Neutral theory of scale-free neural avalanches

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The human cortex has a special feature that is common to all mammalians: it is endogenously active; i.e. cascades of electrochemical activity at multiple timescales pervade its dynamical state even in the absence of any apparent stimuli or task. Mounting evidence suggests that such an endogenous activity is essential for various information processing tasks. Spontaneous bursts of activity were reported to appear in the form of avalanches [1].

Avalanches of activity in brain networks have been empirically reported to obey scale-invariant behavior – characterized by power-law distributions up to some some upper cut-off that scales with system size– both in vitro and in vivo. Elucidating whether such scaling laws stem from the underlying dynamics operating at the edge of a phase transition is a fascinating possibility. The so-called "criticality hypothesis" proposes that some aspects/parts of living systems may work in the vicinity of a critical point [2] and that they can derive functional advantages,such as exquisite sensitivity to signals, large dynamical repertoires, a large variety of attractors endowing them withlarge computational capabilities, etc.[3].

Here we scrutinize one of the most accepted computational models for the generation of scale-invariant avalanches of neural activity. We confirm the emergence of generic scale-free avalanches, but we also elucidate that it has nothing to do with self-organization to the critical point of a continuous phase transition. Instead, it stems from the fact that perturbations to the system exhibit a neutral drift –guided only by stochastic fluctuations– with respect to endogenous activity spontaneously present in the system. Such a neutral dynamics –similar to the one in neutral theories of population genetics of Kimura and the neutral theory of biodiversity of Hubbell– implies marginal propagation of activity, characterized by power-law distributed causal avalanches. We discuss the implications of this finding both in modeling and in experimental observations as well as its possible consequences for actual neural dynamics in real networks [4]

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