Modelling brain states: from single units to populations using mean-field models

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Brain states can be measured at different scales, from single-neuron activity (micro-electrode recordings), mesoscopic scales (local field potentials, calcium imaging, voltage-sensitive dyes), up to large scales (EEG, MEG, …) We show here how to link those scales using computational models. Networks of spiking neurons can address the level of single-neuron activity as seen from microelectrode arrays. To link to larger scales, we use mean-field techniques to derive population models from networks of spiking neurons. We show that mean-field techniques can be applied to complex neuron models, such as non-linear integrate-and-fire models, Hodgkin-Huxley type models or even real neurons recorded in slices. Such mean-field models capture the level of spontaneous activity exhibited by the network, as well as the response to external stimuli. Mean-field models can also capture the state-dependent responsiveness of networks, depending on their level of spontaneous activity, as well as slow oscillatory phenomena such as Up/Down state oscillations. Finally, we show that these models can be adjusted to mesoscopic measurements, such as the traveling waves measured by voltage-sensitive dyes in awake monkey visual cortex. We conclude that, for the first time, we can obtain biologically-realistic population models that are derived from the activity of single neurons, and that can be adjusted to experimental measurements. We discuss the perspective of using such models to study large-scale interactions at the level of the whole brain.

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