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Neural Network Mechanisms Underlying the Combination Sensitivity Property in the HVC of Songbirds

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Abstract : The temporal order of information processing in the brain is an important code in many acoustic signals, including speech, music, and animal vocalizations. Despite its significance, surprisingly little is known about its underlying cellular mechanisms and network manifestations. In the songbird telencephalic nucleus HVC, a subset of neurons shows temporal combination sensitivity (TCS). These neurons show a high temporal specificity, responding differently to distinct patterns of spectral elements and their combinations. HVC neuron types include basal-ganglia-projecting HVCX, forebrain-projecting HVCRA, and interneurons (HVC¬INT), each exhibiting distinct cellular, electrophysiological and functional properties. In this work, we develop conductance-based neural network models connecting the different classes of HVC neurons via different wiring scenarios, aiming to explore possible neural mechanisms that orchestrate the combination sensitivity property exhibited by HVCX, as well as replicating in vivo firing patterns observed when TCS neurons are presented with various auditory stimuli. The ionic and synaptic currents for each class of neurons that are presented in our networks and are based on pharmacological studies, rendering our networks biologically plausible. We present for the first time several realistic scenarios in which the different types of HVC neurons can interact to produce this behavior. The different networks highlight neural mechanisms that could potentially help to explain some aspects of combination sensitivity, including 1) interplay between inhibitory interneurons' activity and the post inhibitory firing of the HVCX neurons enabled by T-type Ca2+ and H currents, 2) temporal summation of synaptic inputs at the TCS site of opposing signals that are time-and frequency- dependent, and 3) reciprocal inhibitory and excitatory loops as a potent mechanism to encode information over many milliseconds. The result is a plausible network model characterizing auditory processing in HVC. Our next step is to test the predictions of the model.

Keywords : combination sensitivity, songbirds, neural networks, spatiotemporal integration
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