Fine temporal structure of neural synchronization

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While neural synchronization is widely observed in neuroscience, neural oscillations are rarely in perfect synchrony and go in and out of phase in time. Since this synchrony is not perfect, the same synchrony strength may be achieved with markedly different temporal patterns of activity (roughly speaking oscillations may go out of the phase-locked state for many short episodes or few long episodes). Provided that there is some average level of phase-locking is present, one can follow oscillations from cycle to cycle and to observe if the phase difference is close to the preferred phase lag or not.

Here we study neural oscillations recorded by EEG in alpha and beta frequency bands in a large sample of healthy human subjects at rest and during the execution of a simple motor task. While the phase-locking strength depends on many factors, dynamics of synchrony has a very specific temporal pattern: synchronous states are interrupted by frequent, but short desynchronization episodes. The probability for a desynchronization episode to occur decreased with its duration. The modes and medians of distributions of desynchronization durations were always just one cycle of oscillations.

Similar temporal patterning of synchrony in different brain areas in different states may suggest that i) this type of patterning is a generic phenomenon in the brain, ii) it may have some functional advantages for oscillating neural networks receiving, processing, and transmitting information, iii) it may be grounded in some general properties of neuronal networks calling for the development of appropriate nonlinear dynamical theory.

To further investigate these conjectures we numerically studied a system of coupled simple neuronal models (of Morris-Lecar type) and showed that coupled neural oscillators exhibiting short desynchronizations require smaller values of synaptic connections between them of weaker common synaptic input to induce specified levels of synchrony strength than oscillators of the same frequency exhibiting more prolong desynchronizations.

The results may suggests that whenever a (partially) synchronous cell assembly must be formed to facilitate some function, short desynchronization dynamics may allow for efficient formation and break-up of such an assembly.