# Signal integration shapes the dynamics of neuronal networks


Leonardo L. Gollo*, Claudio Mirasso, Víctor M. Eguíluz
*IFISC, Instituto de Física Interdisciplinar y Sistemas Complejos*
*CSIC-Universidad de las Islas Baleares 07122-Palma de Mallorca, Spain*


Cognition and consciousness emerge from the outcome of a multitude of interconnected neurons. In this scenario, the integration of incoming inputs from neighboring neurons plays a crucial role. We find that this integration shapes the macroscopic dynamics of the neuronal network[1].

Taking advantage of general aspects of phase transitions and critical phenomena, several features (including distinction of external stimulus[2], transmission and storage of information[3,4], etc.) become optimized near the critical state. Supported by some experimental evidences, the critical brain hypothesis conjectures that the brain operates at a critical point of a continuous phase transition[5].

We address how the features of the neuronal process of signal integration affects the critical brain hypothesis, the dynamic range, and in general the collective behavior of a network of excitable units. By means of numerical simulations and a mean-field approach, we explore the nonequilibrium phase transition in the presence of integration. We show that the firing rate in random and scale-free networks undergoes a continuous or a discontinuous phase transition depending on both the integration time ($\tau$) and the density of integrator units ($d$), as depicted in Fig. 1. Moreover, in the presence of external stimuli, we find that a system of excitable integrator units operating in a bistable regime largely enhances its dynamic range.

These results are compatible with bi- and multi-stable dynamics (which represent an important part of the brain's dynamic repertoire), and constitute a challenge to the conceptual framework of the critical brain hypothesis.

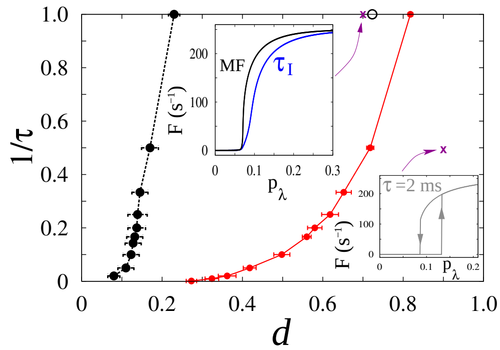


FIG. 1. Dependence of the nature of the phase transition order on the integration time $\tau$ for networks (N = 5000) composed of a mixture of both integrators, which have a density $d$ of nodes with integration threshold $\theta = 2$, and nonintegrators ($\theta = 1$). The red solid (black dashed) line corresponds to the random (scale-free) network. The left-hand side of the curve corresponds to a continuous phase transition whereas the right-hand side corresponds to a discontinuous phase transition. The black open symbol depicts the mean-field shift in the order of the phase transition.


* leonardo@ifisc.uib-csic.es



[1] L. L. Gollo, Claudio Mirasso, Víctor M. Eguíluz, Phys. Rev. E, 85, 040902 (2012).

[2] O. Kinouchi and M. Copelli, Nat. Phys. 2, 348 (2006).

[3] D. Plenz and T. C. Thiagarajan, Trends Neurosci. 30, 101 (2007).

[4] J. M. Beggs, Philos. Trans. R. Soc. London A 366, 329 (2008).

[5] D. R. Chialvo, Nat. Phys. 6, 744 (2010).