Balanced inputs cause ‘firing irregularity clamp’ regardless of large rate fluctuation

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Cortical neurons show highly irregular firing patterns, suggesting that this irregularity may be important for cortical function and that there are mechanisms to actively maintain it. It is not known how this irregularity is maintained and, especially, how much background synaptic activity and intrinsic membrane properties affect firing irregularity.

In many previous studies, the irregularity has been characterized by the coefficient of variation of interspike intervals, $C_V$. However, $C_V$ does not necessarily reflect the irregularity of a spike train if firing rate changes over time. For instance, $C_V$ becomes large when the firing rate of a regular spike train is modulated. We need another mathematical measure which is sensitive only to the irregularity of neuronal firing, but not to the rate modulation. For that purpose, we previously studied the decomposition of the two factors. To be precise, we modeled spike generation as the gamma process, which is a natural extension of the widely-hypothesized Poisson process, and suggested using the ‘shape parameter’ orthogonal to the firing rate as a measure for the spiking irregularity [1].

In this paper, we characterize the irregularity of spike output in response to synaptic inputs in computational models and real cells recorded by whole-cell patch-clamp technique. We found that when excitatory and inhibitory synaptic inputs are balanced or co-tuned, the spiking irregularity varies moderately irrespective of changes in the firing rate. The results suggest that the two dimensions may be functionally decoupled in the information representation by neurons. The degree of irregularity depends on cell’s intrinsic properties and the effective reversal potential $V_r$ of synapses. However, it remains unchanged over time within a balanced regime. Since evidence is accumulating for balanced excitation and inhibition [2], our results may achieve a novel insight into neural code. We briefly argue how the present finding may facilitate the information decoding in the brain machine interface.

Figure 1: Firing rate and regularity for two cortical neurons for various net synaptic conductances.

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References