The Role of Motor Neural Circuitry in the Perception of Vocal Sounds in Songbirds

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Introduction

- Neural circuits for complex behaviors require that sensory and motor representations of a given action be integrated. One example of such sensory-motor integration is the tight linkage between vocal perception and production.
- The "motor theory of speech perception" suggests that the neural circuits for *perceiving* speech sounds rely in part on circuits that control *production* of those same sounds.
- My research uses songbirds as a model for testing this idea because, similarly to humans, they learn their vocalizations and specific brain regions control their vocal motor output.

HYPOTHESIS: If vocal perception relies in part on neural circuits for vocal production, then lesioning a portion of the brain known to be directly involved in vocal production should hinder the bird's ability to discriminate between different vocal stimuli.

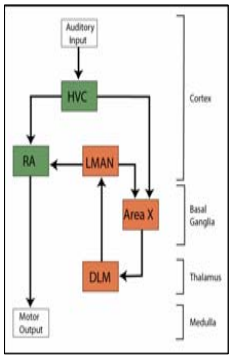


Figure 1: The brain region RA (robust nucleus of the arcopallium) is located in motor cortex and controls vocal production by projecting directly to vocal motor neurons. Auditory brain regions (orange) receive sensory input and project to the vocal motor region HVC.

I lesioned **RA**, the cortical brain region that controls vocal motor output. Lesions of RA cause substantial disruption of normal vocal behavior. I asked whether RA lesions also disrupted the ability of songbirds to perceptually discriminate vocal calls that varied in fundamental frequency (FF).

Lesions of Vocal Motor Cortex Impairs Perception of Vocal Sounds

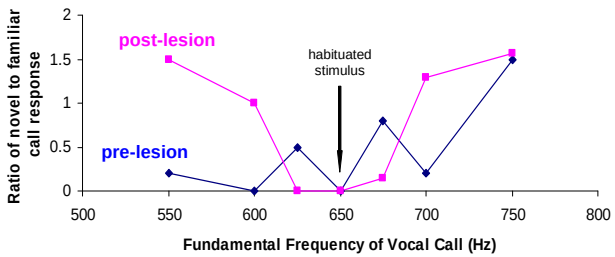
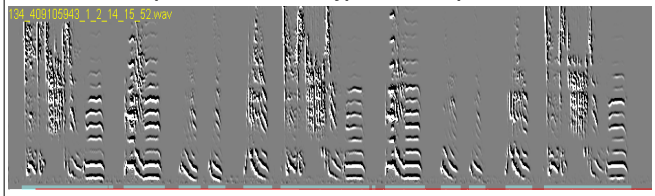


Figure 2: A high ratio indicates that the bird clearly perceives the test stimulus as different from the habituated stimulus. Prior to receiving a lesion of RA, this finch could discriminate between two harmonic stacks that differ in fundamental frequency by 25Hz, but cannot perform this same discrimination task after the RA lesion is made.

Pre-lesion vocal production is stereotyped and complex



Post-lesion vocal production is much less complex

Figure 3: After the cortical motor region RA is lesioned, the bird is unable to produce its learned song, and its vocal production is reduced to simple harmonic stacks.

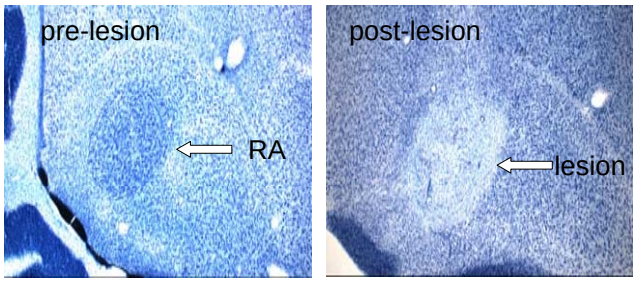


Figure 4: The large neural cell bodies in RA makes it visually distinct from the surrounding tissue.

Results:

- One subject examined thus far had 100% of RA lesioned (Fig 4).
- Perception test results (Fig 2) indicate that the lesion led to a decreased ability to distinguish vocal calls that are similar to the habituated stimulus (e.g., 625 and 675 Hz).
- As expected, vocal motor production was severely impaired following lesion of RA (Fig 3).

Discussion:

- This result suggests that circuits that control vocal production in RA are integrated with those that process auditory information as birds are discriminating between vocal stimuli.
- Information from both auditory and motor systems contribute to the perception of vocal stimuli.
- This pattern of results supports the idea that the neural circuits for *perceiving* speech sounds rely in part on circuits that control *production* of those same sounds.

Methods:

- The stimuli used in this experiment are synthetic vocal calls (harmonic stacks) that vary only in their fundamental frequency (FF); they are modeled after normal calls used for individual recognition.
- Zebra finches respond to vocal calls by producing a call of their own (call-back response).
- Habituation: a single call stimulus (650 Hz) was presented repeatedly until the call-back response habituated (the bird no longer responded).
- Test: habituation was followed by randomized presentations of novel test stimuli that varied in FF, interleaved with the habituation stimulus.
- A bird's ability to perceive the difference between vocal calls was scored by comparing the number of call-back responses to novel test stimuli to the number of call-back responses to the habituated stimulus.
- Following this behavioral test of perception, birds were anesthetized and RA was lesioned; then the perceptual abilities of each bird were tested a second time.