TEMPORAL STRUCTURE OF SPONTANEOUS CORTICAL NETWORKS IN LAYER 2/3 OF THE PRIMARY VISUAL CORTEX OF THE MOUSE

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The brain's neocortex is a six-layered structure that consists of billions of densely interconnected neurons. Over time much has been learned about the computational properties of single neurons of the neocortex. However, there is uncertainty in the responses of single neurons to the same stimulus. Downstream neurons must integrate activity from large neuronal populations that exhibit coordinated activity. Nevertheless, on average, neurons display close to zero correlation [1]. We remain far from understanding how networks of cortical cells interact with each other to process information. Here we study the functional architecture of cortical networks during spontaneous activity, recorded from layer 2/3 neurons of the primary visual cortex of the mouse with mesoscopic two-photon imaging, which allows the near-simultaneous recording of fields of views on the order of millimeters that contain up to some 5000 cells.

We follow the hypothesis that cortical networks are organized into functional sub-networks that can be identified during spontaneous activity [2]. To construct graphs of temporal correlations, we extended the spike time tiling coefficient [3], a correlation metric robust to activity fluctuations, to estimate the directional temporal correlation between neurons. The identification of edges is robust for recording duration longer than about 9 min. The observed graphs exhibit temporal structure across multiple correlation thresholds, beyond that expected from graphs constructed by circularly-shifting the observed activity patterns, which destroys correlations between neurons but leaves inter-event interval distributions intact. Observed graphs have a higher proportion of high-degree nodes, longer average shortest paths, and higher average clustering coefficients compared to equivalent Erdös-Rényi networks, a model of irregular connectivity architecture constructed by shuffling the edges between nodes. The observed graphs manifest a small-world architecture, which is associated with efficient information transfer [4], across multiple scales of correlation strength. Our results show substantial temporal structure in spontaneous cortical activity despite low, on average, pairwise correlation coefficients.

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