Duke scientists map brain pathway for vocal learning

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Scientists at Duke University Medical Center have identified neurons in the songbird brain that convey the auditory feedback needed to learn a song.

Their research lays the foundation for improving human speech, for example, in people whose auditory nerves are damaged and who must learn to speak without the benefit of hearing their own voices.

"This work is the first study to identify an auditory feedback pathway in the brain that is harnessed for learned vocal control," said Richard Mooney, Ph.D., Duke professor of neurobiology and senior author of the study. The researchers also devised an elegant way to carefully alter the activity of these neurons to prove that they interact with the motor networks that control singing.

The study, supported by an NIH grant, was published online in *Neuron* on Jan. 13.

Vocal learning isn't a simple process. "One challenge the brain faces when trying to learn a new behavior is that it only receives feedback about performance tens or even hundreds of milliseconds after it has generated the motor commands controlling that performance," Mooney said. "The challenge is pushed to an extreme if the brain has to use this sensory information in a retrospective way and still make corrections with millisecond precision, as humans and songbirds do when they learn to vocalize."

The problems that juvenile birds solve when they learn a song from a tutor bird are similar to the problems humans solve when we learn to speak, and birds and humans exploit similar neural systems to reach this solution, Mooney said.

The major question of this research was how the brain encodes and harnesses auditory feedback to shape the vocal performance in juvenile birds that are learning to sing.

In a painstaking experiment, lead author Huimeng Lei, Ph.D., used fine microelectrodes to locate neurons that become active in the pupil's brain when it hears its own song, Mooney said. "This was a very difficult procedure that had to be exquisitely accurate. Huimeng was able to get the recordings working just right to locate the feedback-sensing neurons."

Once the scientists knew they had located the correct set of neurons, they passed a brief pulse of electricity through the implanted electrodes to alter neural activity associated with one of the notes that the pupil was learning to sing.

"We think that the stimulation alters what the pupil bird perceives, and it is this altered perception that results in the note becoming distorted (as it sings the song back)," Mooney said. "In contrast, if we stimulated directly in the motor network (which produces the note) we would trigger an immediate distortion of the targeted song syllable."

Because birds sing their song with millisecond precision, the scientists could determine how precisely the brain learned to assign perceived error to the part of the song where the stimulation occurred. "The acoustical features of the stimulated region of the song grew distorted over time," Mooney said.

Three findings of interest emerged. First, the distortion in the bird's singing was delayed and showed up anywhere from hours to weeks after the bird first heard the electrical noise pulse in its song.

Second, the distortion always came in the same place in the pupil bird's song. This means the distortion was temporally precise and occurred at the exact point in the song where the electrical "noise" was introduced. "The brain somehow is learning to associate the stimulation with a certain part of the performance, and then alter the performance accordingly," Mooney said.

Third, by disrupting neural activity at different stages of the learning process, they determined that the distortion effects were strongly age-dependent. The target portion of the song degraded very quickly in the younger birds, sometimes within an hour. The older birds who experienced electrical interference kept singing properly for a while, but slowly their singing degraded, over a period of weeks.

"Because we are directly injecting an electrical pulse into the auditory feedback pathway, the changing ability of the brain to respond to the perceived error in performance likely reflects changes in the motor network itself," Mooney said.

Song precision is vital to songbirds because females select mates based in part on the temporal precision with which they sing. Temporal precision is also highly important in human speech, because acoustical features of two speech sounds may differ on the millisecond level.

This study lays the groundwork for scientists to improve human speech. For example, people whose auditory nerves are damaged may benefit as scientists explore how to stimulate auditory feedback pathways in the human brain that are important for speech learning. This is especially true for older children and adults who have been deaf and who need to learn speech well past the prime time for vocal learning, Mooney said.

This study also opens the door to exploring how the brain compares performance-related feedback to a sensory model, which is the basis of imitation, Mooney said.

"Imitation is the wellspring for much of human culture," he noted. "Because it would be impossible to use humans in experiments about initial vocal learning, songbird tutors and students provide a beautiful substitute system so that we can study the detailed brain mechanisms that underlie this relatively complex type of learning."

Provided by Duke University Medical Center

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