CRITICAL AND RESONANCE PHENOMENA IN NEURAL NETWORKS

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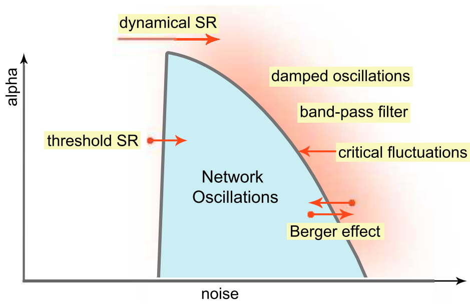
Brain waves are ubiquitous and contribute to every aspect of brain function. Here, we show that not only brain waves but also critical and resonance phenomena preceding their emergence play a ‘biologically useful’ role. Using an explicit solution and simulations of a cortical circuit model of neural networks with stochastic neurons in the presence of noise, we show that spontaneous appearance of network oscillations occurs as a dynamical phase transition at a critical point determined by the noise level, network structure, the balance between excitatory and inhibitory neurons, and other parameters. The relaxation time of neural activity to a steady state, response to periodic stimuli at the frequency of the oscillations, amplitude of damped oscillations, and stochastic fluctuations of neural activity are dramatically increased when approaching the critical point. They signal the second order phase transition and contribute to the criticality of brain dynamics [1]. Remarkably, these phenomena lead to resonance phenomena such as band pass filter behavior and stochastic resonance (SR) (see Figure). Furthermore, the phase transition provides a natural switching mechanism [2] in the brain dynamics. The critical and resonance effects have been observed in mammalian brain and electroencephalogram (EEG) measurements. However a relationship between them and emergence of network oscillations has not been discussed yet.



[1] D. Chialvo, Nature Phys. **6**, 744–750 (2010).

[2] L. Abbott, *23 problems in systems neuroscience*, Oxford: Oxford University Press, 423–431 (2006).