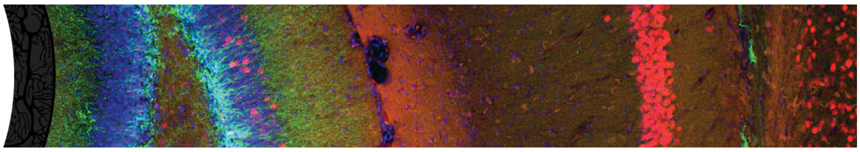
NEUROSCIENCE 2021 50TH ANNUAL MEETING



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Session P863 - Spatial Navigation: Circuits

Add to Itinerary

P863.02 - HCN channels stabilize heterogeneous conductance-based continuous attractor networks

November 9, 2021, 9:30 AM - 10:30 AM | Virtual Only

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Abstract

Continuous attractor network (CAN) models lend a powerful theoretical framework that has provided deep insights about grid cells and head-direction cells. Most models employed for understanding CAN dynamics rely on homogeneous rate-based or artificially spiking neurons with repeating motifs of structured synaptic connectivity. However, this formulation precludes detailed analyses of the impact of neural circuit components and associated heterogeneities on CAN dynamics. To address this caveat, we built multiple populations of conductance-based, physiologically constrained, one-dimensional CAN models consisting of distinct excitatory (E) and inhibitory (I) cell layers, endowed with different heterogeneities. CAN models built with homogeneous E & I neurons were tunable and scalable to exhibit “activity bump” movement across the neural lattice, irrespective of the relative excitability of the neurons. Next, we employed independent stochastic search algorithms to generate biophysically heterogeneous and physiologically validated populations of E (n=449) & I (n=930) neurons. We found I-layer, but not E-layer, heterogeneities to impact attractor dynamics. Specifically, none of 1000 randomized networks built with I-layer heterogeneities manifested activity bump propagation, whereas all 100 randomized networks with E-layer heterogeneities exhibited stable propagation. To address the impact of synaptic heterogeneities on CAN dynamics, we picked distinct homogeneous networks and randomly scaled all synaptic strengths across multiple trials. We found ~65% of these networks to be stable, with no interdependencies or low-dimensional manifolds within the parametric space of stable networks. Finally, motivated by the ability of intrinsic neuronal resonance to stabilize rate-based CAN networks, we asked if modulation of HCN channels altered network stability. Strikingly, the proportion of stable models exhibiting activity propagation increased with increase in HCN-channel density, varying from ~60% to ~85% of the population. As HCN channels also contribute to reduction in excitability, we performed excitability-matched controls with fast HCN channels that do not introduce resonance. Fast HCN channels did not stabilize CAN model dynamics over a wide range of conductance values, suggesting resonance as a critical requirement for stabilization of network dynamics. Together, our conductance-based CAN models demonstrated the critical role of inhibitory neuronal excitability on CAN dynamics, and suggest intrinsic neuronal resonance as an efficacious mechanism to stabilize perturbation introduced by synaptic heterogeneities.