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# Neural Networks Underlying the Generation of Neural Sequences in the HVC

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**Abstract :** The neural mechanisms of sequential behaviors are intensively studied, with songbirds a focus for learned vocal production. We are studying the premotor nucleus HVC at a nexus of multiple pathways contributing to song learning and production. The HVC consists of multiple classes of neuronal populations, each has its own cellular, electrophysiological and functional properties. During singing, a large subset of motor cortex analog-projecting HVCRA neurons emit a single 6-10 ms burst of spikes at the same time during each rendition of song, a large subset of basal ganglia-projecting HVCX neurons fire 1 to 4 bursts that are similarly time locked to vocalizations, while HVCINT neurons fire tonically at average high frequency throughout song with prominent modulations whose timing in relation to song remains unresolved. This opens the opportunity to define models relating explicit HVC circuitry to how these neurons work cooperatively to control learning and singing. We developed conductance-based Hodgkin-Huxley models for the three classes of HVC neurons (based on the ion channels previously identified from in vitro recordings) and connected them in several physiologically realistic networks (based on the known synaptic connectivity and specific glutaminergic and gabaergic pharmacology) via different architecture patterning scenarios with the aim to replicate the in vivo firing patterning behaviors. We are able, through these networks, to reproduce the in vivo behavior of each class of HVC neurons, as shown by the experimental recordings. The different network architectures developed highlight different mechanisms that might be contributing to the propagation of sequential neural activity (continuous or punctate) in the HVC and to the distinctive firing patterns that each class exhibits during singing. Examples of such possible mechanisms include: 1) post-inhibitory rebound in HVCX and their population patterns during singing, 2) different subclasses of HVCINT interacting via inhibitory-inhibitory loops, 3) mono-synaptic HVCX to HVCRA excitatory connectivity, and 4) structured many-to-one inhibitory synapses from interneurons to projection neurons, and others. Replication is only a preliminary step that must be followed by model prediction and testing.

**Keywords :** computational modeling, neural networks, temporal neural sequences, ionic currents, songbird
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