Network topology and dynamical task performance

S. Johnson, J. Marro, and J.J. Torres

Departmento de Electromagnetismo y Física de la Materia, and Instituto Carlos I de Física Teórica y Computacional, University of Granada, Spain.
(e-mail: samuel@onsager.ugr.es; web: http://ergodic.ugr.es/neurofisica/neurofisica.htm)

We study excitable networks in which the connection weights vary rapidly with local fields in a way that mimics resistance or facilitation. The control parameter, Φ, sets the extent to which "static" weights are modified. Considering generic random network topologies, it ensues that the transition to a chaotic regime, or "edge of chaos", depends crucially on the degree of heterogeneity of the connectivity distribution. In a mean-field approximation and at relatively low temperatures, the critical value is found to be

$$\Phi_c \simeq 1 - \frac{\langle k \rangle^{\alpha+1}}{\langle k^{\alpha+1} \rangle}, \qquad (2)$$

where $\alpha > 0$ is a parameter related to the dynamics considered [1]. Equation (1) means that $\Phi_c \to 1$ – i.e., the static synapses limit – for networks with highly heterogeneous connectivity distributions. Applying the model to Hopfield-like neural networks, the fact that synaptic depression in general reduces memory capacity and that the critical temperature, T_c, also increases with topological heterogeneity means that certain dynamical tasks can be carried out most efficiently on highly heterogeneous networks.

We analyse computationally network performance at a pattern recognition task in which arbitrary patterns from a set are briefly "shown" to the system. Random networks with two kinds of connectivity distributions – bimodal and scale free – are considered. We find that the best performance (for low values of synaptic depression) is achieved for scale free distributions such that $p(k) \sim k^{-2}$. This suggests a possible justification for the functional topology of the brain during cognitive tasks to become *scale free* with exponent close to 2, as reported [2].

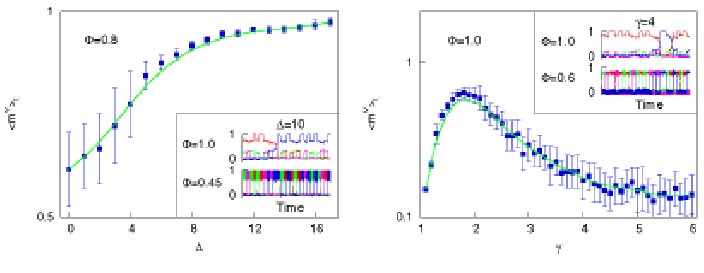

FIGURE 3. Network performance for bimodal (left) and scale free (right) random topologies, as a function of the distance between peaks, 2Δ, and the exponent, γ, respectively.

[1] S. Johnson, J. Marro, and J.J. Torres, *Europhys. Lett.*, in press (2008).
[2] V.M. Eguíluz, D.R. Chialvo, G.A. Cecchi, M. Baliki, and A.V. Apkarian, *Phys. Rev. Lett.* **94**, 018102 (2005).