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Title: Synchronous thalamic inputs drive cortical neurons reliably when excitatory and inhibitory inputs are balanced

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Authors: ***H. WANG**[1], D. SPENCER[1], J.-M. FELLOUS[2], T. J. SEJNOWSKI[1];
[1]Computational Neurobiology Lab., Salk Inst., La Jolla, CA; [2]Psychology, Univ. of Arizona, Tucson, AZ

Thalamic and cortical V1 layer 4 spiny stellate neurons are capable of firing highly reliably and precisely upon repeated presentations of the same visual stimulus to the retina. We simulated a multi-compartment model of a reconstructed spiny stellate cell with dynamic stochastic synapses to compare candidate mechanisms for spike-time reliability. We previously showed that the spike reliability of the spiny stellate neuron was primarily due to synchronously firing thalamic input spike trains and that inputs from surprisingly few synchronous synapses could achieve high reliability.
We now quantify the degree to which synchrony is more effective relative to conductance or input spike rate in controlling output reliability. We found that the spike rate efficiency (reliability divided by firing rate) was highest when there were 50-100 synchronous synaptic inputs and when the input spike rates were low (10 Hz). Under these conditions, the thalamus reliably drives spiny stellate cells with minimum energy expenditure, as measured by firing rate.
We also found that synchronous thalamic inputs were most effective when there was a balance between inhibitory and excitatory synaptic input drives on the spiny stellate cell. The degree of reliability was strongly modulated by the relative rates of the background intracortical excitatory and inhibitory drive. When inhibition predominated, reliability was a superlinear function of the number of synchronous thalamic synapses and the neuron was sensitive to temporal timing of the input. However, when excitation predominated, the reliability curve became linear and depended on the spike rate. These results suggest that the spiny stellate cell can be modulated by intracortical excitation and inhibition between temporal vs. rate decoding and that the thalamus is particularly central to generating synchronous inputs to the cortex.

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