Coherent activity in the mirror neuron system during a 3D mental rotation task

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INTRODUCTION

- Due to its excellent temporal and spatial resolution, magnetoencephalography (MEG) permits the measurement of oscillatory activity within particular regions of interest (ROIs) in the human brain.
- Activity in these ROIs can be related to specific frequency bands.
- Coherence between activity within a set of ROIs may indicate the presence of specific neural networks.
- We used MEG to explore neural networks active during the performance of a mental rotation task.

METHODS

- Stimuli were 48 pairs of Shepard-Metzler figures in a variety of orientations.
- Stimuli were presented at 6000 ms stimulus duration, with a 600 ms constant interstimulus interval.
- Head position was measured with a Polhemus device for co-registration with structural MRIs.
- Participants judged whether the paired images represented the same object viewed from different angles (Match) or different objects (Mismatch), and indicated their response using a fiber optic response pad.
- A 306-channel MEG array (Elekta Neuromag^{TM}) recorded ongoing activity from 5 adult subjects during task performance.
- Signals were band-pass filtered from 0.5-45 Hz
- Stimulus-locked averages were computed off-line.
- Blink and cardiac artifacts were removed using Signal Space Projection (Uusitalo & Ilmoniemi, 1997)
- L1 minimum norm estimates were calculated for correct trials using MCE (Uutela, Hämäläinen, & Somersalo, 1999).
- Activity in left superior temporal cortex, left parietal cortex, and left inferior frontal gyrus was characterized with both MCE and with equivalent current dipoles (ECDs).
- For each participant, an early source (≈250-300 ms) in left superior temporal cortex was used as a seed for a coherence analysis (Bish et al., 2002; Moses et al., 2004)
- 306 semicoherence spectra were computed from the combination of the MCE seed waveform for left ST and each sensor evoked response waveform.
- The set of semicoherence spectra were then subjected to a second MCE analysis in the frequency domain. Activity was examined in the beta (14-30 Hz) and delta (1-3 Hz) bands.

RESULTS

- Coherent oscillations were found between left superior temporal cortex and left parietal cortex in the beta band at ≈20 Hz.

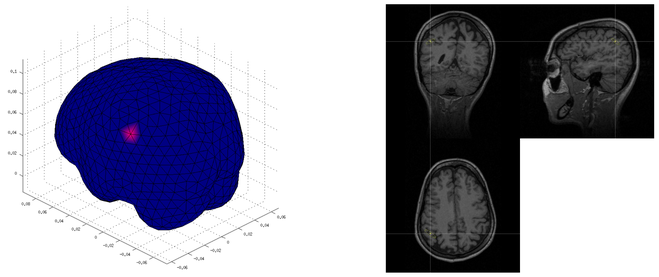

Figure 1. MCE localization and MRI projection of beta band activity.

- Coherent oscillations were also found between left superior temporal cortex and both left inferior frontal gyrus and left posterior parietal cortex in the delta band (1-3 Hz).

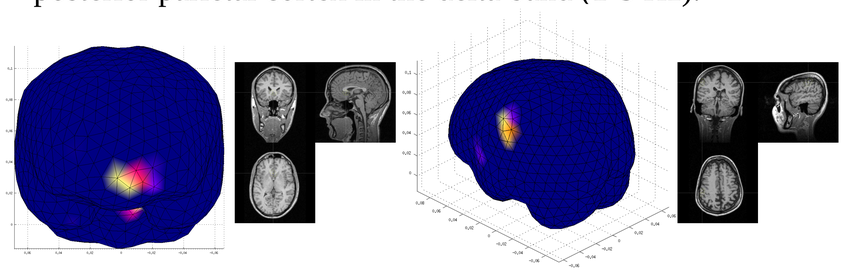

Figure 2. MCE localization and MRI projection of delta band activity.

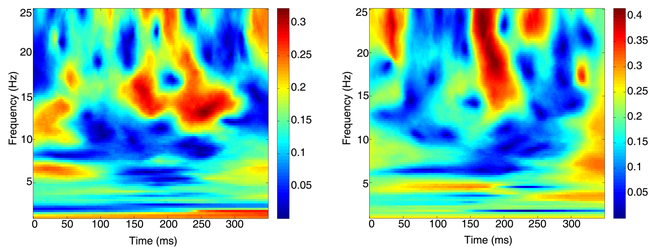

Figure 3. Phase locking factor from typical participants.

DISCUSSION

- The human mirror neuron system responds to both the performance of an action and the observation of another individual performing that same action (Rizzolatti & Craighero, 2004).
- STC, IFG, and PPC participate in the human mirror neuron system.
- We found coherent oscillations between these regions in a task requiring mental rotation of three dimensional objects, at ≈20 Hz for STC and LPC and in the delta band for STC, IFG, and PPC.
- The ≈20 Hz band in particular is associated with the MNS (Hari et al., 1998), and is correlated with muscle movement (Salenius et al., 1997).
- These observations suggest that the mirror neuron system may be activated during mental rotation tasks.
- The activations observed in the present study are consistent with the finding of Engel and colleagues (2008) that the human MNS responds to intentional goals involving movement rather than to sensory processing of observed movement *per se*.

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ACKNOWLEDGEMENTS

The authors would like to thank Suvi Heikkilä and the staff of the BioMag Laboratory for their gracious assistance.

This work was supported in part by funding from the MIND Research Network (www.mrn.org).