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Poster presentation

Phase and frequency synchronization analysis of NMDA-induced network oscillation

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Background

Synchronization is a key feature of simple systems of coupled oscillators. Several synchronization metrics exist including frequency synchronization, phase synchronization, and full synchronization. These general ideas used to analyze simple systems can also be applied to complicated systems, such as neural networks. Investigating different types of synchronization may give answers to how neurons with different properties, such as the ability to produce bursting, may interact to produce an oscillating network, reminiscent of seizure-like activity. We specifically look at the frequency and phase synchronization of cellular behavior with network oscillatory activity using specific techniques designed to analyze spike-driven data.

Methods and analysis

Network oscillations are induced in a frontal cortical slice *in vitro* through amplification of the NMDA conductance. Simultaneous recordings of intracellular and extracellular activity are performed and analyzed for their degree of synchronization (see below). Finally, neurons are isolated in tetrodotoxin to determine if intrinsic oscillatory activity exists.

Frequency synchronization is evaluated by comparing the power spectra (PS) of the integrated extracellular activity and the instantaneous firing rate of the cell. We calculate the PS of the unevenly sampled instantaneous firing rate using Lomb's algorithm by finding a and b such that we minimize the mean squared error between the signal and F, where $F(a, b, f, t_n) = a\cos(2\pi f t_n) + b\sin(2\pi f t_n)$ [1]. A neuron and a network are considered frequency synchronized if the frequencies of corresponding peaks in their PS have a constant ratio (Fig 1).

Phase synchronization is visualized in two ways (Fig 2): a network burst triggered raster plot, and a histogram of phase differences between the integrated network signal and the low pass filtered event-driven cellular spiking response (derived via their Hilbert transforms [2]). A tightly peaked histogram would imply that spiking is highly correlated with a particular phase of the network oscillation.

Results and conclusions

The PS of 6/8 neurons exhibited frequency synchronization with the network bursts (Fig. 1); within this group of six, neurons exhibit a wide range of phase relationships with the network oscillation from low to high levels of phase synchronization (Fig. 2). No differences in phase or frequency synchronization have currently been found between neurons with different capabilities to produce intrinsic oscillation. These tools are needed to further investigate how neuronal firing contributes to network oscillation in both experimental and computational models of epilepsy.

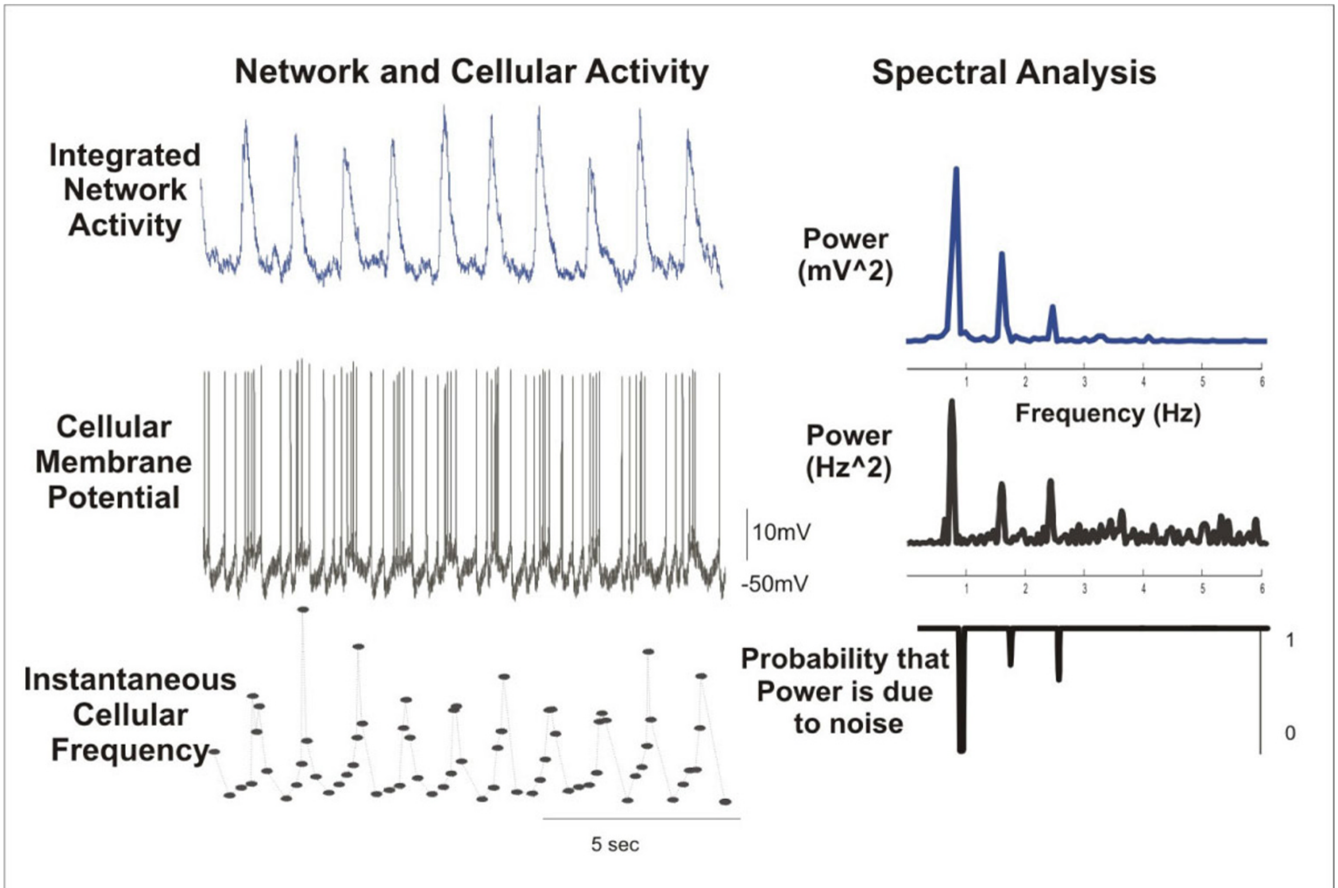

Figure 1
Frequency Synchronization.

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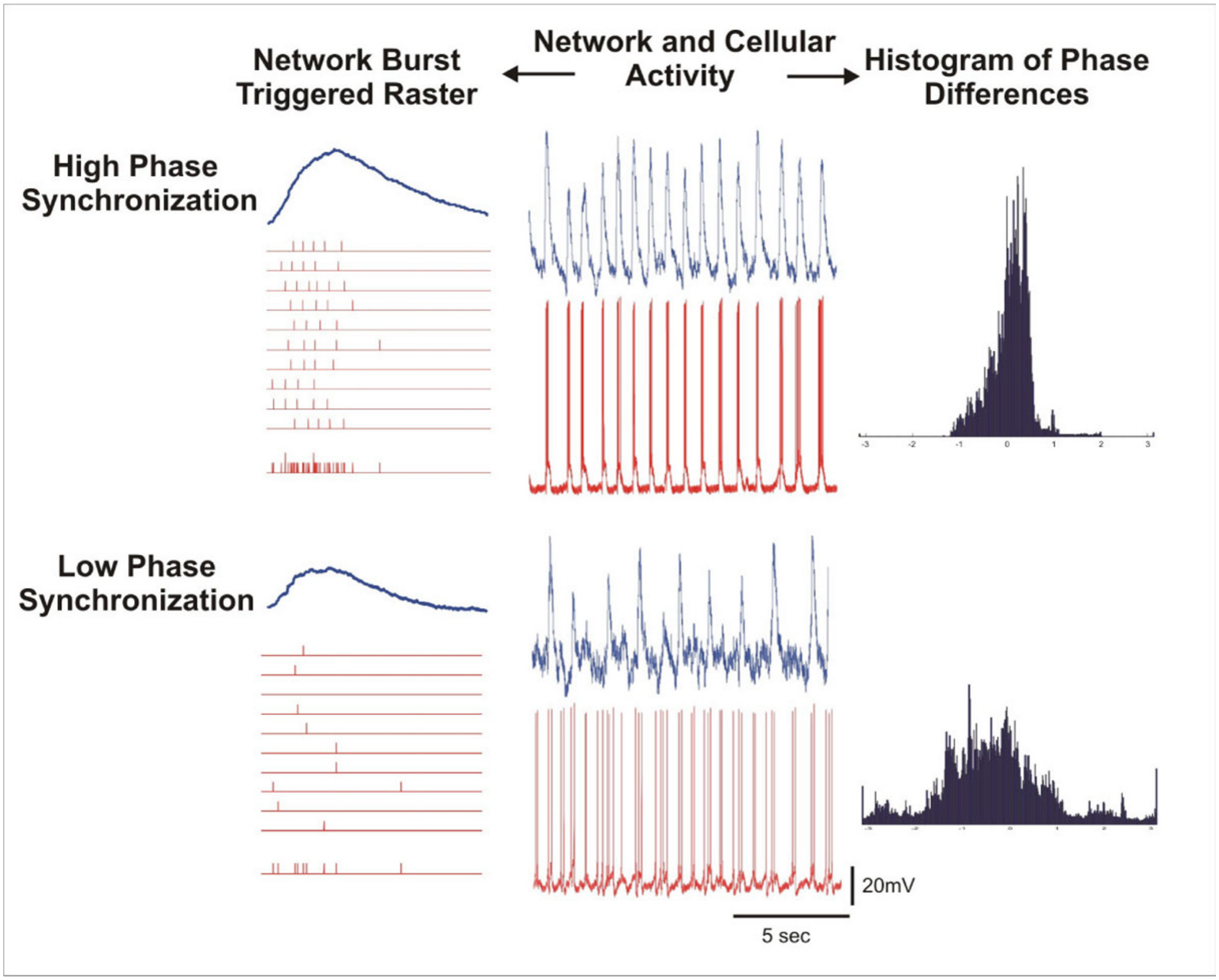

Figure 2
Phase Synchronization.