Neural Dynamics
Underlying Complex Behavior in a Songbird

Thesis by

Anthony Leonardo

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Abstract

Zebra finches memorize a tutor song as juveniles, and then faithfully reproduce this song for the remainder of their lives. This thesis investigates how the intricate and concerted activity of ensembles of neurons in the zebra finch brain gives rise to this complex behavior.

The first section of the thesis demonstrates how neurons in RA, a pre-motor song control nucleus, coordinate their activity to generate the instantaneous spectral and temporal structure seen in the song. Similar sounds are produced by entirely different ensembles of RA neurons. Additionally, rapidly changing patterns of RA neural activity are capable of generating constant acoustic outputs. This is a new form of neural coding, previously unobserved in any other system. This unusual neural representation provides a concise account of an unexplained aspect of song learning.

The second part of the thesis develops a new, noninvasive method of altering the auditory feedback heard by singing zebra finches. This type of feedback perturbation causes the normally stable songs of adult birds to deteriorate, indicating that auditory feedback is essential to song control throughout life. Restoration of the normal auditory feedback heard by these birds enables the gradual recovery of their original songs, demonstrating that a memory of the original song persists in the song control system despite the destabilization of the behavior. The song is thus maintained by an active feedback control process.

The final project investigates the role of nucleus LMAN in real-time song control via auditory feedback. Neurons in nucleus LMAN were previously believed to compare auditory feedback to a memorized song template. The result of this comparison was thought to be used as an error-correction signal to update the motor control program. By recording from individual LMAN neurons while simultaneously manipulating the auditory feedback heard by the singing bird, it is shown that during singing, rather than auditory feedback, LMAN processes an efference copy of the motor commands used to generate the bird's song. This suggests a different model of the system, in which the efference copy is the basis of the real-time error-correction signal.

Taken together, these three projects significantly expand our knowledge of the neural mechanisms responsible for the generation of birdsong.

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