THE SUB-SECOND DYNAMICS OF SPONTANEOUS MIMICRY: AN ELECTROMYOGRAPHY STUDY TRACKING INFANT CAREGIVER DYADS DURING FREE PLAY

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Introduction

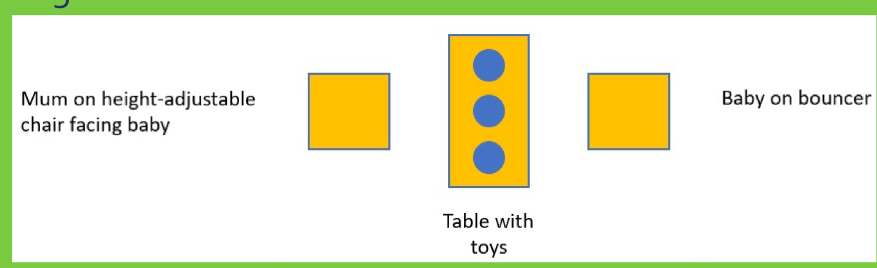
Spontaneous mimicry (SM) is a ubiquitous feature of human communication (Heyes, 2021)..

- In infants, facial mimicry has been studied extensively and is the central focus of a long running debate surrounding the presence of spontaneous facial mimicry (SfM) in early infancy.
- However, most of the studies have used lab-based tasks or non-naturalistic block-design paradigms (Slaughter, 2021; Meltzoff, 2020).
- The few studies that have observed naturalistic interactions hand-coded video data, scoring onset and offsets of actions (Markodimitraki & Kalpidou, 2019). The magnitude of the action was not measured.
- Employing electromyography (EMG) will allow us to track gradations of action and sub-second changes.
- Ecologically-valid hand-coded studies have reported results that are in stark contrast to the lab-based evidence, e.g., Markodimitraki (2019) reported that infants displayed more SM and SfM behaviours than their caregivers at the 1-month & 10-month time points. Whereas the vast majority of lab-based experiments report a lack of evidence for infant SfM until the 5-month/6-month time point (Davis, et al., 2021). Crucially, it is often assumed/asserted that infant SfM/SM responses will be less prevalent than that of adults.
- We aim to contribute to our understanding of SfM ontogeny by assessing the cross-correlation and granger causal relationships between the EMG waveforms (corrugator supercilii; eyebrow movement) of caregiver and infant.

Method

Caregiver-infant pairs were tested during free play, tabletop interactions (N – 24; female caregivers, n – 12; infants, n – 12 [M_{AGE} - 5 months; Range – 4 to 6 months]).

Figure 1



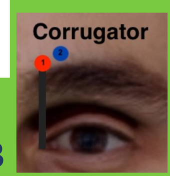


Figure 3

Figure 2

- Two Ag-AgCl electrodes (BioSemi EXG) placed above right eyebrow (see Figure 3, above); inter-electrode distance 1.5 cm; Fridlund & Cacioppo, 1986.
- The signal from the two electrodes was sampled at 512Hz, re-referenced to C_z, and differenced with each other to generate the single EMG signal.
- Pre-process involved bandpass filtering (20 Hz ~ 250 Hz), full-wave rectification (R package 'biosignalEMG') and z-scoring. One standard deviation above & below mean were removed.
- Datasets were analysed both with their original number of time samples and in a truncated form (i.e., number of time sample equalized across dyads).
- All the waveforms were tested for stationarity (ADF; R package 't-series').

Cross-correlations

- Cross correlations (lags: +/- 8500 samples; 16.6 seconds) comparing the EMG corrugator supercilii waveform of infants and caregivers were conducted using the stock R function 'ccf'.
- x_t – z-scored, rectified infant waveform; y_{t-k} – z-scored, rectified caregiver waveform. Where t is the timepoint (in samples) and k is the lag.
- Figure 4 is obtained from the original, non-trimmed datasets and the Figure 5 depicts the cross correlation of truncated datasets that were used for the granger causality analyses.

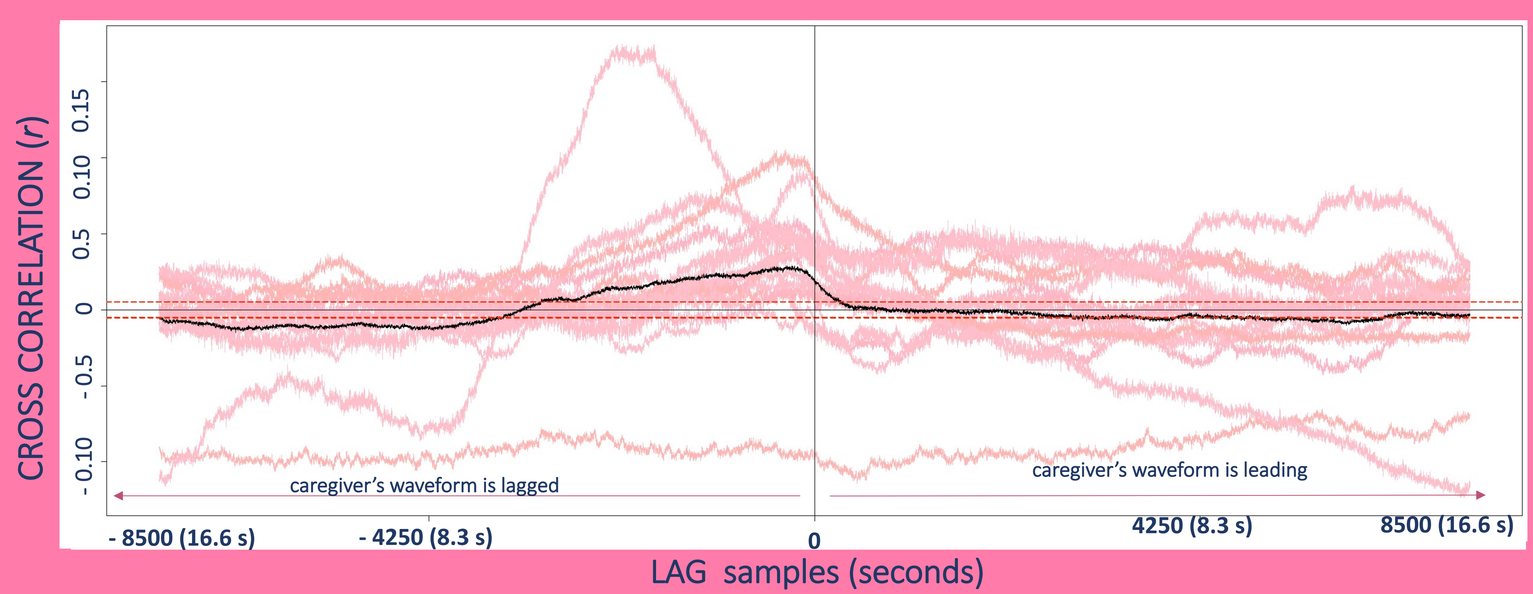


Figure 4. Cross-correlation of EMG corrugator waveforms of infant (x_t) and caregiver (y_{t-k}). The red lines indicate the confidence intervals (p < 0.05) and the black line is the average cross correlation.

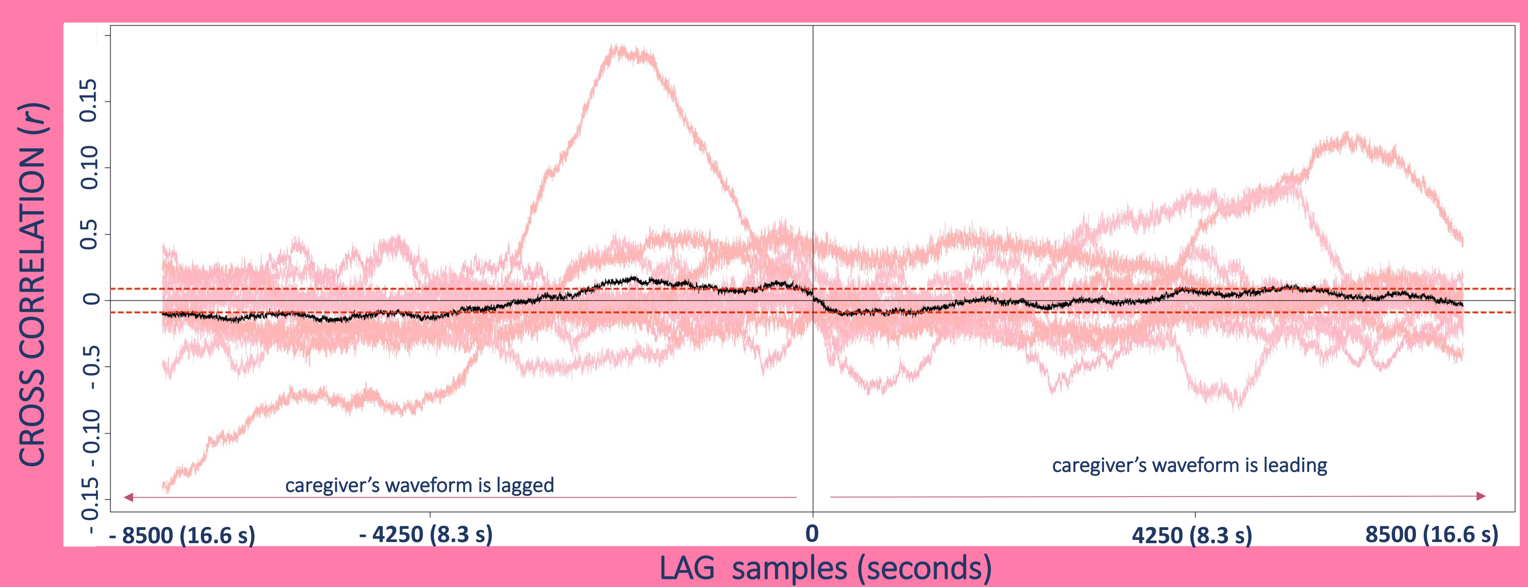


Figure 5. Cross-correlation of *truncated* EMG corrugator waveforms of infant (x_t) and caregiver (y_{t-k}). The red lines indicate the confidence intervals (p < 0.05) and the black line is the average cross correlation.

The results suggest that infant's corrugator activity correlates with lagged muscle activity of the caregiver indicating presence of infant SfM behaviour.

- Further analyses with feature extraction is required to assess the number of action events. It may be the case that infant EMG activity has higher variance and /or a larger portion of their activity manifests in perceptible actions that are not socially salient (and therefore are less likely to be mimicked).

Granger Causality Analyses

Granger Causality Analyses were conducted in order to determine if the EMG activity of a dyad member had causal interactions with EMG activity of the other. The datasets were trimmed (truncated) to ensure that the number of time samples were equal across dyads. Both the infant's predictive ability of the caregiver's corrugator activity and the contrariwise were tested. The lag order was determined using VARselect (R package 'vars'). The granger causality test was computed using grangertest (R package 'lmtest'). Both the infant activity's prediction of caregiver's future activity (p - 0.122; caregiver mimicking infant) and the caregiver activity's prediction of infant's future activity (p – 0.241; infant mimicking caregiver) were found to be non-significant.

To rule out the presence of spurious correlations shuffled datasets were generated to assess if significant relationships could be identified (at the dyad level) even after the disruption of moment-to-moment dynamics. The control analyses did not identify a significant relationship for any of the shuffled pairs.

Figure 6. Granger Causality statistic (F-values) for infant's activity predicting the caregiver's for individual dyads. The upright graph indicates the full (non-truncated dataset) and the lower graph depicts the truncated dataset. Blue bar denotes significance of p < 0.05.

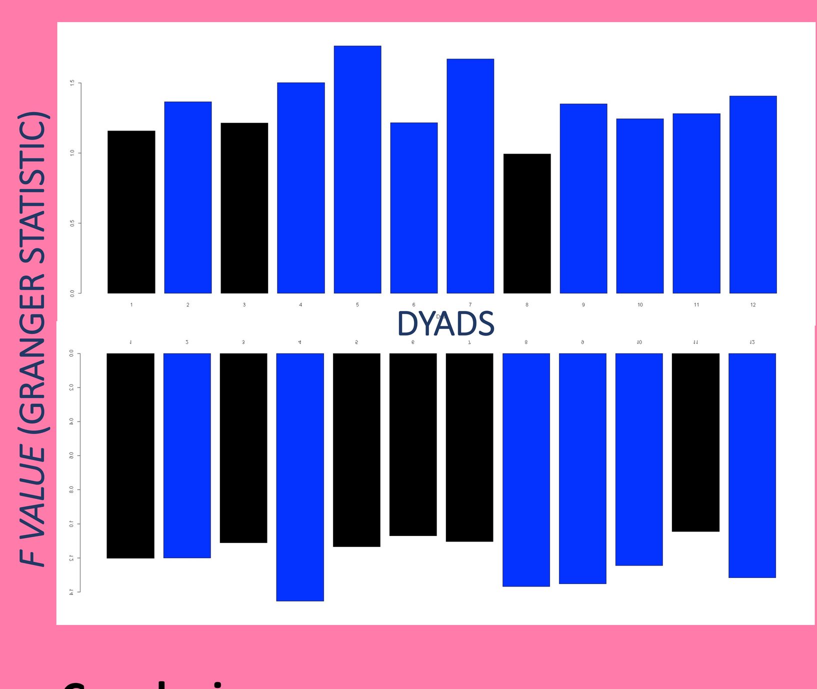
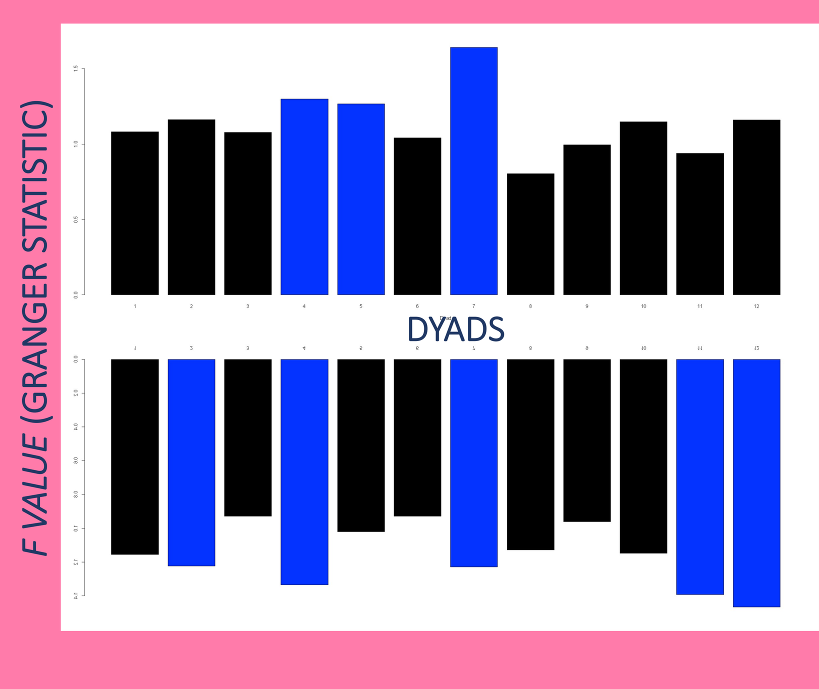


Figure 7. Granger Causality statistic (F-values) for caregivers activity predicting the infants's for individual dyads. The upright graph indicates the full (non-truncated dataset) and the lower graph depicts the truncated dataset. Blue bar denotes significance of p < 0.05.



Conclusion

The results of the cross correlations support the presence of SfM at this timepoint. When comparing infant and caregiver SfM, the cross correlational analysis appears to align with the findings of the Markodimitraki (2019) paper.

- However, the granger causality results indicate further analyses is required. The variance in significance b/n truncated & non-trimmed datasets, and the lack of overlap b/n cross-correlations and the granger analyses require deeper investigation e.g., event-related analyses of feature extracted action events.

References

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Acknowledgements

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