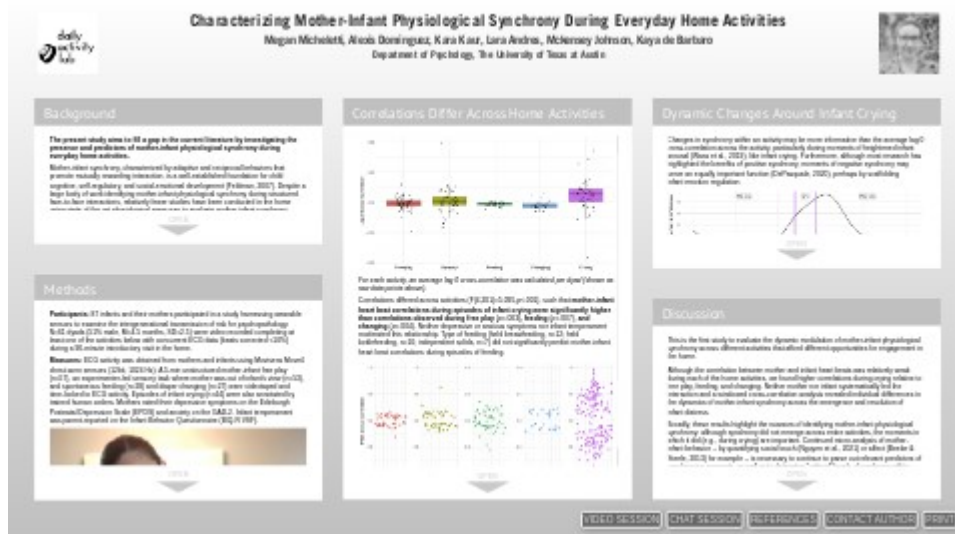


Characterizing Mother-Infant Physiological Synchrony During Everyday Home Activities



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BACKGROUND

The present study aims to fill a gap in the current literature by investigating the presence and predictors of mother-infant physiological synchrony during everyday home activities.

Mother-infant synchrony, characterized by adaptive and reciprocal behaviors that promote mutually rewarding interaction, is a well-established foundation for child cognitive, self-regulatory, and social-emotional development (Feldman, 2007). Despite a large body of work identifying mother-infant physiological synchrony during structured face-to-face interactions, relatively fewer studies have been conducted in the home using state-of-the-art physiological measures to evaluate mother-infant synchrony during daily activities (Leclère et al., 2014).

While physiological synchrony is a dynamic and emergent process (Delaherche et al., 2012; Sameroff, 2009), its presence may also vary systematically across different activities that afford different opportunities for engagement.

METHODS

Participants: 87 infants and their mothers participated in a study harnessing wearable sensors to examine the intergenerational transmission of risk for psychopathology. N=61 dyads (51% male, M=4.5 months, SD=2.5) were video recorded completing at least one of the activities below with concurrent ECG data (beats corrected <10%) during a 90-minute introductory visit in the home.

Measures: ECG activity was obtained from mothers and infants using Movisens Move4 chest-worn sensors (12bit, 1024 Hz). A 5-min unstructured mother-infant free play (n=57), an experimenter-led sensory task where mother was out of infant's view (n=53), and spontaneous feeding (n=28) and diaper changing (n=27) were videotaped and time-locked to ECG activity. Episodes of infant crying (n=44) were also annotated by trained human coders. Mothers rated their depressive symptoms on the Edinburgh Postnatal Depression Scale (EPDS) and anxiety on the GAD-2. Infant temperament was parent-reported on the Infant Behavior Questionnaire (IBQ-R VSF).

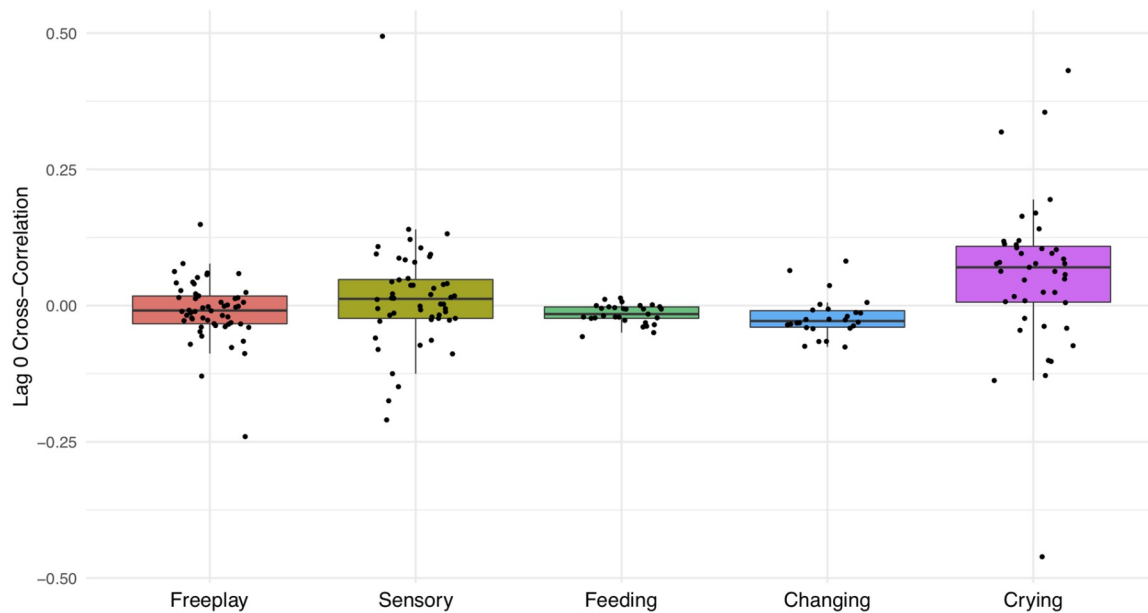


Infant wearing combined ECG/accelerometer affixed via latex-free, hypoallergenic TenderTrode electrodes, similar to a bandaid.

Heart rate (HR) preprocessing: Inter-beat intervals (IBI) were detected offline using Movisens DataAnalyzer. IBIs were passed through KubiosHRV to detect and correct artifacts or ectopic beats, interpolate missing data (4Hz), and detrend using Smoothn priors. IBIs were downsampled to 2Hz and an AR(1) model was used to prewhiten mother's time series in order to remove nonstationarity.

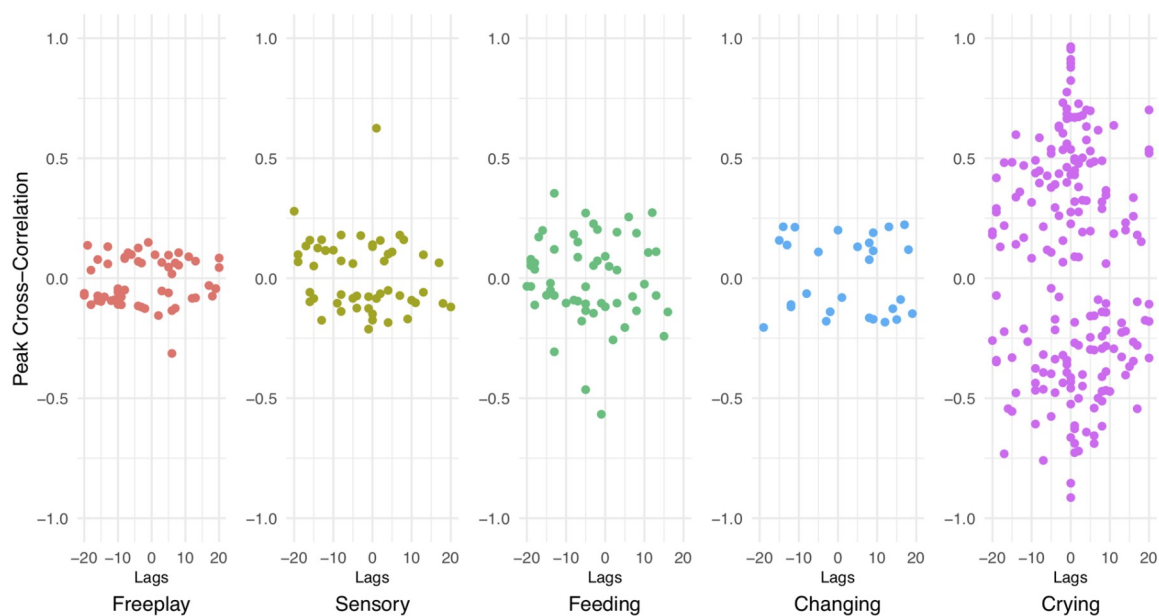
Data analysis: For each task (free play, sensory, feeding, changing, crying), mother's prewhitened residuals were cross-correlated with infant's IBI time series. For episodes of infant crying, the lag 0 cross-correlation was calculated across windows of 5s, with a maximum lag of 10s, window overlap of 2.5s, and steps of 0.5s in order to evaluate dynamic changes in synchrony pre-, during, and post-cry.

CORRELATIONS DIFFER ACROSS HOME ACTIVITIES



For each activity, an average lag 0 cross-correlation was calculated per dyad (shown as raw data points above).

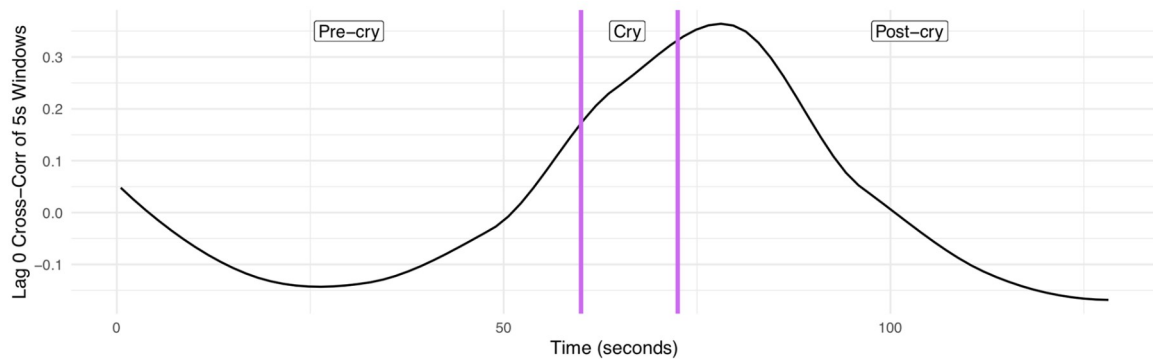
Correlations differed across activities ($F(4,201)=5.095, p<.001$), such that **mother-infant heart beat correlations during episodes of infant crying were significantly higher than correlations observed during free play** ($p=.003$), **feeding** ($p=.007$), and **changing** ($p=.004$). Neither depressive or anxious symptoms nor infant temperament moderated this relationship. Type of feeding (held breastfeeding, $n=12$; held bottlefeeding, $n=10$; independent solids, $n=7$) did not significantly predict mother-infant heart beat correlations during episodes of feeding.



Peak correlations at negative lags suggest that infant's time series predicts mother's time series; at positive lags, a peak suggests that mother's time series predicts infant's time series. To examine the presence and direction of this potential lead/lag relationship, the peak correlation value (Boker et al., 2002) was extracted for each episode of freeplay, sensory, feeding, changing, and crying and plotted at the lag location at which it occurred. Broadly, **neither member of the dyad systematically predicted the other's heart rhythms across episodes of everyday home activity.**

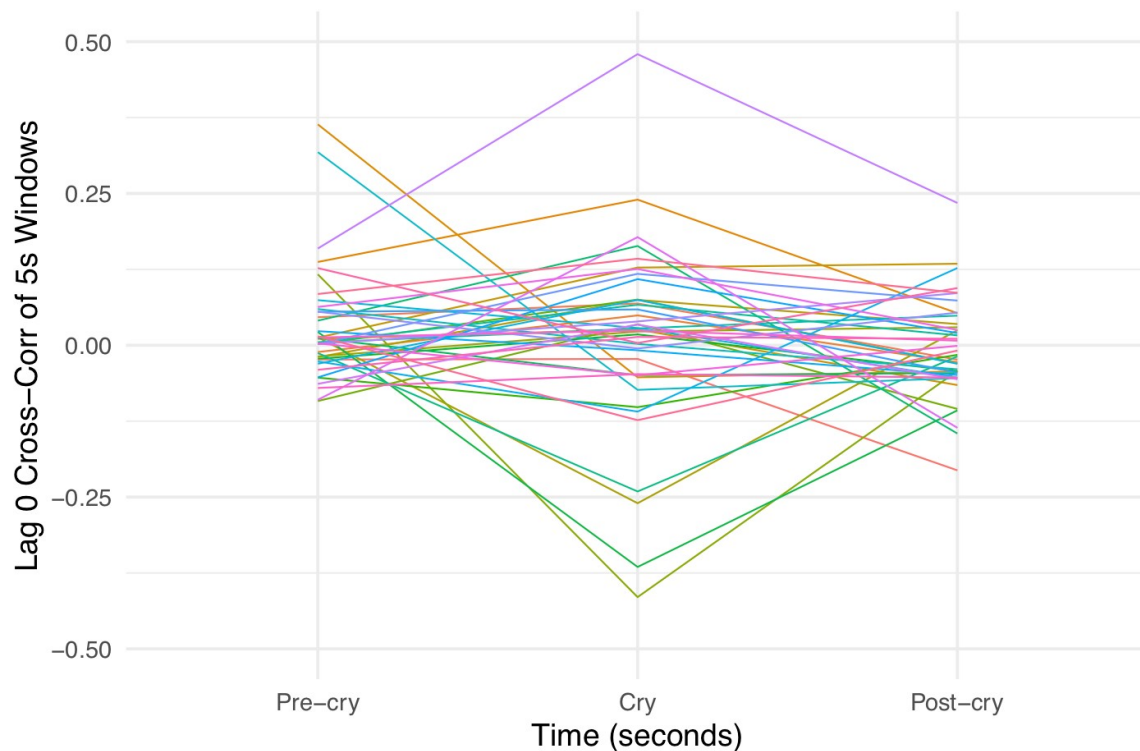
DYNAMIC CHANGES AROUND INFANT CRYING

Changes in synchrony within an activity may be more informative than the average lag 0 cross-correlation across the activity, particularly during moments of heightened infant arousal (Wass et al., 2019), like infant crying. Furthermore, although most research has highlighted the benefits of positive synchrony, moments of negative synchrony may serve an equally important function (DePasquale, 2020), perhaps by scaffolding infant emotion regulation.



Raw data for a single dyad showing the moving correlation between mother and infant heart rate in 5s windows across the 60s prior to cry onset, the duration of the cry, and 60s following cry offset.

Windowed cross-correlations revealed that across participants the M(SD) of the cross-correlation in the 60s pre-cry was 0.03(0.09), during the cry was 0.01(0.15), and post-cry was -0.01(0.08). Individual differences in the trajectory of synchrony (depicted below) exist, however, such that some participants show increases, decreases, or no changes in synchrony during the cry period relative to pre- and post-cry.



DISCUSSION

This is the first study to evaluate the dynamic modulation of mother-infant physiological synchrony across different activities that afford different opportunities for engagement in the home.

Although the correlation between mother and infant heart beats was relatively weak during each of the home activities, we found higher correlations during crying relative to free play, feeding, and changing. Neither mother nor infant systematically led the interaction and a windowed cross-correlation analysis revealed individual differences in the dynamics of mother-infant synchrony across the emergence and resolution of infant distress.

Broadly, these results highlight the nuances of identifying mother-infant physiological synchrony: although synchrony did not emerge across entire activities, the moments in which it did (e.g., during crying) are important. Continued micro-analysis of mother-infant behavior -- by quantifying social touch (Nguyen et al., 2021) or affect (Beebe & Steele, 2013) for example -- is necessary to continue to parse out relevant predictors of synchronous moments, as well as to determine "optimal" levels of synchrony within dyads (DePasquale, 2020).

Future directions include analysis of optimal window size and lag (Behrens et al., 2020), as well as examining moment-to-moment changes surrounding infant distress: what predicts synchrony during infant crying, does this influence cry resolution, and how do patterns emerge over repeated instances of naturalistic crying in the home.

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