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The neural dynamics of song syntax in songbirds[1]

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Songbird is “the hydrogen atom” of the neuroscience of complex, learned vocalizations such as human speech. Songs of Bengalese finch consist of sequences of syllables. While syllables are temporally stereotypical, syllable sequences can vary and follow complex, probabilistic syntactic rules, which are rudimentarily similar to grammars in human language. Songbird brain is accessible to experimental probes, and is understood well enough to construct biologically constrained, predictive computational models. In this talk, I will discuss the structure and dynamics of neural networks underlying the stereotypy of the birdsong syllables and the flexibility of syllable sequences. Recent experiments and computational models suggest that a syllable is encoded in a chain network of projection neurons in premotor nucleus HVC (proper name). Precisely timed spikes propagate along the chain, driving vocalization of the syllable through downstream nuclei. Through a computational model, I show that that variable syllable sequences can be generated through spike propagations in a network in HVC in which the syllable-encoding chain networks are connected into a branching chain pattern. The neurons mutually inhibit each other through the inhibitory HVC interneurons, and are driven by external inputs from nuclei upstream of HVC. At a branching point that connects the final group of a chain to the first groups of several chains, the spike activity selects one branch to continue the propagation. The selection is probabilistic, and is due to the winner-take-all mechanism mediated by the inhibition and noise. The model predicts that the syllable sequences statistically follow partially observable Markov models. Experimental results supporting this and other predictions of the model will be presented. We suggest that the syntax of birdsong syllable sequences is embedded in the connection patterns of HVC projection neurons.

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