Functional architecture of spontaneous cortical networks

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ABSTRACT

The brain's neocortex is a six-layered structure that consists of billions of heavily interconnected neurons arranged in topographic columns. Over time much has been learned about the computational properties of single neurons of the neocortex. However, there is uncertainty in responses of single neurons to the same stimulus. Downstream neurons must integrate activity from large neuronal populations that exhibit coordinated activity. We remain far from understanding how networks of cortical cells coordinate and interact with each other to process information. Here we aim to study the functional topology of cortical networks during spontaneous activity, using the primary visual cortex of the mouse as our experimental model system. Our hypothesis is that cortical networks are organized into functionally linked sub-networks that can be identified by studying spontaneous activity. We used a modified version of STTC[1], a metric that estimates directional temporal correlation and is robust to activity fluctuations, to construct network graphs of functional correlations. These graphs exhibit considerable temporal structure across multiple scales of correlation beyond that expected from networks constructed by circularly-shifting the observed activity patterns. The observed networks had more functional connections, shorter average shortest paths, and higher average clustering coefficients compared to equivalent Erdös-Rényi networks, a model of irregular structure constructed by shuffling the edges between nodes. Consistent with this evidence, the observed graphs approached a "small-world" architecture across multiple correlation scales. We found that neurons with intermediate numbers of connections, i.e. not those with connections of the highest correlation, formed tightly connected neighbourhoods in which neurons were connected with most other neurons. These results were confirmed with datasets containing a large population of neurons (~5000), collected using mesoscopic two-photon imaging. Our results show that spontaneous cortical activity exhibits substantial temporal structure. Neuronal populations of intermediate correlation form tightly connected clusters embedded in a "small-world" architecture.

REFERENCES

[1] Cutts, C. S., and Eglen S. J. 2014. *The Journal of Neuroscience,* **34**: 14288–303.