Nonlinear analysis of the effects of noise and a subthreshold periodic signal in the output of two coupled neurons

Cristina Masoller[1], Maria Masoliver Vila[1]
[1]Departament de física, Universitat Politècnica de Catalunya,
Terrassa Campus, Rambla Sant Nebridi, s/n 08022 Terrassa

We study numerically the dynamics of two mutually coupled neurons using the well-known stochastic FitzHugh-Nagumo (FHN) model. We analyze how the coupling parameters affect the detection of a periodic weak signal that is applied to one of the neurons. In a recent work [1] it was shown that, in a single neuron, the interplay of noise and the periodic weak (subthreshold) signal induced the emergence of relative temporal ordering in the timing of the spikes. Here we analyze under which conditions the coupling to a second neuron can enhance the temporal ordering in the spike sequence of the first neuron, contributing to improve the encoding of the external signal. As in [1], we apply the symbolic method of ordinal analysis [2] to the output sequence of inter-spike intervals (ISIs). We find that for certain periods and amplitudes of the external signal, the coupling to the second neuron changes the preferred ordinal patterns. A detailed study of how the probabilities of the preferred patterns vary with the noise strength, the period and amplitude of the external signal and with the coupling strength is performed and discussed. Our findings contribute to understand how neurons, in noisy environments, encode information about weak external signals in their spike sequences, and can even motivate experimental studies with real neurons to test the FHN model predictions. Our finding can also be relevant to understand the dynamics of coupled excitable systems under the influence of a weak periodic perturbation.

[1] J. A. Reinoso, M.C. Torrent and C. Masoller, Phys. Rev. E **94**, 032218 (2016).

[2] C. Bandt and B. Pomper, Phys. Rev. Lett. **88**, 174102 (2002).