Predicting the Dynamics of Network Connectivity in the Neocortex

By Ikaplan
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Loewenstein, Yonatan, Yanover Uri, and Rumpel Simon. 2015.

Abstract:

Dynamic remodeling of connectivity is a fundamental feature of neocortical circuits. Unraveling the principles underlying these dynamics is essential for the understanding of how neuronal circuits give rise to computations. Moreover, as complete descriptions of the wiring diagram in cortical tissues are becoming available, deciphering the dynamic elements in these diagrams is crucial for relating them to cortical function. Here, we used chronic in vivo two-photon imaging to longitudinally follow a few thousand dendritic spines in the mouse auditory cortex to study the determinants of these spines' lifetimes. We applied nonlinear regression to quantify the independent contribution of spine age and several morphological parameters to the prediction of the future survival of a spine. We show that spine age, size, and geometry are parameters that can provide independent contributions to the prediction of the longevity of a synaptic connection. In addition, we use this framework to emulate a serial sectioning electron microscopy experiment and demonstrate how incorporation of morphological information of dendritic spines from a single time-point allows estimation of future connectivity states. The distinction between predictable and nonpredictable connectivity changes may be used in the future to identify the specific adaptations of neuronal circuits to environmental changes. The full dataset is publicly available for further analysis.

SIGNIFICANCE STATEMENT The neural architecture in the neocortex exhibits constant remodeling. The functional consequences of these modifications are poorly understood, in particular because the determinants of these changes are largely unknown. Here, we aimed to identify those modifications that are predictable from current network state. To that goal, we repeatedly imaged thousands of dendritic spines in the auditory cortex of mice to assess the morphology and lifetimes of synaptic connections. We developed models based on morphological features of dendritic spines that allow predicting future turnover of synaptic connections. The dynamic models presented in this paper provide a quantitative framework for adding putative temporal dynamics to the static description of a neuronal circuit from single time-point connectomics experiments.

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