

EEG Imaging of Toddlers During “Live” Dyadic Turn-Taking: Mu-Rhythm Modulation And Source-Clusters In Natural Action Observation and Execution

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Introduction

The ‘mirror neuron system’ (MNS) is assumed to contribute to action perception and understanding. This facility for representing, perceiving, and planning action has been studied in humans using non-social and “disembodied” contexts. Several recent studies, however, have measured Electroencephalography (EEG) during real-time, ongoing social interactions (Dumas et al, 2010). An EEG phenomenon, sensorimotor mu-suppression, might reflect MNS activity (Pineda, 2005).

A key question is how the brain develops to represent social action. Action perception- and execution-related mu-suppression has been reported in infants while acting or watching an adult act (Marshall et al, 2010). However, the causes of mu-suppression remain unclear. More sophisticated, integrated EEG and behavioral measures can reveal the dynamics of action performance and observation in toddlers: for example, sources of cortical activity, and synchrony of EEG with actions. Also, studying toddlers is critical because they are undergoing profound changes in social cognition and behavior. We precisely measured dyadic action and EEG in a naturalistic mother-toddler social interaction.

Method

Participants

Twenty-two dyads of typically developing toddlers and their caregivers (CGs) participated. Only toddlers’ EEG results are reported here. A total of 12 toddlers (mean age = 41.2 ± 3.8 months) provided enough EEG data to perform critical independent component analysis (ICA).

Data acquisition

Dual-EEG

• High-density EEG of toddler-mother dyads was acquired from two 64-channel caps (Ag/AgCl active electrodes @ 256 Hz, Biosemi, The Netherlands). See Figures 2-3.

Motion capture

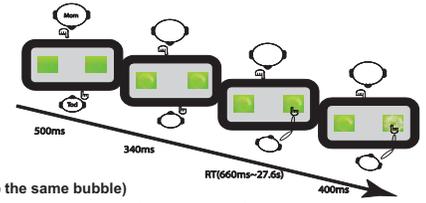
• Motion capture system (NaturalPoint OptiTrack) recorded each dyad’s hand & head movement. “Hot-spots” (virtual 3D spaces) detected when toddler’s or parents’ hands crossed boundaries (e.g., approaching left or right bubble). This was used to synchronize EEG to actions, and to deliver differential real-time feedback (reward) for specific actions.



Figures 2-3

Task : Bubble game

- Toddler and CG sit across from each other at a capacitive touch screen table.
- CG can choose to “pop” either of two bubbles.
- Toddler can either match (pop the same bubble) or mis-match (pop other bubble), causing different reward animations.
- The game continues in a turn-taking manner. reward animations.
- The game continues in a turn-taking manner.



EEG Data Analysis

Channels with grossly abnormal patterns, and epochs with high-amplitude artifacts, were identified using eye inspection and automated EEGLab functions, and removed. After re-referencing to the whole-head average. Data were <1Hz and > 35Hz 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) **Execution** epochs from -800 ms to +200 ms of toddler’s initial screen touch.

Independent Component Analysis (ICA; 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

Each Mom-Toddler dyad completed 2 to 5 blocks of 40 trials each (mean = 130.4 trials total, SD = 45.6), in mostly turn-taking patterns. Choice of target was influenced by the partner’s matching tendencies. For example, Figure 4 shows a dyad’s performance in their 1st and 4th blocks. Matching is indicated by alternating lines on the same side.

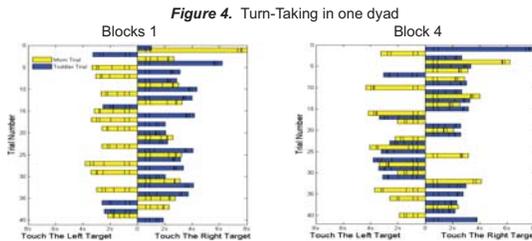


Figure 4. Turn-Taking in one dyad. Note: Touches to left or right bubble: Toddler = blue; Mom = yellow. Each box=40 trials (trial 1 at top); Blue-and-yellow stripes on one side indicate matching; Bar length = reach time.

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=.81, p<.001; Figure 5).

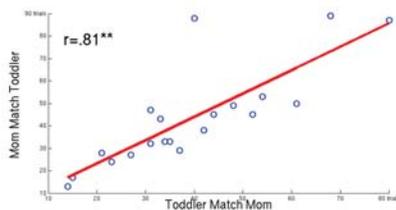


Figure 5. Scatterplot; relation between frequency of last-turn matching by toddlers and mothers, within dyad.

Two clusters of somatomotor mu Independent Components (ICs), in left and right hemispheres, were identified (Figure 6). Power spectrum density of the components peaked near 7-8 Hz, consistent with studies showing lower mu frequency in 3-year-olds than adults (~10-13 Hz) (Henry, 1944, Lindsley, 1938).

We compared mean spectral perturbations of each cluster, across the three epoch types (rest, observation, action). Left somatomotor mu power was significantly stronger in Rest epochs than in Action and Observation epochs, both p<.01. Also, power was stronger Observation than Action epochs, p<.05. Epoch differences in the right somatomotor mu cluster were not significant. This might reflect the fact that both participants used their right hands to touch the screen.

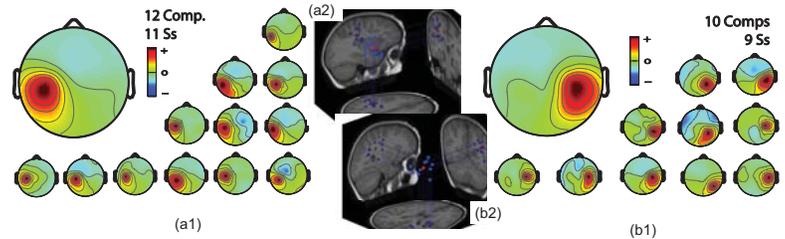


Figure 6. The mean IC scalp map and individual contributed ICs for the left-hemisphere somatomotor mu cluster (a1) and for the right-hemisphere somatomotor mu (b1). Equivalent dipoles (in blue) of each contributed independent component (with the averaged dipole shown in red) of the left-hemisphere (a2) and right-hemisphere (b2) sensorimotor mu cluster, using age appropriate MRI brain template.

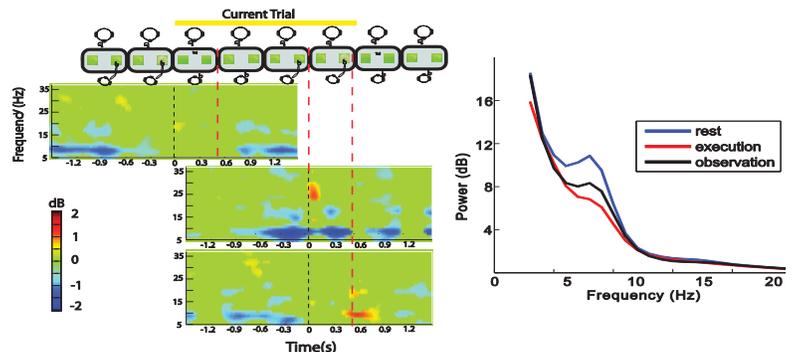


Figure 7. Left: The event-related spectral perturbation (ERSP) of three epochs time locked to different task events for the left somatomotor mu cluster. Right: Power Spectrum Density (PSD) of the three conditions (Rest, Observation, and Execution) for the left somatomotor mu cluster.

Conclusions

1. Within a dyad, each partner’s action choices are interdependent. Toddlers who were matched more often, match their caregivers 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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