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# Glee in threes: Positive affect synchrony in parent-infant triads is moderated by maternal hair cortisol and parenting stress

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A R T I C L E I N F O

*Keywords:*
Affective synchrony
Stress
Parent-child interaction
Positive affect

A B S T R A C T

*Background:* Positive affect synchrony, or the reciprocal exchange of positive affect during free play, can scaffold infants' socioemotional development. However, parental stress may compromise the expression and exchange of positive affect within families. The current study assesses whether parenting stress and hair cortisol are associated with positive affect synchrony during a triadic play interaction.

*Method:* Within 70 different-sex dyads consisting of first-time parents and their six-month-old infants who participated in a four-minute laboratory-based free-play task, facial affect of each member of the triad was observationally microcoded at the second-by-second level. Hair samples were collected from mothers and fathers for cortisol assay, and parents completed a self-report measure of parenting stress.

*Results:* Using dynamic structural equation modeling (DSEM), we found positive between-level and within-level affect synchrony across all family members, with one exception: infants' affect did not predict fathers' affect at the following timepoint. Mother-to-infant affect synchrony was greater in mothers with higher hair cortisol. Similarly, mothers with higher parenting stress tended to have greater infant-to-mother affect synchrony, and had infants that displayed less overall positive affect across the interaction.

*Conclusion:* We found evidence for bidirectional, time-lagged synchrony in the momentary positive affect of mothers, fathers, and infants. Maternal hair cortisol concentration and parenting stress seem to increase affect synchrony between mothers and infants– suggesting that parental stress may correlate with greater affective attunement, but less overall positive affect in infants.

Caregivers attune to and synchronize with their infants in dynamic feedback loops that serve to keep infants in affective and physiological harmony (Beeghly & Tronick, 2011; Feldman, 2012). Parents' positive affect is theorized to create a safe relational space within which infants' emotional expression can emerge and grow (Cohn & Tronick, 1988; Messinger & Fogel, 2007; Mireault et al.,

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2015). Recurrent patterns of shared positive affect encourage infants to explore novelty (Sorce et al., 1985; Walden, 1991), dampen infants' threat response to ambiguous stimuli (e.g., a new toy; Hornik et al., 1987; Moore & Calkins, 2004; Water & Mendes, 2016), support secure attachment (Evans & Porter, 2009), and shape infants' neural processing of emotional faces (Taylor-Colls & Pasco Fearon, 2015). Thus, positive affect synchrony (i.e., time-lagged covariation in parents' and infants' observed positive facial affect) may be an observable behavioral microprocess with longstanding implications for child development (Feldman, 2003; 2012). However, there is emerging evidence that stress may erode families' co-regulatory relationships and compromise their homeostatic balance of affect and arousal (i.e., social allostatic load; Saxbe et al., 2020). The present study assesses positive affect synchrony in a community sample of family triads (mothers, fathers, and infants) during free play, and tests associations between families' positive affective dynamics and indicators of parents' biological stress (e.g., hair cortisol concentration) and psychological stress (e.g., parenting stress).

## 1. The developmental *broaden and build* theory of positive emotion

Research on shared affective dynamics in caregiver-infant relations often centers on the coregulation of negative affect (Cole, 2014; Kopp, 1989). The *still-face paradigm* (SFP), designed to study caregivers' coregulation of infants' negative affectivity, has been used in over 80 different empirical studies (Mesman et al., 2009). Comparatively less work focuses on shared *positive* affect in family interactions during the first year of life. However, Fredrickson's (2004) *broaden-and-build* theory has sparked an emergent interest in the contagious, adaptive qualities of positive emotions in close relationships and these perspectives are beginning to diffuse into models of child development (Stifter et al., 2020).

Fredrickson (2004) proposed that positive emotions increase awareness of (and openness to) novel stimuli, thoughts, and behaviors, which over time avails access to new resources (e.g., social skills) and opportunities (e.g., new acquaintances) that bolster wellbeing throughout the lifespan. From a developmental lens, parents initiate the *broadening* of positive emotion for their infants by cultivating a warm, affiliative social environment that soothes infants – psychologically and physiologically (Busuito et al., 2019; Hornik et al., 1987). Fredrickson contends that openness to novelty leads to enhanced wellbeing (and vice versa) in an *upward spiral* – a process that likely originates early in life from the dynamic exchange of positive affect between parents and infants (Feldman, 2003; 2012). Infants' affective states are tethered to social inputs from their caregivers, especially during the first year of life (Beeghly & Tronick, 2011); thus, the *upward spiral* of children's positive affectivity may emerge and persist vis-à-vis inputs from parents' positive affect, leading to greater prosocial behavior later in toddlerhood, as well as greater cognitive development, educational attainment, and life satisfaction in adulthood (Bridgett et al., 2013; Coffey, 2020; Coffey et al., 2015).

## 2. Positive affect synchrony during free play

Researchers posit that positive affectivity may be an essential building block of resilience (Ong et al., 2010); namely, that individuals whose positive affect is kindled daily (e.g., through spending time with loved ones) may cope better with stressors. Positive affectivity emerges in early childhood through affectionate and stimulatory play with caregivers (Feldman et al., 1999; Feldman, 2012). As such, one approach for studying the social stimulation of infants' positive affectivity is by systematically measuring momentary time-lagged covariation in parents' and infants' positive affect during free-play (i.e., positive affect synchrony). According to this definition, positive affect synchrony strictly refers to time-lagged matching of parent and infant affect. However, synchrony may be indicative of a broader pattern of coordination where parents are actively responding to their infants' cues, and vice versa (see Provenzi et al., 2023 for a review). Observing free play, or unstructured, undirected play between parents and infants without a specific goal and without the presence of an acute stressor (e.g., a stranger sitting in the room), can allow for naturalistic exploration of family interactions that occur regularly in daily life. Free play, specifically, is an ideal interaction for observing positive affect synchrony, as parents are more likely in this setting to elicit and match their infant's positive affect (Feldman, 2012).

### *2.1. Emergence of positive affect synchrony*

Affect synchrony between infants and caregivers increases during the first six months of life as infants develop the ability to detect and respond to the affective tone of their caregivers' facial expression (Forbes et al., 2004; Kokkinaki & Vasdekis, 2015). The sharing of positive affect becomes more salient in the second half of the first year as infants master social smiling and begin to use their caregivers' affective cues to modulate their emotional and physiological arousal. Even in the absence of physical touch, affect synchrony leads to coordinated biological and physiological rhythms in mother-infant dyads (Feldman et al., 2011). For example, Waters et al. (2017) found that when mothers experience a low-arousal positive/relaxation condition (i.e., five-minute nature video with soothing music), infants tend to synchronize with mothers' parasympathetic nervous system (PNS) reactivity – a sign that mothers are scaffolding the development of infants' self-regulatory system. Notably, this effect persisted in groups where infants sat in high-chairs away from their mother, suggesting that the coregulation of affect and physiological arousal can occur in the absence of direct touch. Others find that parents' positive affect is a more stable predictor of infants' observed positive affect than affectionate touch during play (Forbes et al., 2004). Moreover, infant-directed speech draws infants' attention more often when parents display positive affect, above and beyond the effects of prosodic modifications like 'baby talk' and 'motherese' (Singh et al., 2002). Taken together, these studies suggest that the valence of parents' facial expressions shapes infants' momentary affective states and regulatory physiology (Fogel, 1994), even when isolated from other elements of communication like speech, touch, and gaze. The present study builds on these findings by exploring covariation in positive affect among family triads and their infants.

## 3. Triadic family interactions during infancy

While many infants are reared in homes with multiple caregivers, research on shared positive affect has focused almost exclusively on samples of mother-infant dyads (Colonnesi et al., 2012; Forbes et at. 2004; Leclere et al., 2014). A few studies have compared positive affect dynamics across mother-infant and father-infant dyads (Aktar et al., 2017; Colonnesi et al., 2012; Feldman, 2003; Forbes et al., 2004), but these studies do not directly examine interactive dynamics among all three family members (i.e., the *triad*)– choosing instead to statistically control for parent gender. Family systems theory posits that families are comprised of interdependent subcomponents – namely, each member of the family and their constituent emotions and behaviors (Cox & Paley, 1997). As family members interact over time, stable patterns may emerge with transactional and regulatory properties that come to define their relationships. In early childhood, family triads that are highly coordinated are more likely to stimulate infants' positive affect and increase infants' willingness to initiate bids for interaction during play (Fivaz-Depeursinge et al., 2012). Research that focuses solely on mother-infant dyad excludes fathers from the family system – which decreases the ecological validity of family research and biases our understanding of family-level processes that may impact children (Paley & Hajal, 2022).

Despite evidence that affective coordination while coparenting impacts infant development (de Mendonça et al., 2011; Hirshberg, 1990; Teubert & Pinquart, 2010), momentary dynamics of triadic interactions remain understudied. Only two studies have used observationally micro-coded data to study affect dynamics of triads during early childhood (e.g., mother, father, and infant; Gordon et al., 2008, 2010). Positive affect synchrony among family triads may be a micro-level interpersonal process that predicts family functioning (Fivaz-Depeursinge et al., 2012). For example, parent-infant synchrony may differ across mothers and fathers, signaling possible differences in mutual child engagement, and synchrony between caregivers' affect may also be indicative of coparenting effectiveness (McHale & Fivaz-Depeursinge, 2010). Research in this area could inform coparenting interventions that target synchrony in caregivers' coordinated affect (Paley & Hajal, 2022). Therefore, the present study seeks to introduce a framework for studying momentary affect synchrony among family triads that include infants.

## 4. Social allostatic load: Parenting stress and affective dynamics

Infants' emotional states are jointly regulated by both caregivers in dual parent households. However, parents' capacity to regulate infant's emotional states can be limited by their own resources and challenges. The theory of *social allostatic load* suggests that the wear-and-tear of chronic stress may gradually degrade family members' ability to maintain affective harmony – much like the cords of a net fraying over time due to repeated use (Saxbe et al., 2020). The transition to parenthood is a period fraught with novel stressors, responsibilities, and role transitions which may lead to increased psychological stress and dysregulation of the hypothalamic-pituitary-adrenal axis (HPA axis; Saxbe et al., 2018). Indeed, parents' hair cortisol concentration – an indicator of aggregate HPA activity in prior weeks and a retrospective biomarker of chronic stress (Kirschbaum et al., 2009; Stalder et al., 2017) – has been found to positively correlate with parental burnout (Brianda et al., 2020). A recent longitudinal study also found that fluctuations in maternal hair cortisol concentration from the first trimester to six months postpartum were predicted by mothers' exposure to psychosocial stressors (SES-related changes, legal problems, death of a loved one, intimate partner discord, etc.; King et al., 2022).

Parental chronic stress, as indicated by hair cortisol concentration, may also be associated with parent-infant interactions. Preliminary work finds that mothers' postpartum hair cortisol mediates the association between mothers' early life adversity (e.g., history of childhood abuse) and insensitive parenting behaviors such as ignoring, or responding inappropriately, to infants' cues, which may implicate hair cortisol concentration in the processes by which chronic stress shapes family dynamics (Nyström-Hansen et al., 2019). Another study finds that mothers with higher postpartum hair cortisol tended to engage in more intrusive behavior and exhibit less positive affect synchrony with six-month-old infants (Tarullo et al., 2017). Taken together, these findings suggest that when chronic stress is low, positive parent-infant interactions are more likely to occur (Mckelvey et al., 2002). While compelling, these studies have yet to be replicated in samples of both mothers and fathers interacting with their infant. Therefore, the present study tests whether parenting stress and hair cortisol concentrations moderate families' observed affective synchrony and overall levels of positive affect during free-play.

## 5. Present study

This study examines momentary, time-lagged positive affect synchrony in a community sample of mothers, fathers, and their infants during a brief episode of triadic free play. We fit a series of two-level, vector autoregressive models using dynamic structural equation modeling (DSEM) to determine if infants' momentary positive affect is predicted by maternal and paternal positive affect in the preceding moments, employing a time-lag of one second.

**Hypothesis 1**. At the between-family level, we expected that mothers and fathers who display more positive affect, compared to other parents in the sample, would have infants who also displayed more positive affect, on average, across the entire interaction.

**Hypothesis 2.** At the within-family level, we expected positive synchrony to be time-lagged, suggesting that infants tend to mirror positive affect initiated by their caregivers. Namely, we predicted that mothers and fathers who displayed more positive affect *at a given moment*, relative to their own average levels of positive affect, would be more likely to have an infant who is also displayed positive affect *in the following moment* – indexing positive affect synchrony for mothers and fathers, respectively. We did not posit a priori hypotheses for affective synchrony between parents.

**Hypothesis 3.** We expected that parental hair cortisol concentration (measured at the same visit in which the triadic free play interaction took place) would moderate positive affect synchrony at the within- and between-family levels. At the within-level, we predicted 3a) parental hair cortisol concentration would predict a decrease in mother-infant and father-infant positive affective synchrony, providing evidence that higher chronic stress may weaken associations in families' shared positive affect. At the between-level, we predicted 3b) greater parental hair cortisol concentration would be associated with lower overall positive affect in mothers and fathers across the entire free-play paradigm.

**Hypothesis 4.** We also expected self-reported parenting stress would moderate positive affect and synchrony at the within- and between-family levels. At the within-level, we predicted 4a) greater parenting stress would predict less mother-infant and father-infant affective synchrony, similar to our prediction in Hypothesis 3. At the between-level, we predicted 4b) greater parenting stress would correlate with lower overall positive affect in mothers and fathers, respectively.

## 6. Method

### *6.1. Participants*

Families were recruited from the greater Los Angeles area as part of a larger longitudinal assessment of biopsychosocial adjustment to first-time parenthood (the Hormones Across the Transition to Child Rearing or HATCH Study). Laboratory visits for the HATCH study were conducted at a major research university in the western United States. A total of one hundred ($N = 100$) racially, ethnically, and socioeconomically diverse couples were recruited during pregnancy through filers posted in obstetricians' offices, community health clinics, and on social media. This sample size was determined by available grant funding and the planned time frame for data collection.

To be eligible, couples were required to be heterosexual, expecting their first child, anticipating a singleton birth, cohabitating, and planning to cohabitate after the birth of their child. All couples participated in a laboratory visit during pregnancy. When their infant

**Table 1**
Descriptive Statistics.

| **Characteristic** (N = 70 families) | **Father** | **Mother** | **Infant** |
|---|---|---|---|
| Education[a] | | | |
| High School Grad/GED | 2 (2.9 %) | 1 (1.4 %) | |
| Associate's Degree | 3 (4.3 %) | 0 (0 %) | |
| Some College | 8 (11 %) | 8 (12 %) | |
| Bachelor's Degree | 35 (50 %) | 29 (42 %) | |
| Master's Degree | 13 (19 %) | 24 (35 %) | |
| Professional or Doctoral Degree | 9 (13 %) | 7 (10 %) | |
| Ethnicity[a] | | | |
| American Indian/Alaska Native | 0 (0 %) | 1 (1.4 %) | |
| Asian | 10 (14 %) | 12 (17 %) | |
| Black | 6 (8.6 %) | 4 (5.8 %) | |
| Decline | 1 (1.4 %) | 0 (0 %) | |
| Latinx | 12 (17 %) | 16 (23 %) | |
| Other | 5 (7.1 %) | 5 (7.2 %) | |
| White | 36 (51 %) | 31 (45 %) | |
| Age (Years)[2] | 33.6 (7.1) | 31.5 (6.8) | |
| Age (Weeks)[2] | | | 28.73 (2.25) |
| Relationship Status[a] | | | |
| Dating/Cohabiting with a Romantic Partner | 11 (16 %) | 12 (17 %) | |
| Married/Domestic Partnership | 59 (84 %) | 58 (83 %) | |
| Infant Sex[a] | | | |
| Female | | | 31 (53 %) |
| Male | | | 27 (47 %) |
| Missing Birth Charts | | | 12 |
| Negative Affect[3] | 0.01 (0.03) | 0.01 (0.03) | 0.07 (0.10) |
| Neutral Affect[3] | 0.50 (0.25) | 0.42 (0.24) | 0.71 (0.20) |
| Positive Affect[3] | 0.49 (0.25) | 0.57 (0.24) | 0.21 (0.20) |
| Missing Affect[3] | 0.11 (0.18) | 0.11 (0.16) | 0.17 (0.20) |
| Hair Cortisol (pg/mg)[2] | 29.78 (37.20) | 20.73 (23.16) | |
| Parenting Stress (PSI)[2] | 4.29 (0.49) | 4.30 (0.46) | |

[a] n (%); [2]Mean (SD); [3]Proportion of Interaction (SD)

was six months old, participants were invited to return to the lab for a postpartum visit (see Procedure). Of the 100 families recruited, thirteen families opted out of the postpartum visit, eight families completed a remote postpartum visit with no video due to the onset of the COVID-19 pandemic in 2020, seven families' videos were not codable due to audio or visual obstruction, one family had an infant who was asleep during the free-play interaction, and one videotape was compromised due to technical issues. Thus, the final sample consisted of 70 families (210 individuals) who had complete data at both prenatal and postpartum. Sample descriptives are presented in Table 1. Most parents in the sample held a bachelor's degree (42 % of mothers; 50 % of fathers), were married (84 %), and identified as ethnic minorities (55 % of mothers, 49 % of fathers). Mothers and fathers who were included in this final sample did not differ from parents in the 30 other families in terms of education, ethnicity, household income, hair cortisol concentrations, or parenting stress (see Supplementary Materials).

### 6.2. Procedure

Families were invited to attend two in-person laboratory visits: the first visit took place between the second and third trimester of pregnancy (i.e., 20 – 36 weeks) and the second visit at six months postpartum *(M*= 28.42 weeks, *SD* = 2.78 weeks). During the postpartum visit, families were ushered into a room outfitted with audio and video recording devices and instructed to participate in a ten-minute family interaction task. For the first six minutes of the interaction, parents were instructed to help their infant "learn to flip pages of a book" and "write their name on paper with crayons." These tasks were designed to exceed infant's motor skills at six months and introduced specifically to induce mild stress. For the remaining four minutes, parents were asked to play with their infant "like they would at home" (i.e., free play). Video cameras were positioned on the wall and mounted to a small table to capture a frontal view of participants' facial expressions. Three of the 70 families completed the interaction task from home and were videotaped using Zoom (i.e., a video chat software) because they were unable to attend an in-person visit following the onset of the COVID-19 pandemic. These three families were retained in the final sample because the average duration of positive affect in mothers, fathers, and infants was not significantly different from the rest of the sample.

Videotapes of families' free-play interactions were micro-coded according to the *Triadic Micro-Coding* scheme developed by Ruth Feldman and colleagues (Feldman, 2012; see Supplementary Materials). A team of two research assistants led by the second author, a senior-level doctoral student, coded 53 of the families in the sample (see Morris et al., 2021 for technical details), and remaining 17 videos were coded by a second team of five research assistants led by the first author, a junior doctoral student. All members of the second team received two hours of training and practiced coding at least 10 videos to achieve sufficient reliability with the first team before coding the remaining 17 videos. Each video was coded twice – once by a primary coder and once by a reliability coder. Both sets of behavioral codes were than evaluated by a third coder to reconcile inconsistencies until reliabilities exceeded Cohen's $\kappa > .90$.

### 6.3. Measures

*Affect Codes.* Behavioral microanalysis of participants' facial affect was conducted using Datavyu (Datavyu Team, 2014), an open-source platform for graphically coding video data. Maternal, paternal, and infant affect was coded independently using the triadic microanalytic protocol created by Feldman *et al.* (Feldman, 2003; Gordon et al., 2008; 2010). Affect codes were mutually exclusive and exhaustive and assigned to mothers, fathers, and infants using onset and offset times. Namely, participants could only be assigned one code at a time, and the coding scheme accounted for all possible behavior.

Cohen's κ was computed as an indicator of interrater reliability (Cohen, 1960); κ values were computed by first converting onset-offset times into categorical time-series for mothers, fathers, and infants affect, respectively. The smallest epoch within each time-series was 1 s, so an affect code was applied to each family member at each second. Average Cohen's κ for maternal ($\kappa = .95$), paternal ($\kappa = .92$), and infant affect ($\kappa = .95$) were all excellent (Fleis, 1981), considering that Cohen's κ is a stringent metric for intensive micro-coding because behaviors *and* time intervals must be congruent in order to achieve reliability (Weinberg & Tronick, 1994).

*Parental affect.* Parent affect was assessed by coders based on facial expressions, body tone, movements, and other non-verbal signals: 1) *Positive affect* indicates clear signs of joy and exuberance with a clear smile or laughter, 2) *Neutral affect* indicates that parent shows a pleasant and warm expression which is low in arousal and does not contain high positive arousal, 3) *Negative affect* indicates that parents clearly show signs of being withdrawn, angry, impatient, or anxious, and 4) *Uncoded affect* cannot be categorized due to filming obstructions such as the parents' face being off-camera and unobservable.

*Infant Affect.* Infant affect was assessed using the following codes: 1) *Positive affect* indicates infants are expressing clear signs of joy or laughter, 2) *Neutral affect* indicates that infants appear content and engaged but no signs of high positive arousal, 3) *Negative affect* indicates that infants are withdrawn, crying, fussing, or whining (can be subdivided into *withdrawn* or *angry* affect), and 4) *Uncoded affect* due to the infants' face being unobservable.

*Parenting Stress Index – Short Form* (*PSI-SF)*. The PSI-SF, a 36-item questionnaire, comprises three 12-item subscales that assess stress in the parent-child relationship (Abidin, 1995). Respondents rate their agreement with each statement using a 5-point Likert scale (1 = "Strongly Agree", 5 = "Strongly Disagree:"). Participants were provided with this example prompt: "Read each statement carefully, and then or each statement, select the option that best represents your level of agreement or disagreement." Example items include, "*I often have the feeling that I cannot handle things very well,*" "*I find myself giving up more of my life to meet my child's needs than I ever*

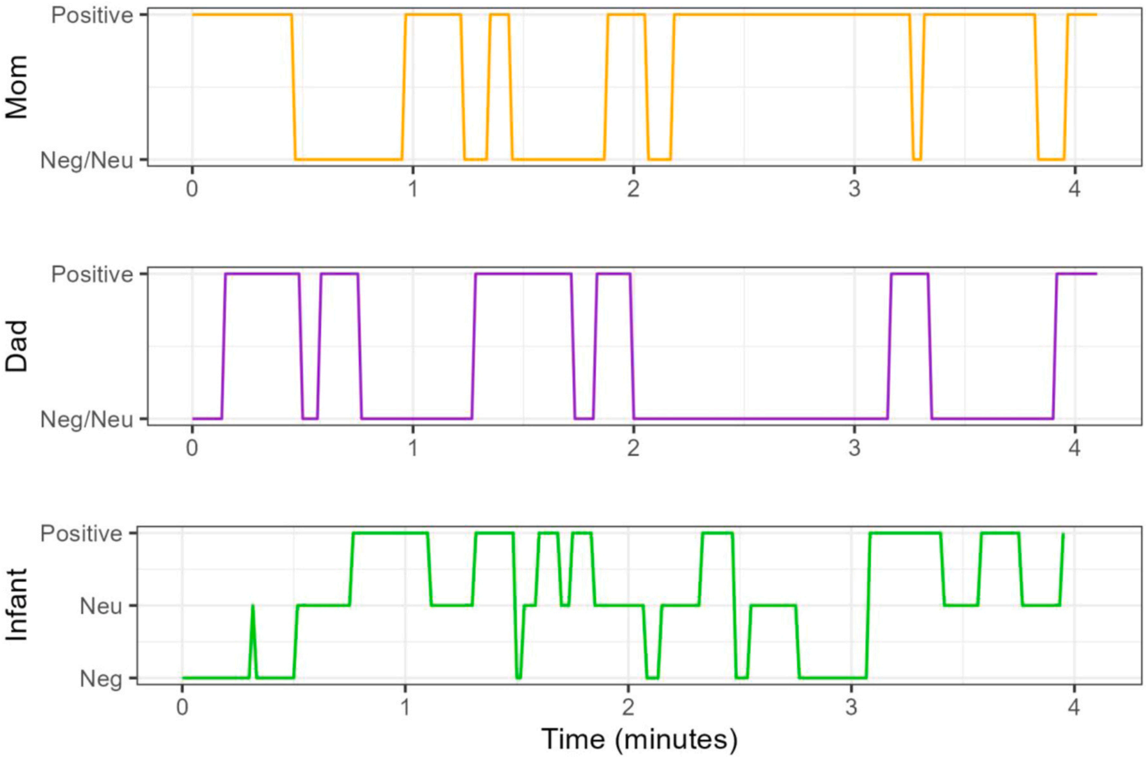


**Fig. 1.** Triadic time series example from a single family, Note. Maternal and paternal negative affect (i.e., Neg) has been combined with neutral affect (i.e., Neu) due to low base rates of negative affect in parents.

*expected,*" and "*I feel trapped by my responsibilities as a parent.*" Consistent with the literature, we computed a mean score from all 36 items to generate one overall PSI score. The PSI-SF has demonstrated internal consistency, convergent validity, and predictive validity in ethnically diverse samples of families with infants (Barroso et al., 2016; Haskett et al., 2006). The PSI-SF demonstrated strong reliability among mothers ($\alpha = .91$) and fathers ($\alpha = .93$) in our sample.

*Hair Cortisol Concentration.* Hair was collected for cortisol assay at the six month postpartum visit from the mother, father, and infant – but only samples from mothers and fathers are used in the present study given our focus on parental stress. Approximately 50–100 strands of hair were tied together using a slipknot created from a loop of packing thread and clipped from the base of the scalp. Research assistants collected hair from parents who came into the lab; for the three families who participated via Zoom, we guided participants through hair collection remotely and received their samples via postal mail. Parents who lacked scalp hair were allowed to provide comparable volumes of hair from other locations on the body (e.g., facial hair, arm hair, etc.). In total, four fathers provided non-scalp hair and all four had hair cortisol concentrations that were within half a standard deviation of the sample mean for fathers. Therefore, we retained these four fathers in the current sample. Cortisol assays were performed on the 2 cm of hair nearest to the scalp (approximating hair growth over the previous couple of months) by the TU Dresden laboratory led by Dr. Clemens Kirschbaum (Kirschbaum et al., 2009). Samples were analyzed using liquid chromatography-tandem mass spectrometry (LC-MS/MS) protocol with established validity in other studies (Gao et al., 2013).

## 7. Data processing

Prior to analysis, onset and offset durations for each participant were binned into 1 s epochs, yielding three separate categorical time-series variables with an average length of 265.94 s (4.43 min; SD =.25 min; Min = 4.05 min, Max = 5.40 min) for each of the 70 families in our sample. One second epochs were selected based on prior work in parent-infant affective microcoding (Somers & Leucken, 2022) and a meta-analysis suggesting that infants' response latency to parents is approximately 1 s (Nguyen et al., 2022).

Consistent with previous research (Aktar et al., 2017; Cohn & Tronick, 1988; Kaitz et al., 2010), most mothers and fathers did not display any negative affect during the free play interaction (91.4 % and 85.7 %, respectively). Therefore, we chose to dichotomize maternal and paternal affect into *Positive Affect* = "1" and *Negative and Neutral Affect* = "0" (see Fig. 1) to prevent convergence issues and bias in our analyses that tend to occur when there are very few observations at a particular level of an ordinal variable (Depaoli & Clifton, 2015; Yang-Wallentin et al., 2010). Infants were more likely than parents to display negative affect, though approximately 50 % of infants displayed little to no negative affect (< 3 % of the interaction). Thus, infant affect was treated as an ordinal variable where *Positive Affect = "2", Neutral Affect = "1", and Negative Affect = "0"*. Instances where participants' faces were off-camera or obscured (i.e., *uncodable*) were treated as data missing at random (MAR). Average rates of missingness for mothers, fathers, and infants were 10 %, 11 %, and 16 %, respectively. Missingness was handled using the *Mplus* Bayesian estimation procedure, which is detailed the Supplementary Materials (see also Asparouhov et al., 2018).

## 8. Data analysis

### 8.1. Dynamic structural equation modeling (DSEM)

We fit a series of two-level, trivariate vector autoregressive (VAR) models using dynamic structural equation modeling (DSEM) to estimate cross-lagged effects in families' momentary affective dynamics (Asparouhov et al., 2018; see Supplementary Materials for details[1]). We chose DSEM because it allowed us to estimate cross-lagged effects while controlling for autocorrelation in each family members' affective time series (Asparouhov et al., 2018). DSEM extends multivariate time-series into a multilevel $N > 1$ framework by estimating random effects to account for between-family differences in the cross-lagged parameters (see McNeish & Hamaker, 2020 for details). This allowed us to regress parenting stress and hair cortisol concentration on to the cross-lagged parameters to determine if affective synchrony varies as a function of parents' stress measures. Given all analyses were conducted using Bayesian estimation, point estimates were derived from the median of the posterior predictive distribution (Asparouhov et al., 2018). Estimates were assumed to be significantly different than zero (H0 ‡ 0) if the 95 % credible intervals of the posterior distributions did not contain zero.

Simulation studies for DSEM with categorical outcomes suggest that, in general, multilevel VAR models evidence acceptable relative bias, efficacy, power, and type-I error rates when outcomes have 2–3 categories pending samples with 200 clusters and 56 timepoints (Savord, 2023). Given our sample had fewer clusters ($N = 70$ families) and more timepoints ($T \sim 250$), we conducted our own Markov Chain Monte Carlo (MCMC) simulation using estimates from our models as population values to evaluate our power, coverage, relative bias, and efficacy (see Savord, 2023 for technical definitions). Finally, we used G*Power to determine our sample size of $N = 70$ was sufficiently powered to detect medium effects ($d$ =.33) using $t$-tests and correlations with a power of.8.

### 8.2. Model equations

**Model 1 – Baseline Models.** Each family member's affective time-series data was regressed on to their own affect (i.e., autoregressive lag-1) and the affect of the other two family members at time $t - 1$ s. Random effects were included for both autoregressive and

[1] Data and *Mplus* code for replicating analyses can be found at this https://github.com/gabepsych/DSEM_glee_in_threes

cross-lagged effects to account for between-level differences in these parameters (McNeish & Hamaker, 2020; Savord et al., 2022). The baseline model took the following form:

$$\text{Within Model}\begin{cases} \text{Mother}_{w,tj} = \alpha_{0j} + \phi_{1j}\text{Mother}_{w,(t-1)j} + \phi_{2j}\text{Father}_{w,(t-1)j} + \phi_{3j}\text{Infant}_{w,(t-1)j} + e_{1tj} \\ \text{Father}_{w,tj} = \alpha_{1j} + \phi_{4j}\text{Father}_{w,(t-1)j} + \phi_{5j}\text{Mother}_{w,(t-1)j} + \phi_{6j}\text{Infant}_{w,(t-1)j} + e_{2tj} \\ \text{Infant}_{w,tj} = \alpha_{2j} + \phi_{7j}\text{Infant}_{w,(t-1)j} + \phi_{8j}\text{Mother}_{w,(t-1)j} + \phi_{9j}\text{Father}_{w,(t-1)j} + e_{3tj} \\ \begin{bmatrix} e_{1tj} \\ e_{2tj} \\ e_{3tj} \end{bmatrix} \sim \mathcal{N}\left( \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & & \\ & 1 & \\ & & 1 \end{bmatrix} \right) \end{cases}$$

$$\text{Between Model}\begin{cases} \alpha_{0j} = -\tau_2 + \mu_{0j} \\ \alpha_{1j} = -\tau_3 + \mu_{1j} \\ \alpha_{2j} = 0 + \mu_{2j} \\ \phi_{1j} = \gamma_{00} + \mu_{3j} \\ \phi_{2j} = \gamma_{10} + \mu_{4j} \\ \phi_{3j} = \gamma_{20} + \mu_{5j} \\ \phi_{4j} = \gamma_{30} + \mu_{6j} \\ \phi_{5j} = \gamma_{40} + \mu_{7j} \\ \phi_{6j} = \gamma_{50} + \mu_{8j} \\ \phi_{7j} = \gamma_{60} + \mu_{9j} \\ \phi_{8j} = \gamma_{70} + \mu_{10j} \\ \phi_{9j} = \gamma_{80} + \mu_{11j} \\ \begin{bmatrix} \mu_{0j} \\ \mu_{1j} \\ \mu_{2j} \\ \mu_{3j} \\ \mu_{4j} \\ \mu_{5j} \\ \mu_{6j} \\ \mu_{7j} \\ \mu_{8j} \\ \mu_{9j} \\ \mu_{10j} \\ \mu_{11j} \end{bmatrix} \sim \mathcal{N}\left( \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma^2_{00} & & & & & & & & & & & \\ \sigma^2_{10} & \sigma^2_{11} & & & & & & & & & & \\ \sigma^2_{20} & \sigma^2_{21} & \sigma^2_{22} & & & & & & & & & \\ & & & \sigma^2_{33} & & & & & & & & \\ & & & & \sigma_{44} & & & & & & & \\ & & & & & \sigma_{55} & & & & & & \\ & & & & & & \sigma_{66} & & & & & \\ & & & & & & & \sigma_{77} & & & & \\ & & & & & & & & \sigma_{88} & & & \\ & & & & & & & & & \sigma_{99} & & \\ & & & & & & & & & & \sigma_{1010} & \\ & & & & & & & & & & & \sigma_{1111} \end{bmatrix} \right) \end{cases} \quad (1)$$

At the within-family level, time-lagged maternal ($Mother_{w,(t-1)j}$), paternal ($Father_{w,(t-1)j}$), and infant affect ($Infant_{w,(t-1)j}$) at time $t-1$ in family $j$ are used to predict affect at time $t$ for mothers, fathers, and infants. Parameters $\phi_{1j}$, $\phi_{4j}$, and $\phi_{7j}$ capture the autoregressive effects – or the *stability* in individuals' affect over time (McNeish & Hamaker, 2020). The remaining $\phi$ parameters represent the cross-lagged effects, which we use as a measure of time-lagged synchrony in families affect. Random effects were estimated for the person-specific latent means ($\alpha_{0j}$, $\alpha_{1j}$, and $\alpha_{2j}$) and slopes ($\phi_{1j}$ – $\phi_{9j}$), allowing these parameters to vary across families.

### *8.3. Moderation effects*

**Model 2 – Moderation by Hair Cortisol.** Mother's and father's hair cortisol concentrations were entered as predictors of the latent means ($\alpha_{0j}$, $\alpha_{1j}$, and $\alpha_{2j}$) and slopes ($\phi_{1j}$ – $\phi_{9j}$) in the baseline model. The model testing for the moderation of hair cortisol took the following form:

$$
\text{Between Model}\begin{cases}
\alpha_{0j} = -\tau_3 + \gamma_{01}\text{HCC}_{Mother,j} + \gamma_{02}\text{HCC}_{Father,j} + \mu_{0j} \\
\alpha_{1j} = -\tau_4 + \gamma_{11}\text{HCC}_{Mother,j} + \gamma_{12}\text{HCC}_{Father,j} + \mu_{1j} \\
\alpha_{2j} = 0 + \gamma_{21}\text{HCC}_{Mother,j} + \gamma_{22}\text{HCC}_{Father,j} + \mu_{2j} \\
\phi_{1j} = \gamma_{30} + \gamma_{31}\text{HCC}_{Mother,j} + \gamma_{32}\text{HCC}_{Father,j} + \mu_{3j} \\
\phi_{2j} = \gamma_{40} + \gamma_{41}\text{HCC}_{Mother,j} + \gamma_{42}\text{HCC}_{Father,j} + \mu_{4j} \\
\phi_{3j} = \gamma_{50} + \gamma_{51}\text{HCC}_{Mother,j} + \gamma_{52}\text{HCC}_{Father,j} + \mu_{5j} \\
\phi_{4j} = \gamma_{60} + \gamma_{61}\text{HCC}_{Mother,j} + \gamma_{62}\text{HCC}_{Father,j} + \mu_{6j} \\
\phi_{5j} = \gamma_{70} + \gamma_{71}\text{HCC}_{Mother,j} + \gamma_{72}\text{HCC}_{Father,j} + \mu_{7j} \\
\phi_{6j} = \gamma_{80} + \gamma_{81}\text{HCC}_{Mother,j} + \gamma_{82}\text{HCC}_{Father,j} + \mu_{8j} \\
\phi_{7j} = \gamma_{90} + \gamma_{91}\text{HCC}_{Mother,j} + \gamma_{92}\text{HCC}_{Father,j} + \mu_{9j} \\
\phi_{8j} = \gamma_{100} + \gamma_{101}\text{HCC}_{Mother,j} + \gamma_{102}\text{HCC}_{Father,j} + \mu_{10j} \\
\phi_{9j} = \gamma_{110} + \gamma_{111}\text{HCC}_{Mother,j} + \gamma_{112}\text{HCC}_{Father,j} + \mu_{11j} \\
\begin{bmatrix} \mu_{0j} \\ \mu_{1j} \\ \mu_{2j} \\ \mu_{3j} \\ \mu_{4j} \\ \mu_{5j} \\ \mu_{6j} \\ \mu_{7j} \\ \mu_{8j} \\ \mu_{9j} \\ \mu_{10j} \\ \mu_{11j} \end{bmatrix} \sim \mathcal{N}\left( \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma^2_{00} & & & & & & & & & & & \\ \sigma^2_{10} & \sigma^2_{11} & & & & & & & & & & \\ \sigma^2_{20} & \sigma^2_{21} & \sigma^2_{22} & & & & & & & & & \\ & & & \sigma^2_{33} & & & & & & & & \\ & & & & \sigma_{44} & & & & & & & \\ & & & & & \sigma_{55} & & & & & & \\ & & & & & & \sigma_{66} & & & & & \\ & & & & & & & \sigma_{77} & & & & \\ & & & & & & & & \sigma_{88} & & & \\ & & & & & & & & & \sigma_{99} & & \\ & & & & & & & & & & \sigma_{1010} & \\ & & & & & & & & & & & \sigma_{1111} \end{bmatrix} \right)
\end{cases} \tag{2}
$$

where $\gamma_{01} - \gamma_{111}$ and $\gamma_{02} - \gamma_{112}$ represent the fixed effects of mothers' and fathers' HCC, respectively, on the latent means, autoregressive effects, and cross-lagged effects.

**Model 3 – Moderation by Parenting Stress.** Like the procedure used to test Model 2, mother's and father's parenting stress (PSI) were entered as covariates of the latent means ($\alpha_{0j}$, $\alpha_{1j}$, and $\alpha_{2j}$) and slopes ($\phi_{1j} - \phi_{9j}$):

$$\text{Between Model}\begin{cases}\alpha_{0j} = -\tau_3 + \gamma_{01}\text{PSI}_{Mother,j} + \gamma_{02}\text{PSI}_{Father,j} + \mu_{0j}\\ \alpha_{1j} = -\tau_4 + \gamma_{11}\text{PSI}_{Mother,j} + \gamma_{12}\text{PSI}_{Father,j} + \mu_{1j}\\ \alpha_{2j} = 0 + \gamma_{21}\text{PSI}_{Mother,j} + \gamma_{22}\text{PSI}_{Father,j} + \mu_{2j}\\ \phi_{1j} = \gamma_{30} + \gamma_{31}\text{PSI}_{Mother,j} + \gamma_{32}\text{PSI}_{Father,j} + \mu_{3j}\\ \phi_{2j} = \gamma_{40} + \gamma_{41}\text{PSI}_{Mother,j} + \gamma_{42}\text{PSI}_{Father,j} + \mu_{4j}\\ \phi_{3j} = \gamma_{50} + \gamma_{51}\text{PSI}_{Mother,j} + \gamma_{52}\text{PSI}_{Father,j} + \mu_{5j}\\ \phi_{4j} = \gamma_{60} + \gamma_{61}\text{PSI}_{Mother,j} + \gamma_{62}\text{PSI}_{Father,j} + \mu_{6j}\\ \phi_{5j} = \gamma_{70} + \gamma_{71}\text{PSI}_{Mother,j} + \gamma_{72}\text{PSI}_{Father,j} + \mu_{7j}\\ \phi_{6j} = \gamma_{80} + \gamma_{81}\text{PSI}_{Mother,j} + \gamma_{82}\text{PSI}_{Father,j} + \mu_{8j}\\ \phi_{7j} = \gamma_{90} + \gamma_{91}\text{PSI}_{Mother,j} + \gamma_{92}\text{PSI}_{Father,j} + \mu_{9j}\\ \phi_{8j} = \gamma_{100} + \gamma_{101}\text{PSI}_{Mother,j} + \gamma_{102}\text{PSI}_{Father,j} + \mu_{10j}\\ \phi_{9j} = \gamma_{110} + \gamma_{111}\text{PSI}_{Mother,j} + \gamma_{112}\text{PSI}_{Father,j} + \mu_{11j}\\ \begin{bmatrix}\mu_{0j}\\ \mu_{1j}\\ \mu_{2j}\\ \mu_{3j}\\ \mu_{4j}\\ \mu_{5j}\\ \mu_{6j}\\ \mu_{7j}\\ \mu_{8j}\\ \mu_{9j}\\ \mu_{10j}\\ \mu_{11j}\end{bmatrix} \sim \mathcal{N}\left(\begin{bmatrix}0\\0\\0\\0\\0\\0\\0\\0\\0\\0\\0\\0\end{bmatrix}, \begin{bmatrix}\sigma^2_{00} & & & & & & & & & & & \\ \sigma^2_{10} & \sigma^2_{11} & & & & & & & & & & \\ \sigma^2_{20} & \sigma^2_{21} & \sigma^2_{22} & & & & & & & & & \\ & & & \sigma^2_{33} & & & & & & & & \\ & & & & \sigma_{44} & & & & & & & \\ & & & & & \sigma_{55} & & & & & & \\ & & & & & & \sigma_{66} & & & & & \\ & & & & & & & \sigma_{77} & & & & \\ & & & & & & & & \sigma_{88} & & & \\ & & & & & & & & & \sigma_{99} & & \\ & & & & & & & & & & \sigma_{1010} & \\ & & & & & & & & & & & \sigma_{1111}\end{bmatrix}\right)\end{cases} \tag{3}$$

## 9. Results

### 9.1. Descriptive statistics

On average, mothers tended to display more positive affect than fathers during the free play interaction ($t(69) = 2.68$, $p < .01$). Mothers and fathers did not differ significantly from each other in either hair cortisol concentration (HCC; $t(65) = 1.43$, $p = .16$), or parenting stress ($t(69) = .24$, $p = .81$).

**Hypothesis 1.** ***Correlation of Mother, Father, and Infant Positive Affect.***

As expected, we observed a significant positive correlation between each family member's average level of positive affect during the interaction, with zero-order correlations ranging from.47 to.52 (see Table 2). Similarly, in the between-level part of the baseline model, the correlations between mothers', fathers', and infants' average positive affect (i.e., $\sigma^2_{10}$, $\sigma^2_{20}$, and $\sigma^2_{21}$) were all statistically significant and positive (see Table 3). This evidence supports Hypothesis 1, which predicted that mothers and fathers who displayed more positive affect would have infants who also displayed more positive affect.

**Hypothesis 2.** : ***Time-Lagged Synchrony in Families' Positive Affect.***

We tested Hypothesis 2 by estimating family's time-lagged synchrony in Model 1 with no moderation effects. As we hypothesized, family members showed synchrony in positive affect with each other, with the exception of infant-to-father time-lagged synchrony ($\phi_6$ =.008, 95 % CR = [−0.004,0.02]), which had 95 % credible intervals that contained zero (see Table 3). Posterior parameter distributions for each autoregressive and cross-lagged parameter are depicted in Panel A of Fig. 4. These posteriors represent predicted values for each parameter, given the data. The median value of each parameter is comparable to a point estimate in frequentist statistics (i.e., posterior medians in Table 1).

**Hypothesis 3a.** : ***Hair Cortisol Concentration (HCC) as a Moderator of Time-Lagged Synchrony in Families' Positive Affect.***

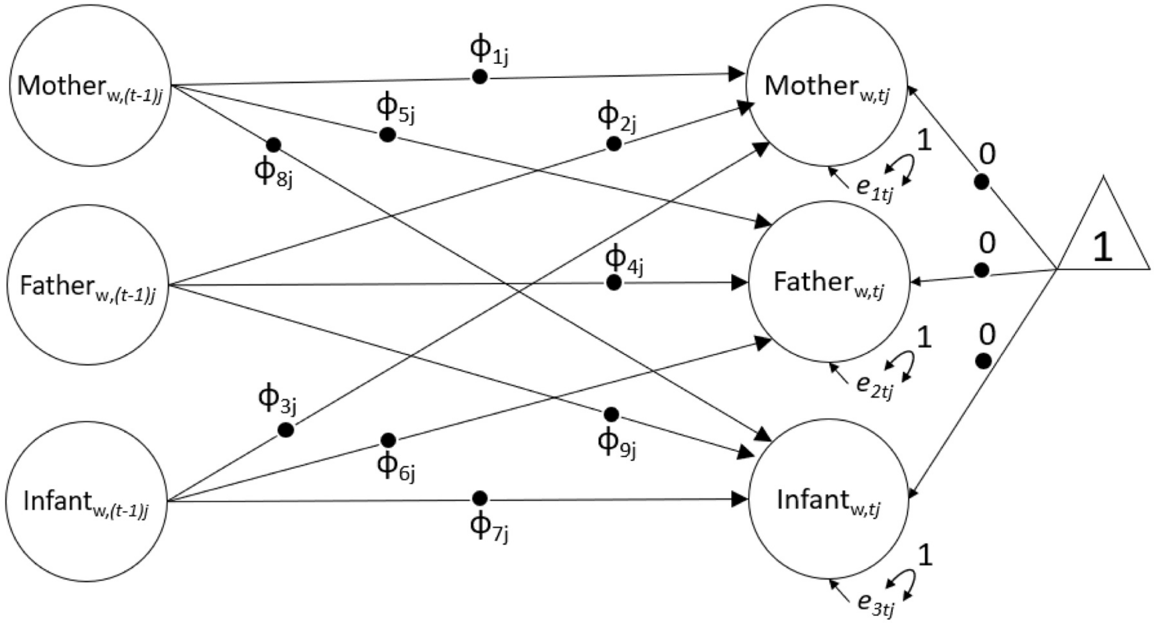


**Fig. 2.** *Within-level model, Note.* Path models depicting three separate multilevel vector autoregressive models for mothers, fathers, and infants, respectively. Random autoregressive and cross-lagged slopes = $\phi_{1j}$ – $\phi_{9j}$. Error terms = $e_{1tj}$ – $e_{3tj}$.

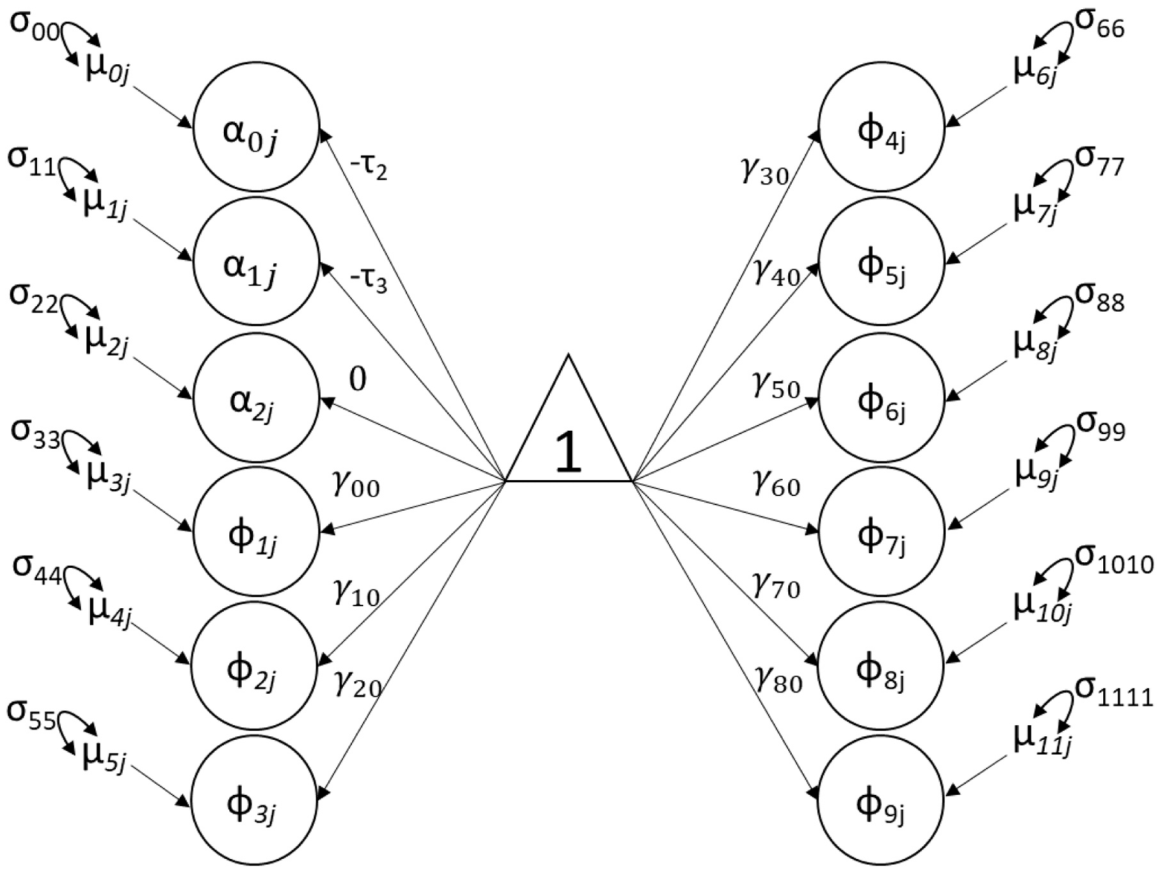


**Fig. 3.** *Between-level model, Note.* Person-specific latent means = $\alpha_{0j}$, $\alpha_{1j}$, and $\alpha_{2j}$. Fixed effects = $\gamma_{00}$-$\gamma_{70}$. Random effects = $\mu_{0j}$ – $\mu_{11j}$. Random effects variances = $\sigma_{00}$ – $\sigma_{1111}$.

When testing the effect of maternal and paternal HCC on all autoregressive and cross-lagged estimates ($\phi_{1j} - \phi_{9j}$) we found that maternal HCC predicted weaker infant-to-mother synchrony (i.e., $\phi_{3j}$), weaker father-to-infant synchrony ($\phi_{9j}$), and stronger mother-to-infant synchrony ($\phi_{8j}$), and paternal HCC predicted weaker mother-to-father synchrony ($\phi_{5j}$; see Table 4 for significant paths; see Supplemental Materials for all estimates). Posterior parameter distributions are depicted in Fig. 4 for all distributions which had 95 % credible intervals that did not contain zero. Finally, we included bivariate regression plots for each of these statistically significant moderate effects in the Supplementary Materials. Three of these four associations were negative, partially aligning with our prediction that higher hair cortisol concentration would attenuate affective synchrony.

**Hypothesis 3b.** ***: Hair Cortisol as a Predictor of Overall Positive Affect.***

Contrary to our hypotheses, neither maternal nor paternal HCC predicted differences in average positive affect for mothers, fathers, and infants (as represented by their person-specific latent means; $\gamma_{01} - \gamma_{22}$).

**Hypothesis 4a.** : ***Parenting Stress as a Moderator of Time-Lagged Synchrony in Families Positive Affect.***

We found that maternal parenting stress predicted greater infant-to-mother synchrony ($\phi_{3j}$) which contradicts our hypothesis that parenting stress would dampen affective synchrony.

**Hypothesis 4b.** : ***Parenting Stress as a Predictor of Overall Positive Affect.***

Partially consistent with our hypotheses, maternal PSI predicted a decrease in infant's overall negative affect ($\gamma_{21}$).

### *9.2. Post-HOc Power analysis*

Results from a post-hoc MCMC simulation using model estimates as population parameters suggest that most autoregressive and cross-lagged effects ($\phi_{1j} - \phi_{9j}$) evidence power > .80, as defined by the number of credible intervals not covering zero divided by the total number of MCMC replications. Power for detecting statistically significant between-family effects in Models 2 and 3 ranged from.55 –.95. Relative bias, efficacy, and 95 % coverage were good to excellent across all other parameters (see Supplemental Materials and Savord, 2023 for technical definitions).

## 10. Discussion

In a sample of 70 different-sex couples and their infants, parent-infant affect synchrony was observed during a observationally microcoded free-play interaction. Affect synchrony was partially moderated by hair cortisol concentration and self-reported parenting stress – possible indicators of biological and psychological stress, respectively. At the between-family level, parents' and infants' positive affect was highly correlated. Although mothers and fathers tended to display positive affect approximately twice as often as infants, parents who expressed greater positive affect had more positive infants. Furthermore, at the within-family level, we found evidence for positive time-lagged affect synchrony from moment to moment as parents interacted with their infant. Parents who displayed positive affect *at a given moment* were more likely to have an infant who displayed positive affect *in the following moment,* and vice-versa. This suggests that when both parents and infants initiate positive affect during free play, their partner tends to reciprocate. However, this was less true for fathers, who tended to mirror the effect of their partner, but not their infant.

Our results suggest that mothers may be attuned to the positive affect of both their romantic partner and their infant, whereas fathers may be only attuned to the positive affect of their partner. This finding may also be explained by the fact that mothers tended to display slightly more positive affect on average during the interaction (57 % of the time) compared to fathers (49 % of the time); therefore, mothers may have simply displayed more positive affect synchrony with infants because they spent more time in positive affective states.

We found mixed support for our hypothesis that hair cortisol concentrations would attenuate time-lagged synchrony in positive affect. When mothers had higher levels of hair cortisol, they showed greater mother-to-infant affective synchrony – that is, their affect in any given moment was more likely to predict infant's affect in subsequent moments. However, maternal hair cortisol concentrations

**Table 2**
Zero-order Pearson correlation matrix.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1. Mother HCC | - | | | | | | |
| 2. Father HCC | 0.15 | - | | | | | |
| 3. Mother PSI | -0.08 | -0.10 | - | | | | |
| 4. Father PSI | -0.12 | -0.11 | 0.37** | - | | | |
| 5. AvgPA Mother | 0.01 | -0.02 | -0.09 | 0.06 | - | | |
| 6. AvgPA Father | 0.09 | -0.09 | -0.06 | -0.12 | 0.47*** | - | |
| 7. AvgPA Infant | 0.01 | -0.09 | -0.15 | -0.02 | 0.50*** | 0.52*** | - |

*Note.* * = p < .05, HCC = Hair cortisol concentration (pg of cortisol/mg of hair), PSI = Parenting Stress Index (mean score), AvgPA = Average time displaying positive affect during free-play (in seconds).
** = $p < .01$,
*** = $p < .001$.

were linked with weaker infant-to-mother and father-to-infant affect synchrony. Said differently, when mothers had higher hair cortisol, their positive affect tended to predict their infants' positive affect more strongly, whereas their partners' positive affect was less predictive of infant positive affect, and infants' positive affect was less predictive of mothers' positive affect. In a similar study, and one of the few examining hair cortisol and mother-infant interactions, maternal hair cortisol predicted greater maternal intrusiveness and less positive engagement synchrony during free play (Tarullo et al., 2017). Tarullo et al. define positive engagement synchrony as the proportion of time that "mother is smiling while infant gazes at the mother" (p. 96). This operationalization does not require that infants display positive affect themselves, which may partially explain our discrepant findings.

In contrast to our findings for mothers, fathers with higher hair cortisol concentration tended to display less affective synchrony with mothers, and paternal hair cortisol was not associated with father-infant affective dynamics. Fathers, in general, demonstrated less affect synchrony with their infants compared to mothers, and it appears that fathers with higher hair cortisol also displayed less affect synchrony with mothers. Thus, fathers' biological stress may correlate with greater affective disengagement and/or misalignment with mothers during, but not less positive affect across, the entire interaction (Brianda et al., 2020). This finding underscores the strengths of a triadic research paradigm which can disentangle the effect of fathers' hormone profile on father-infant and father-mother affective processes at the between- and within-family levels (Paley & Hajal, 2022).

Saxbe and colleagues (2020) explain that the effect of affect synchrony on relational functioning may vary across situational contexts. For example, affect synchrony during free play may indicate shared positivity within the family, whereas synchrony occurring during stressful conditions may suggest parents are struggling to upregulate their own positive affect and soothe their infant. Conceptualized as a dynamic system, parent-child triads which can reflexively shift patterns of synchrony across contexts are highly *flexible,* and flexibility may be a stronger indicator of adaptive functioning than synchrony (Hollenstein, 2015). Consistently high levels of affective synchrony regardless of context may reflect a family system that has become stuck or inflexible. Given the parents in the present study rarely displayed negative affect (< 1 % of the interaction), additional studies are needed to determine if hair cortisol predicts synchrony when parents are experiencing high stress and primed to expressed negative affect.

Although hair cortisol concentration reflects HPA activity in the months prior to hair sampling, studies have found that hair cortisol concentration tends to correlate weakly with self-reported measures of stress and may be a more reliable indicator of adverse life experiences and chronic life stressors (Stalder et al., 2017). Indeed, in our sample, parents' hair cortisol was not significantly correlated with their self-reported parenting stress. Therefore, the question of what hair cortisol represents in the context of behavioral interactions requires greater investigation. Future studies should continue to explore the role of adverse life events, traumatic events, and other stressors in shaping mother-infant affective dynamics, and the possible mediational role of mother's hair cortisol concentration (see Nyström-Hansen et al., 2019 for an example with a modest sample size).

In contrast with our hypotheses, maternal parenting stress was positively associated with infant-to-mother affect synchrony, which may align with evidence that positive affect synchrony during free play correlates with greater inter-brain synchrony in mothers who report greater stress (Azhari et al., 2023). Many of the items within our parenting stress measure ask about parents' ability to manage children's behavior (e.g., "I feel that my child is very moody and easily upset"); thus, mothers who score high on this measure may believe their infant requires extra emotional attention. As such, this may cause mothers to preemptively attune with their infants to manage infants' emotions and behavior. Beebe at al. (2011) make a similar observation, with anxious mothers demonstrating over-arousal and hypervigilance when interacting with infants.

The present study also finds that maternal parenting stress predicts less infant positive affect across the entire interaction. This may reflect mother's tendency to report higher parenting stress if their infants are fussier or more difficult to soothe. Another interpretation is that mothers who report high parenting stress may also report higher anxiety, which has been shown to predict higher mother-infant affect synchrony but lower overall positive affect in infants (Beebe et al., 2011, Granat et al., 2017). Future studies can build on this finding by experimentally manipulating mothers' responsiveness or infants' affect via stress induction or priming to determine if

**Table 3**
Model 1 – Standardized Estimates.

| Par. | Outcome | Predictor | Est. | Post.SD | 95 % Cred.Int. | Sig. |
|---|---|---|---|---|---|---|
| φ1 | Mother Aff. | MA & LAG1 | 0.912 | 0.007 | [0.896,0.923] | * |
| φ2 | Mother Aff. | DA & LAG1 | 0.018 | 0.006 | [0.008,0.03] | * |
| φ3 | Mother Aff. | IA & LAG1 | 0.029 | 0.006 | [0.018,0.04] | * |
| φ4 | Father Aff. | DA & LAG1 | 0.913 | 0.005 | [0.904,0.921] | * |
| φ5 | Father Aff. | MA & LAG1 | 0.023 | 0.006 | [0.01,0.034] | * |
| φ6 | Father Aff. | IA & LAG1 | 0.008 | 0.006 | [− 0.004,0.02] | |
| φ7 | Inf. Aff. | IA & LAG1 | 0.861 | 0.007 | [0.845,0.874] | * |
| φ8 | Inf. Aff. | MA & LAG1 | 0.021 | 0.008 | [0.006,0.035] | * |
| φ9 | Inf. Aff. | DA & LAG1 | 0.023 | 0.008 | [0.007,0.039] | * |
| $\sigma^2_{10}$ | Mother Aff. | FatherAff. | 0.47 | 0.173 | [0.064,0.728] | * |
| $\sigma^2_{20}$ | Mother Aff. | Inf.Aff. | 0.446 | 0.195 | [0.012,0.761] | * |
| $\sigma^2_{12}$ | Father Aff. | Inf.Aff. | 0.695 | 0.135 | [0.37,0.887] | * |

*Note.* 'Par.' = Parameter, 'Est.' = Posterior median, 'Post.SD' = Posterior standard deviation, '95 % Cred.Int.' = 95 % Credible interval derived from posterior distribution, 'Sig.' = Denotes credible intervals that do not contain zero. 'Std.' = Denotes standardized estimates. 'MA & LAG1', 'DA & LAG1', and 'IA & LAG1' refer to maternal, paternal, and infant affect, respectively, measured with a one-second lag parental hypervigilance and synchrony produces stress, or via versa.

## 11. Practical implications

Our findings offer practical implications for both researchers and practitioners working in areas of socioemotional development and parent-child interaction. Cohn and Tronick (1988) posited that a mix of coordination and miscoordination between mothers and infants is ideal (e.g., 70/30 split), suggesting that too much interpersonal synchrony may stifle children's emerging autonomy and self-regulation, whereas too little synchrony may fail to provide adequate scaffolding for infants' regulatory and attachment systems. Broadly, our findings suggest that positive affect synchrony during triadic parent-infant interactions may be indicative of greater parental stress. This study should prompt further investigation of parental factors that predict parent-infant synchrony, as they may serve as potential targets for interventions aimed at cultivating a strong parent-child bond (Paley & Haley, 2022). Interestingly, our study calls attention to possible downsides of *too much* synchrony, prompting future longitudinal studies to explore if prolonged hypervigilance and parent-infant synchrony leads to emotional fatigue, withdrawal, or negative outcomes as children develop (Beebe & Steele, 2013).

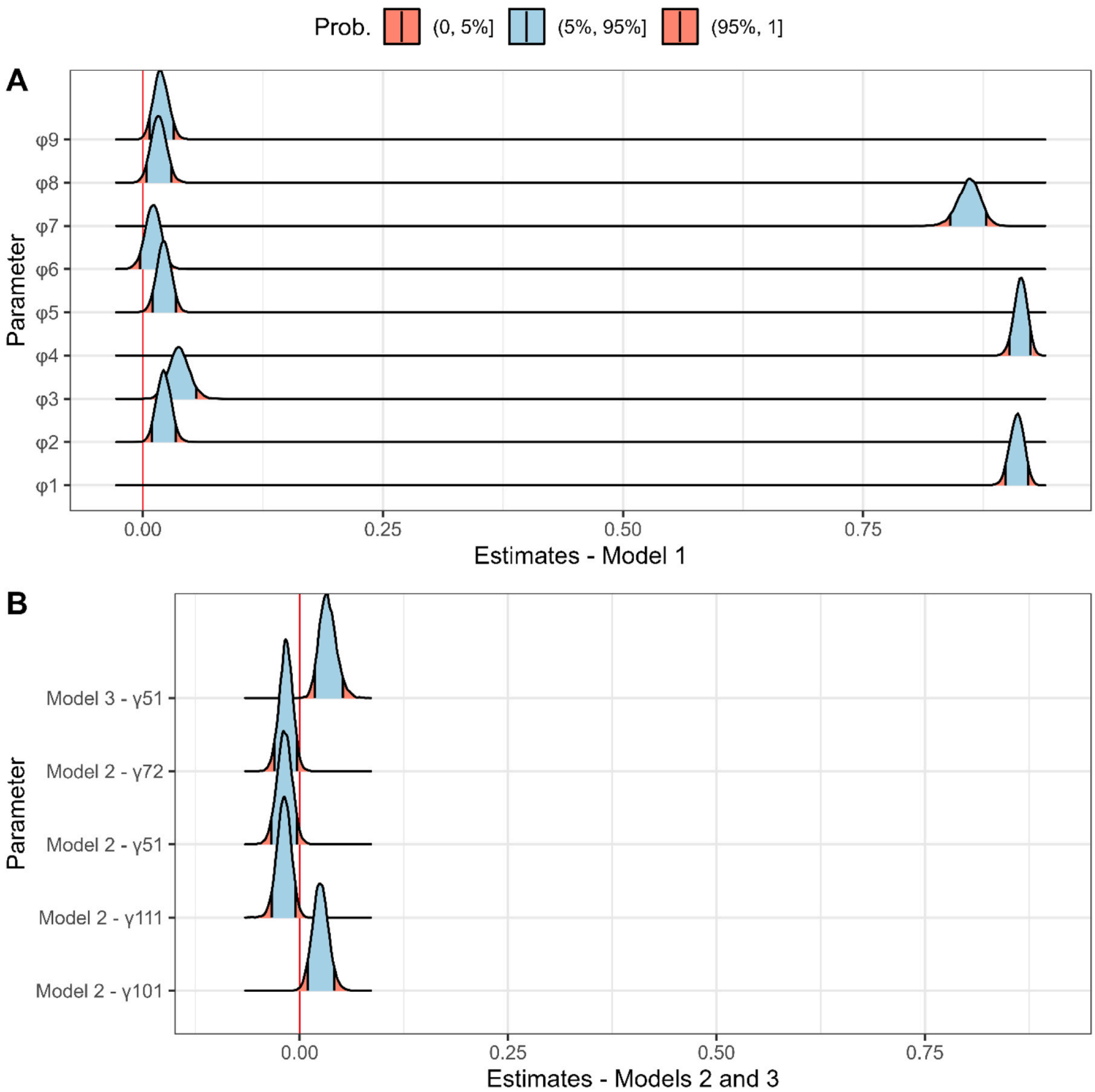


**Fig. 4.** Posterior Parameter Distributions Note. Posterior predicted distributions are depicted for slope estimates in Table 1 (Panel A) and Table 4 (Panel B). 95 % credible intervals are depicted in blue, all other values in red. Only estimates with 95 % credible intervals that do not contain zero are depicted for Models 2 and 3.

**Table 4**
Statistically significant moderation effects from Models 2 and 3.

| Par. | Outcome | Predictor | Est. | Post.SD | 95 % Cred.Int. | Interpretation (Outcome) |
|---|---|---|---|---|---|---|
| $\gamma_{51}$ | φ3 | HCC(Mother) | -0.302 | 0.146 | [– 0.579,– 0.011] | Infant's affect at Lag 1 → Mother's affect |
| $\gamma_{72}$ | φ5 | HCC(Father) | -0.437 | 0.194 | [– 0.775,– 0.024] | Mother's affect at Lag 1 → Infant's affect |
| $\gamma_{101}$ | φ8 | HCC(Mother) | 0.503 | 0.155 | [0.148,0.761] | Father's affect at Lag 1 → Infant's affect |
| $\gamma_{111}$ | φ9 | HCC(Mother) | -0.396 | 0.158 | [– 0.673,– 0.057] | Mother's affect at Lag 1 → Father's affect |
| $\gamma_{51}$ | φ3 | PSI(Mother) | 0.45 | 0.193 | [0.041,0.784] | Infant's affect at Lag 1 → Mother's affect |
| $\gamma_{21}$ | Inf.Aff. | PSI(Mother) | -0.32 | 0.148 | [– 0.576,– 0.002] | Infant's overall positive affect |

*Note.* Only statistically significant moderation effects are displayed. The full table of estimates can be found in the Supplemental Materials. ' Par.' = Parameter 'Est.' = Posterior median, 'Post.SD' = Posterior standard deviation, 'Cred.Int.' = 95 % Credible interval derived from posterior distribution. 'Std.' = Denotes standardized estimates. HCC = Hair cortisol concentration at six-months postpartum. PSI = Parenting Stress.

## 12. Strengths and limitations

The present study provides a proof of concept for applying dynamic structural equation modeling (DSEM) to time-intensive behavioral data collected from families with infants. DSEM is a highly flexible analytic framework for studying interpersonal dynamics and can continue to be expanded to study how time-lagged processes such as affective synchrony are modulated by other indicators of stress that may impact parent-child interactions (Somers & Luecken, 2022).

This study is also the first to explore how both psychological and biological forms of parental stress are associated with parent-infant time-lagged affective dynamics. The inclusion of family triads broadens a literature dominated by dyadic interaction paradigms with mothers and infants. Triadic free-play paradigms with strong interrater reliability, such as the one used in the present study (Feldman et al., 2011), may have greater ecological validity for dual-caregiver households and may generalize better to family interactions that are not limited to only two individuals (Paley & Hajal, 2022).

Despite its strengths, there are several limitations to this study. First, our study only captures a brief interaction of free play (four to five minutes), which limits our ability to generalize to other contexts. Second, our study includes a moderate sample size of 70 family triads, calling for future studies to recruit larger samples to replicate our findings that stress moderates family affective dynamics. Moreover, our sample was limited to different-gender cohabiting couples and, although the sample was racially and ethnically diverse, participants tended to be highly educated, limiting generalizability. Third, we increased our family-wise Type-I error rate by testing for multiple moderation effects across several models, calling for future studies to replicate the between-level effects we observed. Fourth, we only explored time-lagged dynamics of families' facial affect but did not explicitly explore other modalities of interaction behavior including gaze, touch, or vocalization, which have been shown to impact parent-infant interactions (Feldman, 2003; 2012). Fifth, our study measures affective dynamics within a single-family interaction, but our measures of stress (parenting stress index and hair cortisol concentration) are global and retrospective. Therefore, future studies can build on our findings by assessing momentary stress using both behavioral and physiological measures.

## 13. Conclusion

Positive affect synchrony among mothers, fathers, and infants may be one behavioral pathway by which parents' scaffold infants' socioemotional development (Beeghly & Tronick, 2011; Feldman, 2012; Tronick and Beeghly, 2011). However, parental stress may alter parents' patterns of attunement with their infants' emotions (Saxbe et al., 2020). Caregivers are crucial co-regulators of their infants' emotions, and positive affect synchrony during free play may be one mechanism by which caregivers shape infants' behavioral and emotional development (Bell, 2020; Waters & Mendes, 2016). Our findings extend the emerging literature on synchrony within families by finding significant positive associations between mother, father, and infant affect, and also show diverging effects of parents' biological and psychological stress on family's triadic affective dynamics (Saxbe et al., 2020). This study offers grist for future work aimed at utilizing intensive, multimodal data streams to explore the effect of chronic stress on intrafamilial processes across multiple contexts.

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All co-authors have contributed substantively to this work and reviewed our manuscript before submission. This work has not been published and is not under consideration by another publication. We have no conflicts of interest. My email address is gleon@usc.edu. My co-authors are all affiliated with the University of Southern California, and their names and email addresses are Alyssa R. Morris (alyssarm@usc.edu), Chase Gilbertson (chgilber@usc.edu), Alexandra Turner (apturner331 @gmail.com), Haley Betron (betron@usc.edu), Leonardo Dominguez Ortega (leonardodominguezortega@gmail.com), Sam Guillemette (guilleme@usc.edu), Sarah Kuhil (kuhil@usc.edu), Jasmin Wang (jiwang@usc.edu), Vlada Demenko (vdemenko@usc.edu), Jasmine Liu (jsliu@usc.edu), Avery

Longdon (alongdon@usc.edu), Jennifer Ouyang (ouyangje@usc.edu), and Darby Saxbe (dsaxbe@usc.edu). Thank you for your time and attention to this manuscript. We look forward to hearing from you.

## CRediT authorship contribution statement

**Leonardo Dominguez Ortega:** Data curation. **Sam Guillemette:** Data curation. **Sarah Kuhil:** Data curation. **Jasmin Wang:** Data curation. **Jennifer Ouyang:** Data curation. **Alyssa R Morris:** Software, Resources, Project administration, Investigation, Funding acquisition, Data curation, Conceptualization. **Darby E Saxbe:** Writing – review & editing, Writing – original draft, Validation, Supervision, Software, Resources, Project administration, Investigation, Funding acquisition, Data curation, Conceptualization. **Chase H Gilbertson:** Data curation. **Alexandra Turner:** Data curation. **Haley Betron:** Data curation. **Vlada Demenko:** Data curation. **Jasmine Liu:** Data curation. **Avery Longdon:** Data curation. **Gabriel León:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

## Data Availability

Data and code for replicating analyses can be found at this repository: https://github.com/gabepsych/DSEM_glee_in_threes.

## Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.infbeh.2024.101976.

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