

Observed pre-motor firing patterns constrain a network model for vocal learning

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Electrophysiological recordings in adult zebra finch indicate that firing patterns in the robust nucleus of arcopallium (RA), an area activating vocal motor neurons during singing, are (i) only weakly correlated across neurons and (ii) only weakly correlated with the acoustic signal of song. Furthermore, these recordings suggest that (iii) firing in RA neurons tends to be bimodal; at any given time a neuron is either silent or firing at high rate (Leonardo et al., 2005).

Motivated by these experimental results, we pose two broad questions. First, what can we infer from these experimentally observed properties about the architecture of the underlying song generation system in the adult zebra finch? Second, what can we infer about the learning process by which the bird arrives at a mature song driven by neural activity with these properties?

In the current study we use neural network models to address these questions. We show that RA firing patterns that satisfy (i) and (ii) occur quite generally in network models of the song generation system in conjunction with stochastic learning rules. Because of the vast convergence from thousands of RA neurons to a small number of muscles, multiple different firing patterns in RA neurons can sum to produce the same motor output. Stochasticity in the learning rule or in initial conditions insure that the system sample broadly from among all possible firing patterns. The resulting RA firing patterns are weakly correlated across neurons and weakly correlated with acoustic output, experimentally observed properties (i) and (ii). In generic network models, however, bimodal firing patterns, property (iii), make up only a small subset of the possible driving patterns for a given output. As a result, we conclude that either something additional and special about network architecture itself constrains firing patterns to be bimodal or else, something about the learning process selects only bimodal firing patterns. We show that stochastic learning rules on saturating input synapses to RA result in bimodal firing patterns, similar to those observed experimentally. We propose several different, potentially experimentally distinguishable, stochastic learning mechanisms. We also propose and investigate other possible learning mechanisms to see whether they too can generate firing patterns that are consistent with experiment. Finally, other motor systems do not exhibit firing patterns with similar properties. Why not? We discuss possible implications about the nature of memorized vocalization, and more generally, about practiced, stereotyped actions, in contrast to other sorts of motor output.

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References

[1] Ensemble Coding of Vocal Control in Birdsong. A. Leonardo and M.S. Fee, *Journal of Neuroscience* 25(3):652-661, 2005.