-child interactions should be associated with varying degrees of parasympathetic activation. Regulatory responses are elicited due to pressure on the system to change (Cole, Martin, & Dennis, 2004). Correspondingly, a regulatory response at the dyadic level may be prompted by tasks involving external or internal pressure on the dyad, for example, pressure to complete a dyadic goal (Lunkenheimer et al., 2016). For instance, when parents and children need to complete a task with a dyadic goal in a certain way or in a certain period of time (e.g., getting ready for school each day), these tasks may evoke stronger physiological responses than unstructured dyadic situations such as free play. We argue that the next step is to examine how dyadic physiology varies by context, given that contextual demands may affect not just individual parasympathetic responding, but also the dyadic coregulation of these processes.

Parasympathetic Regulation and Risk for Psychopathology

Atypical parasympathetic regulation has been linked to risk for psychopathology in both children and adults (Beauchaine & Thayer, 2015). Specifically, lower resting RSA, RSA reactivity, and heart rate variability have been linked to higher externalizing and internalizing symptoms in children and adults (Beauchaine, 2001; Blood et al., 2015; Crowell et al., 2005; Dietrich et al., 2007; Graziano & Derefinko, 2013; Yaptangco et al., 2015). Also, children showing excessive RSA withdrawal or RSA augmentation to challenge in the laboratory show higher levels of externalizing and/or internalizing problems (Calkins et al., 2007; Conradt et al., 2016; Hinnant & El-Sheikh, 2009; Shanahan, Calkins, Keane, Kelleher, & Suffness, 2014).

Why do we find consistent relations between the parasympathetic nervous system and psychopathology symptoms? Porges (2001; 2007) argues that dysregulated emotion plays a mechanistic role in this link. Parasympathetic processes are integral to social relationships as social encounters proceed via affiliative behaviors, requiring sustained attention and engagement. Sustained attention involves the deceleration of heart rate, mediated by the vagus nerve, which inhibits fight or flight responding by the sympathetic nervous system (SNS) when it is not adaptive (Weber et al., 1994). Fight or flight responses tend to evoke strong emotions that stem from approach (anger) or avoidance (depression) in threatening social situations (Beauchaine, Gatzke-Kopp, & Mead, 2007). Thus, dysfunction of the vagal system and SNS activation when it is inappropriate should increase risk for emotional dysregulation, and dysregulated emotion is a hallmark of psychopathology (Beauchaine, 2001). Given that this dysregulation is typically observed in the context of social situations, it becomes especially important to understand how psychopathology risk influences parasympathetic processes in the context of social interactions.

This issue is particularly relevant in early childhood because it is in this period that children develop risk for psychopathology when regulatory development goes awry (Olson & Lunkenheimer, 2009). In particular, psychopathology risk appears to be related to the absent or discordant coregulation of parasympathetic processes in early childhood. For example, one study offered evidence for risk for psychopathology influencing parent-child coregulation of parasympathetic processes in early childhood, showing that divergence in parent-child RSA over time was linked to preschoolers' higher externalizing problems (Lunkenheimer et al., 2015). Other forms of familial risk (e.g., child maltreatment) have also been linked with absent or divergent relations between mothers and preschoolers' parasympathetic processes (Creaven, Skowron, Hughes, Howard, & Loken, 2014; Giuliano, Skowron, & Berkman, 2015). More research is needed to build on this work, to understand whether dyadic parasympathetic concordance or the lack thereof acts as a dyadic biomarker of risk with its own set of unique relations with psychopathology symptoms and problem behavior in parents and children.

Differences in parasympathetic responding by social context may also vary by risk for psychopathology, given that higher-risk individuals may regulate their emotions and behaviors differently and thus experience social stressors differently (Dahl, Silk, & Siegle, 2012). For example, individuals with higher psychopathology symptoms show more difficulty recovering physiologically (less increase in RSA) from negative social interactions, compared to controls (Shahrestani, Stewart, Quintana, Hickie, & Guastella, 2015). We do not yet know if dyadic patterns of RSA differ by context and psychopathology risk in a similar manner (Porges, 2007).

Present Study

We sought to expand upon prior research on differences in parent-child RSA coregulation by children's externalizing problems (Lunkenheimer et al., 2015) to examine how risk for both externalizing and internalizing psychopathology in both parent and child interacted with the social context to contribute to the dyadic coregulation of parasympathetic processes. Thus, we reanalyzed existing data (Lunkenheimer et al., 2015) with the additions of maternal

aggression and depressive symptoms, children's internalizing problems, the influence of particular social task contexts, and the three-level multilevel models needed for the integrated analyses of within-person physiological processes, risk factor, and context. We were interested in everyday social contexts for mothers and preschoolers that varied in their degree of structure and demands, namely free play, clean-up, and teaching tasks, and whether mother-child RSA concordance within these contexts varied by psychopathology risk in the form of maternal depressive symptoms and aggression and child externalizing and internalizing problems. Participants were drawn from a community sample with levels of psychopathology symptoms typical of the broader population (roughly 10% met or exceeded clinical cutoffs).

A multilevel coupled autoregressive modeling approach was used to examine dynamic individual and dyadic parasympathetic processes over the course of 18 minutes of interaction tasks, using RSA data collected in 30-second intervals. Specifically, individual mean RSA across tasks (to account for baseline RSA levels), individuals' prior RSA at a 30-second time lag (to account for self-regulation of RSA over time), and the partner's concurrent RSA (to reflect the effect of dyadic concordance) were examined as predictors of current RSA for the target participant for each 30-second interval over the course of the interaction. Models were run separately with mothers and children as the target participant to examine differential effects for mother versus child. RSA concordance was defined as the dynamic, positive prediction of child RSA by mother RSA and vice versa over the course of the interaction. Social context and risk for psychopathology were included as between-subjects predictors.

For the effects of risk for psychopathology, we expected relations to follow patterns in the extant literature (e.g., Creaven et al., 2014), such that higher risk would be related to disrupted (weaker or negative) RSA concordance between mother and child. With respect to the combined effects of psychopathology risk and social context, we considered that the additive effect of greater risk and more contextual demands could be associated with greater disruption to dyadic concordance in RSA. However, another possibility was that more contextual demands would create challenges for all dyads, thus "evening out the playing field" between dyads at higher and lower risk for psychopathology. Given the paucity of prior literature on differences in dyadic parasympathetic processes by social context, this examination was exploratory and we made no specific hypotheses about contextual differences.

Method

Participants

Participants were 47 mother-child dyads who were part of a larger study ($N = 100$; Lunkenheimer et al., 2015). These participants were selected because they had complete RSA data for mother and child across all dyadic laboratory tasks. Race was identified as 86% White, 8% Biracial, 3% Asian, and 3% "other" race, and ethnicity was identified as 10% Hispanic or Latino ethnicity. Children (54% female) were 41 months old on average ($SD = 3$ months). Median annual family income was \$65,000 and parental education was high on average (college graduate). Mothers reported marital status as 79% married, 7%

cohabiting, 7% single, 5% separated or divorced, and 1% remarried. Recruitment occurred via flyers in preschools and businesses and through email listserves of agencies serving families. Exclusion criteria included children having a pervasive developmental disorder, parents' inability to speak and read English, or parent or child having a health condition that prohibited cardiac data collection.

Procedure

Laboratory sessions (2 ½ hours) began with the application of electrodes and a respiration strap to mothers and their children (see below). Mothers filled out questionnaires on psychopathology symptoms and child problem behavior. Mothers and children also completed three successive dyadic tasks in a set order. The unstructured Free Play task involved asking mothers and children to “play as they normally would” with a variety of toys (7 minutes). The semi-structured Clean-up task involved asking mothers to have their children clean up the toys they had just played with by putting them into a large bin using only their words (i.e., mothers were asked not to physically help the children) (5 minutes). The Teaching task was a structured puzzle task in which mothers were asked to guide children to complete three specific successive 3D wooden puzzles based on designs from a guidebook using only their words; there was also an added time pressure component and children won a prize upon completion (6 minutes). Families were compensated \$50. All facets of the study were approved by the institutional review board, and participants provided written consent (parents) and verbal assent (children) to partake in the study. See Lunkenheimer et al. (2015) for more information about study procedures.

Measures

Respiratory sinus arrhythmia (RSA)—RSA was collected via the Mindware 3000A Wireless System (Mindware Technologies, Gahanna, OH). Disposable electrocardiogram (ECG) electrodes were placed over the right clavicle and the left side below the ribcage (recording electrodes), and on the right side below the ribcage (grounding electrode). A crystal respiratory effort belt was placed below the diaphragm to monitor respiration. Electrodes were connected to handheld computers placed in backpacks worn by each participant. Handheld computers were linked wirelessly to a desktop computer in an adjacent suite, monitored by a research assistant.

ECG data was processed offline using Mindware Heart Rate Variability 3.0.13 software (Mindware Technologies, Gahanna, OH). Interbeat interval data was edited for artifacts from bodily movement or software misidentification. Misidentified heartbeats were deleted or inserted as needed. Epochs requiring more than 10% editing were dropped from analysis (4.9% or 166 out of 3384 epochs). Five dyads showed more than 10% missing data within-dyad, however these dyads did not significantly differ from other dyads in externalizing problems, $t = -.77$, $df = 45$, n.s., and thus were retained. RSA magnitude was calculated as the natural logarithm of the variance of heart period within the frequency bandpass related to respiration (0.24–1.04 Hz for children and 0.12–0.40 for adults) (Fracasso, Porges, Lamb, & Rosenberg, 1994) using Biolab 2.5 software (Mindware Technologies, Gahanna, OH). Mean RSA was calculated for each 30-sec epoch and statistical outliers were dropped from analysis (16 epochs).

There were wireless interference problems in the laboratory space such that the wireless connection was difficult to establish, or if the connection was broken (e.g., when children needed to use the bathroom mid-task), it was difficult to re-establish. Accordingly, only 47 families out of 100 in the larger study had complete and valid RSA data for all three tasks. On average, families with intact RSA data had higher annual income, $t = 2.32$, $p < .05$, older children, $t = 2.80$, $p < .01$, and children rated lower on externalizing problems by mothers, $t = -2.16$, $p < .05$.

Child externalizing and internalizing problems—Maternal ratings of externalizing and internalizing problems were collected via the Child Behavior Checklist (1.5–5; Achenbach & Rescorla, 2000). The externalizing subscale reflects impulsivity, poor attentional control, and aggressive behavior ($\alpha = .89$). Three children met criteria for clinical levels of externalizing problems ($T \geq 64$), and three children met criteria for borderline clinical levels ($60 \leq T < 63$). The internalizing subscale reflects somatic complaints, anxiety, and depression ($\alpha = .77$). One child met criteria for clinical levels of internalizing problems ($T \geq 64$) and three children met criteria for borderline clinical levels ($60 \leq T < 63$). Raw scores were used in primary analyses.

Maternal depressive symptoms—Mothers reported on their depressive symptoms on the Center for Epidemiological Studies Depression Scale (CES-D; Radloff, 1977). Items were based on how many times they had felt a certain way during the past week (e.g., “I felt that people disliked me”), where “0” = rarely or none of the time, “1” = some or a little of the time, “2” = occasionally or a moderate amount of time, and “3” = most or all of the time. The raw sum score represented the level of depressive symptoms (range = 0 to 60; $\alpha = .72$). Five mothers met criteria for clinical depression based on the CES-D cutoff score of 16.

Maternal psychological aggression—Mothers reported on their psychological aggression towards the child via the Conflict Tactics Scale – Parent-Child Version (CTS-PC; Straus, Hamby, Finkelhor, Moore, & Runyan, 1998). The psychological aggression subscale (5 items) measures parental behaviors and verbalizations intended to cause psychological distress and/or fear in the child. Mothers indicated how many times in the past year they engaged in such behaviors (e.g., “Shouted, yelled, or screamed at [the child],” “Called him/her dumb or lazy or some other name like that”), where “1” = once, “2” = twice, “3” = 3–5 times, “4” = 6–10 times, “5” = 11–20 times, “6” = more than 20 times, “7” = not in the past year, but it happened before, and “0” = this has never happened. In a community sample of 1,000 parents, this subscale was found to be internally consistent at $\alpha = .60$ (Straus et al., 1998). Cronbach’s alpha for the present sample was lower at .52, likely due to the fact that there were certain items in a short scale that no parents in the sample endorsed, e.g., “Telling the child you would send him/her away.”

Analytic Approach

The present study examined individual self-regulation and dyadic coregulation in mother and child RSA over time by fitting multilevel coupled autoregressive models in Mplus version 7.3 (Muthen & Muthen, 1998–2012). Three-level models were utilized to test how RSA varied as function of time (Level 1), task (i.e., social context; Level 2), and person (i.e.,

risk for psychopathology; Level 3). More specifically, we examined how mother and child mean RSA, self-regulation of RSA (SR; prediction of one's current RSA from one's own RSA at a 30-second lag), and concordance in RSA (CO; prediction of one's current RSA from the partner's concurrent RSA) were predicted by social context (free play, clean-up, and teaching tasks; Level 2) and risk for psychopathology (child externalizing, child internalizing, maternal depressive symptoms, and maternal psychological aggression; Level 3). Models were performed separately for each of the four risk factors and the interaction effects of each risk factor by task (i.e., two-way interactions) were examined by creating cross-level interactions between the Level 2 and 3 variables. Models accounted for potential differences in the direction and magnitude of self-regulation and coregulation effects by separately modeling effects of mother on child and of child on mother. Multilevel coupled autoregressive analyses were applied to 30-sec epochs of RSA data for 47 mothers and 47 children on a total of 18 minutes of data. Statistical power is a function of both sample size and the number of repeated measures per person (Maxwell & Delaney, 2003); accordingly, the analyses included 3384 total person-by-time observations.

Within-dyad RSA: Level 1 model—The within-dyad associations in the RSA time series data were modeled using the equations below, in which $pRSA_{ijt}$ and $cRSA_{ijt}$ denote the i^{th} parent and child's RSA values, respectively, during the j^{th} task at time t . The effects of SR in RSA from one prior time point (a 30-sec lag) are denoted by $\beta_{P,SRj}$ for parents and $\beta_{C,SRj}$ for children. The effects of concurrent CO are denoted by $\beta_{P,COj}$ and $\beta_{C,COj}$ respectively.

$$\begin{aligned} pRSA_{i,t} &= \mu_{Pi} + \beta_{P,SR1} pRSA_{i,t-1} + \beta_{P,CO} cRSA_{i,t} + \varepsilon_{Pi,t} \\ cRSA_{i,t} &= \mu_{Ci} + \beta_{C,SR1} cRSA_{i,t-1} + \beta_{C,CO} pRSA_{i,t} + \varepsilon_{Ci,t} \end{aligned} \quad (1)$$

In prior work, up to three time-lagged effects (at 30-, 60-, and 90-sec lags) have been included to reflect intraindividual variability in self-regulation of RSA, although stability in RSA over time has been demonstrated (Lunkenheimer et al, 2015). At present, we examined how RSA SR and CO were moderated by social context, which yielded an average length of 6 minutes per task (twelve 30-sec epochs). Thus, for first-order models containing one 30-sec time-lagged effect, the number of observations used to estimate the parameters was reduced from an average of 30.8 to 10.5 epochs. Note that given the time-delay embedding of the data, one observation was lost for every additional lagged 30-second epoch included, and there was also some missing RSA data. Thus, given the increase in the number of hypothesis tests performed to examine moderation by multiple factors and the reduction in the lengths of time series on which the estimates are based, only one 30-sec lag was included.

Within-dyad differences by social context: Level 2 model—To examine whether mean RSA, SR of RSA, and RSA CO differed by social context, the Level 2 equations were utilized. Three time-varying binary indicators were created for the Free Play, Clean-up and Teaching tasks, which equaled “1” during the task of interest or “0” otherwise. Models were estimated by defining one task as the reference category (i.e., Teaching) by including the

other two task indicators (i.e., Free Play and Clean-up) as Level 2 predictors. Models were then run a second time to obtain estimates for the remaining comparison (i.e., defining Free Play as the referent and including the Clean-up and Teaching task indicators).

$$\begin{aligned}\mu_{Pij} &= \gamma_{P0,Mean} + \gamma_{P1,Mean} \text{Free Play} + \alpha_{P2,Mean} \text{Cleanup} + u_{P\mu i} \\ \beta_{P,SRj} &= \gamma_{P0,SR} + \alpha_{P1,SR} \text{Free Play} + \alpha_{P2,SR} \text{Cleanup} \\ \beta_{P,COj} &= \gamma_{P0,CO} + \alpha_{P1,CO} \text{Free Play} + \alpha_{P2,CO} \text{Cleanup}\end{aligned}\quad (2)$$

These equations include binary indicators for the Free Play and Clean-up tasks, thus defining the Teaching task as the referent. The first terms in each equation (γ_{P0}) denote estimated mean RSA, SR of RSA and CO of RSA during the Teaching task. The second terms in each equation (α_{P1} , And α_{P2}) examine moderation by task (Teaching vs. Free Play and Teaching vs. Clean-up, respectively) of parents' mean RSA ($\alpha_{P,Mean}$), parents' SR of RSA ($\alpha_{P,SR}$), and RSA CO ($\alpha_{P,CO}$). Equations also include one random effect to account for heterogeneity among parents' overall mean RSA values ($u_{P\mu i}$). Similar equations were used for children except with C rather than P subscripts.

Between-dyad differences by social context and risk for psychopathology:

Level 3 model—To examine whether mean RSA, SR in RSA, and RSA CO differed by mother and child risk for psychopathology and whether these effects varied by social context, we used the Level 3 equations. Analyses were performed separately by the four risk factors: child externalizing, child internalizing, maternal depressive symptoms, and maternal psychological aggression.

$$\begin{aligned}\gamma_{P0,Mean} &= \omega_{P0,Mean} + \pi_{P0,Mean} RP_i \\ \gamma_{P0,SR} &= \omega_{P0,SR} + \pi_{P0,SR} RP_i \\ \gamma_{P0,CO} &= \omega_{P0,CO} + \pi_{P0,CO} RP_i \\ \alpha_{P1,Mean} &= \omega_{P1,Mean} + \pi_{P1,Mean} RP_i \\ \alpha_{P1,SR} &= \omega_{P1,SR} + \pi_{P1,SR} RP_i \\ \alpha_{P1,CO} &= \omega_{P1,CO} + \pi_{P1,CO} RP_i \\ \alpha_{P2,Mean} &= \omega_{P2,Mean} + \pi_{P2,Mean} RP_i \\ \alpha_{P2,SR} &= \omega_{P2,SR} + \pi_{P2,SR} RP_i \\ \alpha_{P2,CO} &= \omega_{P2,CO} + \pi_{P2,CO} RP_i \\ u_{P\mu i} &= u_{P\mu i}\end{aligned}\quad (3)$$

These equations model differences in mean RSA, mothers' SR of RSA, and RSA CO by risk for psychopathology (RP) across social contexts. Mother and child risk for psychopathology (RP_i) was grandmean centered in the Level 3 equations; thus, intercepts (denoted as γ_{P0} in Level 2 and ω_{P0} in Level 3 equations) reflect effects of mean RSA, SR in RSA, and CO of RSA for mothers and children with an average level of RP during the Teaching task. The π_{P1} and π_{P2} parameters denote the cross-level interactions, indicating whether the strength

of moderated effects attributable to RP significantly differs during the Teaching vs. Free Play task, and Teaching vs. Clean-up task, respectively. Once again, a random effect was included to account for heterogeneity among parents' overall mean RSA values ($u_{P_{it}}$), and similar equations were used for children except with C rather than P subscripts.

Results

Descriptive Analyses

Average mother and child RSA were not related to SES, maternal education, child sex, or child age, and thus were not controlled for in analyses. Average mother RSA, $D(47) = 0.56$, n.s., child RSA, $D(47) = 0.73$, n.s., and externalizing problems, $D(47) = 1.17$, n.s., were normally distributed. Maternal depressive symptoms, $D(47) = 0.27$, $p < .001$, skewness = 2.050, maternal psychological aggression, $D(47) = 0.15$, $p < .05$, skewness = 0.977, and internalizing problems, $D(47) = 0.19$, $p < .001$, skewness = 0.847, were not normally distributed and thus were log transformed prior to inclusion in primary models. After transformation, standardized skewness was less than 1.96 for each variable (0.347, -0.283, and -0.325, respectively), indicating that additional transformation would not be necessary (Ghasemi & Zahedaisl, 2012).

Descriptive statistics are shown in Table 1. In bivariate correlations, higher levels of child externalizing problems were related to lower child RSA overall, $r = -.30$, $p < .05$, and RSA during the Teaching task, $r = -.32$, $p < .05$. Higher levels of maternal depressive symptoms were marginally related to lower maternal RSA overall, $r = -.29$, $p = .053$ and during the Teaching task, $r = -.27$, $p = .077$, and related to lower maternal RSA during the Free Play task, $r = -.31$, $p < .05$. Otherwise, risk for psychopathology was not correlated with RSA overall or by task.

Primary Analyses

Multilevel coupled autoregressive analyses were performed to examine how self-regulation and coregulation of RSA varied as function of time (Level 1), task (i.e., social context; Level 2), and person (i.e., risk for psychopathology; Level 3), including the interaction effects of social context and risk for psychopathology at Level 3; findings are addressed below in this order. Statistical results are displayed in Table 2 (mother model) and Table 3 (child model).

Level 1: Main effects of time—All intercepts ($\gamma_{P/C}$) for overall mean RSA and almost all intercepts for RSA concordance were significant in predicting current RSA in both models (see Estimated Intercepts for Mean RSA and RSA Concordance during FP, CL, and TT in Tables 2 and 3). Thus, on the whole, *mothers and children displayed positive concordance in RSA over time* such that their partner's concurrent RSA positively predicted their own RSA, showing a dynamic dependence that varied across the interaction. Intercepts for RSA self-regulation (intraindividual variability) were largely not significant, indicating that overall there was no linear increase or decline in within-person RSA over time during parent-child interactions.

Level 2: Main effects of social context—There were main effects of social context on children's mean RSA: *children's mean RSA was significantly lower in the Clean-up task than in the Free Play task* in three of the four models (Figure 1; see Prediction of Mean RSA given FP vs. CL in Table 3; $b = -.386, p < .01$, $b = -.656, p < .001$, and $b = -.554, p < .001$). This finding may have reflected the child's greater arousal when performing an undesirable parent-directed task (clean up) compared with engaging in free play. There were also main effects of social context on RSA coregulation, such that *RSA concordance was weaker in the Teaching task compared to the other tasks* for mother and child models (see Prediction of RSA Concordance given FP vs. TT and CL vs. TT in Tables 2 and 3). Thus, in the context of a mother-child teaching task with external structure and pressure, mothers and children showed weaker dyadic positive concordance in RSA. There were little to no significant main effects of social context on mean RSA or self-regulation of RSA for mothers, or self-regulation of RSA for children.

Level 3: Main effects of risk for psychopathology—There were significant main effects of externalizing problems on mothers' higher mean RSA across all tasks and children's lower mean RSA during Free Play and Clean-up (see Prediction of Mean RSA given RP during FP, CL, and TT in the Child Externalizing Model in Tables 2 and 3). These findings suggest that mothers experienced lesser physiological arousal and children experienced greater physiological arousal as a function of children's higher externalizing problems, which generally did not differ by task. Higher externalizing problems were also associated with weaker concordance of RSA in both directions: the negative effect of child RSA on mother RSA during Free Play and Clean-up and the negative effect of mother RSA on child RSA during Clean-up (see Prediction of RSA Concordance given RP during FP and CL in the Child Externalizing Model in Tables 2 and 3). Higher child internalizing problems and maternal psychological aggression were also both associated with weaker RSA concordance, i.e., the negative effect of child RSA on maternal RSA, during Free Play (see Prediction of RSA Concordance given RP during FP in the Child Internalizing and Maternal Aggression Models in Table 2; $b = -.019, p < .01$, and $b = -.005, p < .05$, respectively). In the corresponding child model (Table 3), these same effects of child internalizing problems and maternal aggression on weaker RSA concordance during FP were trending in significance. Figure 2 illustrates the negative change in (or weakening of) RSA concordance as a function of risk for psychopathology, separately by social context. *In sum, three of the four risk factors for psychopathology were associated with weaker dyadic RSA concordance between mother and child, which were weakest in the unstructured free play context. The fourth risk factor, maternal depressive symptoms, was distinct: it was associated with lower mean maternal RSA across all tasks and children's lower mean RSA and declining RSA during free play, but was not associated with RSA concordance.*

Level 3: Interaction effects of social context and risk for psychopathology—Regarding the interaction effects of risk for psychopathology and social context on mother and child self-regulation of RSA, when maternal depressive symptoms were higher, mother RSA declined more over time during Clean-up and Teaching than during Free Play (see Prediction of RSA Self-Regulation given RP during FP vs. CU and FP vs. TT in the Maternal Depressive Symptoms Model in Table 2; $b = -.006, p < .05$, and $b = -.017, p < .$

01, respectively). This finding suggests that more structured and demanding tasks were more physiologically stressful for mothers with higher levels of depressive symptoms compared to less demanding tasks. When maternal psychological aggression was higher, child RSA declined more over time during Clean-up and Teaching than during Free Play. This finding suggests that more structured and demanding tasks were more physiologically stressful than less demanding tasks for children with more aggressive mothers. Regarding the coregulation of RSA, mothers and children showed stronger concordance in RSA during the Teaching task as compared to the Clean-up task when children's externalizing problems were higher, suggesting the potential benefits of more structured tasks for dyads with children with higher externalizing problems. *In sum, maternal risk for psychopathology was associated with increased individual physiological arousal in more structured and demanding dyadic contexts, depending on the risk factor and person in question. Child externalizing problems were associated with stronger dyadic RSA concordance in a more demanding and structured context, suggesting that higher levels of structure may help mothers and children to be more physiologically synchronous when children are more dysregulated.*

Discussion

Parasympathetic regulatory processes play an important role in mental health through their involvement in the social and emotional resources involved in interpersonal interactions (Beauchaine, 2001). Some argue that individual differences in parasympathetic responding are largely determined by environmental factors (Kupper et al., 2005), which in early childhood consists predominantly of daily parent-child interactions. Yet, we lack sufficient empirical evidence to understand how individual and dyadic parasympathetic processes operate in the context of these interactions. Our goals were to delineate patterns of individual and dyadic RSA during mother-preschooler interactions, examine how they varied by social context, and explore their relation to psychopathology risk, considering that parasympathetic processes have been shown to vary by psychopathology in childhood and adulthood (Beauchaine & Thayer, 2015).

When considering social context, we found both commonalities and distinctions across tasks. One commonality was that overall, mother-child dyads showed positive, dynamic concordance in RSA over time. However, this concordance was weaker during the Teaching task. This task involved the most explicit structure and complex demands, requiring mothers to teach children to complete a puzzle above the child's developmental level using only their words, and under time pressure. These demands may have produced more variability in individual parasympathetic responding, which could have weakened the concordance shown during the other tasks (Free Play and Clean-up). This finding suggests that contextual demands may add complexity and thereby reduce parasympathetic concordance between parent and child. This finding informs the future assessment of RSA coregulation, such that less demanding tasks may be more relevant when pulling for parasympathetic concordance, whereas more demanding tasks may be more relevant when examining challenges to concordance.

There were also differences by social context on children's mean RSA, namely higher RSA during Free Play and lower RSA during Cleanup, and thus notable RSA withdrawal across

these tasks. Children played with novel toys for 7 minutes and then suddenly had to clean up, and this design may have provoked a strong physiological response. This finding underscores what we already know of parasympathetic responding in moments of challenge: performing a challenging social task is more physiologically stressful or requires more regulatory resources than experiencing less challenging play time with others. This finding suggests that asking preschoolers to do something challenging and/or undesired, which parents must do frequently in early childhood, offers children an opportunity to practice self-regulation.

Children's RSA withdrawal from Free Play to Clean-up did not differ by risk for psychopathology. Thus, we did not see the RSA augmentation or excessive RSA withdrawal associated with higher risk for psychopathology that has been shown in clinical samples of children (e.g., Shanahan et al., 2014), though children with higher externalizing problems did show the lower mean RSA demonstrated in prior research with both community and clinical samples (Graziano & Derefinko, 2013). Additionally, the Clean-up and Teaching tasks were more individually physiologically stressful (in that RSA declined more across the task) than the Free Play task for select individuals at risk, namely mothers with higher levels of depressive symptoms and children of mothers with higher psychological aggression. These interaction findings were not robust and will need to be replicated, but they offer some preliminary evidence that parasympathetic responding varies by risk for psychopathology and task, specifically that more challenging tasks may be more individually physiologically stressful for those at higher risk. The question remains as to whether this greater parasympathetic activation at the individual level weakens parasympathetic concordance between interactive partners.

Prior work has shown that RSA concordance between parents and children is weakened when child externalizing problems are higher (Lunkenheimer et al., 2015). We expanded upon this work to illustrate a pattern of the individual and dyadic regulation of RSA unique to externalizing problems as compared to the other risk factors under study. Dyads with higher child externalizing problems showed a combination of higher maternal mean RSA, lower child mean RSA, weaker RSA concordance during Free Play and Cleanup, and stronger RSA concordance during the Teaching task. This pattern was opposite the main effects of social context in which Free Play and Cleanup had shown stronger concordance and the Teaching task weaker concordance. Perhaps children with higher externalizing problems were more physiologically aroused to begin with and the Free Play and Clean-up episodes did not abate this arousal. Perhaps the added structure of the teaching task, despite the additional challenge, was an organizing force in focusing the attention of more dysregulated children. Future work will be needed to explore whether variations in individual RSA contribute to weaker RSA concordance for these high-externalizing dyads (Lunkenheimer et al., 2015), given that this robust pattern of combined atypical individual and dyadic regulation of RSA was not seen with other psychopathology risk factors.

Higher child externalizing, child internalizing, and maternal psychological aggression were all related to weaker RSA concordance for mothers (and trending for children) during Free Play, and higher child externalizing was also related to weaker concordance for mothers and children during Clean-up. These findings supported our main hypothesis that concordance

would be weakened by higher risk for psychopathology, at least with respect to the Free Play and Clean-up contexts. These findings parallel prior research indicating that higher levels of familial risk are associated with weaker or negative concordance of parasympathetic processes between mother and child (Creaven et al., 2014; Lunkenheimer et al., 2015). Findings reflected both maternal effects on child RSA and child effects on maternal RSA, suggesting that neither partner was the primary driver of these effects on RSA concordance.

Higher maternal depressive symptoms were not related to RSA concordance, but were related to lower mean maternal and child RSA and declining child RSA during Free Play. Related prior work has been mixed, with maternal depression showing no effect on RSA concordance in infancy (Ostlund et al., 2016), but contributing to negative synchrony in RSA between mothers and their 7–11 year olds (Woody, Feurer, Sosoo, Hastings, & Gibb, 2016). It may be that the effects of maternal depressive symptoms on parent-child parasympathetic coregulation take more time to emerge, or that there are differences by clinical diagnosis.

Overall, given that these effects were found primarily for the Free Play and Cleanup tasks, these findings suggest that in a community sample of families, differences in risk for psychopathology may be more likely to be revealed as a function of parasympathetic physiology during contexts with less structure and/or pressure. One possibility is that because the structured, time-pressured Teaching task showed lower RSA concordance for all families, differences between higher and lower psychopathology risk were washed out in this context. Another possibility is that contexts with less structure may have allowed for greater variation in physiological responding, perhaps due to greater variation in the type of parenting, discipline, connectedness, or engagement during these tasks, which in turn disrupted RSA concordance. The present findings suggest that the effects of psychopathology risk and degree of contextual challenge were not additive in our community sample, but rather that the more structured, demanding teaching task “leveled out” the playing field for families, weakening RSA concordance for all dyads and obscuring differences by psychopathology risk.

Limitations

Our community sample was not diverse in socioeconomic status or ethnicity, thus findings may not be generalizable across varying sociodemographic groups. Also, levels of psychopathology risk were typical but low in our sample. Although we were interested in risk in typical families, more variation in risk could have offered more power to detect effects. We experienced some data loss due to wireless interference problems in the laboratory space, which was more likely when children were younger or had more behavior problems. This is likely because these children were more likely to interfere with the equipment and therefore break the wireless connection. Thus, the lower-risk nature of our sample should be considered when interpreting findings about RSA concordance. Children’s externalizing problems showed the best variable distribution of the risk factors under study, which may be why findings were most robust for this factor. Children’s behavior problems have been shown to co-occur with maternal depressive symptoms and aggression (Hoffman et al., 2006; Morris et al., 2002), which may explain why there was some shared effects on

RSA concordance across multiple risk factors; comorbidity among these factors could be considered in future research.

With respect to social context, one might argue that RSA concordance dissipated over time due to fatigue or other laboratory effects, given that concordance was weakest in the third (Teaching) task. However, there were no significant changes in concordance strength from the first to the second tasks, and there were unique cases of increases in RSA concordance from the second to the third task. Future research could consider whether changes in RSA concordance during parent-child interactions change as a function of time in a nonlinear fashion.

Given that emotion regulation is thought to be a primary mechanism by which parasympathetic processes relate to psychopathology (Beauchaine, 2012), future research could include measures of emotion regulation during real-time parent-child interactions. These processes have been shown to moderate the influence of parent-child coregulation on children's individual physiology (Blair et al., 2015). This would also serve to offer a more integrated understanding of behavioral and physiological dynamics in parent-child interactions.

Conclusion

The meaning and utility of dyadic physiological concordance as a scientific construct is still unclear: is it epiphenomenal, or mechanistic in supporting children's developing regulatory skills in early childhood? Future research that incorporates children's regulatory outcomes is needed to begin to answer this question. The present findings imply that parasympathetic concordance between typical mothers and preschoolers is normative and potentially adaptive given its negative relations with psychopathology risk across multiple risk factors and contexts. Although research supports these relations between greater physiological synchrony and more adaptive behavioral profiles, for example mother-child dyads characterized by greater maternal sensitivity and empathy (Atkinson et al., 2013; Ebisch Aureli, Bafunno, Cardone, Romani, & Merla, 2012), other studies have suggested that physiological synchrony can also be strong in insecurely attached parent-infant dyads (Smith, Woodhouse, Clark, & Skowron, 2015) and highly negative parent-adolescent dyads (Papp, Pendry, & Adam, 2009). Thus, the meaning of parent-child physiological concordance is still under investigation and likely depends on the biomarker of interest, child age, context, and levels of risk and symptomology. Until we have a better understanding of these differences, the implications for intervention, for example the use of biofeedback in family treatment, are unclear. In general, greater emphasis is needed on research that uncovers meaningful relations between the biology, behavior, and social interactions that explain developmental psychopathology (Dahl et al., 2012). Regardless, the present descriptive findings aid us in understanding how parasympathetic processes in parent-child interactions relate to developmental psychopathology in early childhood, and are informative in designing task-based assessments for the examination of individual and dyadic parasympathetic processes in parent-preschooler interactions.

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Figure 1. Differences in Model Predicted Child RSA by Social Context and Risk for Psychopathology

Note: “Above average” trajectories denote children at +1 SD above the mean for the respective psychopathology risk variable.

Epochs 1–13 = Free Play task; Epochs 14–21 = Clean-up task; Epochs 22–35 = Teaching task;

Mat. = Maternal; Dep. = Depressive symptoms; Agg. = Psychological aggression; Ext. = Externalizing behaviors.

Figure 2. Weakening of Mother-Child RSA Concordance as a Function of Risk for Psychopathology, Separately by Social Context

Note: Beta values displayed represent the model-estimated change in RSA concordance per a one-unit increase in the psychopathology risk factor of interest. Standard error bars are also displayed. Child RSA Concordance refers to maternal effects on child RSA whereas Mother RSA Concordance refers to child effects on maternal RSA. Externalizing = Children's externalizing problems; Internalizing = Children's internalizing problems; Dep Sym = Maternal depressive symptoms; Aggression = Maternal psychological aggression.

Table 1

Descriptive Data

	1	2	3	4	5	6	7	8	9	10	11	12	M	SD
1. Parent RSA Overall Mean	----												6.11	.80
2. Parent RSA Free Play	.91***	----											6.25	.84
3. Parent RSA Cleanup	.89***	.85***	----										6.03	.90
4. Parent RSA Teaching	.97***	.81***	.78***	----									6.09	.85
5. Child RSA Overall Mean	.18	.11	.18	.21	----								5.30	.96
6. Child RSA Free Play	.21	.23	.29†	.19	.75***	----							5.62	.93
7. Child RSA Cleanup	.23	.11	.30*	.24	.87***	.70***	----						5.09	1.07
8. Child RSA Teaching	.15	.08	.11	.17	.96***	.57***	.73***	----					5.23	1.08
9. Child Externalizing	.18	.17	.25	.13	-.30*	-.26†	-.25†	-.28†	----				8.98	6.23
10. Child Internalizing	.08	.06	.17	.06	-.05	.09	-.07	-.12	.34*	----			6.63	4.60
11. Maternal Dep. Symp.	-.29†	-.31*	-.22	-.27†	-.07	-.18	.04	-.15	.16	.08	----		6.11	6.70
12. Maternal Psych. Agg.	.07	.06	.18	.02	.10	-.09	-.01	.18	.20	.07	-.01	----	10.37	9.66

Note: Dep. Symp. = Depressive symptoms; Psych. Agg. = Psychological Aggression;

† $p < .10$,

* $p < .05$,

** $p < .01$,

*** $p < .001$

Table 2

Mother model

	Child Externalizing Model	Child Internalizing Model	Maternal Depressive Symptoms Model	Maternal Psychological Aggression Model
Estimated intercepts:				
During FP:				
Mean RSA	5.850 (.212)***	6.045 (.185)***	6.451 (.131)***	6.210 (.166)***
RSA Self-regulation	-.115 (.087)	-.037 (.095)	-.118 (.078)	-.056 (.083)
RSA Concordance	.289 (.069)***	.326 (.065)***	.197 (.051)***	.233 (.053)***
During CU:				
Mean RSA	5.809 (.193)***	5.975 (1.83)***	6.345 (.128)***	6.057 (.133)***
RSA Self-regulation	-.028 (.053)	-.015 (.073)	.094 (.073)	.035 (.056)
RSA Concordance	.351 (.058)***	.235 (.068)***	.217 (.058)***	.210 (.052)***
During TT:				
Mean RSA	5.730 (.020)***	5.914 (.182)***	6.301 (.132)***	6.052 (.153)***
RSA Self-regulation	.057 (.066)	.010 (.056)	.119 (.053)*	.079 (.057)
RSA Concordance	.080 (.066)	.118 (.065)†	.093 (.043)*	.118 (.053)*
Prediction of Mean RSA given:				
Main Effects:				
FP (0) vs. CU (1)	-.041 (.117)	-.069 (.112)	-.107 (.090)	-.153 (.091)†
FP (0) vs. TT (1)	-.120 (.125)	-.131 (.124)	-.150 (.107)	-.158 (.104)
CU (0) vs. TT (1)	-.079 (.124)	-.061 (.116)	-.044 (.093)	-.005 (.095)
RP during FP	.039 (.016)*	.029 (.018)	-.031 (.016)*	.001 (.007)
RP during CU	.034 (.014)*	.024 (.018)	-.031 (.016)*	.007 (.007)
RP during TT	.040 (.015)*	.026 (.018)	-.033 (.017)†	.007 (.004)
Interactions:				
RP during FP (0) vs. CU (1)	-.006 (.010)	-.005 (.014)	-.005 (.014)	.006 (.004)
RP during FP (0) vs. TT (1)	.001 (.008)	-.003 (.017)	-.003 (.017)	.003 (.005)
RP during CU (0) vs. TT (1)	.006 (.011)	.001 (.015)	.001 (.015)	-.003 (.004)
Prediction of RSA Self-Regulation given:				
Main Effects:				
FP (0) vs. CU (1)	.087 (.088)	.022 (.105)	.282 (.086)*	.091 (.076)
FP (0) vs. TT (1)	.172 (.112)	.048 (.115)	.236 (.088)**	.135 (.091)
CU (0) vs. TT (1)	.085 (.077)	.025 (.092)	-.001 (.008)	.044 (.062)
RP during FP	.009 (.006)	-.001 (.009)	.011 (.006)†	.002 (.004)
RP during CU	.007 (.006)	.011 (.010)	-.006 (.008)	.001 (.004)
RP during TT	.003 (.006)	.010 (.006)†	-.006 (.004)	.000 (.002)
Interactions:				

	Child Externalizing Model	Child Internalizing Model	Maternal Depressive Symptoms Model	Maternal Psychological Aggression Model
RP during FP (0) vs. CU (1)	-.002 (.007)	.011 (.014)	-.006 (.007)*	-.001 (.005)
RP during FP (0) vs. TT (1)	-.006 (.008)	.011 (.011)	-.017 (.006)**	-.002 (.005)
RP during CU (0) vs. TT (1)	-.005 (.007)	.000 (.011)	-.001 (.008)	-.002 (.004)
Prediction of RSA Concordance given:				
Main Effects:				
FP (0) vs. CU (1)	.062 (.080)	-.091 (.081)	.019 (.080)	-.023 (.066)
FP (0) vs. TT (1)	-.209 (.079)**	-.208 (.074)**	-.105 (.067)	-.115 (.071)
CU (0) vs. TT (1)	-.271 (.073)***	-.118 (.082)	-.124 (.064)*	-.092 (.063)
RP during FP	-.011 (.005)*	-.019 (.007)**	-.001 (.004)	-.005 (.002)*
RP during CU	-.016 (.005)**	-.005 (.009)	-.004 (.008)	-.001 (.003)
RP during TT	.001 (.005)	-.002 (.007)	-.001 (.006)	-.003 (.003)
Interactions:				
RP during FP (0) vs. CU (1)	-.005 (.007)	.015 (.011)	-.002 (.009)	.003 (.004)
RP during FP (0) vs. TT (1)	.012 (.006)†	.017 (.009)†	.001 (.008)	.002 (.003)
RP during CU (0) vs. TT (1)	.017 (.006)**	.002 (.012)	.003 (.010)	-.001 (.004)

Note: Values in table denote $b(SE)$ unless noted otherwise. FP = Free Play Task; CU = Clean-up Task; TT = Teaching Task; RP = Risk for psychopathology.

Table 3

Child model

	Child Externalizing Model	Child Internalizing Model	Maternal Depressive Symptoms Model	Maternal Psychological Aggression Model
Estimated intercepts:				
During FP:				
Mean RSA	5.562 (.137)***	5.384 (.208)***	5.639 (.206)***	5.714 (.210)***
RSA Self-regulation	0.013 (.068)	0.057 (.104)	.135 (.074) [†]	-.087 (.088)
RSA Concordance	0.264 (.053)***	0.396 (.081)***	.313 (.077)***	.317 (.067)***
During CU:				
Mean RSA	5.119 (.133)***	5.204 (.223)***	4.983 (.184)***	5.170 (.203)***
RSA Self-regulation	0.056 (.053)	-.0007 (.073)	.133 (.073) [†]	.076 (.076)
RSA Concordance	0.238 (.057)***	0.314 (.103)**	.311 (.094)**	.267 (.078)**
During TT:				
Mean RSA	5.280 (.128)***	5.350 (.203)***	5.324 (.188)***	5.180 (.191)***
RSA Self-regulation	0.110 (.029)***	0.061 (.052)	.098 (.039)*	.108 (.040)**
RSA Concordance	0.075 (.045)	0.162 (.176)*	.068 (.057)	.078 (.059)
Prediction of Mean RSA given:				
Main Effects:				
FP (0) vs. CU (1)	-.386 (.184)*	.180 (.172)	-.656 (.158)***	-.554 (.154)***
FP (0) vs. TT (1)	-.282 (.200)	-.033 (.204)	-.315 (.184) [†]	-.534 (.175)**
CU (0) vs. TT (1)	.104 (.171)	.147 (.173)	.341 (.126)**	.010 (.137)
RP during FP	-.035 (.016)*	.025 (.030)	-.020 (.027)	-.012 (.009)
RP during CU	-.041 (.018)*	-.017 (.026)	.013 (.023)	-.007 (.010)
RP during TT	-.035 (.022)	-.011 (.029)	-.008 (.024)	.007 (.009)
Interactions:				
RP during FP (0) vs. CU (1)	-.006 (.016)	-.042 (.025) [†]	.034 (.016)*	.005 (.006)
RP during FP (0) vs. TT (1)	.000 (.021)	-.036 (.031)	.012 (.016)	.020 (.008)*
RP during CU (0) vs. TT (1)	.006 (.016)	.006 (.018)	-.022 (.016)	.014 (.007)*
Prediction of RSA Self-Regulation given:				
Main Effects:				
FP (0) vs. CU (1)	.065 (.113)	-.063 (.122)	-.002 (.090)	.163 (.094) [†]
FP (0) vs. TT (1)	.035 (.091)	.004 (.114)	-.037 (.076)	.195 (.083)*
CU (0) vs. TT (1)	-.029 (.086)	.067 (.073)	-.035 (.067)	.032 (.067)
RP during FP	.001 (.006)	-.007 (.015)	-.007 (.015)**	.009 (.003)**
RP during CU	-.002 (.006)	.010 (.007)	-.013 (.007) [†]	-.002 (.003)
RP during TT	.007 (.005)	.007 (.007)	.001 (.005)	.000 (.002)
Interactions:				

	Child Externalizing Model	Child Internalizing Model	Maternal Depressive Symptoms Model	Maternal Psychological Aggression Model
RP during FP (0) vs. CU (1)	-.002 (.008)	.016 (.014)	.004 (.010)	-.010 (.004)**
RP during FP (0) vs. TT (1)	.007 (.007)	.014 (.016)	.018 (.006)**	-.009 (.004)*
RP during CU (0) vs. TT (1)	.009 (.007)	-.003 (.008)	.014 (.009)	.001 (.004)
Prediction of RSA Concordance given:				
Main Effects:				
FP (0) vs. CU (1)	.068 (.128)	-.082 (.126)	-.002 (.133)	-.050 (.097)
FP (0) vs. TT (1)	-.290 (.094)**	-.234 (.099)*	-.245 (.093)**	-.239 (.078)**
CU (0) vs. TT (1)	-.358 (.112)**	-.004 (.013)	-.243 (.107)*	-.189 (.087)*
RP during FP	-.013 (.007)	-.019 (.010)†	-.008 (.006)	-.006 (.004)†
RP during CU	-.023 (.010)*	-.008 (.014)	-.008 (.013)	-.001 (.005)
RP during TT	-.002 (.008)	-.012 (.007)†	.001 (.004)	-.001 (.003)
Interactions:				
RP during FP (0) vs. CU (1)	-.010 (.014)	.011 (.018)	.000 (.015)	.005 (.006)
RP during FP (0) vs. TT (1)	.011 (.010)	.007 (.011)	.009 (.008)	.006 (.004)
RP during CU (0) vs. TT (1)	.022 (.011)*	-.004 (.013)	.008 (.013)	.001 (.006)

Note: Values in table denote $b(SE)$ unless noted otherwise. FP = Free Play Task; CU = Clean-up Task; TT = Teaching Task; RP = Risk for psychopathology.