Travelling waves in the brain: a network approach to their propagation [1]

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Introduction: The sleep slow waves

Slow waves constitute the main signature of sleep in the electroencephalogram (EEG). This pattern consists of a large-amplitude low-frequency (<1Hz) oscillation caused by the synchronization of large groups of neurons that propagates through the cerebral cortex.

The slow wave is the result of two different consecutive processes: the synchronization of populations of neurons in a silent hyperpolarization phase followed by a depolarization phase where neurons are recruited to fire synchronously.

The slow waves are thought to be involved in memory consolidation, synaptic homeostasis and the restorative functions of sleep. However, a comprehensive characterization of their large-scale dynamics across multiple cortical regions is still missing.

Detection of the Slow Wave events

We examined slow wave cortical activity during sleep-wake states using simultaneous scalp EEG and intracranial recordings in 10 subjects (with a total of 417 investigated intracranial electrode sites).

After the identification of a slow wave in the scalp signal (FP1 electrode), a correlation analysis was performed to identify which intracranial contacts had detected the event. The order of detection was established from the position of the hyperpolarization and depolarization onsets in the signals.

Propagation through hubs

We identified for each subject the set of intracranial contacts that showed a larger percentage of detected events. We called these contacts hubs because the slow wave events in their travel through the cortical networks seemed to have a great probability of passing through the region close to the contact.

We calculated in which ordinal position (first, second, etc.) each hub was more likely to have been visited (probability calculated over all the events of a subject). This allowed us to reconstruct a preferential propagation network for each subject.

Results

Slow waves have been reported to propagate across the cortical area with multiple propagation paths and several points of origin [2]. This may reflect the level of activity-dependent synchronization achieved in cortical neural ensembles, which depends on the local homeostatically regulated average synaptic strength [3].

By studying the position of the first and last hubs of all subjects we were able to establish that the slow waves have a preference to start in the prefrontal cortex and to end in posterior and temporal regions of the cortex. This further confirms the presence of cortical generators in the frontal cortex with enhanced intrinsic excitability, which could consistently generate slow waves during sleep.

References