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Differences in Mother-Child and Father-Child RSA Synchrony: Moderation by Child Self-Regulation and Dyadic Affect

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Abstract

Parents and preschoolers show respiratory sinus arrhythmia (RSA) synchrony, but it is unclear how child self-regulation and the dyadic affective climate shape RSA synchrony and how synchrony differs for mothers and fathers. We examined child average RSA, externalizing problems, and dyadic positive affect as moderators of the synchrony of dynamic, within-epoch child and parent RSA reactivity during a challenging task. Mothers (*N*=85) and fathers (*N*=60) oversampled for familial risk participated with their 3-year-olds. For mothers, when children showed either higher externalizing or lower average RSA, negative RSA synchrony was observed as dynamic coupling of maternal RSA augmentation and child RSA withdrawal, suggesting inadequate support of the child during challenge. However, when children showed both higher externalizing and lower average RSA, indicating greater regulatory difficulties overall, positive synchrony was observed as joint RSA withdrawal. The same patterns were found for father-child RSA synchrony but instead with respect to the moderators of higher externalizing and lower dyadic positive affect. Findings suggest moderators of RSA synchrony differ by parent and shared positive affect plays a robust role in fathers' RSA reactivity and synchrony. Mothers may be more attuned to children's regulatory capacities whereas fathers may be more influenced by the immediate behavioral context.

Keywords

RSA; externalizing; fathers; synchrony; coregulation

After the birth of a child, parental physiology, behavior, and affect become increasingly synchronized to infant cues to provide external regulation of biological and social processes, thereby supporting child survival and development (Feldman, 2007). In early childhood, children continue to need external regulation around these basic functions and around parents' new behavioral expectations. However, increasing child autonomy may add challenges to the synchronization process as parent and child work out how to coordinate new behavioral patterns to meet goals. This process may be more difficult when children show dysregulation in the form of externalizing problems, which include aggressive, impulsive, and disruptive behaviors and can indicate early regulatory deficits (Olson et al., 2005). Child aggression and impulsivity can be stressful and dysregulating for parents

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(Slagt et al., 2016), and in turn, parent self-regulation deficits can exacerbate children's externalizing problems via their effects on parenting (Kim et al., 2010). These relations suggest that dysregulation in the child may prompt dysregulation in the parent and vice versa (Mackler et al., 2015), which could shape the nature of dyadic regulatory processes. However, more evidence is needed about how individual child regulatory capacities shape dyadic parent-child synchrony in early childhood.

Neurophysiological substrates of regulatory behaviors such as respiratory sinus arrhythmia (RSA; Porges, 2007) allow researchers to go under the skin to measure self-regulation in ways that are less biased by self- or observer report. Relations between parent and child RSA can be studied to understand dyadic coregulation and have emerged as an informative dimension of face-to-face interaction dynamics (Davis et al., 2017; Palumbo et al., 2017). Both individual RSA and dyadic parent-child RSA synchrony are disrupted by children's externalizing problems (Kahle et al., 2018; Lunkenheimer et al., 2015, 2018). Higher externalizing problems have been linked to atypical individual RSA reactivity in response to challenge (Graziano & Derefinko, 2013), such as RSA augmentation, an increase in RSA thought to reflect avoidance of a challenging stimulus or failure to respond to contextual demands (Boyce et al., 2001; Calkins, 2007; Porges et al., 1996). Higher child externalizing has also been linked to negative mother-child RSA synchrony during challenging laboratory tasks where mothers show RSA increases while children show RSA decreases, a pattern thought to reflect mothers not engaging to support children adequately when asked to do so (Lunkenheimer et al., 2015).

Despite evidence that externalizing problems disrupt individual and dyadic RSA, there remain major gaps in the RSA synchrony literature. First, almost all research to date has been conducted with mothers. Fathers play a key role in children's regulatory development (Rinaldi & Howe, 2012), yet we know nothing about father-child RSA synchrony in early childhood or how it differs by individual or dyadic factors. Second, prior studies have not sufficiently accounted for other factors likely to influence the moment-to-moment dynamics of RSA synchrony. For example, the child's individual physiological regulatory capacity in the context of actively challenging situations is likely to shape parent-child RSA synchrony. Further, whether the interaction is generally experienced as positive or negative, which could also reflect the level of challenge experienced, could shape the nature of dyadic RSA synchrony and the degree to which children's individual regulatory difficulties influence synchrony between parents and children.

To examine these questions about how differences in children's individual self-regulation (average RSA and externalizing problems) and the dyad (observed affective climate) influenced parent-child RSA synchrony, we employed novel dynamic analytic methods. Multilevel intradyad dynamics models (also often called "state-trait" multilevel models) accounted for the effects of these moderators and their interactions on the moment-to-moment synchrony of parent and child RSA reactivity (operationalized as related changes in RSA). RSA reactivity was modeled as deviation from one's own task average RSA within each time segment to more accurately reflect the meaning of RSA change with respect to each individual's own functioning. These relations were examined in a community population oversampled for lower income, higher parent stress, and child maltreatment risk, and during a pivotal developmental window in which parent-child interactions act as a primary socialization influence for young children (Kochanska et al., 2008). Thus, the prospective contributions of this work were to offer novel information about how child and dyadic factors influenced parent RSA reactivity and parent-child RSA synchrony in early childhood, and how these processes differed with mothers and fathers in families at risk.

Individual RSA and Externalizing Problems

RSA is an index of prefrontal cortex-modulated high-frequency heart rate variability, reflecting variation in the R-R interval heart rate time series that is related to the respiration rate (Beauchaine & Bell, 2020; Thayer & Lane, 2000). It is generally thought of as a biomarker that represents the ability to maintain physiological homeostasis, respond to stress, and regulate emotion (Beauchaine & Bell, 2020; Porges, 2007). Polyvagal theory (Porges, 2007) suggests RSA acts as a biomarker of the engagement and stress involved in socially demanding interactions with others. As part of a greater neurovisceral network, RSA also serves as a periphery measure of executive self-regulation processes (Thayer & Lane, 2000). RSA is an index of the parasympathetic nervous system, which plays an inhibitory role such that it promotes "rest and digest" processes in the body; however, when this system is disengaged and RSA decreases (i.e., RSA withdrawal), it allows the sympathetic nervous system to respond with the arousal needed to meet environmental stressors or demands (Porges, 2007). Thus, RSA withdrawal is considered a typical or adaptive response to stress, allowing activation of the "fight or flight" response. Conversely, RSA increases (i.e., RSA augmentation) in a stressful context is thought to reflect avoidance or disengagement from the stimulus, suggesting the regulatory system may be responding insufficiently to environmental demands (Porges, 2007).

The regulation of physiological arousal indexed by RSA provides support for emotion regulation (i.e., the ability to monitor, evaluate, and modify emotional responses in accordance with goals; Thompson, 1994). Thus, when RSA is dysregulated, it is thought to reflect poorer emotion regulation skills, which in turn underlie mental health symptoms (Beauchaine, 2015). Accordingly, RSA can be a biomarker of psychopathology risk in young children. This risk is often assessed in two ways. First, lower resting RSA, thought to reflect the chronic activation of the stress response, is associated with higher risk, such as higher externalizing problems in children (Hinnant & El-Sheikh, 2009). Second, RSA augmentation in the context of challenging tasks is thought to reflect the lack of engagement of the stress response and is associated with higher externalizing problems in non-clinical samples (Boyce et al., 2001; Calkins, 2007; Porges et al., 1996). For example, preschoolers who display RSA augmentation during a challenging task show the highest externalizing problems two years later (Kahle et al., 2018). But it should be noted that not all research supports these relations; for example, children's higher resting RSA has been positively related to externalizing problems in middle childhood (Dietrich et al., 2007) and higher parent resting RSA has been shown to predict higher externalizing in preschoolers (Skoranski & Lunkenheimer, 2020). In laboratory studies, higher RSA or RSA augmentation may also represent the absence of stress for that individual, making it especially important to use validated tasks that prompt a regulatory response (Lunkenheimer et al., 2017).

Parents experiencing stress in challenging parent-child interactions may also show typical or atypical RSA responses. We expect to see parent RSA withdrawal during challenging tasks that require parental engagement to help the child, particularly with young children who require ample help from parents (Lunkenheimer et al., 2019; Shih et al., 2019). Conversely, parent RSA augmentation in goal-oriented tasks with preschoolers is associated with less supportive parenting (e.g., less repair of conflict, more disengagement) (Lunkenheimer et al., 2019; Skoranski et al., 2017). There may also be distal (e.g., parents' history of maltreatment) or proximal risk factors (e.g., challenges parenting this child) that lead to parent's atypical RSA responses. For example, in maltreating mothers, the decreases in RSA that accompany positive parenting of preschoolers are followed by hostile control, suggesting these mothers find it more physiologically taxing to parent in positive ways (Skowron et al., 2013). These atypical individual parent patterns of RSA may have repercussions for dyadic RSA synchrony (Lunkenheimer et al., 2015, 2018).

Parent-Child RSA Synchrony

In early childhood, parent-child coregulation is thought to lay the foundation for children's internalization of regulatory skills (Lunkenheimer et al., 2017). One form of RSA coregulation is synchrony, which we categorize as positive synchrony (related change in the same direction, where partners increase or decrease together), negative synchrony (related change in opposite directions, where one decreases and the other increases), or asynchrony (no related change) of RSA in close temporal proximity. Mothers and children in community samples exhibit positive RSA synchrony in face-to-face interactions, linked with more supportive parenting and children's better self-regulation (Lunkenheimer et al., 2015; Skoranski et al., 2017). However, RSA synchrony may also vary by risk factor, child age, task, and/or individual differences in RSA (Davis et al., 2017; Lunkenheimer et al., 2018; Suveg et al., 2016; Suveg et al., 2019). Thus, we explored multiple moderators to better understand the influence of child and dyadic factors on parent-child RSA synchrony.

Moderators of RSA Synchrony

Externalizing Problems.—When mothers are instructed not to engage with their children in the Still Face task, children show RSA decreases (indicative of challenge) while mothers show RSA increases (indicative of disengagement; Moore et al., 2009). However, if we observe this same pattern when parents are explicitly asked to support their children, it may index insufficient parental support. In fact, this particular negative RSA synchrony pattern has been linked with higher child externalizing problems and maternal hostility (Lunkenheimer et al., 2015) within and across lab tasks (e.g., free play, cleanup; Lunkenheimer et al., 2018). This suggests parents may be overwhelmed by or fail to adequately support higher-externalizing children who may have lower regulatory capacities. This evidence is from lower-risk community samples, thus it is unclear whether findings generalize to higher-risk and clinical samples; for example, clinical studies show positive RSA synchrony may be detrimental when children are synchronized with parents with greater psychopathology (Suveg et al., 2016). It is also unclear whether these prior findings apply to father-child dyads, and whether or not moderators of RSA synchrony influence father-child dyads similarly to mother-child dyads.

Average RSA.—Higher resting RSA is generally thought to reflect the greater capacity to respond to contextual demands and thus more optimal regulatory capacities (Porges, 2007). But it is not yet clear how individual differences in child RSA shape RSA synchrony. Higher resting RSA may be beneficial in allowing for more flexibility to respond, such that a greater degree of RSA withdrawal is available during challenge (Rigoni et al., 2017), which could support synchrony if it allows for more flexible responding to a partner. In contrast, lower resting RSA, thought to reflect regulatory difficulties (Beauchaine, 2015), may constrain this range. In the present work we were interested in task average RSA instead of resting RSA to better reflect the child's typical functioning during challenging tasks, expecting that higher RSA during challenge would reflect better regulatory skills. Prior work has shown higher maternal task average RSA to be related to weaker positive synchrony with preschoolers (Skoranski et al., 2017), which could reflect the parent's lack of engagement overall, yet a child's higher task average RSA may mean something different, for example that they were buffered by a parent's support. Presently, we parsed the effects of child task average RSA from child RSA reactivity within each time unit on parent RSA reactivity in order to more precisely model these respective child RSA contributions to synchrony in light of each individual child's own typical functioning, in the hopes of providing novel insights into the determinants and meaning of parent-child RSA synchrony in early childhood.

Dyadic Affect.—Theories regarding the importance of RSA (Polyvagal Theory, Porges, 2007; Neurovisceral Integration Model, Thayer & Lane, 2000) suggest RSA underscores emotional expression in social contexts. In fact, many researchers consider RSA reactivity a proxy of emotion regulation (e.g., Calkins, 2007). Positive affect and emotionality are generally associated with less stress and higher RSA, including RSA in face-to-face interactions (Oveis et al., 2009; Rousseau et al., 2020; Wang et al., 2013). Thus, the inclusion of dyadic positive affect may allow for a greater understanding of whether or not the dyad is challenged by the task and whether dyadic positive affect is a correlate of higher RSA synchrony.

Positive affect is likely to be a supportive factor in challenging parent-preschooler interactions. Displaying positive affect is an effective parenting strategy to maintain child engagement in challenging tasks (Kochanska et al., 2008) and is more commonly observed in laboratory studies of parent-child interaction compared to negative affect (Lunkenheimer et al., 2017). Parent positive affect directly benefits preschooler self-regulation (Eisenberg et al., 2001) and more synchronous positive affect between parent and child predicts fewer externalizing problems in early childhood (Lunkenheimer et al., 2020). Conversely, low parent positive affect has been associated with greater child RSA augmentation in children with externalizing disorders (e.g., ADHD; Musser et al., 2018). However, the role of positive affect may be more complex in relation to externalizing problems; for example, exuberant children tend to show both higher externalizing problems and higher-intensity positive affective displays (Dollar et al., 2017). Thus, although we generally expected higher dyadic positive affect to reflect less challenge and relate to higher RSA per prior research (Rousseau et al., 2020), questions regarding its moderating role on synchrony alongside the other moderators of child externalizing and average RSA were ultimately exploratory.

Differences in Synchrony with Mothers vs. Fathers

Fathers play a critical role in children's lives and contribute to regulatory development in early childhood (Davidov & Grusec, 2006; McDowell et al., 2002). Father-child synchrony of positive behavior predicts better child self-regulation and fewer externalizing problems across early childhood (Kochanska et al., 2015; Lindsey et al., 2009; Lunkenheimer et al., 2020). However, we know of no prior research on father-preschooler RSA synchrony. Some work shows physiological synchrony between fathers and older children but that there are differences of direction between mothers and fathers: in a stress contagion paradigm, mothers shaped child physiology, whereas children shaped father physiology (Waters et al., 2020). Other studies show no evidence of father-child RSA synchrony (Li et al., 2020). We might expect RSA synchrony to differ by parent in early childhood given evidence that mothers and fathers show differential RSA reactivity in challenging tasks with preschoolers: specifically, only paternal RSA augmentation, but both maternal RSA augmentation and excessive RSA withdrawal, predict greater child externalizing problems over time (Skoranski & Lunkenheimer, 2020). Overall, the dearth of research on father-child RSA synchrony limits our understanding of its role in early child development and more research is warranted (Abraham & Feldman, 2018).

Similar to mothers, fathers' maladaptive parenting is related to children's higher externalizing problems (Rinaldi & Howe, 2012; Verhoeven et al., 2010) and fathers tend to be less sensitive than mothers when parenting young children with higher externalizing problems (Trautmann-Villalba et al., 2006). This reduced sensitivity may disrupt RSA synchrony in father-child dyads in the context of externalizing problems. Father-child interactions also tend to show more variable and higher intensity positive affect and arousal than mother-child interactions (Feldman, 2003; Lunkenheimer et al., 2011). Father-child shared positive affect also relates to better child emotion regulation, which is sometimes but not always the case with mother-child positive affect (Kochanska et al., 2008; Lunkenheimer et al., 2020; Thomassin & Suveg, 2014). Given these differences in the roles of externalizing problems and positive affect with fathers, we may see differences in their moderating influences on mother- vs. father-child RSA synchrony.

Present Study

The goal of this study was to understand how mother-child and father-child dynamic RSA synchrony in early childhood was moderated by individual child and dyadic factors, including individual differences in children's externalizing problems and average RSA, as well as the dyadic affective climate of the interaction. RSA synchrony was modeled as the dynamic effects of child RSA reactivity (state RSA) on parent RSA reactivity (state RSA) using multilevel intradyad dynamics models (see Analytic Plan) given particular interest in how individual differences in the child contributed to parent RSA reactivity and thus shaped synchrony. State RSA was operationalized as the deviation from one's own average RSA (as an increase or decrease) within each respective time segment of a challenging parent-child task in order to model reactivity specifically with respect to the individual's own typical functioning.

We hypothesized higher externalizing problems would be associated with negative RSA synchrony in the form of the coupling of maternal RSA augmentation and child RSA withdrawal, as shown in prior research (Lunkenheimer et al., 2015). It was less clear how externalizing would interact with average child RSA to influence RSA synchrony, but based on work showing lower average child RSA may also be a risk factor (Beauchaine, 2001), we anticipated it could also be related to the coupling of maternal RSA augmentation and child RSA withdrawal. Given the benefits of positive affect in parent-child interactions (Kochanska et al., 2008), we considered that higher positive affect could facilitate positive synchrony and/or buffer individuals from stress, which would likely be manifested via higher RSA or RSA augmentation. However, these questions were ultimately exploratory given the complexity of these interactions and the dearth of evidence for these moderating effects of RSA synchrony in prior research.

Additionally, we aimed to better understand how these processes differed in mothers and fathers. Given the lack of studies on father-child RSA synchrony, we did not have specific hypotheses about how child externalizing problems, average RSA, and dyadic positive affect would interact to shape RSA synchrony in father-child dyads. In order to best reflect how each parent's perception of the child's externalizing problems was related to their own physiological reactivity, and given that mothers and fathers may have distinct perceptions of the child (Baker & Heller, 1996; Treutler & Epkins, 2003), mother reports of externalizing were examined in mother-child models and father reports of externalizing were examined in father-child models.

Methods

Participants

Participants were mother- and father-child dyads from a larger study ($N = 150$, 80 girls) oversampled for familial risk. Families were assessed at child age 2 ½ years ($M = 2.48$, $SD_{age} = 0.15$), 3 years ($M = 3.04$, $SD_{age} = 0.11$), and 4 years ($M = 4.00$, $SD_{age} = 0.12$) and recruited through the Department of Human Services and community agencies and preschools serving lower-income families. To be eligible, families met at least one of the following criteria: an income less than 200% of the federal poverty level (108 families), use of government assistance (e.g., food stamps, WIC; 122 families), higher levels of reported stressful life events (i.e., 5 or more in the past year on an adapted Life Stress Inventory; Holmes & Rahe, 1967; 107 families), or any involvement with Child Protective Services (34 families). Families were excluded if children had a diagnosed physical or mental disorder or if parents or children had cardiac problems that could interfere with the collection or interpretation of heart rate data. A subsample of 82 mother-child and 60 father-child dyads were included in the present analysis, based on families who completed the dyadic task and provided at least some RSA data.

Participants were from a Western university town and were sociodemographically representative of that area. Children's race/ethnicity was 64% Non-Hispanic White, 22% Hispanic, 7% Multi-ethnic, 3% African American, 1% Native American, and 3% unknown or did not wish to respond. At study entry, parents were married (66.7%), living together (12.7%), single (11.3%), separated or divorced (8.7%), or unknown/unreported (0.6%). The average annual income was $30,000 to $39,000. Mothers' education ranged from junior high school to graduate level, with median educational level being an Associate's degree. Nine percent of children met clinical cutoffs for externalizing problems based on T-scores from the Child Behavior Checklist (Achenbach & Rescorla, 2000).

Procedures

All study procedures were approved by the university Institutional Review Board. Informed consent was obtained by trained research staff and parents provided consent for children. As part of the larger study, families participated at three time points. For the purposes of this study, data was only utilized from the age 3 visit. At each 2-hour lab visit, mother-child dyads completed several tasks. One task required parents and children to work together to complete a set of puzzles above the child's cognitive ability level to win a prize. Additionally, parents completed surveys about parenting, child behavior, and family characteristics.

Measures

Parent-Child Challenge Task (PCCT)—Dyads completed the PCCT (Lunkenheimer et al., 2017), which was designed to assess interaction patterns during a challenging problem-solving task. The 10-minute task involved baseline, challenge, and recovery conditions. Parents and children were asked to complete three puzzles that increased in difficulty and were beyond the child's cognitive ability level for the child to win a prize, thus requiring guidance from the parent. Parents were asked to use only their words and not to physically handle the puzzle. During baseline, parents and children worked on the puzzles for four minutes. The challenge condition began after the experimenter briefly stated that the dyad only had two minutes to complete the task. Following the challenge condition (which in reality lasted three minutes), the recovery condition involved the experimenter entering the room, providing the prize (regardless of how many puzzles the dyad finished), and asking the parent and child to play with the prize (for three more minutes).

Dyadic Positive Affect—The PCCT was videotaped using Noldus Observer 10.0 and coded offline by trained graduate and undergraduate student coders using a validated coding system. The parent and child were coded for 5 affective states: high positive – regular positive fluctuations in vocal tones (such as sing-song rhythm), smiles with teeth showing, laughing or giggling, low positive – slight positive fluctuations in vocal tone, closed mouth smiles, neutral – relative absence of facial expression, vocal tone that is neither positive or negative, low negative – brief and minor expressions of frustration including frowns and heavy exhales, high negative – expressions of disgust and anger, raising voice in anger, rubbing eyes or forehead, crying, or shrugging shoulders in apathy. Affect was coded on a continuous second-by-second time scale, requiring coders to capture the same affect at the same window of time using a standard 3-second criterion in Noldus Observer to determine agreement. Reliability analysis was not only performed on content but also for the precise duration and timing of coding for the entire task. Interrater reliability for content, duration, and timing of each code was conducted on 20% of the total number of videos coded (average interrater agreement = 78%). *Dyadic positive affect* was calculated as the total duration of time in seconds across the entire interaction in which either or both members of the dyad were in a positive affective state (high or low positive affect). Thus, it captured the total duration of any expressed positive affect as a proxy of the affective climate.

Respiratory Sinus Arrythmia (RSA)—We collected RSA using the Mindware 3000A wireless system and disposable electrocardiogram (ECG) electrodes. Electrodes were placed over the right clavicle and below the rib cage on the left and right sides (the right side was the grounding electrode). Additionally, we used a crystal respiratory effort belt placed below the diaphragm to monitor respiration. Electrodes were then connected to small handheld computers. These computers were placed in backpacks that participants wore throughout the lab visit. Handheld computers transmitted data wirelessly to a computer in an adjacent room that was monitored by a trained research assistant. Using Mindware Heart Rate Variability 3.1.4 software, ECG data was processed offline. Interbeat interval data (IBI) were binned into 30 second epochs and edited for artifacts created by bodily movements. Epochs that required editing of more than 10% of the IBI series were dropped from analysis. RSA was calculated using the natural logarithm of variance of heart rate period within the frequency bands related to respiration, at a range of 0.24–1.04 Hz for children and 0.12–0.40 for adults (Fracasso et al., 1994).

Externalizing Problems—Child externalizing problems included aggression, hyperactivity, and inattention and were measured at age 3 via maternal report on the Child Behavior Checklist 1.5–5 (Achenbach & Rescorla, 2000). Each of 100 items is rated on a 3-point scale: 0 = “not true (as far as you know)”, 1 = “somewhat or sometimes true” and 2 = “very true or often true.” The externalizing scale was formed by aggregating a subset of 24 items; items on this scale included behaviors such as, “Can’t stand waiting, wants everything now” and “Destroys things belonging to his/her family or other children.” Cronbach’s alpha for maternal report of externalizing at age 3 was $\alpha = 0.87$ and for paternal report at age 3 was $\alpha = 0.90$.

Analytic Plan

Missing Data—To be included in the analytic subsample, dyads needed to provide RSA data. Thus, only families with some RSA data were included in primary analyses, which included 82 mother-child dyads with a total of 1505 observations and 60 father-child dyads with a total of 1141 observations. Little’s Missing Completely at Random test (MCAR; Little & Rubin, 1989) revealed data were missing completely at random, X^2 (119) = 139.80, $p = 0.09$.

Multilevel Intradyad Dynamics Models—First, the analytic separation of average and state RSA components was conducted to partial out effects of between-dyad and within-dyad variance. This allows one to more easily interpret results, which is critical given that between-dyad effects can be different in magnitude and direction than within-dyad effects (Bolger & Laurenceau, 2013). Moreover, this approach permits a more direct analysis of the complex relations that may exist between individual differences in regulatory functioning and dyadic RSA synchrony (Creaven et al., 2014; Suveg et al., 2016). Accordingly, we broke child RSA predictors into two orthogonal components, one time-invariant (task average RSA; between-dyad) and one time-varying (state RSA; within-dyad), following Bolger and

Laurenceau (2013). Child average RSA was RSA averaged across all segments of the task and child state RSA was the individual child's deviation from their task average RSA within each respective time segment. For example, if the child's task average RSA was 5.63 and their raw RSA value for a given segment was 6.24, their state RSA for that segment would be +0.61, or a positive deviation (i.e., RSA augmentation) relative to their average. Thus, RSA reactivity was modeled in relation to the individual's average, as opposed to only modeling an overall increase or decrease, so that there was a reference point for what the RSA change meant for that particular individual.

Next, RSA synchrony was modeled as the effects of children's RSA reactivity (state RSA) on parents' RSA reactivity (state RSA) within-epoch, modeled repeatedly across all epochs of the task. We used the lmer package in R (Bates et al., 2015) to run random intercept and slope multilevel models examining how child state RSA predicted parent state RSA. Child average RSA was included as a time-invariant moderator of the relation between child state RSA and parent state RSA. Positive RSA synchrony was interpreted as a positive prediction of parental state RSA by child state RSA, meaning that both members of the dyad showed either joint RSA withdrawal or joint RSA augmentation within that time segment. Negative RSA synchrony was interpreted as a negative prediction of parent state RSA by child state RSA such that partners moved in opposite directions, for example, child RSA withdrawal paired with parent RSA augmentation or child RSA augmentation paired with parent RSA withdrawal.

In addition to the moderator of children's average RSA described above, we examined two additional moderators of RSA synchrony, externalizing problems and dyadic positive affect, which were included as time-invariant, between-dyad effects. Considering the role of externalizing problems in atypical RSA functioning (Beauchaine, 2015) and our interest in how individual differences in child regulatory capacities were related to parent RSA reactivity, we included two two-way interaction terms (externalizing X average RSA, externalizing X state RSA). Given previous research demonstrating the effects of externalizing on both individual and dyadic RSA, we also included a corresponding three-way interaction term (externalizing X average RSA X state RSA). Additionally, the three-way interaction term of externalizing X positive affect X state RSA was included to address the aim of understanding whether and how dyadic positive affect influenced relations among externalizing, child state RSA, and parent state RSA. Finally, the first RSA time segment was set to 0 and time was included as a covariate in order to account for the effects of interaction time on parent state RSA. Given that time was set to 0, intercepts represent the model estimated mean at the beginning of the interaction.

Equation 1.1 specifies that parental state RSA at segment t in dyad j is a function of: an intercept for parent RSA specific to the respective dyad j ($\beta 0_j$), a slope specific to dyad j representing the effects of within-person variation in child state RSA ($\beta 1_{jt}$), a slope representing the passage of time ($\beta 2_{jt}$), and a residual specific to time t for dyad j (ε_{jt}). For the within-dyad equation, a positive $\beta 1_{jt}$ represents moments of positive synchrony such that parent and child RSA moves in the same direction (joint RSA withdrawal or joint RSA augmentation), whereas a negative $\beta 1_{jt}$ represents negative synchrony such parent and child RSA moves in opposite directions (parental RSA augmentation coupled with child RSA withdrawal or vice versa). The $\beta 2_{jt}$ in this equation represents the slope of parental RSA across the task as a function of time.

Equation 1.2 then specifies the between-dyad variations in the coefficients of the Level-1 equations. Specifically, variations in intercepts are a function of child average RSA, externalizing, dyadic positive affect, and the interactions between these moderators. Between-dyad variations in slopes $\beta 1_{jt}$ are a function of child average RSA, externalizing, dyadic positive affect, and the interactions between these moderators, and $\beta 2_{jt}$ is represented by a constant value on Level 2. At Level 2, $\beta 0_{jt}$ and $\beta 1_{jt}$ represent the moderation on the within-dyad intercept and the synchrony slope, respectively.

Within-dyad RSA: Level 1

$$\text{Parent state RSA}_{jt} = \beta 0_j + \beta 1_{jt} * (\text{child state RSA}) + \beta 2_{jt} * (\text{time}) + \varepsilon_{jt} \quad (1.1)$$

Between-dyad RSA: Level 2

$$\beta 0_j = \gamma 00 + \gamma 01 * (\text{child average RSA}) + \gamma 02 * (\text{externalizing}) + \gamma 03 * (\text{dyadic positive affect}) + \gamma 04 * (\text{child average RSA} * \text{externalizing}) + \gamma 05 * (\text{child state RSA} * \text{externalizing}) + + \gamma 06 * (\text{child state RSA} * \text{externalizing} * \text{dyadic positive affect}) + \gamma 07 * (\text{child average RSA} * \text{child state RSA} * \text{externalizing}) + \mu 0j_P \quad (1.2)$$

$$\beta 1_j = \gamma 00 + \gamma 01 * (\text{child average RSA}) + \gamma 02 * (\text{externalizing}) + \gamma 03 * (\text{dyadic positive affect}) + \gamma 04 * (\text{child average RSA} * \text{externalizing}) + \gamma 05 * (\text{child state RSA} * \text{externalizing}) + + \gamma 06 * (\text{child state RSA} * \text{externalizing} * \text{dyadic positive affect}) + \gamma 07 * (\text{child average RSA} * \text{child state RSA} * \text{externalizing}) + \mu 0j_P$$

$$\beta 2_j = \gamma 20$$

Results

Preliminary Analyses

Descriptive statistics and correlations are in Table 1. Parent and child RSA, externalizing problems, and dyadic positive affect demonstrated normal distributions. Child resting RSA and task average RSA were strongly positively correlated in mother-child, $r = 0.89$, $p < 0.001$, and father-child interactions, $r = 0.84$, $p < 0.001$, supporting the use of task average RSA as an index of individual regulatory capacity. Relations with sociodemographic variables were tested to account for potential confounding factors. There were negative correlations between income and dyadic positive affect for mother-child dyads, $r = -.25$, $p < 0.01$, and between father race/ethnicity and dyadic positive affect for father-child dyads, $r = -.25$, $p < 0.04$, but given their modest relations with only one moderator, they were not considered further. Child sex, maternal and paternal education, and maternal race/ethnicity were not related to any study variables.

Primary Analyses

Mother-Child Dyad Results—We examined whether mother-child dyads displayed RSA synchrony via relations between child state RSA and parent state RSA and whether this was moderated by externalizing problems, child average RSA, and dyadic positive affect (Table 2). Though there was no significant main effect of child state RSA on parent state RSA, indicating synchrony was not present on average for the entire sample without the inclusion of a moderator, the random intercept was significant, revealing considerable between-dyad variability in RSA synchrony.

There was a significant two-way interaction showing that externalizing problems interacted with child state RSA to influence mother-child RSA synchrony. Specifically, children with higher externalizing displayed positive RSA synchrony with mothers (joint RSA withdrawal) whereas those lower in externalizing displayed negative synchrony (child RSA withdrawal paired with maternal RSA augmentation), $b = 0.06$, $t(82) = 2.90$, $p = 0.007$.

However, these two-way results should not be interpreted in isolation given that there was also a significant three-way interaction between child externalizing, child average RSA, and child state RSA in relation to parent state RSA, $b = -0.009$, $t(82) = -2.52$, $p = 0.02$ (Figure 1). Specifically, for children with *higher* externalizing and *higher* average RSA, mothers and children showed dynamic negative RSA synchrony such that when children displayed RSA withdrawal, mothers showed RSA augmentation. Children with *lower* externalizing and *lower* average RSA also displayed dynamic negative RSA synchrony such that when children displayed RSA withdrawal, mothers showed RSA augmentation. Comparatively, children with *higher* externalizing and *lower* average RSA had dynamic positive RSA synchrony with their mothers, where mothers and children displayed joint RSA withdrawal. Children with *lower* externalizing and *higher* average RSA also showed dynamic positive RSA synchrony with their mothers in the form of joint RSA withdrawal.

To explore these results further, post-hoc simple slopes were calculated for +/− 1 SD and mean values of the moderators and compared to one another (Robinson et al., 2013). Analyses confirmed that for children with either higher or lower externalizing, the slopes of RSA synchrony for high average RSA and low average RSA were significantly different from one another, $t = -3.33$, $p = 0.003$, and $t = 2.20$, $p = 0.04$, respectively. In each case, the slopes for high or low RSA were not different from the mean average RSA.

There were no significant interaction effects involving dyadic positive affect in mother-child interactions. However, there was a main effect for positive affect such that higher overall dyadic positive affect was related to greater likelihood of dynamic maternal RSA augmentation in the moment, $b = 0.007$, $t(82) = 2.77$, $p = 0.007$.

Father-Child Dyad Results—Next, we examined whether father-child dyads displayed dynamic RSA synchrony in terms of relations between child state RSA and parent state RSA and whether this was moderated by externalizing problems, child average RSA, and dyadic positive affect. Similar to mothers, there was no overall significant main effect of child state RSA on paternal state RSA, indicating synchrony was not present without the inclusion of a moderator. However, the random intercept was significant, again revealing considerable between-dyad variability in RSA synchrony.

There were significant moderation effects for father-child RSA synchrony in relation to the three-way interaction between child externalizing, dyadic positive affect, and child state RSA, $b = -0.006$, $t(60) = -3.29$, $p = 0.002$ (Figure 2). For children *higher* in externalizing in dyads with *higher* positive affect, there was negative RSA synchrony such that when children displayed RSA withdrawal, fathers displayed RSA augmentation. Father-child dyads *lower* in child externalizing and *lower* in positive affect also showed negative RSA synchrony such that as children displayed RSA augmentation, fathers displayed RSA withdrawal. Comparatively, dyads with *higher*-externalizing children and *lower* positive affect showed positive RSA synchrony such that father and child displayed joint RSA withdrawal. For children *lower* in externalizing in dyads with *higher* positive affect, there was positive synchrony of RSA with fathers such that fathers and children displayed joint RSA augmentation.

To explore these results further, post-hoc simple slopes were calculated for +/− 1 SD and mean values of the moderators and compared to one another (Robinson et al., 2013). Results confirmed that for children with higher externalizing, the slopes of RSA synchrony for high and low positive affect were significantly different, $t = -5.00$, $p < 0.001$, though neither were different from mean positive affect. For children with lower externalizing, all slopes were significantly different, including high positive compared to mean, $t = 2.56$, $p = 0.02$, low positive compared to mean, $t = -4.40$, $p = 0.0004$, and high positive compared to low, $t = 2.20$, $p = 0.04$.

There were no interaction effects among child state RSA, average RSA, and externalizing in relation to father state RSA, signifying that these factors did not relate to father-child synchrony. However, we did find that child externalizing and average RSA influenced fathers' individual dynamic RSA reactivity, $b = -0.05$, $t(60) = -2.16$, $p = 0.04$. This two-way interaction showed that for children with *higher* externalizing and *higher* average RSA, fathers demonstrated more RSA withdrawal in the moment, whereas for children with *higher* externalizing and *lower* average RSA, fathers demonstrated more RSA augmentation in the moment. Children *lower* in externalizing with *higher* average RSA had fathers who displayed more RSA augmentation in the moment, whereas children *lower* in externalizing problems with *lower* average RSA had fathers who showed more RSA withdrawal in the moment.

Discussion

This study was designed to gain a better understanding of RSA synchrony between parents and children in early childhood. We expanded on prior work in three major ways: 1) by examining differences in RSA synchrony between mothers and fathers, thus contributing the first known work on RSA synchrony between fathers and preschoolers; 2) by examining key moderators expected to influence RSA synchrony in early childhood, including individual differences in child behavioral dysregulation in the form of externalizing problems, individual differences in child physiological regulatory functioning in the form of average RSA, and the dyadic affective climate of the interaction; and 3) by modeling RSA reactivity in relation to one's own average level of functioning and modeling RSA synchrony as related changes in parent and child RSA reactivity in the moment. On the whole, our results suggest that the drivers of parent-preschooler RSA synchrony in the moment are complex; that there are some similarities but more differences across mothers and fathers; and that children's regulatory capacities play a role in shaping synchrony with both mothers and fathers, but the affective climate may only play a particularly important role for father-child RSA synchrony.

Mother-Child RSA Synchrony

Our approach to examining the drivers of parent-child RSA synchrony was to consider multiple moderating factors that theory suggests should be related to parent RSA reactivity in challenging social interactions with their young children. The inclusion of these factors was a strength in terms of aligning with theory about the ways in which RSA relates to emotional arousal (Porges, 2007), how one's typical regulatory functioning impacts reactivity in the moment (Beauchaine, 2001), and how RSA relates to externalizing problems (Hinnant & El-Sheikh, 2009). We were especially interested in externalizing because when parents perceive children to be behaviorally dysregulated, we believe these perceptions and/or children's disruptive behaviors are likely to alter synchrony between parent and child. We expanded on prior work on externalizing and mother-preschooler RSA synchrony by including the additional moderators of children's average RSA and dyadic positive affect to gain a clearer picture of how children's self-regulation influenced synchrony, accounting for the affective climate of the interaction.

Interestingly, when children's externalizing problems were higher, we discovered the same negative synchrony pattern found in previous studies, specifically maternal RSA augmentation paired with child RSA withdrawal, thought to reflect risk because it suggests maternal disengagement despite the child's active need for support and the explicit request to support the child (Lunkenheimer et al., 2015, 2018). This pattern suggests mothers may not be adequately engaging to help support their young children with higher externalizing problems. However, presently, this effect was found in the context of a three-way interaction such that children's dynamic RSA withdrawal (indicating greater challenge), higher externalizing, and higher child average RSA interacted to predict mothers' dynamic RSA augmentation in the moment. Thus, this pattern only manifested when child average RSA was also high, suggesting that these higher-externalizing preschoolers had physiological regulatory capacities that may have supported them in navigating challenging tasks. Further, the combination of *lower* externalizing and *lower* child average RSA was also associated with this same negative synchrony pattern between mother and child – and yet comparatively, when children had both *higher* externalizing and *lower* average RSA, suggesting multiple types of regulatory difficulties, mothers and children showed joint RSA withdrawal in the moment. Taken together, these findings suggest that if children had heightened risk in terms of either behavioral or physiological dysregulation, but not in the other domain, mothers were less likely to respond to their child's difficulties in the moment, but when children showed deficits in both domains, perhaps mothers were then stressed by the task and/or needed to engage to support their children. Thus, it is possible that mothers are less engaged when they believe their children have other resources available to them, but are more driven to support children when they have multiple regulatory deficits. Mothers may also be more stressed themselves by preschoolers with greater overall regulatory difficulties if these difficulties hinder interaction goals or are correlated with other risk factors in the parent.

Another notable feature of mother-child results was that there appeared to be differences in maternal RSA reactivity only when children were actively challenged, i.e., only when children showed dynamic RSA withdrawal in the moment. Figures 1a and 1c illustrate these effects such that there were differences by low child state RSA (i.e., withdrawal) but not high child state RSA (i.e., augmentation). Collectively, findings suggest that on the whole, mothers are responsive to their children as evidenced by RSA (Giuliano et al., 2015; Skowron et al., 2013) – they respond to children's dynamic reactivity and experience in the moment as well as to children's more trait-like behavioral and physiological regulatory capacities, suggesting that children's individual differences in self-regulation play an important role in early childhood mother-child synchrony dynamics. Also, these results were found above and beyond the main effects of shared positive affect on mother's RSA reactivity, suggesting that despite the importance of affect for mother and child RSA (Calkins, 2007; Moore et al., 2009), the child's regulatory capacities played a bigger role in shaping mothers' regulatory response than did the affective climate.

These findings are complex and suggest the continued need to understand differences in RSA synchrony by levels and type of risk, and whether risk factors contribute to qualitatively different experiences of parent-child interactions, thus influencing the nature of dyadic synchrony in early childhood. For example, prior work in lower-risk families had shown higher externalizing was related to negative synchrony with preschoolers (Lunkenheimer et al., 2015, 2018), but by extending this question to higher-risk families with higher average levels of child externalizing and including additional risk factors, we uncovered a new pattern of joint RSA withdrawal characterizing mother-child RSA synchrony for children with the greatest regulatory difficulties. However, dyads with children with the least regulatory difficulties also displayed joint RSA withdrawal. Prior research has shown positive RSA synchrony in both lower-risk samples, where RSA synchrony is thought to underlie adaptive behavioral processes (Lunkenheimer et al., 2015), and clinical samples, where positive synchrony may reflect stress contagion or parents who are unable to support children as needed (Suveg et al., 2016). Future research would benefit from establishing better empirical distinctions between moderate and excessive RSA withdrawal and/or using person-centered approaches to determine whether there are two different types of dyads characterized by positive synchrony: those engaged effortfully to meet difficult goals in ways that may enhance children's regulatory skills, and those that are more overwhelmed by the difficult demands of the task. Ultimately, these findings support the notion that positive RSA synchrony between parents and children in early childhood is not always adaptive and that specificity of risk level, risk type, and task context are needed to interpret the meaning of RSA synchrony results.

Father-Child RSA Synchrony

There is a concerning lack of research on fathers' self-regulation, regulatory dynamics of fathers' interactions with their children, and the neurophysiological processes by which these individual and dyadic regulatory processes operate. The present study aimed to fill this gap and examine how various moderators influenced dynamic relations between child and father RSA in real time. We found both similarities and differences in mother- and father-child synchrony, but on the whole, results revealed that the predictors of father RSA reactivity were distinct from that of mothers, which led to unique patterns of RSA synchrony for father-preschooler dyads.

Similar to mothers, when children's externalizing problems were higher, there was a significant three-way interaction associated with the particular pattern of paternal RSA augmentation paired with child RSA withdrawal during a challenging task. However, in father-child interactions, it was the interaction of children's dynamic RSA withdrawal, higher externalizing, and higher dyadic positive affect (rather than child average RSA) that predicted fathers' dynamic RSA augmentation in the moment. Thus, when children were challenged and had greater behavioral dysregulation, but shared positive affect was higher, fathers were less responsive or stressed by the task. Also similar to mothers, when child externalizing was higher and dyadic positive affect was lower, suggesting two potential risk factors were present, fathers and children showed joint RSA withdrawal, suggesting that both father and child were challenged by and/or engaged in the task. Thus, the same potential interpretation applies to fathers as to mothers – perhaps when there is an additional resource or protective factor present in spite of the child's higher externalizing problems, fathers are less engaged, but when multiple challenges or risks are present, both fathers and children engage in or are stressed by the task. This implies a potential similarity across parents regarding the threshold at which they respond based on child or dyadic difficulties: both mothers and fathers appear to show greater RSA reactivity when more challenges to dyadic RSA synchrony are present.

On the other hand, a major difference was that for fathers, this three-way interaction was related to shared positive affect as opposed to the child's physiological regulation. Thus, this negative synchrony pattern should be considered in light of multiple indices that the positive relation between positive affect and RSA was especially robust for fathers, as also shown in prior research (Rousseau et al., 2020; Wang et al., 2013). For example, higher positive affect was associated with paternal RSA augmentation and lower positive affect was associated with paternal RSA withdrawal regardless of child externalizing levels (Figures 2a, 2c). Further, there were significant differences in father RSA reactivity by positive affect even when children showed lower externalizing problems and may not have been stressed by the task (Figure 2a), suggesting shared positive affect with fathers may differentiate RSA synchrony among both lower-risk and higher-risk children. Also, joint RSA augmentation characterized father-child dyads with lower externalizing and higher positive affect, suggesting the potential absence of stress or perhaps a buffered physiological response due to social support (Giuliano et al., 2015; Skoranski et al., 2017).

Given these robust relations between positive affect and paternal RSA augmentation, perhaps the negative synchrony pattern can be explained by fathers reading higher positive affect as a cue that their support was not needed even when children were challenged, or that they attempted to address children's difficulties with positive affect in ways that were not effective. We know early father-child interactions are characterized by higher intensity and variability in positive affect than mother-child interactions (Feldman, 2003; Mills-Koonce et al., 2011; Lindsey et al., 2009) and fathers' affective expression is heightened by both positive and negative affect in more reactive children (Fields-Olivieri et al., 2017). Further, higher positive affect is positively correlated with externalizing behaviors in exuberant children (Dollar et al., 2017), and fathers are less sensitive in responding to higher-externalizing children (Trautmann-Villalba et al., 2006). Thus, the combination of higher externalizing and higher dyadic positive affect may not support synchrony in this case. Therefore, although the affective climate of father-child interactions has been shown to have a robust influence on fathers (Fields-Olivieri et al., 2017), and synchronous and reciprocal positive affect with fathers has special benefits for children (Lunkenheimer et al., 2020; Thomassin & Suveg, 2014), we should also consider that increased positive arousal may provide an opening for fathers to misunderstand what children need in certain contexts, which could perhaps lead to overstimulation rather than calm focus to meet goals. These results raise new questions about when positive affect is adaptive vs. maladaptive for father-child RSA synchrony, given that heightened positive affect may confer additional risk for children with externalizing problems by disrupting synchrony.

These findings illustrate meaningful differences in mother-child and father-child RSA synchrony in early childhood, adding to a growing body of literature showing that fathers and mothers interact differently with their children (John et al., 2013; Kochanska et al., 2015; Richardson et al., 2019). Synchrony with fathers may be more influenced by salient, observable behaviors such as positive affect than by more trait-like characteristics or capacities in the child. It is possible that mothers are more aware of children's regulatory capacities and their interactions are more shaped by this awareness or history of repeated experiences with the child (Baker & Heller, 1996; Treutler & Epkins, 2003). Fathers tend to spend less time than mothers on caregiving in the early years (Planalp & Braungart-Rieker, 2016), and if fathers do not have the same awareness or history with the child, affective expressions in the moment could play a larger role in their physiological reactivity, thus shaping synchrony. However, it should be noted that there were some effects of child average RSA on fathers' individual RSA reactivity. Fathers were more likely to show RSA augmentation when children had either the most regulatory difficulties indexed by higher externalizing and lower average RSA, or the least regulatory difficulties indexed by lower externalizing and higher average RSA. As this pattern echoes findings for father-child positive affect models when positive affect was high, it may support the interpretation that fathers are typically less engaged when children either have the most difficulty or the least difficulty in terms of resources with which to manage a challenging task, and that only when positive affect is low does this pattern shift to reflect fathers' engagement with children with regulatory difficulties.

Limitations, Future Directions, and Conclusions

Despite its strengths, this study is not without limitations. First, families were characterized by lower income, higher stress, or child maltreatment risk, which is a relevant population for the present questions, but may also limit generalizability to these families. Second, only one-third of children were of ethnic minority background, thus future research is needed to understand if findings replicate in ethnic minority families. Third, we observed affect, average RSA, and RSA reactivity in a validated laboratory task shown to prompt regulatory processes, which are major strengths in studying regulatory processes, but converting RSA and affect to the same time scale and examining dynamic affect in tandem with RSA changes could be informative in future work given the potentially dynamic role of RSA in emotional arousal. Fourth, although sample sizes were sufficient for the selected time series analytic models and using complete RSA time series data and fathers' perceptions of their children's externalizing problems were strengths of the present analyses, larger sample sizes would still have increased power to detect effects with respect to father-child dyads. Fifth, all interpretations of mother-father differences should be made cautiously given that direct comparisons between mothers and fathers could not be made given the present analytic approach; future work could consider direct comparisons. Further, we were not powered to examine differences by child sex, but this should be considered in future research given that dyadic interactions with mothers and fathers have been shown to differ by child sex (Kochanska et al., 2008). Sixth, a longitudinal design would have allowed us to draw stronger conclusions about whether differences in RSA synchrony by risk and by parent portend adaptive versus maladaptive longer-term outcomes for children.

There is heterogeneity and complexity in operationalizations of synchrony in the field, which can limit replication of results. Presently, we operationalized RSA synchrony as the dynamic, concurrent coupling of parent and child RSA reactivity in each time unit, where reactivity was modeled in relation to one's own average RSA levels; these are important advances in modeling RSA synchrony. However, given our focus on average RSA during challenge instead of resting RSA and the complexity of our models, it is difficult to map these results onto prior research that defines reactivity as the difference between resting and task RSA levels, or that examines resting RSA only in relation to risk factors like externalizing problems. As future research moves into more dynamic modeling and corresponding operationalizations of reactivity, we hope to gain a more consistent knowledge base on how RSA synchrony operates.

Overall, by investigating moderators of parent-child RSA synchrony at individual and dyadic levels, we learned new information about how parent-child RSA synchrony functions during early childhood. In particular, we learned that preschoolers' regulatory capacities shape parent-child RSA synchrony in challenging tasks and that predictors of synchrony vary for mothers and fathers, such that mothers may be especially responsive to individual differences in children's self-regulation whereas fathers may be especially responsive to shared positive affect with the child. We conclude that future research should continue to investigate individual contributions to the dyadic coregulation of neurophysiological processes as well as the role of fathers and father-child interaction dynamics in children's early regulatory development.

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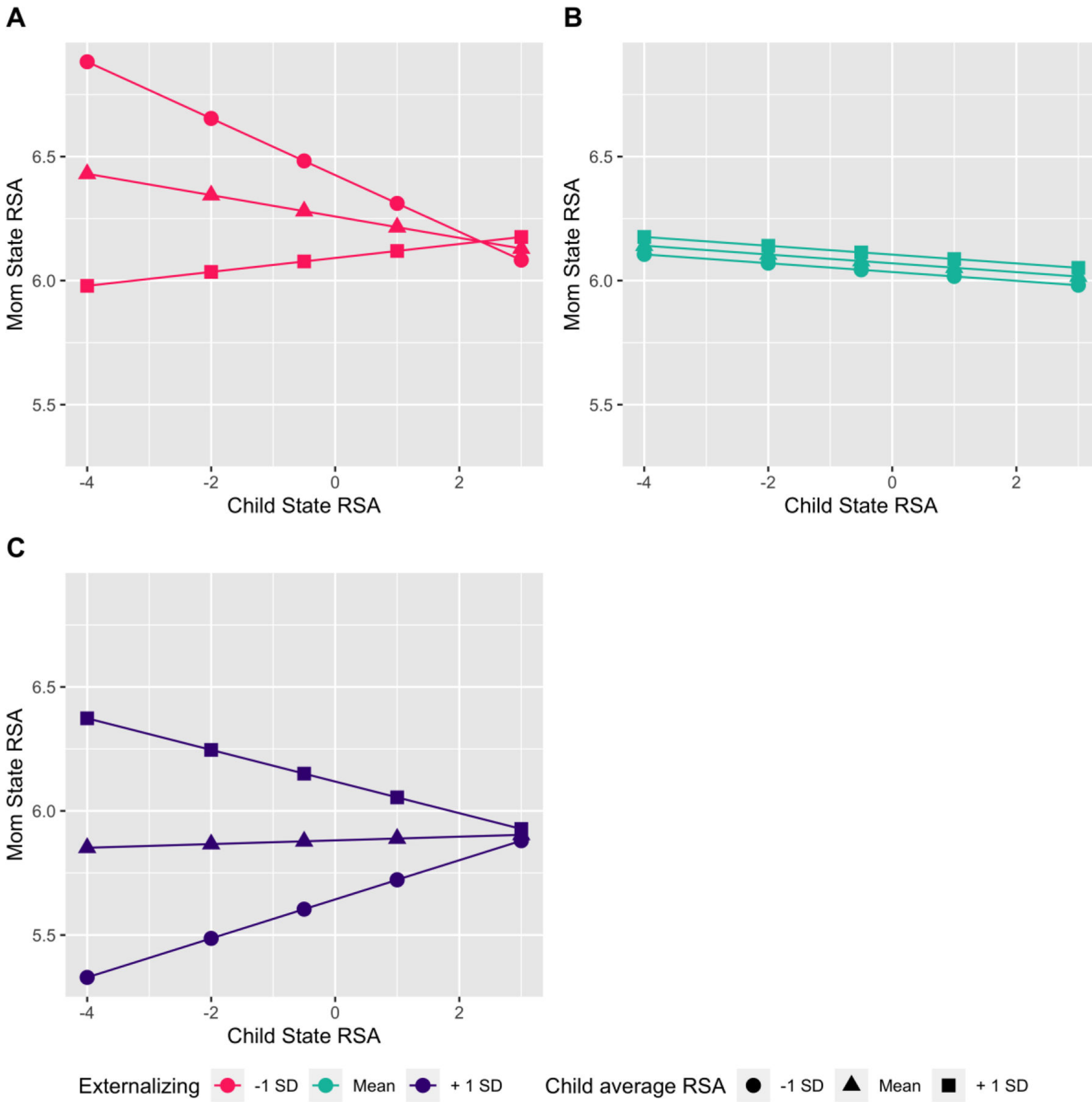

Figure 1:
The moderating effects of child externalizing and child average RSA on mother-child RSA synchrony. Child state RSA is mean centered using individual child means. A = Low Externalizing Problems. B = Average Externalizing Problems. C = High Externalizing Problems.

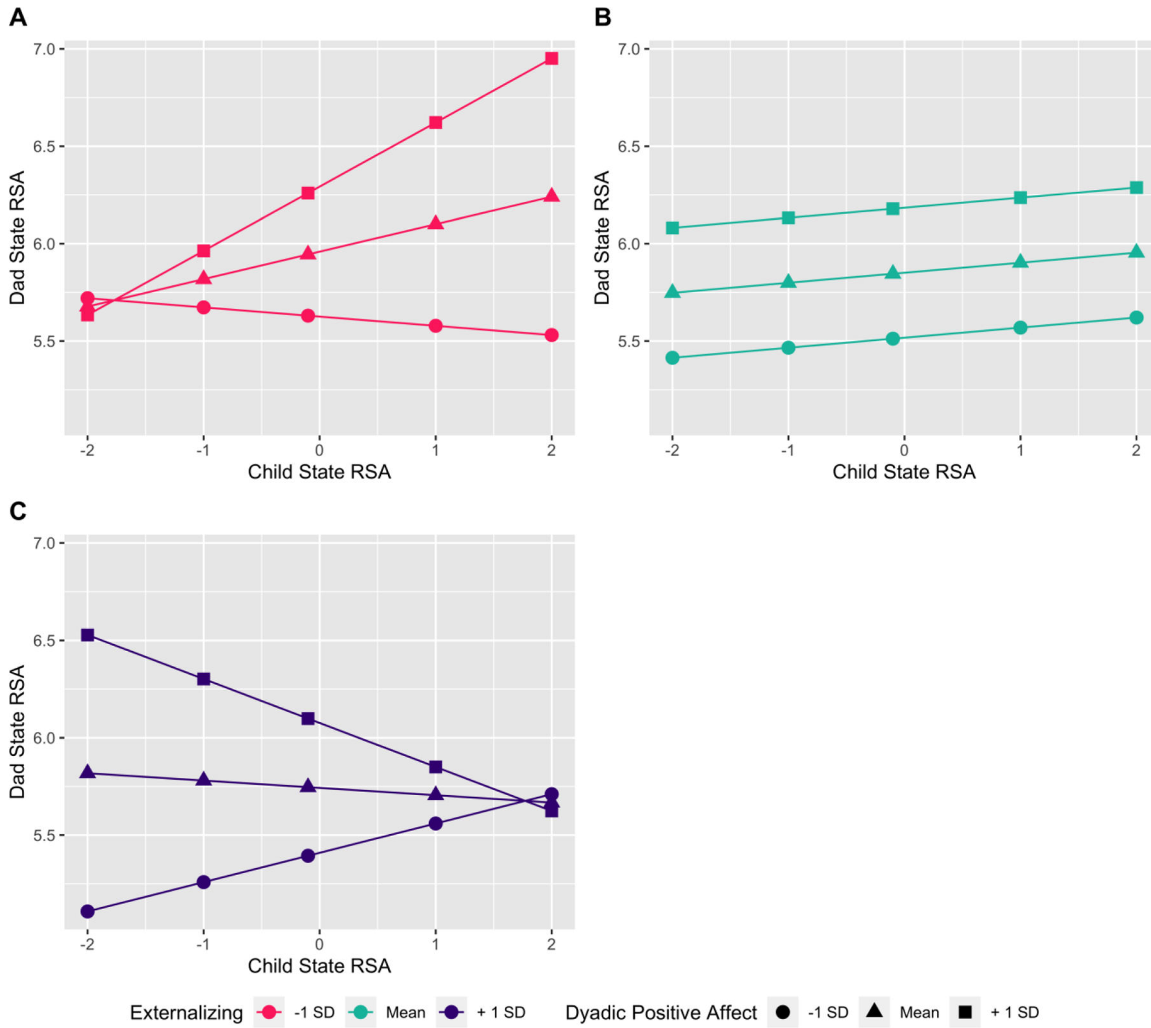

Figure 2:

The moderating effects of child externalizing and dyadic positive affect on father-child RSA synchrony. Child state RSA is mean centered using individual child means. A = Low Externalizing Problems. B = Average Externalizing Problems. C = High Externalizing Problems.

Table 1

Means, Standard Deviations, and Bivariate Correlations

Variable	*M*	*SD*	1	2	3	4	5	6	7
1. Externalizing *(mother reported)*	12.07	6.75							
2. Externalizing *(father reported)*	10.10	6.86	.41**						
3. Mother RSA *(avg)*	6.21	1.04	−.07	.18					
4. Child RSA *(avg with mother)*	4.91	1.12	.05	.18	.05				
5. Father RSA *(avg)*	5.84	1.02	−.04	−.14	.28*	−.03			
6. Child RSA *(avg with father)*	4.82	1.01	.26*	.11	.20	.69**	.01		
7. Dyadic positive affect *(with mother)*	75.38	49.48	.01	−.16	.28**	.04	.02	−.02	
8. Dyadic positive affect *(with father)*	70.37	54.72	−.05	.03	−.04	−.01	.30**	.10	.12

Note.

* $p < .05$.

** $p < .01$.

Avg = Average. Dyadic positive affect is measured as total duration in seconds.

Table 2

Parent-Child RSA Synchrony Models

	Mother-Child			Father-Child		
	Estimate	**SE**	***p*–value**	**Estimate**	**SE**	***p*–value**
Fixed Effects						
Intercept	5.45	0.55	< 0.001 ***	5.89	0.70	<0.001 ***
Time	−0.005	0.003	0.11	0.01	0.004	0.007 **
Dyadic Positive Affect	0.007	0.003	0.007 *	0.006	0.003	0.03 *
Externalizing	−0.16	0.09	0.07 †	0.21	0.12	0.07 †
Child Average RSA	0.03	0.11	0.76	−0.12	0.14	0.37
Child State RSA	−0.02	0.03	0.54	0.05	0.04	0.18
Externalizing x Child Average RSA	0.03	0.02	0.12	−0.05	0.02	0.04 *
Externalizing x Child State RSA	0.06	0.02	0.007 **	0.05	0.03	0.07
Externalizing x Dyadic Positive Affect x Child State RSA	−0.00	0.00	0.29	−0.001	0.0002	0.002 **
Externalizing x Child Average RSA x Child state RSA	−0.009	0.004	0.02 **	−0.006	0.004	0.28
Random Effects	**Estimate**	**Corr**		**Estimate**	**Corr**	
Intercept	1.04			1.04		
Child State RSA	0.008	−0.44		0.02	−0.27	
Residual	0.55			0.59		

Note. Estimate = unstandardized beta coefficient; 1505 observations nested within 82 dyads for mothers; 1141 observations nested within 60 dyads for fathers.

*** $p < 0.001$

** $p < 0.01$

* $p < 0.05$

† $p < 0.10$