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In Sync: Daily Mood and Diurnal Cortisol Synchronization between Pre-adolescents and their
Mothers and Fathers

A dissertation submitted in partial satisfaction of the
requirements for the degree Doctor of Philosophy
in Psychology

by

Delana Marie Parker

2017

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ABSTRACT OF THE DISSERTATION

In Sync: Daily Mood and Diurnal Cortisol Synchronization between Pre-adolescents and their
Mothers and Fathers

by

Delana Marie Parker

Doctor of Philosophy in Psychology

University of California, Los Angeles, 2017

Professor Rena L. Repetti, Chair

Daily interactions may function as opportunities for family members to impact one another in ways that replenish or deplete coping resources. Evidence of synchronization in affect, behavior, and arousal has been observed in parent-infant dyads and coregulation of mood and physiology has also been demonstrated in marital partners. However, little is known about whether pre-adolescents and their parents may serve a similar regulating function for one another. The current study draws upon three repeated measures samples to test transmission of daily mood states and physiology in pre-adolescent children aged 7-13 and their mothers and fathers. Synchrony hypotheses predict bidirectional transmission between parent and child, and child and parent in both daily mood and diurnal cortisol. The hypothesis that mother-child dyads would show

synchrony in daily positive mood was supported by all three samples. Father-child dyads did not evidence positive mood synchrony. Father-child and mother-child dyads evidenced negative mood synchrony in one of three samples. In both of the sample that included diurnal cortisol measures, pre-adolescents showed synchrony with both mothers and fathers. Overall, the current project supports a reciprocal view of parent-child influences in both physiology and mood during the pre-adolescent period of development.

The dissertation of Delana Marie Parker is approved.

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2017

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Abstract

The current paper draws upon three intensive repeated measures studies to test whether mood is transmitted between parents and children in the early adolescent period (7-13 years). Studies included between 3 and 56 days of diary data, with mood ratings on one to four sampling occasions per day. Bidirectional mood transmission, or mood synchrony, wherein each member of the parent-child dyad transmits mood to the other was expected for both positive and negative mood. Synchrony hypotheses were tested using dyadic multilevel Actor-Partner Interdependence Models. Results from all three studies suggest mother-child positive mood synchrony, such that when mothers demonstrate higher than typical positive mood children are also likely to have higher positive mood, and when children evidence higher positive mood mothers tend to also demonstrate higher positive mood. None of the three studies supported positive mood synchrony between fathers and children. One of three studies supported negative mood synchrony in both mother-child and father-child dyads. Results support a dyadic approach to testing and conceptualizing changes in daily mood within the family environment, and raise questions about the mechanisms and long-term effects of daily mood synchrony in the family.

Keywords: mood, synchrony, transmission, coregulation, parent-child relationship

Positive and Negative Daily Mood Synchrony In Mother-Child and Father-Child Dyads

Though a traditional view of emotion focuses on individual subjective experience, it is clear that the social environment shapes the timing, intensity, and expression of experience. At birth, humans demonstrate limited affect expression and rely heavily on external mechanisms of regulation. However, infants soon begin to utilize information from their environment to learn culturally appropriate emotion labels, methods of expression, and strategies for regulation. The influence of close others on affective experience across the life span is emphasized in a social functional perspective of emotions (Keltner & Haidt, 2001). This perspective suggests that affective experience and expression serve inherently interpersonal functions by providing outside observers with information about an individual's current state, and opportunities to make adjustments to their own behavior. One implication of this perspective is that people of all ages are likely to attend to the emotions of social partners, and to react in ways that will affect the other person. This dynamic interdependence presents challenges to affective researchers by suggesting that a complete understanding of an individual's affective experiences and behaviors requires simultaneous examination of close others.

The idea that one person's feelings are almost unavoidably perceived and experienced by close others is implicit in colloquial expressions like "contagious laughter," an "infectious smile," or "misery loves company." In the psychological literature this idea is encapsulated by the term emotion contagion, which refers to observations of emotion-relevant behaviors of one person generating a similar response in a social partner (Hatfield, Cacioppo, & Rapson, 1994; Saarni, Mumme, & Campos, 1998). Several related lines of research have examined how the affective experiences of one partner produce change in the behavior or feelings of a close other. For example, job stressors may cause emotional distress in a spouse and are referred to as "cross-

over.” Discord among marital partners is associated with spillover conflict in parent-child dyads (Almeida, Wethington, & Chandler, 1999; Margolin & Christensen, 1996; Repetti, 1994; Sears, Repetti, Reynolds, & Robles, 2016). People engaged in social interaction, such as friends, family members or even strangers, may unconsciously mirror the non-verbal behaviors another (Lakin, Jefferis, Cheng, & Chartrand, 2003; van Baaren, Holland, Kawakami, & van Knippenberg, 2004). Sharing happiness with a loved one can lead to increases in own and partner happiness through positive emotion capitalization (Hicks & Diamond, 2008). A dynamic interpersonal perspective suggests that these processes are bidirectional, such that each partner in a dyad is sensitive to and affected by the other. Such bidirectional affective processes have been documented in the daily mood of marital or romantic partners, and sometimes considered to be examples of emotion coregulation (Saxbe & Repetti, 2010; Schoebi, 2008).

In the early years of life the family environment is the predominant social context, with parents as salient and frequent social partners. Indeed, mothers and fathers sculpt children’s developing emotion expression and regulation through a number of pathways, including modeling of emotion expression and regulation, talk about emotion, through specific parenting practices like emotion coaching, and through their reactions to children’s emotions (Cole, Martin, & Dennis, 2004; Eisenberg et al., 2001; Eisenberg et al., 2003; Morris, Silk, Steinberg, Myers, & Robinson, 2007). In the search to understand daily processes that underlie associations between parenting practices and children’s affective development, two related lines of research suggest that daily interactions in the family serve as a creative force for both children and parents. Just as parents may shape children’s emotional experiences through daily interaction, children also influence parents’ emotions, and the daily emotional experiences of an individual family member may best be understood as co-created through interactions with close others.

Dyadic Synchrony

Foundational research on affect coordination in the family focused on the coordinated behavior and affect observed in mother-infant face-to-face interactions (Feldman, 2007; Harrist & Waugh, 2002). Mothers appear to act as external regulators of infant affect, attention, and physiological arousal through a process of dyadic synchrony, characterized by a shared focus of attention, mutual responsiveness, and temporally contingent behavior and affect (Harrist & Waugh, 2002). Mothers mirror infants' vocalization, body posture, or gesture, and tailor their behavior to the infant's state and goals. These interactions help infants up- or down-regulate attention, arousal, physiology, and quality of affective experience. Greater synchrony has been linked with more positive outcomes for infants, including greater prosocial behavior. Though synchrony is largely driven by caregiver attunement, even in their earliest months of life infants likewise affect their caregivers, thereby influencing the very system regulating their neural and physiological affective development. The view of the parent-child dyad as a closed mutually responsive system with bidirectional effects is critical for understanding the unfolding of developmental processes in the family.

Studies of affect and behavior coordination in the early years of life suggest that mother and child coalesce such that the behavior and emotion of each partner cannot be understood in isolation. This perspective emphasizes a socio-ecological view of human development and encourages investigation of bidirectional effects. Studies of dyadic synchrony have largely focused on mother-child dyads with few studies including fathers. However, the studies that have included father-child dyads suggest that like mothers, fathers engage in reciprocal interactions with young children, but may display different patterns of affect expression (Feldman, 2003). A more holistic perspective on affect coordination in the family must continue to include fathers.

There have also been few studies that have considered focused, reciprocal interactions beyond the first few years of a child's life. The studies that have included older children and adolescents suggest shared moments between caregivers and children may continue to serve a regulatory and socialization purpose. A focus on the pre- and early adolescent years may provide fruitful information about a period of increased risk for the development of affective and social problems. Time spent with family declines at this age, and intensive repeated measures studies indicate that youth emotional states become less positive and more frequently negative (Larson & Richards, 1991; Larson, Moneta, Richards, & Wilson, 2002). Positive and negative affect, though correlated, show distinct relationships with risk for negative psychosocial outcomes and may be more or less sensitive to modulation by family members at various periods of development. Thus, future investigations of dyadic synchrony processes should take care to include children across the span of development, and include both positive and negative interactions with both parents.

Emotion Transmission in the Family

A second line of research has informed our knowledge of social forces that shape child daily affect. Emotion transmission research built upon studies that found evidence of conflict or mood spillover (Higgins, Duxbury, & Irving, 1992; Katz & Gottman, 1996; Margolin & Christensen, 1996; Repetti, 1994; Repetti, 1996; Williams & Alliger, 1994) and crossover of work stress to spouses (Bolger, DeLongis, Kessler, & Wethington, 1989; Chan & Margolin, 1994; Jones & Fletcher, 1993; Westman & Etzion, 1995), by leveraging intensive repeated measures methods to investigate interrelatedness in family members' emotions (Larson & Almeida, 1999). Emotion transmission is a process wherein exposure to the emotions of another individual results in similar emotional states in another. Intensive repeated measures offers an

opportunity to assess within person change, and identify which family members' demonstrate the most influence on others. Because these methods rely on subjective self-report of emotion, they have been utilized only in families with children old enough to comply with report procedures.

Though informative, there have been few studies of emotion transmission that utilize EMA methods or repeated diary measures to investigate emotion transmission in parent-child dyads. Two of these naturalistic emotion transmission studies have exclusively focused on mothers and adolescents. A mother-to-adolescent pattern of negative emotion transmission was tested among a sample of adolescents and mothers, half of whom were diagnosed with a chronic pain condition associated with higher levels of anger. Each dyad member provided diary reports on mood, including depression, anger, and anxiety, one time per day on 28 days. Mothers were found to transmit anger to children, only among families that did not include a mother with chronic pain, even though mothers with chronic pain endorsed higher anger relative to control mothers. The authors suggested that anger may not be transmitted among families who included a mother with chronic pain, because adolescents may have perceived the likely cause of maternal anger to be related to chronic pain (Downey, Purdie, & Schaffer-Neitz, 1999). A second mother-adolescent emotion transmission study utilized EMA methods to test both parent and child transmission of emotion in a sample of single-mothers and adolescents. Mothers and adolescents rated positive and negative mood several times per day on 6 to 7 consecutive days. Mothers transmitted anger and anxiety, but not happiness, to adolescents. Adolescents did not transmit either negative or positive emotion to their mothers (Larson & Gillman, 1999). Finally, in the only study to date to evidence transmission of positive mood, mothers were found to transmit end of work-day anger and happiness to adolescents (Matjasko & Feldman, 2005).

One prior study has tested emotion transmission in families including children, mothers, and fathers. Each family member rated affect on a single bipolar scale ranging from pleasant to unpleasant at several occasions throughout the day on five days. Emotion transmission from each family member to all others was tested. Daughters were found to transmit emotions to both parents, and father ratings were marginally associated with change in affect among mothers and sons (Larson & Richards, 1994). In sum, intensive repeated measures studies support the concept of emotion transmission and suggest potentially different relationships for sons and daughters and same and opposite-sex parents. Despite acknowledgement that transmission is likely to be bidirectional (e.g. mothers transmit to adolescents and adolescents transmit to mothers), to date no EMA or intensive measures diary studies have examined bidirectional emotion transmission simultaneously in parents and children.

Current Study

The current study investigates daily positive and negative mood transmission in three samples of children between the ages of 7 and 13, and their mothers and fathers. A focus on short term interactions has suggested that family members share similarities in daily affect, with several studies supporting a pathway of parent to child transmission. To gain a better understanding of the dynamic family processes that comprise the social context of emotional development the current study tests the hypothesis that mother-child and father-child dyads will evidence bidirectional transmission of positive and negative mood, utilizing dyadic multilevel Actor-Partner Interdependence Models (APIM; Cook & Kenny, 2005; Kashy & Kenny, 1999; Kenny, Kashy, & Cook, 2006; Laurenceau & Bolger, 2005; Raudenbush, Brennan, & Barnett, 1995). These models have previously been utilized to test same-day transmission of emotion among marital partners (Saxbe & Repetti, 2010), and will be extended to the parent-child

relationship to test independent and simultaneous mood transmission from parents to children, and children to parents.

Data include parent and child self-report positive and negative mood ratings on at least one occasion per day over multiple days (3, 5, or 56 days). These three similar samples provide a unique opportunity to test bidirectional parent-child mood transmission in three independent samples with both mothers and fathers. Furthermore, in the two studies that include multiple mood ratings per day, a prospective change model in which an individual's prior mood is controlled for when testing for partner transmission effects (Larson & Almeida, 1999)

Methods

Data from three repeated-measures diary studies were used to test parent-child mood synchrony. The studies share several important commonalities, including mood reports by a target child between the ages of 7 and 13, and independent mood reporting by mothers and fathers. Families were recruited from the same greater metropolitan area in the southwestern United States and completed diary mood reports as one component of a larger multi-method study. Each participant self-reported on mood at the end of the day on multiple days; additional mood reporting within the day and the number of days varied across studies. Key study features, including participant characteristics, procedures, and measures are described below and are summarized in Table 1.

Participants

UCLA Families and Health Study. The sample of 47 families included 47 target children aged 8 to 13 years old (28 girls, 19 boys; M age = 11.28, SD = 1.50), 47 mothers (M age = 43.29, SD = 6.31) and 39 fathers (M age = 43.67, SD = 8.10). Median annual family income was between \$32,000 and \$82,000 in 2009-2012 dollars. The ethnic composition of target

children included 38.3% non-Hispanic white, 14.9% Latino/Hispanic, 14.9% African American, 10.6% Asian, and 21.3% 'Other' (primarily mixed ethnicity). Mothers included 40.4% non-Hispanic white, 27.7% Latino/Hispanic, 14.9% African American, 14.9% Asian, and 2.1% Native American. Among participating fathers, 51.3% identified as non-Hispanic white, 15.4% as Latino/Hispanic 20.5% as African American, and 10.3% as Asian.

UCLA Center for Everyday Lives of Families. The sample was comprised of 32 families, including 32 target children aged 7 to 12 years old (17 girls, 15 boys; M age = 9.41, SD = 1.12), 34 fathers (M age = 42.53, SD = 5.51), and 30 mothers (M age = 40.57, SD = 5.21). For two families headed by gay parents, data were utilized from one randomly chosen father. The median annual family income was \$100,000 in 2002-2005 dollars. Among target children 64.5% were European-American ethnicity, 9.7% were Asian-American, 3.2% were African-American, 3.2% were Latino/Hispanic, and 19.4% endorsed mixed ethnicity. Among participating mothers 70% identified as European-American, 16.7% as Asian-American, 10% as African-American, and 3.3% as Hispanic/Latino. Among fathers, 75% identified as European-American, 15.6% as Asian-American, 6.3% as African-American, and 3.1% as Hispanic/Latino.

UCLA Family Development Study. Eighty-three target children aged 9 to 12 years old (42 boys, 41 girls; M age = 10.91, SD = 0.53), 83 mothers (M age = 43.23, SD = 4.16), and 55 fathers (M age = 45.35, SD = 4.18) participated in the diary portion of a larger longitudinal study. Median annual family income was reported to be greater than \$80,000 in 1993-1996 dollars and the sample was predominately non-Hispanic white (79%). Mother self-reported ethnicity was 81% Caucasian, 7% Latino, 5% Native American, and 4% Asian/Pacific-Islander. Father self-reported ethnicity was 64% Caucasian, 4% Latino, 1% Asian/Pacific-Islander, and 1% 'Other.'

Procedures

Diary reports of mood in each study were embedded within three larger multi-method studies.

UCLA Families and Health Study. Participants completed diary mood reports once per day as a component of a larger study of stress and health in families (Repetti, Reynolds & Sears, 2015; Robles et al., 2016; Sears, Repetti, Robles & Krull, 2016). Other study procedures included questionnaires, a laboratory stress reactivity task, blood draw, and eight days of ambulatory salivary cortisol sampling. Diary mood reports were collected via computer at the end of the day, prior to bed, on 56 consecutive days. Before the diary phase of the study a trained research assistant visited each family's home to familiarize participants with a web portal used to collect diary and questionnaire data. Each parent and child were given an honorarium of \$350 and \$300 per week, respectively, for on-time completion of all daily diaries, including a \$5 bonus for each week of full on-time compliance with diary procedures.

UCLA Center for Everyday Lives of Families. Mood reports were collected at four points per day on three not necessarily consecutive weekdays as part of a larger, multidisciplinary study documenting daily home life among dual-earner families (Ochs et al., 2006; Campos, Graesch, Repetti, Bradbury, & Ochs, 2009). Participants completed questionnaire measures, provided saliva samples, completed home tours, and were video-taped by ethnographers on 2 of the 3 diary days during non-work or school hours. Pre-programed pagers reminded participants to complete paper and pencil diaries at four sampling occasions: morning, early afternoon before lunch, late afternoon at the end of school or work day, and before bed. Each family was given a \$1000 honorarium for participation in all study procedures.

UCLA Family Development Study. The diary component of this investigation took place during the second year of a three year longitudinal study of family life and daily stressors

(Lehman & Repetti, 2007; Story & Repetti, 2006). Out of the 248 families in the longitudinal study a subset of 83 target children and parents were eligible and agreed to participate in the diary phase; 71 families completed the diary component while the target child was in 5th grade, and 12 completed diary measures at the beginning of the child's 6th grade academic year. Participants completed paper and pencil mood reports on five consecutive weekdays, at three occasions per day: at home in the morning, at lunch, and at bedtime. An honorarium of \$50 for each parent and \$20 for each child was provided.

Measures

Parents and children independently assessed their moods in each of the three studies by rating a series of adjectives or mood-related statements, described below and detailed in Appendix A. Within-person reliability was assessed using a generalizability theory framework. Estimates indicate how reliable each diary mood measure is in detecting systematic variance within a reporter, or day-to-day change (R_c ; Cranford et al., 2006; Shrout & Lane, 2012). Internal scale consistency was calculated for mothers, fathers, and children at each diary occasion, the median alphas across all study sampling occasions are reported with each measure.

Parent Positive and Negative Mood.

UCLA Families and Health Study. At bedtime the parent diary asked the participant to indicate how he or she had felt that day by marking an 'x' to rate 14 mood adjectives mood on a 1 (*completely inaccurate*) to 4 (*completely accurate*) scale (Cohen et al., 2003). Six adjectives assessed positive mood ("happy", "lively," "at ease," "full of energy," "cheerful," and "calm") and eight items assessed negative mood ("sad," "angry," "on edge," "hostile," "unhappy," "tense," "stressed," and "overwhelmed.") Positive mood items were averaged, yielding a daily positive mood scale (mothers: $\alpha = 0.87$ and $R_c = 0.84$, fathers: $\alpha = 0.92$ and $R_c = 0.83$). Negative

mood items were averaged to yield a daily negative mood scale (mothers: $\alpha = 0.90$ and $R_c = 0.85$, fathers: $\alpha = 0.90$ and $R_c = 0.87$). Out of 56 days, mothers and fathers completed an average of 52.6 and 51.6 diaries, respectively. As expected, positive mood scores were high (mother $M = 2.76$ $SD = 0.67$; father $M = 2.83$ $SD = 0.60$) and negative mood scores were low (mother $M = 1.45$ $SD = 0.51$; father $M = 1.26$ $SD = 0.38$).

UCLA Center for Everyday Lives of Families and UCLA Family Development Study.

Parents in both of these studies were asked to rate how well 15 adjectives described how they had been feeling since the prior diary occasion (or beginning of the day). Response choices were 1 (*not at all*), 2 (*slightly applies*), or 3 (*definitely applies*). Four items assessed positive mood (“kindly,” “playful,” “elated,” and “energetic”) and eleven assessed negative mood (“frustrated,” “sad,” “tired,” “angry,” “emotionally drained,” “skeptical,” “tense,” “overwhelmed,” “nervous,” “clutched-up” and “impatient”; Saxbe & Repetti, 2010; Story & Repetti, 2006). Items were averaged to yield negative and positive mood scales for mothers and fathers. In the UCLA Center for Everyday Lives of Families investigation mood scales demonstrated adequate internal consistency and intraindividual variability for both positive mood (mother $\alpha = 0.61$ and $R_c = 0.17$; father $\alpha = 0.80$ and $R_c = 0.24$) and negative mood (mother $\alpha = 0.84$ and $R_c = 0.52$; father $\alpha = 0.86$ and $R_c = 0.59$). In the UCLA Family Development Study, internal scale consistency and intraindividual variability estimates were good for positive mood scales (mother $\alpha = 0.66$ and $R_c =$; father $\alpha = 0.74$ and $R_c =$), as were reliability estimates for negative mood scales (mother $\alpha = 0.84$ and $R_c = 0.52$; father $\alpha = 0.86$ and $R_c = 0.59$ for fathers). Compliance with diary procedures was good; parents in the UCLA Center for Everyday Lives of Families completed 11 out of 12 possible diaries. Average positive mood was similar for parents (mother $M = 1.43$, $SD = 0.37$; father $M = 1.47$, $SD = 0.36$), as was negative mood (mother $M = 1.30$, $SD = 0.51$; father $M =$

1.28 $SD = 0.29$). Parents in the UCLA Family Development Study were also compliant with diary procedures, completing an average of 13 out of 15 diaries. Parent positive mood scores were in the moderate range (mother $M = 1.63$, $SD = 0.43$; father $M = 1.68$, $SD = 0.43$) as were negative mood scores (mother $M = 1.40$, $SD = 0.37$; father $M = 1.33$ $SD = 0.34$).

Child Positive and Negative Mood.

UCLA Families and Health Study. Mood diary instructions asked children to think about how they felt today and rate agreement with 14 mood adjectives adapted from Cohen, Doyle, Turner, Alper, & Skoner (2003) and the Youth Everyday Social Interaction and Mood (YES I AM) mood scales (Repetti, 1996). Scale response options included: 1 (*not at all*), 2 (*some of the day*), 3 (*most of the day*), and 4 (*all day*). Eight items were averaged to form the positive mood scale (“lively,” “happy,” “relaxed,” “full of energy,” “cheerful,” “calm,” “proud,” and “loved”) and six items were averaged to form the negative mood scale (“mean,” “tense,” “sad,” “unhappy,” “angry,” and “worried”). Positive and negative mood scales demonstrated good internal consistency and ability to capture intraindividual variability (positive mood: $\alpha = 0.94$ and $R_c = 0.81$; negative mood: $\alpha = 0.83$ and $R_c = 0.72$). Children completed an average of 52 out of 56 diary days. Average positive mood was high ($M = 2.98$, $SD = 0.79$) and negative mood was low ($M = 1.26$, $SD = 0.38$).

UCLA Center for Everyday Lives of Families and UCLA Family Development Study.

Children in both studies were asked how well a series of statements described their feelings since the prior sampling occasion, or beginning of the day. Items were adapted from the YES I AM scales (Lehman & Repetti, 2007; Repetti, 1996). Response options were 1 (*definitely false*), 2 (*mostly false*), 3 (*mostly true*), and 4 (*definitely true*). At each diary occasion, seven items were averaged to form the positive mood scale (“I was confident,” “I felt proud,” “I was happy,” “I

was smiling,” “I was acting cheerful,” “I was excited,” and “I felt loved”), and ten were averaged to form the negative mood scale (“I was angry,” “I felt ashamed,” “I was sad,” “I was scared,” “I was tense,” “I felt that others were pressuring me,” “I felt worried, distracted, or preoccupied,” “I felt alone,” “I felt that others were expecting too much from me,” “I felt confused”). In the UCLA Center for Everyday Lives of Families scales demonstrated good internal reliability and ability to capture within-person change (positive mood: $\alpha = 0.82$ and $R_c = 0.48$; negative mood: $\alpha = 0.80$ and $R_c = 0.51$). Children completed an average of 9 out of 12 diary occasions in that study, children completed an average of 9 diaries; average child positive mood was high ($M = 3.11$, $SD = 0.71$) and negative mood was low ($M = 1.24$, $SD = 0.36$). Children in the UCLA Family Development sample completed an average of 13 out of 15 diaries; on average child positive mood was high ($M = 3.18$, $SD = 0.80$) and negative mood was low ($M = 1.35$, $SD = 0.53$). Internal scale consistency and ability to capture within person change were also estimated to be good (positive mood: $\alpha = 0.92$ and $R_c = 0.52$; negative mood: $\alpha = 0.89$ and $R_c = 0.67$).

Results

Data Analytic Approach

A dyadic multilevel Actor-Partner Interdependence Model (APIM) was used to simultaneously test associations between parent and child mood at the same sampling occasion. In the two studies with more than one mood reading per day, associations between parent and child mood are tested controlling for own mood at the prior reading within the same day. The multilevel model used nests all mood readings within a dyad. Data for each member of the dyad at a given sampling occasion is represented in the data set once as an outcome and a second time as a predictor of partner mood at the same occasion. Mood readings were numbered across days (e.g. four occasions on three days would be represented as 12 sampling occasions). Due to

differing scales across family members and studies, mood data were standardized within each person by computing a z-score. Thus, scores at a given sampling occasion represented an individual's deviation from their average positive or negative mood over the course of the study, taking into account the amount of variation in their mood scores. Each model included separate partner mood variables for the parent and child, and a within-dyad error term. To illustrate, the full level 1 equation, modeling mother-child positive mood synchrony was:

$$Y_{ij} = \text{Mother}(\pi_{0i} \text{PartnerPosMood}_{ij}) + \text{Child}(\pi_{1i} \text{PartnerPosMood}_{ij}) + \varepsilon_{ij},$$

in which Y_{ij} is dyad j 's positive mood at sampling occasion i . Mother and Child are orthogonal dummy variables that indicate which individual is modeled as “actor” or person whose data are represented as the outcome and which is modeled as the “partner” or person whose data are utilized to predict partner mood. PartnerPosMood is the variable representing the partner's positive mood as a predictor, where π_{0i} is the coefficient estimate of child positive mood predicting mother positive mood, and π_{1i} is the coefficient estimate of mother positive mood as a predictor of child positive mood. Two significant positive partner coefficients indicate synchrony, wherein each partner's mood predicts the other's mood, such that higher than typical mood in one dyad member is associated with higher than typical mood in their partner. The final term in the model, ε_{ij} represents within-dyad error.

When there was evidence of synchrony in a study that included more than one mood ratings within the same day, own prior mood was also included as a control variable, to determine whether partner mood predicted a change in actor mood beyond a mere continuation of previous actor mood. The level 1 equation illustrating mother-child positive mood synchrony, including prior mood is:

$$Y_{ij} = \text{Mother}(\pi_{0i} \text{PartnerPosMood}_{ij} + \pi_{2i} \text{PriorPosMood}_{ij}) + \text{Child}(\pi_{1i} \text{PartnerPosMood}_{ij} +$$

$$\pi_{3i} \text{PriorPosMood}_{ij}) + \varepsilon_{ij},$$

The model was identical to the prior model, except for the addition of mood at the prior sampling occasion indicated by the variable PriorPosMood_{ij} and paired with the coefficient π_{2i} when parent is actor, and π_{3i} when the child is actor.

An additional aim of the current project was to test dyad-level characteristics of the age and sex of the included child as moderators of synchrony. The level 2 equation testing group-centered child age, as a moderator of the association between mother positive mood and child positive mood, is:

$$\pi_{0i} = \beta_{00j} + \beta_{01j} \text{ChildAge}_j$$

Where child age is tested as a moderator of the level one association between mother positive mood and child positive mood. A second identical level 2 equation tested moderation of the level 1 association between child positive mood and mother positive mood. Child sex was also tested as a potential moderator of parent-child synchrony, in a separate model from the test of child age. The level 2 equation testing child sex as a moderator of parent-child mood synchrony is:

$$\pi_{0i} = \beta_{00j} + \beta_{01j} \text{ChildSex}_j$$

As above, this equation represents the test of child sex as a moderator of the level 1 association between mother positive mood and child positive mood. Sons were represented by '0' on the child sex variable, daughters were indicated by '1'. A second level two equation tested child sex as a moderator of the level 1 association between child positive mood and mother positive mood.

Parent-Child Positive Mood Synchrony

Results of the models testing mother-child and father-child synchrony in positive mood are reported for each of the three samples in Table 2.

UCLA Families and Health Study. The results of the test of mother-child and father-child positive mood synchrony in the first sample (56 days, 1 mood reading per day) are shown in the top panel of Table 2. In this study, synchrony in mood ratings at the end of the day was tested. The two positive partner coefficients in mother-child models indicate that partner positive mood was a significant predictor for both mother and child end-of-day positive mood. Father-child dyads did not evidence synchrony in positive mood.

UCLA Center for Everyday Lives of Families. Results from the second sample (3 days, with 4 mood readings per day) are presented in the middle panel of Table 2. Among mother-child dyads, partner positive mood ratings significantly predicted both mother and child mood ratings at the same occasion. Among father-child dyads, there was no evidence of synchrony in positive mood. When prior mood was included in the mother-child positive mood synchrony model, mother mood continued to marginally predict child positive mood ($\pi_{3i} = 0.15$, $p = 0.06$) and child positive mood continued to marginally predict concurrent mother positive mood ($\pi_{2i} = 0.12$, $p = 0.08$).

UCLA Family Development Study. As shown in the bottom panel of Table 2, positive mood synchrony at the same occasion throughout the day was observed in mother-child, but not father-child dyads in the third sample (5 days, 4 mood readings per day). Positive mood synchrony was observed among mother-child dyads, such that child positive mood significantly predicted mother positive mood, and mother positive mood also significantly predicted child positive mood. Among father-child dyads neither partner's positive mood predicted the other dyad member's positive mood. When prior positive mood was included in the mother-child positive mood synchrony model, partner coefficients were no longer significantly associated with

concurrent child positive mood ($\pi_{3i} = 0.07, p = 0.12$) or mother positive mood ($\pi_{2i} = 0.07, p = 0.12$).

Child age and sex positive mood synchrony moderators. Moderation of positive mood synchrony was tested in each of the samples, with child age and sex tested separately. Of 6 positive mood synchrony tests, child age was found to moderate the partner effects on positive mood only in the UCLA Family Development Study. The coefficient testing child age as a moderator of the level 1 association was 0.19 ($SD = 0.06$); $t = 2.96, p < .01$ for the child association with mother positive mood, and 0.20 ($SD = 0.07$); $t = 3.05, p < .01$ for the level one association between mother and child positive mood. Mother-daughter dyads also showed marginally stronger positive mood synchrony compared to mother-son dyads for both level one partner effects. The coefficient testing moderation of the level one association between child predicting mother positive mood was 0.12 ($SD = 0.07$); $t = 1.75, p < .10$. The coefficient that tested moderation of the level one association between mother and child positive mood was 0.11; ($SD = 0.06$), $t = 1.77, p < .10$

Parent-Child Negative Mood Synchrony

It was predicted that mother-child and father-child dyads would show synchrony in negative mood. Results of the 6 negative mood synchrony models are presented in Table 3.

UCLA Families and Health Study. Results of models testing negative mood synchrony in end of day mood ratings in the first sample (56 days, 1 mood reading per day) are presented the top panel of Table 2. Among mother-child dyads, partner negative mood was significantly associated with mother and child negative mood on the same day. Same day negative mood synchrony was also evident among father-child dyads in the first sample, with both partner

negative mood coefficients significantly predicting father and child negative mood on the same day.

UCLA Center for Everyday Lives of Families and Family Development Study. As observed in the second and third panels in Table 2, when parents and children reported on mood several times per day as in the second sample (3 days, 4 mood readings per day) and the third sample (5 days, 4 mood readings per day), there was no evidence of associations in either mother-child or father-child concurrent negative mood ratings.

Child age and sex negative mood synchrony moderators. Neither child age nor child sex moderated the associations between parent and child negative mood among mother-child or father-child dyads in any of the three studies.

Discussion

The present paper explores the interrelatedness of mother-child and father-child positive and negative mood as rated over differing spans of time in three intensive repeated measures samples. Mothers and children evidenced synchrony in positive mood in each of the three studies included. Thus, at an occasion when a mother endorsed higher-than typical positive mood her child was also likely to endorse higher-than-typical positive mood. Similarly, at an occasion when child positive mood was elevated, mother positive mood was also likely to be elevated. Though few prior studies have tested positive mood or emotion transmission in parent-child dyads our results are consistent with the only prior repeated measure study that demonstrated positive emotion transmission from mothers to adolescent children (Matjasko & Feldman, 2005). Though consistent with this prior work our findings differ in that we focus on mood rather than emotion, and demonstrate reciprocal transmission between mothers and children. Our findings of mother-child positive mood synchrony are also consistent with empirical work documenting

momentary contingent positive affect in infants and young children and their mothers, although this study utilizes a methodological approach and covers a later period in child development, (Feldman, 2007).

These bidirectional associations in mother and child positive daily mood states highlight the importance of a family systems perspective in studying daily mood. Mood is roughly thought to be a barometer for individual well-being and internal resources available to respond to challenges in the environment. In contrast to emotion, mood is thought to particularly influence patterns of cognition which may in turn impact propensity of engaging in adaptive behavior. Consistent with the broaden-and-build model of positive emotions, mood may similarly drive people to seek social contact (Fredrickson, 2004). Similarly, synchrony in positive mood is also consistent with capitalization processes in which social sharing of positive events may further enhance enjoyment in the person who experienced the event and benefit the relationship (Gable & Reis, 2010). In the family context, positive mood synchrony and daily propensity to experience positive mood states may be one mechanism through which the mother-child relationship confers long term mental and physical health benefits or risk (Repetti, Robles, & Reynolds, 2011). Additional work is needed to test whether positive mood synchrony is a beneficial process for mothers and children, and under what circumstances. Future work may be able to extract dyad-level estimates of synchrony to test associations between strength of synchrony and relevant markers of parent-child relationship, and individual mental and physical health. Additionally, it may be possible to infer the adaptive utility of positive mood synchrony by testing whether strength of synchrony differs among dyads known to be more strongly attached or who evidence other characteristics indicative of a more positive relationship (e.g. Saxbe & Repetti, 2010).

Our findings also raise questions about how mother-child positive mood synchrony may occur. Prior work has suggested that maternal presence impacts degree of synchrony in mood and behavior, and is likely to play a role in mother-child positive mood synchrony. However, little is known about the dyadic or individual behaviors that enable transmission of positive mood. For instance, transmission may be facilitated by shared activity, interpersonal disclosure, or observation of partner mood-related cues (e.g. tone of voice, body posture, or movement). Indeed, an observational study focused on children's spontaneous positive emotion expressions suggests that such expressions are sustained by parent positive emotion expression, shared leisure activity, and touch (Bai, Repetti, & Sperling, 2016).

Though the current study provides evidence that mothers and pre-adolescent children are impacted by fluctuations in partner positive mood, we do not yet know how this synchrony may change over the span of child development. In one of the three samples, with mood ratings three times per day on five days, mother-child positive mood synchrony was strongest among older children and mothers. However, mother-child positive mood synchrony was not moderated by child age in the other two samples, and across all of the samples a fairly restricted range of child development (8-13 years) was represented. In the same sample, mother-child positive mood synchrony was also stronger among mothers and daughters, compared to sons. However, there was no difference in degree of synchrony based on child gender in either of the other two samples. The sample with three mood ratings per day on five days included the highest number of families, and therefore was best positioned to detect differences between dyads. Thus, though there was not overwhelming evidence to suggest child gender or age moderation, it remains important to test for these potential effects in future studies.

Father-child positive mood synchrony was not detected in any of the three samples. The detection of mother-child, but not father-child, positive mood synchrony may suggest a difference in the interactions children have with mothers compared to fathers. Some prior work has suggested mothers and fathers hold differing parental roles, with mothers more often viewed as a supportive figure that helps regulate emotion and manage daily care routines, while fathers are more often viewed as a playmate and disciplinarian figure (Denham, Bassett, & Wyatt, 2010). Consistent with this view, fathers report expressing more positive emotion, inciting greater emotional arousal, and utilizing a warmer emotional tone in interactions with children (Brand & Klimes-Dougan, 2010). However, other studies suggest that mothers demonstrate more positive emotion around children than fathers (Garner, Robertson, & Smith, 1997), and talk more with children about emotions (Fivush, Brotman, Buckner, & Goodman, 2000). Findings of mother-child, but not father-child positive mood synchrony may thus be attributable to differential roles in affect socialization, and may also be explained by children spending more time with mothers compared to fathers (Yeung, Sandberg, Davis-Kean, & Hofferth, 2001).

Negative mood synchrony was detected in both mother-child and father-child dyads in only one of the three samples; that dataset included one mood rating per day over 56 days. At occasions when either a parent or child had higher-than-typical negative mood, the partner tended to demonstrate a similar fluctuation. It is notable that this sample differed from the others included here, in that it was remarkably well equipped to detect change within-dyads over a longer span of time, with 56 days of repeated measures. Though two months is a long period of observation for an intensive repeated measures study, it is a relatively short period of time in family life. It is possible that in fairly typical families with children in early adolescence the within person variance in negative mood ratings is modest, and the effects of negative mood

synchrony are subtle. If so, negative mood synchrony processes may lend themselves to study only over larger spans of time, but are nonetheless present. These findings suggest negative mood synchrony during this period of development should continue to be further studied.

A strength of the present study is the use of dyadic multilevel Actor-Partner Interdependence Models to test for associations in mood among two related individuals. Multilevel dyadic models for distinguishable dyads are well-suited to model expected non-independence in family members' residual variance, and to test for effects of one partner on the other, while controlling for the opposing partner effect. Though complex and challenging to appropriately model interdependent family members simultaneously, future studies of parent-child mood synchrony should consider dyadic models that are capable of testing bidirectional effects. Through simultaneous estimation of partner effects, the test for partner influence is much more conservative than a unidirectional test, and thus, greater confidence may be placed in findings.

The current study is also limited by several factors. Most notably, the total number of dyads included in each sample is relatively small. The heavy participant burden and resources required for intensive repeated measures studies often result in smaller sample sizes and power to detect between-dyad effects. Differing mood measures across parents and children may have caused associations in mood to be less clear than if participants had been responding to identical questions. Synchrony was tested separately for mother-child and father-child dyads, which does not allow for us to explore relative influence of multiple family members simultaneously or to observe potential indirect effects (i.e. mother and child may demonstrate similar change due to simultaneous influence by a father).

However, in spite of these limitations the current study significantly contributes to knowledge of daily mood regulation processes in the family through simultaneous testing of positive and negative mood synchrony in both mother-child and father-child dyads. In light of the results presented here, additional questions emerge for future study. It is not yet known what dyadic or individual processes mediate synchrony, or how synchrony might contribute to more stable or long lasting patterns in mood, that may in turn be associated with more distal physical and mental health outcomes. The current study focuses on pre-adolescent children, and cannot address how parent-child mood synchrony may change over the course of development. Daily mood is influenced by social relationships, and psychologists should strive to understand the mechanisms that underlie the social regulation of mood across development.

Table 1. Characteristics of participants and mood sampling procedures

	UCLA Families and Health	UCLA Center for Everyday Lives of Families	UCLA Family Development
Target Children (N)	47	32	83
Mothers (N)	47	30	83
Fathers (N)	39	34	55
Number of diary days	56	3	5
Frequency and timing of mood sampling occasions within each diary day	1 (before bed)	4 (morning, lunchtime, afternoon at end of work/school day, before bed)	3 (morning, lunchtime at school/afternoon at work, before bed)

Table 2. Parent-Child Positive Mood Synchrony

	Mother-Child		Father-Child	
	Coefficient (SE)	T ratio	Coefficient (SE)	T ratio
UCLA Families and Health Study				
Partner Mood As Predictor				
Child as Partner	0.06 (0.02)	2.94**	0.04 (0.02)	1.68
Parent as Partner	0.06 (0.02)	2.98**	0.04 (0.02)	1.65
UCLA Center for Everyday Lives of Families				
Partner Mood As Predictor				
Child as Partner	0.16 (0.06)	2.45*	0.09 (0.07)	1.19
Parent as Partner	0.15 (0.06)	2.30*	0.09 (0.07)	1.26
UCLA Family Development Study				
Partner Mood As Predictor				
Child as Partner	0.07 (0.06)	1.95†	-0.04 (0.04)	-1.02
Parent as Partner	0.07 (0.04)	1.98†	-0.04 (0.04)	-1.02

† $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

Table 3. Parent-Child Negative Mood Synchrony

	Mother-Child		Father-Child	
	Coefficient (SE)	T ratio	Coefficient (SE)	T ratio
UCLA Families and Health Study				
Partner Mood As Predictor				
Child as Partner	0.07 (0.02)	2.67**	0.05 (0.02)	2.26*
Parent as Partner	0.07 (0.03)	2.67**	0.05 (0.02)	2.28*
UCLA Center for Everyday Lives of Families				
Partner Mood As Predictor				
Child as Partner	0.05 (0.08)	0.66	0.01 (0.08)	0.18
Parent as Partner	0.05 (0.07)	0.75	0.02 (0.07)	0.23
UCLA Family Development Study				
Partner Mood As Predictor				
Child as Partner	0.02 (0.03)	0.63	-0.06 (0.04)	-1.54
Parent as Partner	0.02 (0.03)	0.63	-0.06 (0.04)	-1.48

† $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

Appendix A. Parent and Child Mood Scales

UCLA Families and Health		UCLA Center for Everyday Lives of Families & UCLA Family Development Study	
Response Scale	Positive Mood Items	Negative Mood Items	
Child	1=Not at all 2=Some of the day 3=Most of the day 4=All day	Lively Happy Relaxed Full of energy Cheerful Calm Proud Loved	Sad Mean Unhappy Tense Angry Worried
Parent	1=Completely inaccurate 2=Mostly inaccurate 3=Mostly accurate 4=Completely accurate	Lively Happy At ease Full of energy Cheerful Calm	Sad On edge Hostile Unhappy Tense Angry Stressed Overwhelmed
	Response Scale	Positive Mood Items	Negative Mood Items
	1=Definitely false 2=Mostly false 3=Mostly true 4=Definitely true	I felt proud. I was happy. I felt loved. I was excited. I felt confident. I was smiling. I was acting cheerful.	I felt tense. I felt confused. I felt worried, distracted, or preoccupied. I was scared. I felt others were pressuring me. I felt that others were expecting too much from me. I was sad. I felt alone. I felt ashamed. I was angry.
	1=Not at all, did not experience this mood at all this (morning) 2=Slightly applies to how I felt this (morning) 3=Definitely applies to how I felt this (morning)	Kindly Playful Elated Energetic	Frustrated Sad Tired Angry Emotionally drained Skeptical Tense Overwhelmed Nervous Clutched-up Impatient

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Abstract

Parent-child physiological synchrony, reflected in coordinated diurnal cortisol between children and their parents, was investigated in two intensive repeated measures studies of school-aged children and their families. The first study investigated the diurnal cortisol of 8-13 year old children (N = 47), their mothers (N = 47) and fathers (N = 39) with four samples per day on eight days. The second study examined the diurnal cortisol of 7-12 year old children (N = 32), mothers (N = 30), and fathers (N = 32) four times per day over three days. Dyadic multilevel Actor-Partner Interdependence Models tested associations between actor and partner cortisol in mother-child and father-child dyads. Results from both studies supported a physiological synchrony hypothesis in mother-child and father-child dyads. Elevations in partner cortisol were associated with elevations in actor cortisol, after accounting for sampling time and potential sampling confounds. Thus, child cortisol elevations were associated with mother cortisol elevations and mother cortisol elevations were associated with child cortisol elevations. Similarly, increases in child cortisol were predictive of increases in father cortisol, and increases in father cortisol predicted increases in child cortisol. Bidirectional associations between members of parent-child dyads suggest that diurnal cortisol may be regulated in part by family members. Evidence of physiological synchrony with parents was observed in school-age children, an age range largely overlooked in prior studies of physiological synchrony.

Keywords: diurnal cortisol, adrenocortical attunement, synchrony, coregulation, parent-child relationship

Physiological synchrony of diurnal cortisol between pre-adolescents and their mothers and fathers

Acquiring the capacity to build and maintain strong relationships is perhaps the single most important task an immature human must achieve. In infancy, even relatively basic needs like maintaining physical comfort and adequate nutrition are dependent on the infant's ability to successfully attract and reward attention from caregivers. Throughout the life course, social relationships remain critical to well-being, protecting against or conferring risk for deleterious psychosocial and physical health outcomes. Given the central role of relationships with others, it is not surprising that many of the internal systems that organize individuals, including cognitive, affective, and physiological processes are sensitive to the social environment. One such physiological system, the hypothalamic pituitary adrenocortical (HPA) axis serves a critical role in an organism's ability to mount an effective response to stressors (Taylor & Stanton, 2007). HPA axis functioning has been demonstrated to be sensitive to input from the early social environment and malleable during development (Gunnar & Donzella, 2002; Gunnar & Quevedo, 2007).

The primary end product of the HPA axis is cortisol, a hormone that enables mobilization of energy stores in the body to adequately respond environmental demands. In healthy individuals the HPA axis demonstrates a predictable daily, or diurnal, pattern of secretion. Cortisol is released in bursts throughout the day, such that levels of unbound cortisol follow a curvilinear pattern, with a sharp increase following waking and more gradual tapering through the remainder of the day, reaching the lowest point near midnight (Kirschbaum & Hellhammer, 1989). Though increased cortisol output is adaptive for responding to challenge in the short-term, repeated or prolonged activation of the HPA axis may contribute to allostatic load, and over time

increase risk for physical and psychological illness (Repetti, Robles, & Reynolds, 2011).

Allostatic load may manifest itself in the HPA axis through flatter diurnal slopes, in contrast to the steep decline generally observed in healthy populations (e.g. Gunnar & Vasquez, 2001, Shirtcliff & Essex, 2008).

Maturation of the biological stress response system is embedded within a child's broader social ecological environment, and shaped by the early family environment and interactions with caregivers (Gunnar & Donzella, 2002). Several indices of HPA axis functioning, including patterns of diurnal cortisol secretion, basal cortisol levels, and both reactivity and recovery in response to a stressor have been linked to aspects of early environmental experience. For instance, young children from families that are highly emotionally expressive or very low in expressivity have higher cortisol throughout the day (Chryssanthopoulou, Turner-Cobb, Lucas, & Jessop, 2005). Interparental violence has been associated with failure to mount an adaptive cortisol response to a stressor (Sturge-Apple, Davies, Cicchetti, & Manning, 2012), and lower parental marital quality is associated with flatter diurnal cortisol slopes and higher evening cortisol among children (Pendry & Adam, 2007). Maternal characteristics thought to impair parenting quality, including a diagnosis of depression and higher stress, have been linked with higher basal cortisol levels in children (Lupien, King, Meaney, & McEwen, 2000) and increased reactivity to naturally occurring stressors (Gutteling, deWeerth, & Buitelaar, 2005). In contrast to associations between negative parent or family characteristics and HPA axis dysregulation, presence of a secure attachment figure can buffer children's reactivity to stressors (Gunnar, Brodersen, Nachmias, Buss, & Rigatuso, 1996). Together, these findings suggest children's HPA axis functioning is calibrated according to early interactions with caregivers.

One potential mechanism that may shape HPA axis functioning in childhood is physiological synchronization, wherein individuals demonstrate coordinated change in HPA axis activity with a social partner. This process is also sometimes referred to as adrenocortical attunement, or coregulation. Most often parent influence on child HPA axis functioning has been emphasized, with little attention to possible reciprocal influences of children on parent HPA axis functioning. Yet, a family systems perspective suggests that children will likewise affect parents' daily physiology (Cox & Paley, 2003; Ha & Granger, 2016). Indeed, adult HPA axis functioning also seems responsive to close others, including marital partners (Saxbe & Repetti, 2010; Schoebi, 2008). Looking beyond the HPA axis, parents demonstrate sensitivity to other facets of children's daily experience, including emotions and behaviors (Feldman, 2007; Harrist & Waugh, 2002; Larson & Richards, 1994).

Investigations of physiological synchrony in parents and children have primarily focused on mother and infant or toddler responses to stressors. Reactivity studies have demonstrated that maternal cortisol secretion is correlated with infant and toddler cortisol secretion, particularly during periods of infant distress or difficulty (Hibel, Granger, Blair & Finegood, 2015; Middlemiss, Granger, Goldberg, & Nathans, 2012; Sethre-Hofstad, Stansbury, & Rice, 2002). Linkage in mother-child cortisol secretion has also been demonstrated in daily life. Mother-toddler cortisol-awakening responses (CAR) are correlated on non-work days (Hibel, Trumbell, & Mercado, 2014). Correlations in mother and infant diurnal cortisol have also been demonstrated at morning, afternoon, and evening occasions, and in father and child cortisol at afternoon and evening occasions (Stenius et al., 2008).

Very few studies have examined cortisol synchrony in mothers and children in the early years of childhood. During an in-home research visit, mothers and preschool children were

instructed to play and took part in a challenge task in the form of an IQ assessment (Ruttle, Serbin, Stack, Schwartzman, & Shirtcliff, 2011). Maternal cortisol was a significant predictor of child cortisol at the same sampling occasion and was most closely linked following the challenge task (Ruttle et al., 2011). A second study also focused on early childhood and sampled parent and child cortisol once per day in the early evening over several days. Mother and child cortisol levels were correlated on the same evening, and father and child cortisol was correlated at the afternoon sampling occasion (Schrieber et al., 2006). On the whole, few studies have focused on familial influences on cortisol regulation during early childhood, but those that have provide evidence suggesting that parents and children evidence cortisol synchrony in daily life.

Beyond early childhood little is known about how stress physiology may be related in parents and children. During the period preceding adolescence, parent-child relationships change, as do children's daily activities and social partners (McHale, Crouter, & Whiteman, 2003). Children's stress physiology continues to mature, and differences are first observed between male and female patterns of cortisol secretion (Netherton, Goodyear, Tamplin, & Herbert, 2004; Shirtcliff et al., 2012). Even within the relatively narrow age range of the pre-adolescent years, children demonstrate developmental differences in stress physiology as they age, with older children generally showing higher levels of diurnal cortisol (Kiess et al., 1995; Klimes-Dougan, Hastings, Granger, Usher, & Zahn-Waxler, 2001; Shirtcliff et al., 2012).

A few studies have investigated synchrony of diurnal cortisol secretion in mothers and children during middle childhood or adolescence; no studies in this age range have tested potential diurnal cortisol synchrony in fathers and children. In one case, maternal diurnal cortisol predicted child cortisol on two weekend days among both depressed and healthy control mothers and their six-year old children (Pratt et al., 2017). Schreiber and colleagues (2006) included a

sample of eight year-olds and their mothers in an investigation of familial associations in evening cortisol over several days, and found that both mother and child cortisol were associated with partner cortisol, even after accounting for sampling time and medication use. Another study focused on school-age children and their mothers with an oversampling participants with clinical anxiety. Saliva samples assayed for cortisol were collected three times per day over two days. Actor-Partner Interdependence Modeling (APIM) was used to demonstrate bidirectional associations between mother and child diurnal cortisol. The cortisol levels of mothers and children were predictive of partner cortisol, across anxious and nonanxious mother-child dyads (Williams et al., 2013). And, in a sample of 9-15 year olds, mother diurnal cortisol predicted child cortisol (LeMoult, Chen, Foland-Ross, Burley, & Gotlib, 2015). Two additional studies examined physiological synchrony in adolescent samples. Replicating patterns observed with slightly younger children, one study found that mother cortisol predicted adolescent diurnal cortisol on two weekdays (Papp, Pendry, & Adam, 2009). Though not focused on diurnal HPA activity, Saxbe and colleagues (2014) demonstrated bidirectional associations in parent-adolescent cortisol reactivity following a laboratory conflict discussion.

There is also a small body of research testing associations between father and child diurnal cortisol. Two studies have demonstrated associations in father-child cortisol, in infancy and early childhood (Schreiber et al., 2006; Stenius et al., 2008). Papp and colleagues (2009) tested, but failed to find associations between father and adolescent diurnal cortisol. However, because only a subsample of 23 families included fathers who provided cortisol, the study was likely underpowered to detect father-adolescent associations. These few investigations of father-child physiological synchrony in cortisol are promising, but limited, and evidence of diurnal cortisol synchrony does not extend past the first few years of childhood. Notably, one study of

cortisol reactivity to a laboratory stressor has found evidence of associations between father and adolescent cortisol (Saxbe et al., 2014), suggesting fathers and adolescents may continue to impact partner physiology beyond early childhood.

In sum, available research suggests that children's stress physiology is influenced by mothers, particularly in the first years of life. There have been few tests of father and child coordination of stress physiology, and of associations in HPA axis functioning between parents and youth in middle childhood or early adolescence. The period before adolescence is replete with change in social relationships and biological maturation. As a period of identified risk for development of psychological problems, it is important to understand the daily processes of physiological regulation within the family. One approach is to test whether both mothers and fathers demonstrate daily physiological synchrony with pre-adolescent children.

Notably, a wide variety of statistical tests have been utilized to test parent-child physiological synchrony. Many researchers have presented correlations between parent and child cortisol levels, that are unable to parcel out variance attributable to stable shared factors including similar environment and genetic influences. A challenge inherent in analyzing dyadic data is that parent and child data are expected to be non-independent, violating the assumptions of parametric statistical tests. One method used to address this issue of non-independence in family member data has been to utilize outcome data from only one member of the dyad, or to test the influence of each member of the dyad on the other, in separate models. However, without including both members of the parent-child dyad in the same model it is not possible to estimate the unique influence of each partner on the other, or to include predictors best conceptualized as belonging to the dyad rather than an individual. Multilevel models are well-suited to nest repeated measures of cortisol, tolerant to missing data, and capable of testing for associations

between partners after accounting for stable factors that explain individual variance, including time of day and genetic similarities (Hruschka, Kohrt, & Worthman, 2005). However, a truly dynamic interactive perspective of the parent-child relationship would expect simultaneous bidirectional influences, including parent effects on the child, and child effects on the parent. In some occasions, dyadic models have been adapted to simultaneously test each partner's influence on the other's stress physiology, representing a promising method to address many of the challenges associated with dyadic repeated measures data.

Current Study

The current study expands upon prior literature by testing for parent-child physiological synchrony, or bidirectional associations in concurrent cortisol levels, in two samples of mothers, fathers, and children 7 to 13 years old. Among studies of diurnal cortisol coordination within the family, the strongest evidence of interrelated HPA axis functioning exists between mothers and infant or toddler children. There is very limited information about mother-child physiological synchrony among school-aged children and mothers. Additionally, very few studies have examined father and child physiological synchrony. However, the two studies of diurnal cortisol synchrony in fathers and children suggest that fathers may be similarly influential in child physiology (Schreiber et al., 2006). To our knowledge the current study is the first to test physiological synchrony of diurnal cortisol in a typical population of school-aged children and both mothers and fathers, and will inform knowledge of physiological synchrony in the family during this period. It is hypothesized that school-aged children will demonstrate reciprocal bidirectional associations in diurnal cortisol levels, with both mothers and fathers. To simultaneously test for bidirectional associations, and account for the nested structure of

intensive repeated measures data multilevel APIM models are utilized. Child sex and age will be included as potential dyad-level moderators of parent-child physiological synchrony.

Methods

The current paper draws data from two larger intensive repeated measures studies of school-age children and their families. Each study is described in greater detail below.

Participants

UCLA Families and Health Study. Families were recruited from the greater Los Angeles area for a larger study of family processes and health (Repetti, Reynolds & Sears, 2015; Sears, Repetti, Reynolds, Robles, & Krull, 2016). Participating families included 47 target children between 8-13 years of age (M age = 11.28, SD = 1.50), 47 mothers (M age = 43.29, SD = 6.31) and 39 fathers (M age = 43.67, SD = 8.10). Median annual family income was in the bracket between \$32,000 and \$82,000. Parents reported target children's ethnicities as 38% non-Hispanic white, 15% Latino/Hispanic, 15% African-American, 11% Asian, and 21% "Other" (primarily mixed ethnicity). Mother self-reported ethnicities were 40% non-Hispanic white, 28% Latino/Hispanic, 15% African-American, 15% Asian, and 2% "Other." Father self-reported ethnicities were 51% non-Hispanic white, 15% Latino/Hispanic, 21% African-American, 10% Asian, and 3% "Other."

UCLA Center for Everyday Lives of Families. Thirty-two families in the greater Los Angeles area were recruited as part of a larger study of family life in dual-earner families (Campos, Graesch, Repetti, Bradbury, & Ochs, 2009; Ochs, Graesch, Mittman, Bradbury, & Repetti, 2006). Each family included one target child between the ages of 7 and 12 (M age = 9.25, SD = 1.10), and up to two additional siblings. All parents who lived in the home participated, yielding data from 34 fathers (M age = 42.01, SD = 5.65) and 30 mothers (M age =

39.93, $SD = 4.78$). Two families were headed by two fathers; the present analyses include data from one randomly chosen father in each of those households. Median annual family income was \$100,000. Target child ethnicity was 65% European-American, 10% Asian-American, 3% African-American, 3% Hispanic/Latino, and 19% mixed ethnicity. Mother ethnicities were 70% European-American, 17% Asian-American, 10% African-American, and 3% Hispanic/Latino. Father ethnicities were 75% European-American, 16% Asian-American, 6% African-American, and 3% Hispanic/Latino.

Procedure

Participants in both studies provided saliva samples four times per day over multiple days, but differed in the timing of saliva sampling occasions within a day and total number of sampling days. Research assistants trained participants on saliva collection and storage during home visits that occurred prior to the collection period, as part of more extensive procedures in both studies.

UCLA Families and Health Study. Data were collected in three cohorts between 2009 and 2012. Parents and children could earn \$350 and \$300 per week, respectively, for on-time completion of daily diaries over 56 consecutive days, including a \$5 bonus for each week of full on-time compliance with diary procedures. Parents and children self-collected saliva samples four times per day on a total of eight days, organized in two sets of four consecutive days each containing two weekdays and two weekend days. There were four sampling occasions per sampling day: 1) upon awakening; 2) 30 minutes after awakening; 3) early evening; and 4) bedtime. Participants were instructed to complete and time stamp a self-report measure assessing factors that may impact sample integrity at the time of each sample completion.

Prior to the initial week of saliva collection, research assistants visited participant's homes to drop off necessary materials and review collection and storage procedures. Participants were given 32 labeled cryogenic vials, a stopwatch to time saliva collection, and a time stamp to verify completion time on the provided sampling form. Straws to aid collection of saliva were provided in bottle capped with a Medication Event Monitoring System (MEMS) device that participants were told would electronically monitor sampling time.

Participants were instructed not to eat or drink anything other than water in the 30 minutes prior to saliva collection. Self-report forms asked participants to indicate whether they had consumed anything other than water, performed exercise, or encountered a stressful situation in the preceding 30 minutes. Forms also asked participants to indicate any use of medication or cigarettes in the hours prior to sample collection, and to note whether they had brushed their teeth or experienced any bleeding within the mouth. Participants were asked to keep saliva samples cool with a provided ice pack if sampling took place away from home. Once able to do so, participants were asked to store salivettes in their home freezer until submitted to researchers at the final study visit.

Saliva vials were frozen and shipped under climate-controlled conditions to Biological Psychology Laboratory at the Technical Institute of Dresden (Dresden, Germany), directed by Clemens Kirschbaum. Cortisol samples were assayed for free cortisol using chemiluminescence immunoassay. This procedure required .50 μL of saliva and had a lower limit of sensitivity of .003 $\mu\text{g/dL}$. The mean of duplicate sample assays was utilized in analyses.

Children's mean collection times for the four sampling occasions were: 7:36 a.m., 8:08 a.m., 6:41 p.m., and 9:38 p.m. Children's collection times varied the most for the bedtime sample ($SD = 50$ min) and least for the waking sample ($SD = 35$ min). Mothers' mean collection times

for each of the four samples were: 7:19 a.m., 7:53 a.m., 6:46 p.m., and 10:23 p.m., with greatest variability at the bedtime sampling occasion ($SD = 53$ min) and least at the late afternoon occasion ($SD = 47$ min). Fathers' mean collection times were 7:18 a.m., 7:50 a.m., 6:35 p.m., and 10:37 p.m., the greatest variability was at the sampling occasion 30 minutes after waking ($SD = 65$ min) and least at the late afternoon occasion ($SD = 48$ min). Across all sampling occasions (4 per day on 8 days), mothers and children both provided saliva on 1135 occasions, and fathers and children both provided saliva on 987 occasions.

UCLA Center for Everyday Lives of Families. Data were collected between 2002 and 2005. Each family was given a \$1000 honorarium for participation in an extensive set of study procedures, including videotaping, diaries, questionnaires, and interviews. Parents and children were asked to provide saliva samples four times per day on three weekdays, which were not necessarily consecutive. The four sampling occasions within each day were: 1) early morning; 2) prior to lunch; 3) afternoon prior to leaving work or school; and 4) bedtime.

Prior to the week of saliva collection, a research assistant visited each family to provide saliva collection materials and train participants in collection and storage procedures. Each participant was provided with 12 labeled 5-mL screw-cap cryogenic vials, straws, and a thermos for storing samples collected outside the home, and a programmed reminder beeper.

Participants were instructed to not eat or drink anything other than water in the 30 minutes prior to saliva collection. Self-report forms completed at the time of each collection asked participants to indicate the time the collection was completed, whether they had consumed anything other than water in the preceding 30 minutes, taken any medications or smoked cigarettes, brushed their teeth or experienced mouth bleeding. Parents and children were asked to

keep saliva samples in provided thermoses until they could be stored in the family refrigerator to be picked up by research assistants.

Saliva vials were frozen and shipped under climate-controlled conditions to Salimetrics (College Park, PA) where they were immunoassayed using a highly sensitive enzyme immunoassay – US FDA (510k). The immunoassay required 25 μ L of saliva and had a lower limit of sensitivity of .007 μ g/dL. Sensitivity ranged from .007 μ g/dL to 1.8 μ g/dL. The average of duplicate assays for each sample was used in analyses.

The mean self-reported collection times for children at each sampling occasion were: 7:00 a.m., 11:58 a.m., 3:40 p.m., and 8:39 p.m., with greatest variability at the afternoon prior to leaving school occasion ($SD = 73$ min) and least in the morning upon awakening ($SD = 34$ min). Mother mean collection times were: 6:25 a.m., 11:57 a.m., 4:46 p.m., and 10:17 p.m., with greatest variability at the afternoon prior to leaving work occasion ($SD = 70$ min) and least in the morning upon awakening ($SD = 43$ min). Father mean collection times were 6:21 a.m., 12:09 p.m., 4:29p.m., and 10:04p.m., with the greatest variability at the afternoon prior to leaving work occasion ($SD = 73$ min) and least for the occasion prior to lunch ($SD = 46$ min). Across all sampling occasions (4 times per day on 3 days), there were 270 occasions where both mothers and children provided saliva, and 259 occasions where both fathers and children provided saliva.

Results

Treatment of Dyadic Data and Analytic Approach

Dyadic multilevel Actor-Partner Interdependence Models (APIM) were utilized to test bidirectional effects by simultaneous inclusion of data from both members of the dyad as an outcome and predictor of partner physiology (Campbell & Kashy, 2002; Kenny, Kashy, & Cook, 2006; Cook & Kenny, 2005; Laurenceau & Bolger, 2005; Raudenbush, Brennan, & Barnett,

1995). Multilevel APIM models treat the dyad rather than the individual as the lowest unit of independent sampling, thereby allowing observations within a dyad to covary, and permitting inclusion of factors that vary both within and between dyads. Multilevel APIM models have previously been used to test mother-child physiological synchrony (Williams et al., 2013), as well as physiological synchrony in marital partners (Saxbe & Repetti, 2010; Schoebi, 2008).

The hypothesis that parent-child dyads evidence synchrony in diurnal cortisol was tested using a multilevel Actor-Partner Interdependence Model for dyadic diary data, treating all sampling occasions across days as one long day. Though data may be organized into three conceptual levels (sampling occasions nested within individuals nested in parent-child dyads), random variation only occurs and is modeled at two levels (sampling occasions nested within dyads). The lower level of this model includes variability due to repeated measures within dyads, and the upper level models variance between-dyads. This model includes two intercepts, one specific to parents and one to children. As cortisol declines in a predictable curvilinear pattern across the span of a day, it is modeled with both a linear and quadratic sampling time term. The linear term, Time, represents the slope and instantaneous deceleration of cortisol slope represented in military time in hours, centered on 5:00am. The quadratic term for time helps the model to better fit the natural diurnal decline of cortisol. Participant endorsement of any sampling integrity concerns at the time of sample provision was represented by a dichotomous variable SalivaControl. Finally, the variable PartnerCortisol represents the cortisol value for an individual's partner at the same sampling occasion. Prior to analysis cortisol values were log transformed to correct for a positive skew.

An example of a level 1 equation modeling mother-child dyads is:

$$Y_{ij} = \text{Mother}(\pi_{1i}\text{Intercept} + \pi_{3i}\text{Time}_{ij} + \pi_{5i}\text{Time}_{ij}^2 + \pi_{7i}\text{SalivaControl}_{ij} + \pi_{9i}\text{PartnerCortisol}_{ij}) + \text{Child}(\pi_{2i}\text{Intercept} + \pi_{4i}\text{Time}_{ij} + \pi_{6i}\text{Time}_{ij}^2 + \pi_{8i}\text{SalivaControl}_{ij} + \pi_{10i}\text{PartnerCortisol}_{ij}) + \varepsilon_{ij}$$

In which Y_{ij} and represents dyad j 's cortisol values at sampling occasion i for the dyad member specified as “actor” for the corresponding observation. Each individual in the dyad has an intercept denoted by π_{1i} and π_{2i} , for mother and child, respectively. The model also contains coefficients associated with both the linear (π_{3i} and π_{4i}) and quadratic (π_{5i} and π_{6i}) sampling time predictors. Each partner within a dyad also has a coefficient estimate, denoted as π_{7i} and π_{8i} , associated with the saliva control variable. Finally, both the parent and child have a coefficient, π_{9i} and π_{10i} , that estimates the association between partner and actor cortisol. When both the parent and child coefficient estimates associated with the partner predictor are positive and significant, results are considered to be consistent with the physiological synchrony hypothesis.

Additionally, the sex and age of the child were tested as level-2 moderators of the strength of associations between partner and actor cortisol. The age of the child in the dyad was grand mean centered, and child sex was coded with sons represented by 0 and daughters represented by 1. A sample level-2 equation denoting child age as a dyad-level moderator of the partner cortisol estimates for mothers is:

$$\pi_{9i} = \beta_{90j} + \beta_{91j}\text{ChildAge}_j$$

Mother-Child and Father-Child Physiological synchrony

Results of the models testing mother-child and father-child physiological synchrony in each sample are summarized in Tables 1 and 2. For both mother-child and father-child dyads in each study the inclusion of intercepts, linear and quadratic time terms significantly improved model fit. The variable indicating sampling integrity concern did not explain significant variance

in cortisol in any of the models testing parent-child synchrony. The coefficient estimates associated with the partner cortisol predictor can be interpreted to represent the predicted increase in actor cortisol for every one unit increase in partner cortisol.

UCLA Families and Health As hypothesized, partner cortisol level was associated with parent and child cortisol in mother-child and father-child dyads even after accounting for anticipated effects of time or saliva sampling concerns, as summarized in Table 1. Child cortisol was a significant predictor of maternal cortisol levels. Likewise, maternal cortisol levels predicted child cortisol levels. Similar bidirectional associations were seen in father-child dyads. Father cortisol was a predictor of concurrent child cortisol. Child cortisol also predicted father cortisol at the same occasion.

In testing differences between dyads, the effect of child cortisol as a predictor of mother and father cortisol was weaker in dyads including a daughter compared to those including a son. Child cortisol was also a weaker predictor of parent cortisol among dyads including older children in both mother-child and father-child dyads.

UCLA Center for Everyday Lives of Families As shown in Table 2, a similar pattern of results emerged in the second sample. As hypothesized, partner cortisol was predictive of the other dyad member's cortisol at the same sampling occasion, explaining additional variance beyond that expected by time since waking. Mother cortisol was associated with child cortisol at the same sampling time point, and child cortisol was likewise associated with mother cortisol at the same occasion. An identical pattern emerged in father-child dyads. Father cortisol predicted concurrent child cortisol. Child cortisol was a significant predictor of father cortisol, as well.

At the level of a dyad, associations between mother cortisol and child cortisol are stronger when the dyad includes a daughter compared to a son. The effect of child cortisol as a

predictor of father cortisol is weaker when dyads include older children.

Discussion

Drawing upon two intensive repeated measures studies of everyday family life, we found pre-adolescent children evidenced synchrony in diurnal cortisol with both mothers and fathers. Thus, at a sampling occasion where one member of a parent-child dyad demonstrates higher-than-typical levels of cortisol, the other is also likely to evidence higher-than-typical cortisol. The present study contributes to the small but growing body of literature that has examined parent-child diurnal cortisol synchrony sampled during daily life. Our findings are consistent with prior work that demonstrated mother-child cortisol linkage by testing maternal cortisol as a predictor of child cortisol at the same sampling occasion (Papp et al., 2009; Stenius et al., 2008; Williams et al., 2013; LeMoult et al., 2015; Pratt et al., 2017) as well as one prior study that found bidirectional mother-child associations in a sample of school-aged children and mothers oversampled for clinical anxiety (Williams et al., 2013).

Our finding that fathers and children evidence synchrony in diurnal cortisol builds upon nascent work demonstrating father-child cortisol linkage. Though synchrony in father-child cortisol has previously been observed following laboratory stress tasks (Saxbe et al., 2014), very few studies have examined father and child diurnal cortisol associations (Schreiber et al., 2006; Stenius et al., 2008). The results presented here are the first to demonstrate father-child diurnal cortisol synchrony in pre-adolescent children. The knowledge that children and fathers are physiologically attuned to one another, suggests that future research should not overlook the role of both parents in understanding the environmental factors that shape children's HPA axis functioning.

In each of the samples there was evidence that the older children exerted a weaker influence on parent cortisol than did the younger children. However, we did not find evidence that the predictive strength of parent cortisol differed as children in the preadolescent range aged.. Prior studies have demonstrated diurnal cortisol synchrony with mothers, and sometimes fathers, in infants (Stenius et al., 2008), toddlers (Hibel et al., 2014), young children (Schreiber, 2006), school-age children (Pratt et al., 2017; Williams et al., 2013; LeMoult et al., 2015) and adolescents (Papp, Pendry, Adam, 2009), but have not demonstrated that synchrony varies by child age. The finding that child age is associated with changes in strength of synchrony in children between 8 and 13 years old raises questions about how parent-child diurnal cortisol synchrony may differ over the full span of child development, and whether entrainment of this physiological process ends before youth reach adulthood and no longer live with parents. Child age is an important moderator of parent-child diurnal synchrony to continue to explore. Additional research is needed to understand why older children might have less influence on the physiology of parents and whether age may be acting as a proxy for a related variable, such as physical maturation, time spent with peers, or affective tone of interactions.

Daughters emerged as weaker predictors of mother and father diurnal cortisol, but were no less susceptible to parent effects than sons. Prior investigation of child sex as a potential moderator of associations between diurnal mother-child cortisol did not evidence differences based on child sex (Papp et al., 2009). However, in prior work mother cortisol was tested as a predictor of child cortisol, and the differences we found were in child effects on parent cortisol. Thus, these findings are not inconsistent with prior work and illustrate the importance of delineating independent contributions of parents and children in diurnal cortisol synchrony.

The current study adds considerably to our knowledge of diurnal cortisol synchrony processes among pre-adolescents and their mothers and fathers. Child HPA axis functioning has been linked to child health and well-being (Adam et al., 2010; Gunnar & Vazquez, 2001; Shirtcliff et al., 2012), and thus has received much attention. In the quest to understand how a child's social environment may shape HPA axis responses and potentiate development of physical and psychological health problems, diurnal cortisol synchrony may be one relevant process. Equally important is the impact that children appear to have on parents, as our data suggest that diurnal cortisol associations are driven by both partners in a parent-child dyad. The bidirectional associations observed in mother-child and father-child dyads suggest that cortisol secretion throughout the day is not an individual process occurring in isolation within an individual, but is at least partially in sync with changes in close others. These analyses demonstrate bidirectional associations, even after accounting for average cortisol at that time of day, thereby demonstrating that partner influence is independent of the covariation expected from two individuals each demonstrating a typical pattern of diurnal cortisol secretion, and regardless of mean levels of cortisol secreted by the individual.

Though the current study suggests new insights into social conditioning of HPA axis functioning in pre-adolescent children and parents, there were several limitations that should be noted in interpreting findings and pursuing related future research. Diurnal cortisol synchrony was observed in families over only 3-8 days. Further investigation is needed to determine the degree to which cortisol synchrony is a relatively stable characteristic within a parent-child dyad over both short and long term periods. In working to understand the potential utility or risks associated with parent and child cortisol synchrony, it will be important to distinguish between synchrony in diurnal cortisol and synchrony in other aspects of HPA axis functioning (e.g.

cortisol reactivity, total cortisol output over the day) which may not correlate with diurnal synchrony observed over a short period. For instance, a dyad might demonstrate a relatively constant degree of linkage during a study period, but simultaneously each be progressing toward flatter overall slope (Butler, 2011). In addition, synchrony may be affected by the momentary context for the dyad, such as individual or dyadic behaviors that facilitate physiological synchrony. Prior work has found greater linkage in mother-child cortisol at moments of increased negative affect (Papp et al., 2009) and when the dyad demonstrates behavioral synchrony (Feldman, Gordon, & Zagoory-Sharon, 2010; Feldman, Magori-Cohen, Galili, Singer & Louzon, 2011). Laboratory studies may be helpful in providing insight into the mechanisms that underlie physiological synchrony by experimentally controlling aspects of the environment and interactions. Another limitation of this study is that mother-child and father-child synchrony were tested in separate models, which did not allow for exploration of simultaneous connections among multiple family members, or the relative influence of each family member. Recent work examined triadic physiological synchrony among mothers, fathers and children in a laboratory context, and represents an exciting direction for future naturalistic family research (Saxbe et al., 2014). Finally, the number of dyads in each study was relatively small and families were fairly homogenous. Future work may seek to replicate these findings in the context of households that vary in family member composition, and socioeconomic status, and that include parents or children with clinical disorders.

Nonetheless, in demonstrating that parent-child cortisol synchrony is bidirectional, and occurs with both mothers and fathers, we gain additional insight into the complex picture of development in the family context. Not only are parents influential through the rearing of children, but our data suggest one of the ways that children may shape the very system exerting

those influences. A fuller picture of the longitudinal implications of physiological synchrony over time should be pursued in future research. Better understanding of the short-term dyadic and individual processes that enhance bidirectional cortisol synchrony may provide a foothold for the development of intervention strategies that utilize the parent-child relationship to improve well-being of adults and children alike.

Table 1. Parent-Child Physiological Synchrony in UCLA Families and Health Study with Child Age and Sex Moderation

Fixed Effects	Mother-Child		Father-Child	
	Estimate (SE)	<i>t</i>	Estimate (SE)	<i>t</i>
Intercept				
Parent's	2.17 (0.07)	35.60***	2.11 (0.06)	36.26***
Child's	2.33 (0.07)	31.25***	2.47 (0.07)	33.26***
Slope of Time				
Parents' Time	-0.06 (0.02)	-3.60***	-0.05 (0.02)	-2.76**
Children's Time	-0.17 (0.02)	-8.13***	-0.22 (0.02)	-9.92***
Slope of Time ²				
Parents'	0.00 (0.00)	3.51***	0.00 (0.00)	2.53*
Children's	0.00 (0.00)	8.13***	0.01 (0.00)	10.07***
Cortisol Sampling Control				
Parents'	0.11 (0.09)	1.15	0.18 (0.12)	1.58
Childrens'	-0.08 (0.07)	-1.26	-0.13 (0.08)	-1.57
Partner Cortisol Predictor				
Children Predicting	0.83 (0.04)	22.96***	0.73 (0.04)	18.55***
Parents'				
Parent Predicting	0.69 (0.03)	21.48***	0.63 (0.03)	18.34***
Child's				
Level 2 Effect of Child Sex				
Child Predicting Parent	-0.12 (0.04)	-3.07**	-0.13 (0.05)	-2.96**
Parent Predicting Child	0.05 (0.04)	1.14	-0.01 (0.04)	-0.25
Level 2 Effect of Child Age				
Child Predicting Parent	-0.03 (0.01)	-2.61**	-0.06 (0.01)	-4.12***
Parent Predicting Child	0.00 (0.01)	0.06	-0.02 (0.01)	-1.32

† $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

Note: Estimation method = REML, Satterthwaite degrees of freedom

Table 2. Parent-Child Physiological Synchrony in UCLA Center for Everyday Lives of Families with Child Age and Sex Moderation

Fixed Effect	Mother-Child		Father-Child	
	Estimate (SE)	<i>t</i>	Estimate (SE)	<i>t</i>
Intercept				
Parents'	-1.11 (0.13)	-8.74***	-1.08 (0.14)	-7.63***
Children's	-1.20 (0.16)	-7.57***	-1.02 (0.15)	-6.70***
Slope of Time				
Parents'	-0.16 (0.03)	-6.27***	-0.15 (0.03)	-5.08***
Children's	-0.11 (0.03)	-3.56***	-0.14 (0.03)	-4.48***
Slope of Time ²				
Parents'	0.00 (0.00)	4.32***	0.00 (0.00)	3.72***
Children's	0.00 (0.00)	1.04	0.00 (0.00)	1.37
Cortisol Sampling Control				
Parents'	-0.07 (0.10)	-0.73	0.07 (0.11)	0.62
Children's	-0.13 (0.11)	-1.29	-0.06 (0.11)	-0.60
Partner Cortisol Predictor				
Children Predicting	0.35 (0.06)	5.77***	0.38 (0.07)	5.24***
Parents'				
Parent Predicting	0.43 (0.07)	5.83***	0.43 (0.07)	6.12***
Children's				
Level 2 Effect of Child Sex				
Child Predicting Parent	0.07 (0.07)	1.04	-0.00 (0.07)	-0.12
Parent Predicting Child	0.28 (0.08)	3.43***	0.04 (0.08)	0.43
Level 2 Effect of Child Age				
Child Predicting Parent	0.00 (0.04)	0.04	-0.08 (0.04)	-2.10*
Parent Predicting Child	-0.03 (0.04)	-0.86	-0.05 (0.05)	-1.12

† $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

Note: Estimation method = REML, Satterthwaite degrees of freedom

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