Computational Neuroscience Seminar

Cross-level coupling between single neurons and large-scale LFP patterns in multi-scale brain networks

Ryan T. Canolty Ph.D.

HELEN WILLS NEUROSCIENCE INSTITUTE &
DEPARTMENT OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCES
UNIVERSITY OF CALIFORNIA, BERKELEY
http://knightlab.berkeley.edu/profile/rcanolty/

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Brains exhibit structure across a variety of different scales – from single neurons (micro-scale) to functional areas (meso-scale) to large-scale cortical networks (macro-scale). Furthermore, the different levels of multi-scale brain networks often interact with each other – that is, activity and information at one level can influence other levels, a phenomenon termed cross-level coupling (CLC). Neuronal oscillations have been suggested as a possible mechanism for dynamic cross-level coordination, but the functional role of oscillations in multi-scale networks remains unclear. We investigated CLC by recording local field potentials (LFPs) and single unit activity using multiple microelectrode arrays in several brain areas of the macaque, and then modeled the dependence of spike timing on the full pattern of proximal and distal LFP activity. We show that spiking activity in single neurons and neuronal ensembles depends on dynamic patterns of oscillatory phase coupling between multiple brain areas, in addition to the effects of proximal LFP phase and amplitude. Neurons that prefer similar patterns of LFP phase coupling exhibit similar changes in spike rates, potentially providing a basic mechanism to bind different neurons together into coordinated cell assemblies. Surprisingly, CLC-based spike rate correlations are independent of inter-neuron distance – that is, two neurons in opposite hemispheres may prefer the same global LFP pattern and exhibit correlated rate changes, while two neurons recorded on the same electrode may prefer different global LFP patterns and exhibit uncorrelated spiking activity. CLC patterns correlate with behavior and neural function, remain stable over multiple days, and show reversible, task-dependent shifts when engaging in multiple tasks. These findings suggest that neuronal oscillations enable selective and dynamic control of distributed functional cell assemblies, supporting the hypothesis that CLC may play a key role in the functional reorganization of dynamic brain networks.

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