Modeling asynchronous irregular network states constrained by experiments, their responsiveness and possible mechanisms for sensory awareness

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Desynchronized brain states are known to be associated with arousal and increased awareness, but the underlying cellular and network mechanisms are unknown. Here, we explore networks of excitatory and inhibitory neurons displaying asynchronous irregular (AI) states, where the activities of the two populations are balanced. At the single-cell level, it was previously shown that neurons subject to balanced and noisy synaptic inputs can display enhanced responsiveness. We show here that this enhanced responsiveness is also present at the network level, but only when single neurons are in a regime where their conductance state and fluctuation level are consistent with experimental measurements. By scanning a large number of AI states, we show that the network responsiveness can be explained based on the mean conductance state, the mean membrane potential (Vm), and the amplitude of Vm fluctuations in individual neurons. Optimal responsiveness is obtained when these parameters are all consistent with experimental measurements. Multi-layer networks endowed with such "realistic" AI states are capable of transmitting information reliably across layers. We conclude that when displaying "realistic" AI states, networks can be exquisitely sensitive to afferent inputs, transmit information reliably, and make the information available to the entire network. We propose that these features define a low-level form of sensory awareness, which can be modulated at the millisecond scale.

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