Abstract of Presentation

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Statistical modeling of sequential behavior, decision making, and emotional information processing.

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Hidden Markov processes can explain complex sequencing rules of birdsong: a statistical analysis and neural network modeling

Abstract :
Complex sequencing rules observed in birdsong provide an opportunity to investigate the neural mechanism for generating complex sequential behaviors. In this study, we investigate the statistical properties of the complex birdsong of the Bengalese finch. Based on manual-annotated syllable labels, we first show that there are significant higher-order context dependencies in Bengalese finch songs, that is, which syllable appears next depends on more than one previous syllable. We then investigated the statistical models for explaining the higher-order dependencies. To do this, we used the Bayesian inference method and a model selection technique. We applied hidden Markov models (HMMs) with various context dependencies to the acoustic features of Bengalese finch song and selected a suitable model based on the Bayesian model comparison, the predictive performance, and the degree of agreement with manual annotation. As a result, the first-order HMM, in which the present state depends only on the last state, was sufficient and suitable for describing the Bengalese finch songs. We found that this result is due to a many-to-one state mapping to song syllables by which the first-order HMM can generate apparently complex sequences with higher-order dependencies. These results imply that the songbird brain has parsimonious neural representation for generating apparently complex sequences. To describe a possible mechanism by which the neural circuit acquires a representation of sequence with the many-to-one mapping, we developed a simple neural network model of the nucleus HVC in Bengalese finch. We show that a synaptic modification rule with a Hebbian component and heterosynaptic competition enables the network to acquire such implementation. Our study will give insight into the neural mechanisms of learning and representation of complex sequential behavior.