Numerical study of the interplay of noise and a subthreshold periodic signal in the output of two coupled neurons

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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 and transmission of a periodic weak signal that is applied to only one of the neurons. In a recent work [1] it was shown that, in a single FHN neuron, the interplay of noise and periodic subthreshold modulation induced the emergence of relative temporal ordering in the timing of the spikes. Different types of relative temporal order were found, in the form of preferred and infrequent *ordinal patterns* [2] that depended on both, the strength of the noise and the period of the input signal. A resonance-like behavior was also found, as the probability of the preferred (infrequent) pattern was maximum (minimum) for certain periods of the input signal and noise strengths.

Here we analyze under which conditions the coupling to a second neuron, which is assumed to be linear and instantaneous, can further enhance the temporal ordering in the spike sequence of the first neuron, improving 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 (and also the infrequent) ordinal patterns. A detailed study of how the ordinal probabilities vary with the coupling strength is performed. In a second step, we consider the situation in which the external signal is applied to both neurons. We discuss under which conditions mutual coupling enhances (or degrades) the encoding of the signal in the neuronal spike sequences.

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