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On the temporal structure of correlated activity in a pair of neurons

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To understand the origin, temporal properties and strength of interneuronal spike correlations, it is essential to analyze how neurons subject to correlated synaptic inputs coordinate output spiking activity. We used a simple statistical framework for the analysis of spike correlations between neurons driven by correlated inputs [1] to examine the synchronization acuity of a pair of neurons subject to a variable percentage of common fluctuating input of different correlation times (Fig. 1). First, we calculated the auto conditional firing rate of an individual neuron and analyzed its short and long time asymptotics. For large time lags, we find a substantial influence of the second derivative of the voltage correlation function. In the limit of short times, we find an algebraic rise out of a period of intrinsic silence after each spike that mimics a refractory period. Additionally, we computed the Fano factor for an individual spike train and identified bursting and regular spiking regions and showed that spike count correlation coefficient for small time bins is proportional to the value of spike correlation function at zero. We studied the cross conditional firing rate of a pair of neurons for 1) low and 2) high common input fraction and 3) with firing rate heterogeneity. In the low correlation regime, we identified a rate dependence of the rate of synchronous firing corroborating previous observations [2] and predict that spike correlations in this regime reflect detailed properties of input correlations. In the high correlation regime, however, the synchronous rate ceases to depend on the stationary firing rate of individual neurons and the structure of spike correlations is governed by the input correlation time and the coupling strength, but is insensitive to firing rate and the detailed form of input correlations. For all strengths of correlations, the model predicts the appearance of a systematic delay of firing of the lower rate neuron relative to the higher rate neuron. This effect can significantly decrease spike count correlation coefficient for large time bins. We tested the theoretical predictions of our framework with in vitro experiments in slices of rat visual cortex and injected in pyramidal neurons fluctuating currents with a varying degree of common input. Cross and autoconditional firing rates computed from these recordings, confirmed all basic theoretical predictions of our formalism.

References

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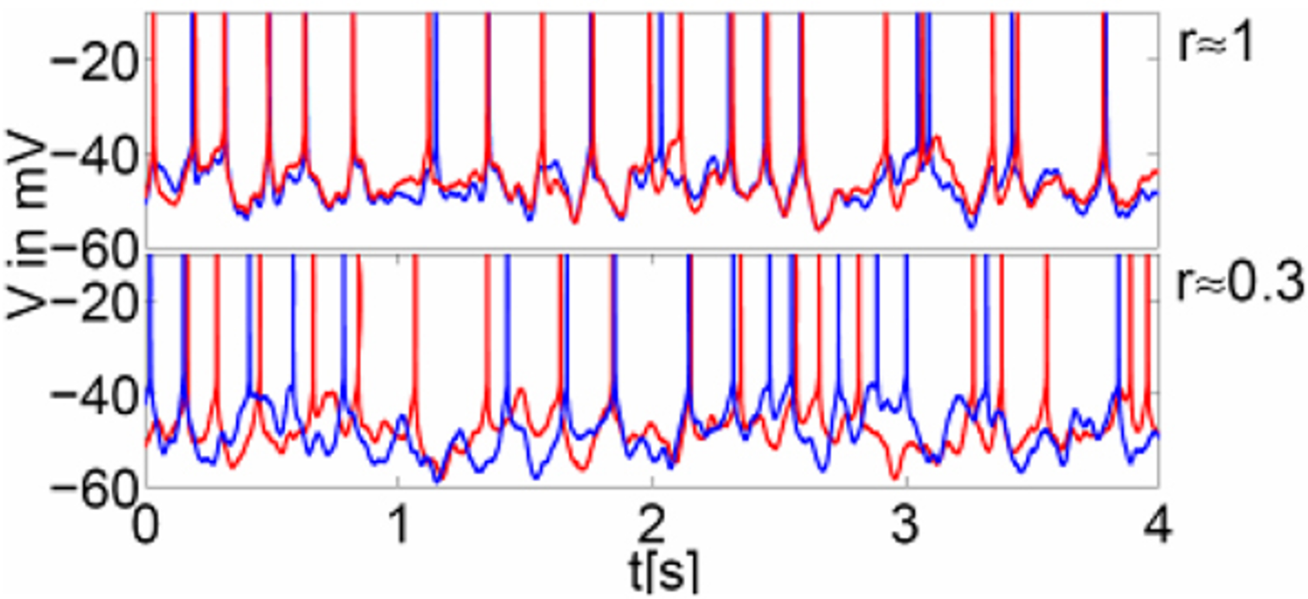

Figure 1
Membrane Potential traces of two neurons in response to injections of correlated fluctuating currents with varying correlation strength *r*.