Mental Simulation of Natural Actions Synchronizes Action Observation Circuits Across Individuals


Introduction
Simulation of others’ mental and bodily states supports understanding of their action goals. During this process, the observer automatically mirrors some motor and somatosensory information that supports tracking and replicating the mental life of the target (Gallese & Goldman, 1998; Keysers, et al., 2010). As simulation of others’ mental and bodily states helps individuals to understand and view the external world in a similar fashion (Hari & Kujala, 2009), increased synchronization of the action-observation network (AON, Kilner 2011) across individuals could be the prerequisite of mutual action understanding. Here we used instantaneous phase synchrony (IPS) analysis of fMRI data (Glerean et al., in press) to show that AONs become increasingly synchronized across observers while they are mentally simulating somatomotor events depicted in movies.

Methods
3-T fMRI and eye movements were recorded from 20 adults who viewed a set of 18 short movie clips depicting highlights of boxing matches (Fig. 1). Before each clip, participants were instructed either to watch the movie passively, or simulate the mental, somatic and motor states of a specified (winning or losing) boxer. Voxel-wise IPS between every pair of subjects was calculated for the whole time series, to produce moment-by-moment IPS values and average IPS maps for each condition. Instantaneous seed-based phase synchronization (SBPS) was used as a time-varying connectivity group measure between components of the AON. Time series of the experimental conditions were convolved with a gamma function, and used to predict moment-to-moment fluctuations in IPS and SBPS. Intersubject synchronization of eye movements was measured by computing trial-wise similarity of subject’s eye positions.

Results
Eye movements (Fig. 2) and brain activity (Fig. 3) were highly synchronized across participants throughout the experiment. When contrasted with passive viewing, active simulation of both losing and winning increased IPS in premotor, somatosensory and intraparietal cortices and middle and superior temporal sulcus (Fig. 4a). Moreover, active simulation significantly increased SBPS in left- and interhemispheric connections within the AON (Fig. 4b).

Eye movements are synchronized during the task

Eye movements were synchronized across participants throughout the task (Msimilarity = .40) with no differences across tasks.

Brain activity is synchronized across participants during passive observation and active simulation

Conclusions
Mentally simulating others’ actions triggers synchronized and spatially selective brain activity across individuals. When participants mentally simulated humans engaged in vigorous motor behaviour, significant time-locking of brain activity was observed in the visual and auditory cortices and frontal lobes, but also in the somatosensory cortices and in the AON. SBPS analysis also confirmed that these regions constitute a functional network whose connectivity is enhanced during mental simulation. Such enhanced synchrony in somatosensory and motor mapping of others’ actions and mental states in the observer’s brain may support social interaction via mechanism of contextual understanding. We propose that temporally synchronized, shared somatosensory representations of other agents’ actions may be the crucial neural mechanism underlying mutual action understanding.

References

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