Slow time-scales in songbird neural sequence generation

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Synfire theories demonstrate that redundant, feedforward chains of neurons can stably produce temporal sequences with high precision. The fundamental time-scale of the synfire chain is the time-scale of an individual link in the chain. In songbirds, sparse, stereotyped bursts of projection neurons in nucleus HVC resemble a synfire chain built from 5ms units[1]. Here we present evidence that firing times of projection neurons and interneurons in HVC are grouped together, but over time-scales significantly slower than the time-scale of individual neural units. This synchrony is evident both within HVC in a single hemisphere, and across hemispheres. In parallel, long term recordings with minimally invasive electrodes reveal that the precise firing patterns of interneurons are stable for as long as they have been observed—weeks to months. We consider theoretically how slow time-scale synchronous patterns in HVC may stabilize sequence production based on topological chains.

In addition to this mesoscopic time-scale in HVC neural activity, we demonstrate that some bird songs are shaped by long-range correlations in syntax. Recent behavioral work in Bengalese finches[2,3] suggests that song contains non adjacent dependencies betweens syllables. We apply prediction suffix trees[4] to analyze the syntax of a complex singer, the canary. This analysis reveals that for canaries, the decision about what to sing next depends on choices made up to ten seconds earlier in song.

Taken together, these results indicate that birdsong sequence generation is governed by stereotyped dynamics in wide a range of time-scales—timescales that must be integrated into any parsimonious dynamical or statistical model for song.

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