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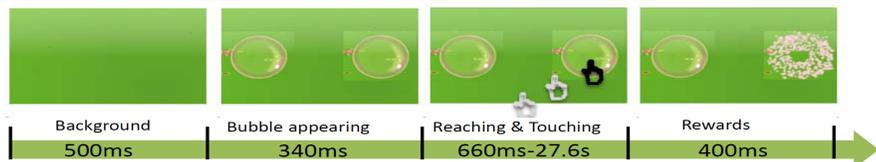
Introduction

The ‘mirror neuron system’ is assumed to contribute to action perception and understanding. This facility for representing, interpreting, and planning action has been studied mostly in “disembodied” context. However, several recent efforts have assessed Electroencephalography (EEG) during real-time, ongoing social interactions. In the first study to precisely measure dyadic action and electrophysiology, we recorded synchronized EEG from mothers and infants while motion-capturing their hand and head movements. Twenty-two typical toddlers and mothers played a fun turn-taking bubble popping game on a capacitive touch screen monitor. This invited action-matches and mismatches, as well as action-observation and action-execution.

Method Participants

Twenty-two dyads of typically developing toddlers and their caregivers (CGs) participated in this study. Only child EEG results are reported here. Recordings from twelve (mean 41.2 ± 3.8 SD) children provided enough data to perform critical independent component analysis.

Paradigm : Bubble game



- Toddler and CG are seated across from one another at a 26” capacitive touch screen.
- Two bubbles appear on the left and right side of the screen.
- CG can choose to pop either of the two bubbles.
- Toddler can either match (pop the same bubble) or mis-match (pop the other bubble) their CG’s turn. Different rewards were assigned to match and mismatch trials.
- The game continues in a turn-taking manner.

Data acquisition



Dual-EEG

- Dual high-density EEG recordings of toddler-mother dyads are acquired from two 64-channel caps (Ag/AgCl active electrodes @ 256 Hz, Biosemi, The Netherlands).

Motion capture

- An Optitrack motion capture system (NaturalPoint, Corvallis) recorded each dyad’s hand & head movement. “Hot-spots” are virtual 3D spaces defined to detect when toddler’s or parents’ hands cross boundaries (e.g., approaching the left or right bubble). This allows us to deliver differential feedback (reward) based on exact movement criteria.

Acknowledgements

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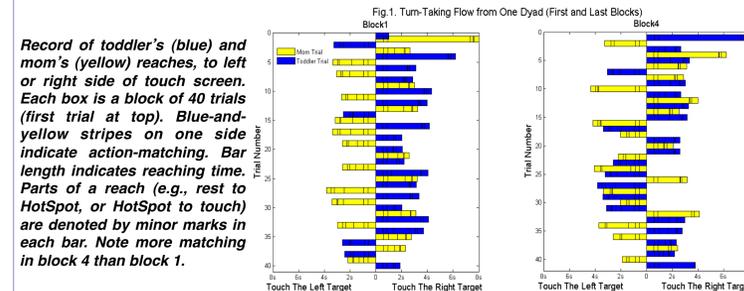
Data Analysis

- Channels with grossly abnormal patterns and epochs with high-amplitude muscle noise and other artifacts, identified by eye inspection and cross-checking functions, were removed. After re-referencing to the whole-head average. Data were <1Hz filtered.
- Three different types of epochs were extracted:
 - 1) Rest periods from -200 ms to +800 ms of background stimulus onset (i.e., trial start);
 - 2) Observation epochs from -800 ms to +200 ms of mother’s initial screen touch;
 - 3) Action epochs from -800 ms to +200 ms of toddler’s initial screen touch.
- Independent Component Analysis (ICA) by AMICA (Palmer et al, 2007) was used to decompose the EEG data from each subject into separate neural and non-neural source activities. Brain source independent components (ICs) were identified by inspection of their time courses, spectra, and scalp maps.

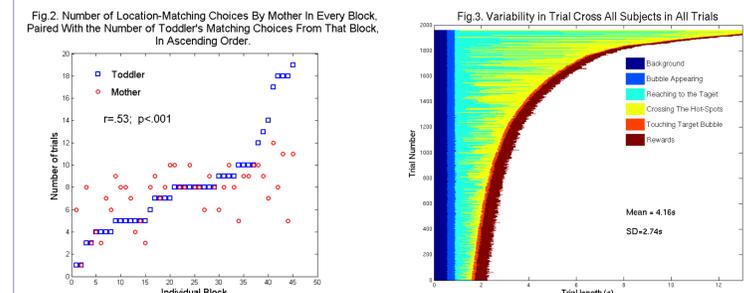
Results

Behavioral results

Each Mom-Toddler dyad finished 2 to 5 blocks of 40 trials each (mean = 130.4 trials, SD = 45.6). Each dyads finished in a turn-taking fashion. Choice of target became more influenced by the partner’s prior choice as the task went on: Figure 1 showed a dyad’s performance in their 1st and 4th blocks. In each block, the number of trials when moms matched the toddler’s prior choice was correlated with the number of trials when toddlers matched the mom’s prior choice (R=.53, p<.001; Figure 2).



Trial lengths ranged from 2.1 to 68.6sec (Figure 3). This wide range is due to between-subject differences (subject averages ranged from 3.0s to 4.9s), and within-subject differences (individual ranges from 0.9s to 6.2s). The causes of this variability are unknown.



EEG results

Two clusters of somatomotor mu Independent Components (ICs), in the left hemisphere and right hemisphere, were identified (Figure 4). The power spectrum density of these components peaked near 7-8 Hz, confirming that mu rhythm frequency band in 3-year-olds is lower than adult mu band rhythms (~10-13 Hz). This is consistent with previous studies (Henry, 1944, Lindsley, 1938).

We then compared the mean spectral activity perturbations of each of the clusters, across the three epoch types (rest, observation, action). The left somatomotor mu power was significantly stronger in Rest epochs than the action and observation epochs, both p<.01. Also, power was stronger when toddlers observed rather than acted, p<.05. Epoch differences in the right somatomotor mu cluster is not significant.

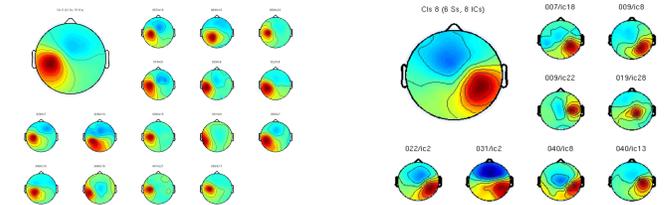


Fig.4. The mean IC scalp map and individual contributed ICs for the left-hemisphere somatomotor mu cluster (left) and for the right-hemisphere somatomotor mu cluster (right)

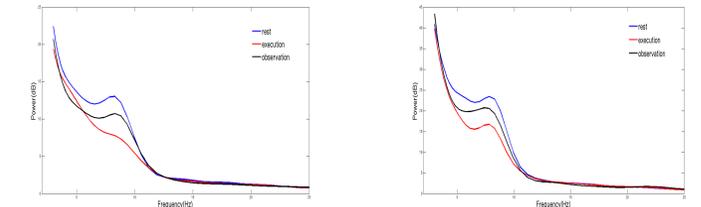


Fig.5. The Power Spectrum Density (PSD) of the three conditions: Rest, Observation (Toddlers watch their CGs’ popping bubbles) and Execution (Toddlers pop bubbles) for the left somatomotor mu cluster (left) and the right somatomotor mu cluster (right).

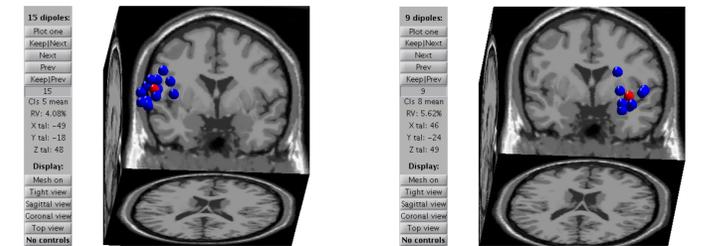


Fig.6. Equivalent dipole locations of the somatomotor mu cluster (left) and the right somatomotor mu cluster (right). Each blue dot is the imputed source of an IC dipole. Red dot means the centroid of all contributed ICs

Conclusion

1. Within a dyad, each partner’s choice is correlated with the other’s. Toddlers who are matched more often, match more often.
2. There are adult-like changes in mu-rhythm activity shown by young children in response to “live” social interaction. The ICs are localized in clusters in left and right parietal (sensorimotor cortex) regions.

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