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# Dynamical entropy production in cortical circuits with different network topologies

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The prevailing explanation for the irregularity of spike sequences in the cerebral cortex is a dynamic balance of excitatory and inhibitory synaptic inputs - the socalled balanced state [1].

Nevertheless its statistical properties are well described by a mean field theory that is independent of the single neuron dynamics, its dynamics is far from being understood. Recently it was found that the stability of the balanced state dynamics depends strongly on the detailed underlying dynamics of individual neurons. Inhibitory networks of leaky integrate-and-fire neurons show stable chaos [2,3], while a balanced network of neurons with an active spike generation mechanism exhibits deterministic extensive chaos [4].

Previous studies of the dynamics of the balanced state used random (ErdŐs-Rényi) networks. We extended this analysis to arbitrary network topologies and analyzed the entropy production in small world topologies [5], ring networks [6], clustered networks [7], multi-layered networks [8] and topologies with different frequencies of certain network motifs [9]. We derived an analytical expression for the single spike Jacobian containing elements of the coupling matrix, which enabled us to calculate the full Lyapunov spectrum for any desired topology. Using a single neuron model in which action potential onset rapidness [10] and synaptic time constant are adjustable, we simulated the dynamics in numerically exact event-based simulations and calculated Lyapunov spectra, entropy production rate and attractor dimension for a variety of connectivities. We found that the importance of the internal single neuron dynamics for the network stability persists in different topologies. While the Entropy production and Attractor Dimension in clustered [7] and ring networks was very similar to random networks, these dynamical properties were changed substantially when introducing second order network motifs or a small world topology.

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