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Phase response curves determine network activity of all to all networks of pulse coupled oscillators

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Introduction

Under the assumptions that the oscillator relaxes back to the limit cycle between perturbations and that the perturbations received in a circuit are similar to those used to generate the phase resetting curve (PRC), the PRC of the individual components of the circuit are used to predict clustering in all to all networks. Applications include central pattern generators for repetitive motor neuron behavior and the synchronization of assemblies of cortical neurons postulated to mediate cognitive functions.

Methods

For identical oscillators, the synchronous mode exists; however periodicity criteria were developed for the splay mode (The simplest example of the splay mode is antiphase locking of two oscillators.). Stability for both cases was determined by constructing pulse coupled maps for an assumed firing order based on the PRCs by linearizing the coupled map. The nonlinear summation of phase resetting in response to multiple inputs was explicitly incorporated. The stability of clusters of neuronal oscillators is determined by applying the synchrony criterion within clusters and splay criterion between clusters. A pulse coupled simulator that does not assume any firing order, but merely takes an initial condition in terms of phases of the network oscillators and updates the phases on each cycle based on the PRC was also developed (see Fig 1).

Results

The slope of the PRC at a phase of zero is the key determinant of synchronization properties, but surprisingly, a robust antiphase mode between two clusters can sometimes enforce synchronization within a cluster even if synchrony with a stand-alone cluster is not stable. Simulations with Wang and Buzsaki (WB) model neurons confirm that the PRCs contain all the information required to predict network activity in the parameter ranges studied.

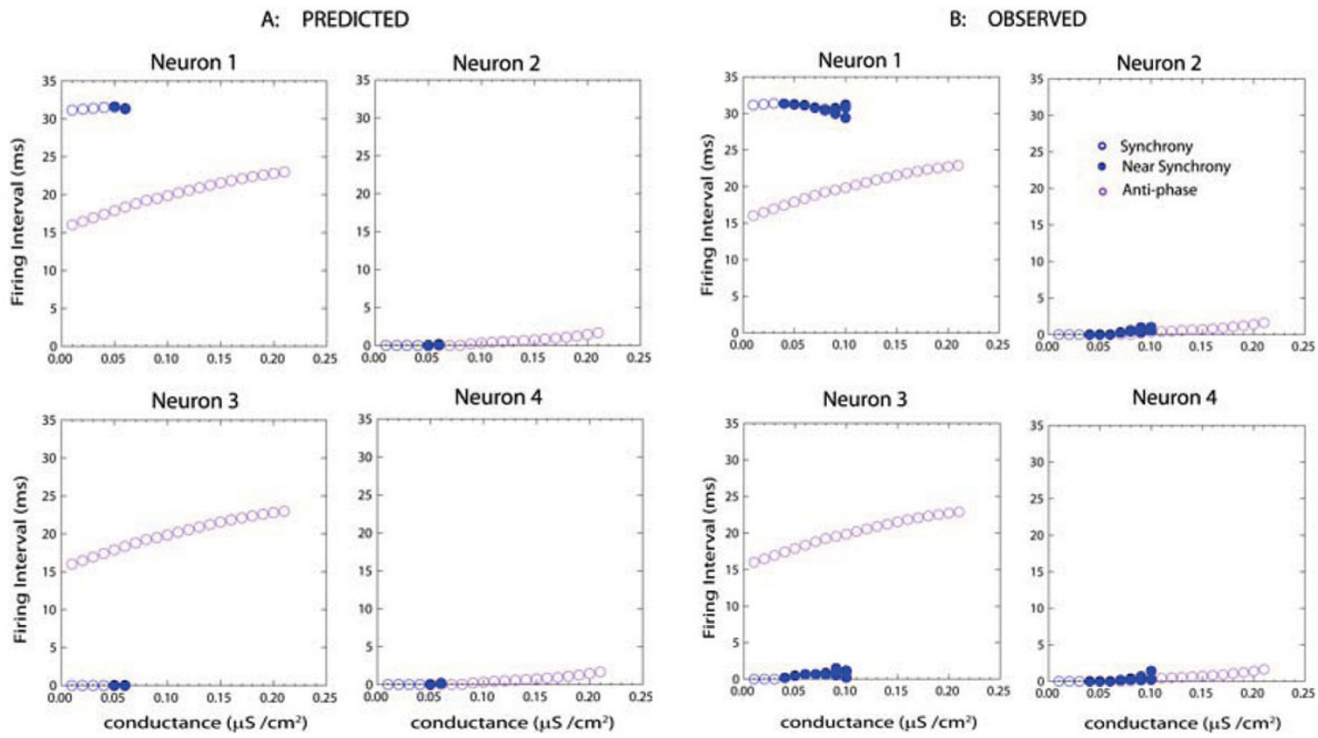

Figure 1
Predictions of the pulse coupled simulator (A: PREDICTED) compared to the observed modes (B: OBSERVED). The results are for a four neuron network with Type I PRC and inhibitory synaptic connections. The intervals between the firing time of each neuron and that of the neuron that immediately precedes it are shown for each neuron. Purple indicates two clusters in antiphase whereas blue indicates one synchronous (or nearly synchronous) cluster.

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