Multiplicative dynamics underlie the emergence of the log-normal distribution of spine sizes in the neocortex in vivo.

Loewenstein, Yonatan, Kuras Annerose, and Rumpel Simon. 2011.

Abstract:

What fundamental properties of synaptic connectivity in the neocortex stem from the ongoing dynamics of synaptic changes? In this study, we seek to find the rules shaping the stationary distribution of synaptic efficacies in the cortex. To address this question, we combined chronic imaging of hundreds of spines in the auditory cortex of mice in vivo over weeks with modeling techniques to quantitatively study the dynamics of spines, the morphological correlates of excitatory synapses in the neocortex. We found that the stationary distribution of spine sizes of individual neurons can be exceptionally well described by a log-normal function. We furthermore show that spines exhibit substantial volatility in their sizes at timescales that range from days to months. Interestingly, the magnitude of changes in spine sizes is proportional to the size of the spine. Such multiplicative dynamics are in contrast with conventional models of synaptic plasticity, learning, and memory, which typically assume additive dynamics. Moreover, we show that the ongoing dynamics of spine sizes can be captured by a simple phenomenological model that operates at two timescales of days and months. This model converges to a log-normal distribution, bridging the gap between synaptic dynamics and the stationary distribution of synaptic efficacies.

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