Selectivity and Sparseness in Randomly Connected Balanced Networks

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Abstract:

Neurons in sensory cortex show stimulus selectivity and sparse population response, even in cases where no strong functionally specific structure in connectivity can be detected. This raises the question whether selectivity and sparseness can be generated and maintained in randomly connected networks. We consider a recurrent network of excitatory and inhibitory spiking neurons with random connectivity, driven by random projections from an input layer of stimulus selective neurons. In this architecture, the stimulus-to-stimulus and neuron-to-neuron modulation of total synaptic input is weak compared to the mean input. Surprisingly, we show that in the balanced state the network can still support high stimulus selectivity and sparse population response. In the balanced state, strong synapses amplify the variation in synaptic input and recurrent inhibition cancels the mean. Functional specificity in connectivity emerges due to the inhomogeneity caused by the generative statistical rule used to build the network. We further elucidate the mechanism behind and evaluate the effects of model parameters on population sparseness and stimulus selectivity. Network response to mixtures of stimuli is investigated. It is shown that a balanced state with unselective inhibition can be achieved with densely connected input to inhibitory population. Balanced networks exhibit the "paradoxical" effect: an increase in excitatory drive to inhibition leads to decreased inhibitory population firing rate. We compare and contrast selectivity and sparseness generated by the balanced network to randomly connected unbalanced networks. Finally, we discuss our results in light of experiments.

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