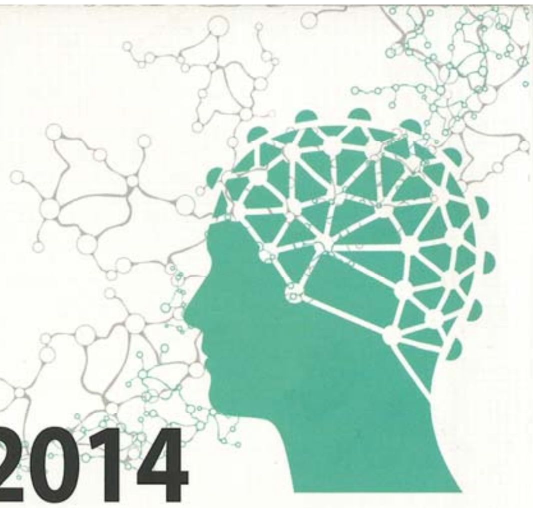

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TRANSFORMATION OF GRID CELL ACTIVITY TO PLACE CELL REQUIRES ASYMMETRIC RAMP-LIKE INPUTS: A COMPUTATIONAL MODEL STUDY

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Place cells in the hippocampus and grid cells in the medial entorhinal cortex(mEC) are specialized in spatial information processing. Especially, place cells show spike phase precession where each spike codes for the exact location within the place field. Place cell receives inputs from mEC, but how hexagonal 2-D grid firing can be transformed into 1-D place firing with the phase precession is still unknown. Therefore, we constructed computational models to investigate the mechanism underlying the transformation from the grid cell to place cell. The oscillatory-interference(OI) grid cell model was based on in vivo trajectory data, and place cell was modeled using a multi-compartment Hodgkin-Huxley (HH) model which received 5 Hz theta oscillation. The synapse between the grid cell and the place cell was modeled using the single synapse double exponential equation. Spike phase was calculated relative to the theta oscillation. Simulations and analysis were done using the NEURON and MATLAB. The OI grid cell model successfully generated spikes with the grid-pattern, and the grid input transformed into EPSPs of place cells gave rise to different ramp shapes. Phase precession of place cells were analyzed upon receiving the excitatory ramp inputs. By categorizing the ramp inputs by their skewness, we found that more significant phase precession occurs as the EPSP is more positively skewed(r^2=0.360), indicating a positive-skewed ramp input is required for phase precession. Our results demonstrate that the grid cell inputs to place cell give rise to compound EPSPs with different ramp shapes, and the positively-skewed excitatory ramp input alone is sufficient to generate hippocampal spike phase precession. However, both our OI and HH models include only simplified electrophysiological characteristic of the cells. Models with more detailed cell and network properties would help us to better understand the mechanism underlying the transformation from the grid cell to place cell.

Key Words: Place cell, Grid cell, Phase precession, Computational model, Spatial information

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NOISE-INDUCED BURST AND SPIKE SYNCHRONIZATIONS IN AN INHIBITORY SMALL-WORLD NETWORK OF SUBTHRESHOLD BURSTING NEURONS

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For modeling complex synaptic connectivity, we consider the Watts-Strogatz small-world network which interpolates between regular lattice and random network via rewiring, and investigate the effect of small-world connectivity on emergence of noise-induced population synchronization in an inhibitory population of subthreshold bursting Hindmarsh-Rose neurons. Thus, noise-induced slow burst synchronization and fasg spike synchronization are found to appear in a synchronized region of the J−D plane. As the rewiring probability p is decreased from 1 (random network) to 0 (regular lattice), the region of spike synchronization shrinks rapidly in the J−D plane, while the region of the burst synchronization decreases slowly. Population synchronization may be well visualized in the raster plot of neural spikes which can be obtained in experiments. Instantaneous population firing rate, R(t), which is directly obtained from the raster plot of spikes, is a realistic population quantity exhibiting collective behaviors with both the slow bursting and the fast spiking timescales. Through frequency filtering, we separate R(t) into Rb(t) (describing the slow bursting behavior) and Rs(t) (describing the fast intraburst spiking behavior). Then, we develop thermodynamic order parameters and statistical-mechanical measures, based on Rb(t) and Rs(t), for characterization of the burst and spike synchronizations of the bursting neurons and show their usefulness in explicit examples. With increase in p, both the degrees of the burst and spike synchronizations are found to increase because more long-range connections appear. However, they become saturated for some maximal values of p because long-range short-cuts which appear up to the maximal values of p play sufficient role to get maximal degrees of the burst and spike synchronizations.

Key Words: Subthreshold Bursting Neurons, Small-World Networks, Noise-Induced Burst and Spike Synchronizations, Computational model, Spatial information