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Integrating a Multilevel Approach to Examine Family Conflict and Parent-adolescent Physiological Synchrony

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Abstract

The present study investigated physiological synchrony across mothers, fathers, and adolescents during a conflict discussion. In particular, a multilevel, within-dyad approach was used to parameterize synchrony within the parasympathetic nervous system. Moreover, we examined how domains of conflict within the larger family system influenced the level of synchrony between family members. Participants were 191 families with adolescents (*M* age = 12.4 years), whose respiratory sinus arrhythmia (RSA) were measured during a triadic family conflict discussion. On the minute-to-minute basis, mothers and adolescents as well as mothers and fathers exhibited positive RSA concurrent synchrony, whereas no such concordance was observed between adolescents and fathers. In addition, the presence of conflict between parents with respect to co-parenting moderated the level of mother-adolescent synchrony such that no concordant RSA synchrony emerged between mother and adolescents under high levels of co-parenting conflict. In contrast, general interparental conflict did not moderate levels of physiological synchrony among any of the dyads. Findings suggest that mothers may be particularly physiologically in tune with family members in the context of conflict discussions and specific domains of family conflict may influence concordant physiological dynamics. Taken together, this is one of the first studies to examine physiological synchrony during the adolescent period and results suggest this may be an important developmental period for these dynamics.

Keywords

physiological synchrony; co-parenting conflict; respiratory sinus arrhythmia; parent-child relationship; adolescence

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Parent-child physiological synchrony, defined as coordinated exchanges in physiological cues, has been conceptualized as an important indicator for parent-child relationship functioning that shapes child social and emotional development (Davis, Bilms, & Suveg, 2017). During family interactions, physiological synchrony is usually manifested by the positive concordance in stress response indicators between partners (e.g., parent and child), including heart rate (Creaven, Skowron, Hughes, Howard, & Loken, 2014), cortisol (Saxbe et al., 2014), and respiratory sinus arrhythmia (RSA; Woody, Feurer, Sosoo, Hastings, & Gibb, 2016). Whereas early work on parent-child synchrony primarily focused on the developmental period of infancy and between mother and child, synchrony at later ages as well as the role of fathers remain less understood. The present study seeks to address this gap by examining synchrony in RSA between mothers, fathers, and adolescents during a triadic conflict discussion. Furthermore, given that the manifestation of synchrony might be conditional on broader family contexts within which individuals are embedded (Davis, West, Bilms, Morelen, & Suveg, 2018), we sought to investigate the moderating effects of interparental relationship dynamics on physiological concordance. Guided by family systems theory (Cox, Paley, & Harter, 2001) and the spillover hypothesis (Sturge-Apple, Davies, & Cummings, 2006a, 2006b), we examined how two types of interparental conflict—general interparental conflict and coparental conflict—may operate as potential moderators of coordinated physiological exchanges among family members.

Physiological synchrony

Parent-child synchrony is broadly defined as the coordinated exchanges of affective, behavioral and physiological signals during social interaction (Feldman, Magori-Cohen, Galili, Singer, & Louzoun, 2011). From infancy, parent and child respond to the signals of each other and start to show coordinated physiological activity during interactions, which serves as a foundation for children's bonding and attachment with parents (Feldman, 2012). Although empirical findings for how physiological synchrony is related to adolescent functioning is quite scarce to date, physiological synchrony is regarded as an important indicator of the quality of parent-child relationship (Davis et al., 2017), with the former being observed for families with greater parent-child relationship quality (e.g., Papp, Pendry, & Adam, 2009).

At the physiological level, the autonomic nervous system (ANS) is considered a primary driver of the neurobiological stress response and may provide a unique opportunity to examine the temporal dynamics of the parent-child synchrony in real time. One branch of the ANS, the parasympathetic nervous system (PNS), is primarily responsible for shifting resources towards recovery, restorative and homeostatic functioning after exposure to stress (Porges, 1992). According to polyvagal theory (Porges, 2007), the withdrawal of the PNS (i.e., vagal control) serves as the first-wave stress response that enhances the engagement of attention with external stressors and facilitates coping. As such, the withdrawal vs. activation of the PNS is an indicator for the up- vs. down-regulation of the physiological arousal in the stress response system. In particular, RSA, a well-established indicator for PNS activity, reflects physiological reactivity to external stressors within relatively short time window (e.g., minute-to-minute), affording the capture and modeling of real-time physiological dynamics (e.g., Woody et al., 2016).

Early empirical work examining the relationship between parent and child RSA has provided evidence for coordinated physiological changes between parents and children. For example, Bornstein and Suess (2000) utilized a between-person design and reported that mothers showing greater RSA suppression when conducting a stress-evoking task had children who also demonstrated greater RSA reductions to stress. Although informative, the use of a between-person approach only reveals the magnitude to which one partner (e.g., child) demonstrates greater overall stress activity (compared to other persons in the population) when the other partner (e.g., mother) also has greater-than-average stress activity (compared to the rest of the population). In other words, the between-person approach examines the between-partner associations in the aggregated person mean levels of stress reactivity—when compared to other individuals in their own groups. As a result, this approach does not capture (a) fluctuations in physiological states over time, and (b) the within dyad, moment-to-moment synchrony in the physiological activity as it unfolds over time.

An alternative approach that allows for parameterizing these types of concordant dynamics is the within-person/dyad approach (e.g., Helm, Miller, Kahle, Troxel, & Hastings, 2018; see more details in "Data analysis plan"). Relying on this approach, several studies have documented concordant RSA changes between mothers and children (e.g., Woody et al., 2016;). For example, Lunkenheimer and associates (2015) investigated mothers' and preschoolers' RSA activity during multiple lab tasks (e.g., free-play) via a multilevel within-dyad/person approach. The study revealed a positive mother-child RSA synchrony, in that increases in mothers' RSA at a certain occasion were associated with greater children's RSA concurrently (i.e., at the same occasion). These associations were robust after accounting for the autoregressive effects of RSA for each individual (e.g., mothers' RSA at certain occasion predicting their subsequent time points) and the overall averaged levels of RSA (i.e., between-person effects: the effects of the averaged RSA levels compared to the rest of the sample).

Despite the substantial contributions of this line of work to our understanding of physiological synchrony, much of the extant literature has focused on the mother-child dyad, with limited attention drawn on father-child synchrony. This is a substantial gap in knowledge given the role that fathers' play within parenting domains. Furthermore, the majority of this work has examined parent-child physiological synchrony with young children (e.g., Lunkenheimer et al., 2015; Lunkenheimer, Tiberio, Skoranski, & Buss, 2018a). Although important in establishing the presence and meaning of this within this developmental period, very limited work has extended this line of inquiry through evaluating synchrony in other developmental time periods (e.g., Woody et al., 2016). This gap is noteworthy given the developmental changes in family relationship dynamics that occur during the adolescent period (e.g., Martin, Sturge-Apple, Davies, Romero, & Buckholz, 2017).

Physiological synchrony within the Broader Family Context

Physiological synchrony within family member dyads also operates within the broader context of family dynamics. As such, empirical work has also investigated how various familial risks may moderate parent-child RSA synchrony including maternal depression (Woody et al., 2016), maternal psychological aggression (Lunkenheimer et al.,2018) and maltreatment (Lunkenheimer, Busuito, Brown, & Skowron, 2018b). For example, Woody et al (2016) had school-age children (age 7–11 years old) discuss positive and negative issues with their mothers with or without diagnosis for major depressive disorder. When RSA synchrony was examined on the within-person, moment-to-moment basis, a positive mother-child synchrony was observed for the never-depressed group, such that when mothers' RSA went beyond her personal-averaged level at a certain occasion, the child also fluctuated above his/her averaged RSA at the same occasion. In contrast, children with depressed mothers showed negative RSA synchrony with their mothers, such that higher levels of mothers' RSA were associated with lower concurrent RSA for the children. In the current study, we were interested in extending this line of inquiry regarding family functioning towards examining how conflict within the interparental relationship may differentially influence within dyad synchrony among family members during a conflict discussion task.

Family systems theory stipulates that family dynamics consist of multiple subsystems (e.g., interparental, parent-child), which are affected by one another (e.g., Cox et al., 2001;). In particular, the interparental system is viewed as the cornerstone of the family that modulates relationship dynamics across family members. According to the spillover hypothesis, disturbance within the interparental subsystem (e.g., interparental adjustment, co-parenting relationship) may "spill over" and result in negative interactions in other family subsystems (e.g., parent-child relationships), thereby disrupting relational processes (e.g., Erel & Burman, 1995; Tuebert & Pinquart, 2010). As such, if parents are struggling and emotionally drained when coping with interparental conflict and/or co-parenting conflict with their partners, they might be less capable to accurately perceive and understand their children's needs and respond in a loving and supportive manner (e.g., Sturge-Apple, Davies, & Cummings, 2006a, 2006b). Consistent with the spillover hypothesis, evidence has linked interparental conflict with compromised parenting and parent-child relationship (Erel & Burman, 1995; Cox et al., 2001; Sturge-Apple et al., 2006b). However, research has demonstrated the importance of disaggregating dimensions of conflict between parents and has focused on the potential impact of both general relationship conflict and conflict that centers around childrearing issues (e.g., Sturge-Apple, Davies, & Cummings, 2006a). In particular, research has suggested that co-parenting conflict is associated with less sensitive and consistent parenting (e.g., Feinberg, Kan, & Hetherington, 2007; Sturge-Apple et al., 2006a) and more negative parent-child relationships (e.g., Martin et al., 2017).

Notably, even though both general interparental conflict and co-parenting conflict have been linked to poorer parenting and parent-child relationships, limited research has considered them jointly with respect to understanding their effect on physiological synchrony among parents and their children, which is conceptualized as an indicator for parent-child relationship (e.g., Woody et al., 2016). Among the limited work within this domain, research has focused on other physiological systems (e.g., salivary alpha amylase[sAA] as an indicator for sympathetic nervous system [SNS] activity: Gordis, Margolin, Spies, Susman, & Granger, 2010). For instance, Gordis et al. (2010) investigated parent-adolescent synchrony in SNS activity (i.e., sAA) around the triadic family conflict discussion. Using a between-dyad approach, they revealed a positive correlation between mothers' and adolescents' sAA pre- and post-discussion. Furthermore, interparental aggression significantly moderated the sAA synchrony, such that mother-adolescent sAA synchrony only emerged within families reporting no interparental aggression but not within families with greater interparental aggression. Taken together, even though Gordis et al.'s (2010) work examined physiological synchrony within other system and adopted a between-person, this line of research indicates that family conflict might moderate the levels of physiological synchrony among family members.

The Present Study

In summary, the present study endeavored to evaluate the moment-to-moment (i.e., minute) physiological synchrony of RSA between mothers, fathers, and adolescents during a triadic family conflict discussion. In addition, we examined the moderating role of two types of family conflict—general interparental conflict and co-parenting conflict—on RSA synchrony within dyads. The present inquiry advances the literature in the following ways. First, in addition to mother-child dyad, the inclusion of fathers in the study provides a unique opportunity to gain greater understanding for fathers' role in physiological regulation during family interaction. To our knowledge, scant work to date has investigated the synchrony in RSA activity between mothers, fathers, and adolescents simultaneously, with a few exceptions focusing on other physiological systems (e.g., sAA, Gordis et al., 2010; cortisol: Saxbe et al., 2014). Notably, the inclusion of fathers in analyses might provide a closer approximation to the natural family interactions, during which all family members participate and may have an influence on one another.

Second, we tested the moderating role of two types of interparental conflict (i.e., general interparental conflict and co-parenting conflict) on physiological synchrony among family members. Whereas previous work has documented the effects of multiple environmental risks on parent-child synchrony(e.g., maltreatment, maternal depression), to our knowledge this is the first study to (a) investigate the role of interparental conflict on RSA synchrony at this age group, and to (b) evaluate the specificity of different types of conflict by contrasting general interparental conflict vs. co-parenting conflict.

Third, whereas much synchrony research has focused on earlier age groups (infancy, e.g., Feldman et al., 2011; early childhood: Creaven et al., 2014; Lunkenheimer et al., 2015, 2018; Smith, Woodhouse, Clark, & Skowron, 2016), our study promotes the understanding for how physiological synchrony works between *adolescents* and their parents. This is particularly important because during early adolescence, teens start to gain greater autonomy and re-negotiate rules with parents (Eccles, 1999), which might pose greater emotional challenge to parents. Such changes might dampen parents' ability to form reciprocal and coordinated emotional and physiological exchanges with the adolescents. In addition, even though adolescents are more competent in self-regulation compared to younger children, parents still play a crucial role in their emotion regulation, particularly when dealing with difficult family issues (e.g., Morris, Silk, Steinberg, Myers, & Robinson, 2007). As such, parent-adolescent synchrony through physiological stress-response systems remains a critical issue to investigate. We also note, however, that empirical evidence on how physiological synchrony may be linked to adolescent development is still quite limited to date. Our endeavor in examining the pattern of physiological synchrony within the triadic family task is a critical first step in this line of work.

Method

Participants

Participants were 191 families recruited from a mid-sized city in the Northeastern area of the United States. Families were recruited broadly through school districts, family-center internet sites, and flyers. Interested families were included in the study if the following criteria were fulfilled: (a) having an adolescent between the ages of 12 to 14, (b) the target adolescent had been living together with the two parental figures for at least the previous three calendar years, (c) at least one of the parental figures was the biological or adoptive parent for the target adolescent, (d) all participants were fluent in English, and (e) the target adolescent did not have significant cognitive impairment. Families were followed for two annual waves with high retention rate (91.62%, 175 families), although the present study only focused on the first measurement occasion. Means age for adolescents were 12.4 years at Wave 1, and 49.7% were female ($N = 95$). 77.0% of the adolescents were identified as White, with another 10.5% identified as African American, and 9.9% as mixed race. In addition, 11.5% of the adolescents were identified as Hispanic or Latino ethnicity. The vast majority of the parents were legally married (82.2%), engaged (5.8%) or in a serious long-term committed relationship (11.0%), and the mean duration for the two adults living together was 15.5 years. The median household income fell in the $ 55,000 to $74,999 range, with 11% of families having a household income below $ 23,000. Mean ages for fathers and mothers were 44.2 and 41.6 years during the first measurement occasion, respectively. Median parental education was an Associate's degree (i.e., completing two-year college study) and bachelor's degree for fathers and mothers, respectively. This study was approved by the Institutional Review Board of the University of Rochester (Title of the study: Family Relationships in Early Adolescence, case number: RSRB00030791).

Procedures

Family conflict discussion.—At the first measurement occasion, fathers, mothers, and adolescents participated in the triadic family conflict discussion task (e.g., Li, Sturge-Apple, Martin, & Davies, 2019). Family members were brought together and sat in a room resembling a living room and were instructed to come up with a topic that they commonly disagree about. They were given standard instructions to talk about the topic for seven minutes as they usually would and try to get their points across. A vast majority of the topics were centered around adolescents (e.g., chores), with the rest being closely related to adolescents (e.g., family trip, moving; See details in Supplemental material, Table S3). Post-discussion survey indicated that the most common topics chosen were chores (35.1%), use of electronics (11.5%), relationship with siblings (11.0%) and adolescent attitude and behavior (e.g., being disrespectful, disobeying, 12.0%). In addition, 44.0%, 48.7%, and 50.8% of the fathers, mothers, and adolescents respectively rated the lab-discussion to be *about the same* with the discussions they normally have at home, with lower percentages indicating the lab discussion was slightly more positive or negative than their home discussions.

During the discussion, both parents' and adolescents' EKG signals were recorded by BioGraph Infiniti software with a precordial, two-pole electrocardiogram lead. The EKG signals were sampled at 300 Hz with a voltage ranging from −2.5V to 2.5V. The recorded EKG data were then transmitted and stored in a portable unit with an SD card and saved when each visit was completed. The EKG data were processed by the CardioPro Infiniti's HRV analysis module, which screened the EKG data, corrected the detected artifacts for R-waves, and saved data for further analyses.

Measures.

RSA.: RSA activity during the family conflict discussion was indicated by heart rate variability. More specifically, whereas one minute was treated as the unit for each epoch, we derived the root mean square of successive differences (RMSSD) of the interbeat interval in each epoch to serve as the indicator for RSA activity. Notably, RMSSD is widely-accepted time-domain indicator for vagal activity, and it is robust to the influence of respiration (e.g., Laborde, Mosley, & Thayer, 2017). One minute was chosen as the unit for each epoch to obtain a reliable estimate for variability in the interbeat intervals of heart rate (Esco & Flatt, 2014). RMSSD values outside the range of +/−3 *SD* were changed to missing values, resulting in some missing data points (one to five for adolescents, two to six for mothers, and two to five points for fathers were changed to missing across six epochs). Furthermore, due to the variations in the length of the conflict discussion in the last minute as families finalized discussion at different points, many families did not have enough EKG data (i.e., 30 seconds of consecutive EKG recording without interruption or substantial noises) to reliably estimate RSA at the seventh minute (Non-missing before removing +3*SD* values: $N_{adolescents} = 89$, $N_{\text{mothers}} = 59$, $N_{\text{fathers}} = 61$). Given that the proportion of missingness during the seventh minute for all three family members exceeded 50% (i.e., 53.4%, 69.1%, and 68.4% for adolescents, mothers, and father, respectively) and may not be reliably handled by missing data techniques (e.g., multiple imputation), the seventh minute was thus not included in further analyses.

Co-parenting conflict.: At wave 1, both mothers and fathers completed the 14-item Childrearing Disagreements Questionnaire (CRD, Jouriles et al., 1991), rating the frequency to which they had irritating disagreement with their partners during the past six months regarding the child rearing issues (e.g., "Not taking an equal hand in disciplining our child", "Doing the easy or fun things, but not too many of the hard or boring things in childcare"). Responses were on five-point Likert scale ("1" = *Never*, to "5" = *Always*), with higher scores reflecting more disagreement between parents over childrearing. Mothers' (Cronbach $\alpha = 0.85$) and fathers' ($\alpha = 0.86$) mean scores of the CRD scale were each created and entered multiple imputation (see details in data analysis plan). As we were interested in obtaining a parsimonious indicator for family-wide co-parenting conflict instead of contrasting the effect of parent subjective perception, mother and father were treated as two informants for the overall co-parenting conflict within the family. Thus, the multiple imputed mother- and father-reported co-parenting conflict were averaged to indicate the overall co-parenting conflict between parents (e.g., Feinberg et al., 2007).

Interparental conflict.: The verbal- and physical- aggression subscales of the Conflict Problem Solving questionnaire (CPS; Kerig, 1996) were completed by mothers and fathers at Wave 1, rating the frequency to which they adopt different strategies when they have disagreements with their partner ("0" = *Never*, "3" = *Often*). Whereas the 8-item verbal aggression subscale measures verbal hostility between partners (e.g., "name calling, cursing, insulting"), the 7-item physical aggression subscale measures the physical aggression between marital partners ("push, pull, shove, grab, handle partner roughly"). Mean score for mothers' and fathers' physical (αs=0.76(mother)/0.86(father)) and verbal (αs=0.86(mother)/0.82(father)) aggression were each created before entered in multiple imputation, with higher score reflecting greater verbal and physical hostility. As our measure reflects each parent's rating of their own aggression towards their partner, to obtain a family-level overall interparental conflict, verbal and physical aggression were created by averaging mother and father reports after imputation (e.g., Shelton & Harold, 2008). Finally, to form a parsimonious indicator and avoid multiple tests, the standardized verbal and physical scores were aggregated together to create the grand indicator for interparental conflict (e.g., Cummings, Kouros, & Papp, 2007).

Data analysis plan.: Data analysis proceeded in two stages: the preliminary and primary stages. The preliminary stage involved addressing missing data via multiple imputation and detrending the RSA trajectories. The primary stage consisted of testing the concurrent synchrony in RSA between different dyads (e.g., mother-adolescent), and evaluating the moderating role of co-parenting conflict and interparental conflict on physiological synchrony.

Preliminary stage.: The first step of the preliminary analysis involved multiple imputation (MI) of the missing data (see details in Table 1) (Rubin, 1987; Schafer, 1997; Schafer & Graham, 2002). To do so, we adopted the SAS PROC MI procedure and used the Markov Chain Monte Carlo (MCMC) method to generate 100 imputed datasets. Given the information to be imputed are RSA and questionnaire measures, a minimum boundary of zero was set for the imputed data (i.e., all imputed values had to be greater than zero). All the following analyses were run 100 times across all of the imputed datasets, and results were summarized across the datasets via PROC MIANALYZE procedure (i.e., parameters estimates were averaged across the 100 imputed datasets, the standard error of the parameter estimates was calculated following Rubin's [1987] rule). The repeated measure of RSA over time (i.e., epoch one to six) for family members was treated as separate variables in multiple imputation (Allison, 2001). In addition, RSA were changed back to missing after MI for participants missing RSA data for all epochs (i.e., adolescents: N=10; mothers: N=10; fathers: N= 5), which ensures RSA was not completely imputed for the participants involved. For co-parenting and interparental conflict, father- and mother-report were entered into MI separately, after which composited variables (e.g., co-parenting conflict) were created. The final indicators for co-parenting conflict and general interparental conflict after imputation were positively and moderately correlated (r = 0.48, p < .001), suggesting that the two constructs had decent level of unique variances that are not completely overlapping.

The second step of the preliminary stage involved detrending the RSA trajectories across the conflict discussion. Concurrent synchrony in RSA captures the concordant fluctuations between interacting partners around their own personal means. Therefore, detrending the RSA is necessary because systematic trends in RSA trajectories may confound the estimates for concurrent synchrony (Helm et al., 2018). This was because concurrent synchrony reflects the level to which dyad partners co-occur above or below their personal mean levels. Thus, for example, a common trend may increase the likelihood for dyad partners to co-occur either above or below their personal means, biasing the estimates towards greater values than the true concurrent synchrony.

To do this, we fitted a series of multilevel growth curve models to adolescent' and parents' RSA separately. Time was centered around the first epoch (i.e., time= zero for epoch one), which represents the beginning of the task. In addition, a minute/epoch was treated as the unit of time. Three models were each fitted to mothers, fathers, and adolescents: (a) a null model (i.e., fixed and random intercept only model), (b) a linear effect of time model (i.e., fixed and random intercept and linear time effect), and (c) a quadratic effect of time model (i.e., fixed and random intercept, linear, and quadratic time effects). Note that fixed effect refers to the overall averaged effect in the sample, whereas random effect denotes the interindividual differences. We took a data driven approach to evaluate the most appropriate growth trajectories to detrend the data, based on (a) model fit indices, including −2 Log likelihood, Akaike Information Criterion (AIC and AICC), and Bayesian Information Criterion (BIC); (b) significance of the parameter estimates (e.g., linear slope for time effect), and (c) significance of the random effects(e.g., random linear slope variance). In the case when random effects were estimated to be zero (i.e., non-positive definite G matrix), we altered the model by only including the fixed effect of that term (e.g., quadratic time effect) for the model.

In summary (see Supplemental material, Table S1), mothers, fathers, and adolescents demonstrated an overall linear decrease in RSA (i.e., significant fixed linear decrease: $B_{mother} = -2.46$, $p < .01$; $B_{father} = -2.52$, $p < .01$; $B_{adolescents} = -3.16$, $p = .01$) and a quadratic increase ($B_{mother} = 0.26$, $p = .11$ with a significant random effect; $B_{father} = 0.38$, $p = .01$; $B_{adolescents} = 0.43$, $p = .05$) during the conflict discussion. Such patterns of changes reflected a vagal withdrawal at the beginning of the conflict discussion, followed by a flattened pattern (i.e., negative slope gets closer to zero) or a recovery of vagal activity towards the end of the discussion for all three family members. For adolescents, it was the quadratic time effect model (i.e., fixed and random intercept, linear, and quadratic time effect) that fitted the data best, indicated by lowest −2 log likelihood, AIC, AICC, and BIC values, and that fixed and random effect for both linear and quadratic slopes for time achieved significance. As such, adolescents' RSA was detrended according to the quadratic time effect model. Mothers' RSA was also detrended according to the quadratic time effect model because of: (a) lowest model fit indices, reflecting best model fit; (b) a significant fixed and random linear decrease in RSA trajectory; and (c)the emergence of a significant random quadratic slope despite a nonsignificant fixed quadratic time effect. Finally, fathers' RSA trajectory was detrended according to the alternated quadratic time effect model (random quadratic effect was omitted due to an estimate of zero) given best model fit and significant fixed linear and quadratic slopes. As such, RSA for mothers, fathers, and adolescents were detrended within the corresponding models (i.e., at each time point, subtracting the predicted value by the polynomial model [e.g., quadratic time effect model] from the observed RSA value), and time-specific residuals were saved for further analyses.

Primary stage.: The primary stage focused on evaluating the concurrent RSA synchrony between the three interacting partners and testing the influences of family-level predictors (i.e., co-parenting conflict and interparental conflict) on RSA synchrony. Regarding within-dyad concurrent physiological synchrony, the triadic conflict discussion resulted in three possible dyad composition (i.e., mother-adolescent, father-adolescent, and mother-father). The within dyad, minute-to-minute synchrony between mothers and adolescents, for example, was operationalized as the association in the RSA between the two dyad members at the same occasion on Level 1.

$$\text{Level1}: Y_{dt} = \beta_{0d} + \beta_{1d} * \left(X_{dt} - \overline{X}_{.d}\right) + \epsilon_{dt}$$

$$\begin{aligned}\text{Level2}: \beta_{0d} &= r_{00} \\ \beta_{1d} &= r_{10} + u_{1d}\end{aligned}$$

X_{dt} refers to mother's RSA for dyad d at time t, whereas Y_{dt} denotes the adolescent RSA for dyad d at time t. On level 1(i.e., within-dyad level), adolescent RSA(i.e., Y_{dt}) was predicted by an overall intercept (i.e., β_{0d}), the mother's person-mean centered RSA(i.e., $(X_{dt} - \overline{X}_{.d})$, with greater values referring to greater deviation of a specific occasion from the mother's personal mean), and a level-1 residual (i.e., ϵ_{dt}). On level 2 (i.e., between-dyad level), no random effects were tested for the intercept (i.e., $\beta_{0d} = r_{00}$) given that the detrended RSA should have an overall mean of zero; however, the slope (i.e., β_{1d}) was allowed to differ among dyads. As such, r_{10} refers to an averaged level of mother-adolescent concurrent synchrony in the whole sample, and u_{1d} represents the deviation of a particular dyad from the sample-mean concurrent synchrony level. Thereby, a higher positive β_{1d} value represents stronger links between maternal deviations in RSA from their personal mean at a certain occasion and adolescents' fluctuations from their personal means at the same occasion. In addition, given that all RSA trajectories were detrended, no between-person/dyad effects of synchrony were tested. This model was run with maternal RSA predicting adolescent RSA, and the other way around (i.e., adolescent RSA predicting maternal RSA), and for father-adolescent, and mother-father dyads as well.

The next step of data analysis involved evaluating the moderating effect of family conflict (i.e., co-parenting conflict and interparental conflict) on concurrent RSA synchrony between partners. Given that family conflict (e.g., co-parenting conflict) are level-2 factors (i.e., between-dyad level), their effect on physiological synchrony is thus operationalized as the cross-level interaction between level-2 family predictor and the level-1 RSA.

$$\text{Level1}: Y_{dt} = \beta_{0d} + \beta_{1d} * \left(X_{dt} - \overline{X}_{.d}\right) + \epsilon_{dt}$$

$$\text{Level2}: \beta_{0d} = r_{00}$$
$$\beta_{1d} = r_{10} + r_{11} * v_1 + u_{1d}$$

Inspection of the model indicates that everything remains the same except that the concurrent synchrony, β_{1d} is now predicted by the $r_{11}* v_1$ term as well. v_1 represents family contextual factors (i.e., co-parenting conflict, interparental conflict), and a significant parameter estimate, r_{11}, indicates a significant impact of family predictor on synchrony. Effects of co-parenting conflict and interparental conflict were tested in separate models. A significant cross-level interaction is further probed at +/−1 *SD* of the family factor for synchrony level to illuminate the pattern of the interaction. Notably, both family factors were within-imputation standardized to make sure that the mean was zero for each imputation, and standard deviation was the same (i.e., $SD = 1$) across imputations. In other words, the parameter coefficient, r_{11}, represents the change in concurrent physiological synchrony when the family predictor (e.g., co-parenting conflict) goes one unit beyond its sample mean within each imputation. An identical *SD* across imputations enables the accurate probing for RSA synchrony at +/−1 *SD* of the family predictors.

Results

Concurrent RSA synchrony

As shown in Table 2, significant positive within-dyad physiological synchrony emerged between mothers and adolescents (maternal RSA predicting adolescents RSA: $B = 0.13$, $p = .02$). More specifically, when mothers' RSA fluctuates beyond their personal mean at a specific occasion, their adolescents' RSA also go beyond their personal means in the same epoch. The same results emerged when mothers' RSA was predicted by adolescents' RSA ($B = 0.06$, $p = .05$), although the magnitude of effect was somewhat weaker. Turning to the father-adolescent dyad, no significant within-dyad RSA synchrony was found between fathers and adolescents (paternal RSA predicting adolescent RSA: $B = -0.08$, $p = .10$; adolescent RSA predicting paternal RSA: $B = -0.04$, $p = .13$), reflecting no physiological linkage between fathers and adolescents during the family conflict discussion. Notably, even though fathers and adolescents did not exhibit physiological synchrony, fathers and mothers showed positive RSA synchrony on average (i.e., paternal RSA predicting maternal RSA: $B = 0.07$, $p = .04$; maternal RSA predicting paternal RSA: $B = 0.11$, $p = .05$).

Further tests were carried out to examine the robustness of the detected concurrent RSA synchrony among mother-adolescent and father-mother dyads (See details in supplemental material, Table S2). As such, lagged synchrony (e.g., $\text{mother}_{(t-1)} \rightarrow \text{adolescent}_{(t)}$) as well as autoregressive effects of RSA (e.g., $\text{adolescent}_{(t-1)} \rightarrow \text{adolescent}_{(t)}$) were included while examining concurrent synchrony (e.g., $\text{mother}_{(t)} \rightarrow \text{adolescent}_{(t)}$). Whereas no significant lagged synchrony was found among any dyad, the mother-adolescent and mother-father concurrent synchrony remained significant after controlling for lagged synchrony and autoregressive effect of RSA. Furthermore, additional tests also suggested adolescent gender did not operate as a significant moderator for the strength of RSA synchrony among any dyad.

Effects of co-parenting conflict and interparental conflict

As shown in Table 3, the moderating effects of co-parenting conflict and interparental conflict on physiological synchrony were tested in separate models and thus results were introduced separately. Notably, a significant cross-level interaction between RSA and co-parenting conflict emerged within the mother-adolescent dyad. More specifically, co-parenting conflict was a significant moderator of the mother-adolescent RSA synchrony (mother predicting adolescents: $B = -0.12$, $p = .03$). Further analyses which probed the interaction indicated that adolescents showed significant positive RSA synchrony with their mothers when co-parenting conflict between parents were low (−1 *SD*, $B = 0.24$, $p = .001$), but not when parents had high levels of co-parenting conflict (+1*SD*, $B = -0.01$, $p = .93$). The moderating effect for co-parenting conflict was not significant when mothers' RSA was predicted by adolescents', even though there was a marginally significant trend (RSA-x-co-parenting conflict interaction, $B = -0.05$, $p = .07$). Further test suggested the pattern for this trend finding was consistent, such that mothers tend to show RSA synchrony with adolescents when co-parenting conflict were low (−1*SD*, $B = 0.10$, $p = .01$), but not when co-parenting conflict was high (+1*SD*, $B = 0.01$, $p = .87$). In addition, even though co-parenting conflict significantly moderated mother-adolescent RSA synchrony, the former did not turn out as a significant moderator for RSA synchrony within father-adolescent or father-mother dyads. In contrast to co-parenting conflict, there was no significant moderating effect of general interparental conflict on physiological synchrony among any of the dyad composition.

Discussion

The present study examined RSA synchrony between mothers, fathers, and adolescents during a conflict discussion. In addition, we evaluated the moderating role of two domains of the interparental relationship on physiological synchrony among family members. Positive physiological concordance was found between adolescents and their mothers, as well as between mothers and fathers. Moreover, co-parenting conflict significantly moderated the levels of the mother-adolescent RSA synchrony such that positive mother-adolescent RSA synchrony was only observed under lower co-parenting conflict. No synchrony was found when co-parenting conflict was high. Furthermore, general interparental conflict did not significantly moderate the RSA synchrony among any dyads. The present work extends the literature from a conceptual standpoint in documenting the concurrent synchrony of parasympathetic system activity among mothers, fathers, and their adolescent as well as demonstrating the specificity of conflict within the interparental dyad on physiological concordance among family members. Further, the present study adds to the literature on methodological approaches to family research through demonstrating the application of multilevel within-person/dyad methods in examining the coupling of physiological states among family members over time.

During the triadic discussion, our findings that mothers and adolescents exhibited positive minute-to-minute physiological synchrony are consistent with the broader literature (e.g., Lunkenheimer et al., 2015, 2018; Woody et al., 2016). That is, when mothers' vagal activity fluctuated beyond her personal averaged levels, adolescents also demonstrated higher-than-average vagal activity at the same occasion, and vice versa. The coordinated mother-adolescent physiological activity may reflect shared attention, experiences and feelings during the interaction, and yet may reflect the mother-adolescent bidirectional influences (Davis et al., 2018). That is, mothers might be attentive and responsive to adolescents' cues during the interaction, manifested by matching her physiological arousal in response to adolescents' signals. In other words, mothers who are more sensitive to the happy or distressed cues of the children might show corresponding physiological arousal with their adolescents. On the other hand, mothers may try to engage the adolescents by directing the conversations, raising issues, and initiate the talks about positive or negative feelings with the children, which may shape the adolescents' physiological arousal. Notably, even though adolescents are more competent in self-regulation, the input from mothers might still serve as an important factor that helps them navigate the emotional challenges during the difficult family discussions (Morris et al., 2008).

Compared to mothers, even though fathers were also involved in the discussion, we did not find any evidence for father-adolescent RSA concurrent synchrony. Instead, fathers only exhibited concordant physiological exchanges with mothers. Given that very few physiological synchrony studies have included fathers, the findings of the present work were partially consistent with previous research (Gordis et al., 2010; Saxbe et al., 2014). More specifically, Saxbe et al. (2014) assessed cortisol activity around family triadic conflict discussion revealed cortisol attunement when mothers' cortisol levels predicting fathers' cortisol at the subsequent time point, adolescents' predicting mothers', and fathers' predicting adolescents' cortisol. Our finding for father-mother RSA synchrony aligns with Saxbe et al.'s (2014) results for interparental cortisol attunement, although concurrently. In contrast, the evidence for father-adolescent synchrony (Saxbe et al., 2014) did not emerge in our study or Gordis et al.'s (2010) low interparental-aggression families. We suggest this might be related to the following reasons. First, Saxbe et al. (2014) measured cortisol responses before and after the conflict discussion (i.e., six measurement occasions ranging from before to an hour after the discussion), our focus was limited to the several minutes *during* the discussion. As such, the discrepancy might be attributed to the different time frames of the studies. Second, we assessed different physiological markers compared to previous studies, thereby the inconsistent results might be accounted by the different systems of interest.

Turning to our findings for the lack of father-adolescent concurrent RSA synchrony, it is well acknowledged that the fathers' role is less well defined by the social norms. Compared with mothers, fathers spend less time with children (e.g., Yeung, Sandberg, Davis-Kean, & Hofferth, 2001) and are more likely to be less involved in childrearing activities (e.g., McBride & Mills, 1993). Furthermore, paternal parenting practices may be susceptible to the influences of mothers' inputs, including mothers' confidence and approval, and mothers' positive feelings about the paternal parenting (e.g., mother feeling good about seeing father interacting with their child; McBride & Rane, 1998). Considered within the context of the present study, the lack of father-adolescent RSA synchrony might be accounted for by fathers letting mothers take the lead of the discussion and being more engaged and attuned to mothers' cues rather than actively involved in the discussion with the adolescents. In fact, such an approach may indicate a fathers' strategy in teaming up with mothers to resolve the family conflict related to adolescents. It is also possible that fathers approached the family conflict issues more calmly, used humor, and/or took a distancing strategy instead of being involved in the most heated discussion with adolescents. These interpretations are speculative and bear future investigation.

Our finding concerning the moderating role of co-parenting conflict in the association between mother-adolescent RSA synchrony is noteworthy. Whereas mothers and adolescents exhibited concordant physiological activity when co-parenting conflict was low, no synchrony was observed when co-parenting conflict were high. Our finding is consistent with previous literature that has documented a dampened parent-child synchrony with the presence of risky factors (e.g., maternal depression, Woody et al., 2016; maternal psychological aggression: Lunkenheimer et al., 2015; 2018; maltreatment: Lunkenheimer et al., 2018). As such, it seems plausible that mother-adolescent synchrony reflects well-adjusted mother-teen relationship within the current context. Even though scant empirical work examined the implications of positive and negative physiological synchrony on adolescent development, physiological synchrony has been conceptualized as an important source of external input that may operate as the basis for children's emerging attachment, self-regulation, and social skills in early life (Feldman, 2007). Certainly consistent with this perspective are findings that parent-child synchrony on the behavioral level are linked with secure attachment (e.g., Isabella & Belsky, 1991) and better child adjustment (Harrist, Pettit, Dodge, & Bates, 1994). Furthermore, diminished mother-adolescent synchrony under high co-parenting conflict was consistent with the spillover hypothesis, which stipulates that conflict within the coparental relationship "spills over" to the parent-child relationship, compromising parents' ability to provide supportive and sensitive caregiving(Sturge-Apple et al., 2006a; Martin et al., 2017). That is, if mothers' self-regulation resources are exhausted when coping with negativity within coparental relationship, they might not be able to attend and respond sensitively to adolescents' signals, and/or to effectively initiate and maintain reciprocal interactions with adolescents, particularly when their partner is involved in the discussion.

In contrast to co-parenting conflict, general interparental conflict did not turn out as a moderating factor for mother-adolescent synchrony during the triadic conflict discussion. This finding is consistent with theory and literature suggesting that co-parenting conflict might be a more proximal factor that is more tightly linked to the parent-child relationship (Feinberg, 2003), and uniquely predicts parent-child relationship quality over and above the effects of general interparental conflict (Feinberg et al., 2007; Jouriles et al., 1991; Tuebert & Pinquart, 2010). For example, Feinberg et al. (2007) examined the influence of co-parenting conflict within two-parent families with adolescents. In particular, controlling for interparental relationship quality and partner disagreements, mother- and father-reported co-parenting conflict significantly predicted greater parent negativity, characterized by greater parent-adolescent conflict and hostility, and more harsh and punitive parenting. Moreover, the difference between co-parental and general interparental conflict might be particularly evident within the current context of the *triadic* discussion, as the conflicts are usually centered around adolescent-related issues (e.g., chores, use of electronics) and include both members of the parental dyad.

Several limitations need to be considered when interpreting the findings of the present study. First, while the present sample primarily consisted with white, middle- to low-SES families, the generalization of findings should be cautious. Second, although our environmental measures were multi-informant (i.e., mother, father), we only relied on self-reported questionnaires to obtain the information. Third, while we only focused on a single physiological indicator—RSA—to assess physiological synchrony, future studies are encouraged to evaluate synchrony within multiple physiological systems (e.g., HPA and PNS). Fourth, while the present paper did not evaluate whether and how RSA synchrony shapes adolescent development, it is a critical issue that remains to be understood. We thus urge future research to address this inquiry.

These limitations notwithstanding, the present study applied a multilevel approach to examine the within-dyad physiological synchrony among fathers, mothers, and adolescents in the real-time family conflict discussion. We documented mother-adolescent as well as father-mother concurrent RSA synchrony, and the moderating role of co-parenting conflict on mother-adolescent physiological synchrony. The findings promote our understanding in the physiological concordance among family members, particularly with regard to fathers' role. In addition, the results underscored the importance of co-parenting conflict on mother-adolescent coordinated interactions, highlighting the importance to mitigate such risks for adolescents to form coordinated and reciprocal parent-child relationship. Our findings, if replicated, may inform intervention programs for (a) better identifying target family member for potential training(e.g., maternal RSA was directly linked with both father and adolescent RSA concurrently, mothers might be an important target for training); and (b) identifying families in greatest needs (i.e., families with high co-parenting conflict) for potential training to facilitate positive parent-child synchrony (e.g., via mutual eye-gaze during conversation, emotion regulation strategy to stay calm and being responsive to each other's signal, noticing and understanding non-verbal emotional signals). The findings also highlighted the importance in applying multilevel, within-dyad approach to evaluate family dynamics in real-time interactions.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1.

Descriptive Information for the Primary Variables before Multiple Imputation.

	N	Mean	SD	Min	Max
Adolescent RSA [a]					
1st Epoch/Min	180	63.97	33.75	14.83	169.93
2nd Epoch/Min	180	61.03	32.80	12.65	161.63
3rd Epoch/Min	176	55.66	29.62	13.24	166.20
4th Epoch/Min	179	58.90	33.00	8.95	159.75
5th Epoch/Min	177	57.40	31.44	10.37	158.38
6th Epoch/Min	180	58.10	32.58	13.03	156.60
Mother RSA					
1st Epoch/Min	178	42.72	24.40	6.82	123.19
2nd Epoch/Min	178	42.39	25.76	5.94	126.17
3rd Epoch/Min	179	40.80	24.46	7.41	115.88
4th Epoch/Min	177	36.68	18.99	6.86	97.78
5th Epoch/Min	177	37.60	22.32	7.67	104.58
6th Epoch/Min	175	37.72	21.21	5.57	113.52
Father RSA					
1st Epoch/Min	182	39.07	23.75	6.14	126.24
2nd Epoch/Min	183	37.80	26.71	3.51	123.69
3rd Epoch/Min	184	36.55	24.16	6.03	118.84
4th Epoch/Min	182	35.67	24.77	4.34	125.35
5th Epoch/Min	181	34.36	22.48	4.39	116.82
6th Epoch/Min	184	37.12	26.23	3.84	123.40
Coparenting Conflict [b]	191	1.86	0.48	1.04	4.00
Interparental Conflict [c]	190	0	0.83	−1.59	3.54

Note.

[a.] RSA for adolescents, mothers, and fathers presented in this table were after removing +/− *3SD* values.

[b.] Coparenting conflict in the table was created by averaging the existing score for mother- and father-report. However, mother- and father-report imputed separately in multiple imputation before creating the average score for the primary analyses.

[c.] Interparental conflict in this table was created based on existing data. Verbal- and physical- aggression was each created by averaging mother- and father-report, and these two constructs were standardized and aggregated together to form the final indictor for interparental conflict.

Table 2.

Concurrent RSA Synchrony Between Dyad Partners.

	Intercept		Fixed effects /Concurrent Synchrony		Random effect variances	
	Estimate (SE)	***p***	**Estimate (SE)**	***p***	**Estimate (SE)**	***p***
Mother → Adolescent RSA [a]	−0.06(0.39)	.88	0.13(0.06)	.02 *	0.08(0.04)	.03 *
Adolescent → Mother RSA	0.01(0.28)	.97	0.06(0.03)	.05 *	0.04(0.01)	.01 **
Father→ Adolescent RSA	−0.002(0.40)	.99	−0.08(0.05)	.10	0.05(0.04)	.21
Adolescent → Father RSA	−0.01(0.34)	.98	−0.04(0.03)	.13	0.01(0.01)	.35
Father → Mother RSA	−0.03(0.27)	.90	0.07(0.03)	.04 *	0.03(0.01)	.07 †
Mother → Father RSA	−0.02(0.34)	.96	0.11(0.06)	.05 *	0.12(0.05)	.02 *

Note.

** $p < .01$

* $p < .05$

† $p < .10$.

[a.] "Mother → Adolescent RSA": maternal RSA predicting adolescent RSA. Fixed effect/concurrent synchrony: the concurrent RSA synchrony between dyad partners within the whole sample. Random effect variance: the variance of the random effect for concurrent synchrony. The results were summarized across 100 imputed datasets, including 1146 intervals for all dyads per imputation (i.e., 191 dyads * 6 intervals/dyad= 1146 total intervals). Given that some participants' RSA were completely missing, a total of 1026(i.e., $N_{missing}$ =102 intervals), 1056(i.e., $N_{missing}$ =90 intervals), and 1056(i.e., $N_{missing}$ =90 intervals) intervals were included for each imputation for mother-adolescent, father-adolescent, and mother-father dyads, respectively.

Table 3.

Concurrent RSA Synchrony Between Dyad Partners Moderated by Family Conflict.

	Coparenting conflict		Interparental conflict	
	Estimate (SE)	*p*	Estimate (SE)	*p*
Mothers→ Adolescents				
Intercept	−0.06(0.39)	.88	−0.06(0.39)	.88
Fixed effect (L1_RSA)	0.12(0.06)	.04 *	0.12(0.06)	.03 *
Fixed effect (L1_RSA-x-L2_Family predictor)	−0.12(0.06)	.03 *	−0.05(0.05)	.32
Random effect variance (L1_RSA)	0.08(0.04)	.03 *	0.08(0.04)	.03 *
Adolescents -> Mothers				
Intercept	0.01(0.28)	.97	0.01(0.28)	.97
Fixed effect (L1_RSA)	0.06(0.03)	.06 †	0.05(0.03)	.07 †
Fixed effect (L1_RSA-x-L2_Family predictor)	−0.05(0.03)	.07 †	−0.04(0.03)	.25
Random effect variance (L1_RSA)	0.03(0.01)	.01 *	0.03(0.01)	.01 *
Fathers → Adolescents				
Intercept	−0.002(0.40)	.99	−0.002(0.40)	.99
Fixed effect (L1_RSA)	−0.08(0.05)	.10	−0.08(0.05)	.11
Fixed effect (L1_RSA-x-L2_Family predictor)	0.01(0.05)	.89	−0.001(0.04)	.98
Random effect variance (L1_RSA)	0.05(0.04)	.21	0.05(0.04)	.22
Adolescents → Fathers				
Intercept	−0.01(0.34)	.98	−0.01(0.34)	.98
Fixed effect (L1_RSA)	−0.04(0.03)	.13	−0.05(0.03)	.13
Fixed effect (L1_RSA-x-L2_Family predictor)	−0.003(0.03)	.90	−0.01(0.03)	.83
Random effect variance (L1_RSA)	0.01(0.01)	.36	0.01(0.01)	.37
Fathers → Mothers				
Intercept	−0.03(0.27)	.90	−0.03(0.27)	.90
Fixed effect (L1_RSA)	0.07(0.03)	.03 *	0.07(0.03)	.03 *
Fixed effect (L1_RSA-x-L2_Family predictor)	−0.02(0.03)	.51	−0.01(0.03)	.75
Random effect variance (L1_RSA)	0.02(0.01)	.10 †	0.03(0.01)	.07 †
Mothers → Fathers				
Intercept	−0.02(0.34)	.96	−0.02(0.34)	.96
Fixed effect (L1_RSA)	0.11(0.06)	.05 *	0.11(0.06)	.05 *
Fixed effect (L1_RSA-x-L2_Family predictor)	0.01(0.06)	.88	0.03(0.05)	.58
Random effect variance (L1_RSA)	0.12(0.05)	.02 *	0.12(0.05)	.02 *

Note.

** $p < .01$

* $p < .05$

† $p < .10$. L1_RSA: RSA on the within-person level (i.e., Level-1). Level 2_Family predictor: family predictor (i.e., co-parenting conflict vs. interparental conflict) on the between-person level (i.e., Level 2). Again, a total of 1026(i.e., $N_{missing}$ =102 intervals), 1056(i.e., $N_{missing}$ =90 intervals), and 1056(i.e., $N_{missing}$ =90 intervals) intervals were included for each imputation for mother-adolescent, father-adolescent, and mother-father dyads, respectively.