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Bird Brains Show How Trial and Error May Contribute to Learning

The adult male zebra finch knows only one scratchy tune learned in its youth, which it performs repeatedly and intensely when females are listening. But occasionally, the finch might improvise, experimenting with a slower, more sultry variation or emphasizing different notes.

Neurobiologists studying the finch now say the improvisation arises from a component of a crucial learning circuit in a section of the forebrain that seems to generate the trial and error necessary to master sophisticated motor skills, such as singing in birds or speech and sports in humans.

"The basal ganglia play a special role in generating motor variability."

— Mimi Kao

"It means this part of the brain is important for instructing or allowing changes in the song," said Mimi Kao, first author of a paper in the February 10, 2005, issue of the journal *Nature* that demonstrates how the region modulates bird song in real time. Kao, a Howard Hughes Medical Institute (HHMI) predoctoral fellow, is in the final months of her doctoral training in the laboratory of co-author Allison Doupe at the University of California, San Francisco's Keck Center for Integrative Neuroscience.

A similar brain pathway in humans may explain how children learn to talk by listening to themselves and others, and how adults learn and hone new motor skills, such as tennis. The process relies on feedback about what works and what doesn't, also called experience-dependent or performance-based learning.

"That all requires paying attention to how we're doing, experimenting with different things, and gradually getting better," said senior author Michael Brainard, assistant professor of physiology at UCSF, whose lab is funded in part by a grant from HHMI. "It makes sense that one part of the brain has as part of its job introducing that kind of variability."

Kao began with an experiment to stimulate the region of the forebrain called LMAN (lateral magnocellular nucleus of the anterior nidopallium). In the

avian brain, LMAN receives input about complex movements from the basal ganglia and forwards the information to motor neurons that participate in song production. Without LMAN, scientists have long known, a young bird cannot learn its song, but an adult bird can sing its song without that region of the brain. A postdoctoral fellow on another project had noticed greater and more variable brain activity when the finches were singing to themselves compared to when they were serenading females. Kao wondered whether she could cause changes in bird song by manipulating this region.

Learning takes some time, so Kao expected to wait for her results. But stimulating the LMAN had an immediate impact. The tune and rhythm of the basic song did not change, but a tiny burst of electricity would show up a few notes later as a change in volume or pitch at a particular time in the song.

The variations are usually too subtle for human ears, Kao said, but sensitive recording equipment can detect them. The systematic trials were possible with the aid of a computer program that could track the bird twitters and trigger stimulations to LMAN at precise moments to elicit measurable effects on a predetermined syllable, song after song.

The researchers found that different areas of LMAN tuned the same note in different directions, one area raising the pitch of a certain note and another area lowering its frequency. The moment-by-moment influence of this brain region on song is a new observation, Brainard said.

Next, the researchers analyzed the relationship between song and the natural neural activity of LMAN during the two types of male finch song, the performance-quality song directed at females, accompanied by some posturing and feather plumping, and the experimental solo variations, called "undirected," akin to singing in the shower. The brain region showed greater activity and more variable signaling during the undirected song, suggesting that this area is generating the variations of solo song.

Finally, they showed that birds with damage to that region of the brain lost their improvisational ability. In birds without a functioning LMAN, Kao and her colleagues still found differences between the two types of songs, but the solo song lost its subtle variations.

"In a nutshell, our paper suggests that the basal ganglia play a special role in generating motor variability," Brainard said. "It's been known for a long time that this circuit is important in learning. Our data supports the hypothesis that one of the things it could be doing is introducing variability."

Other researchers in the Brainard and Doupe labs are following up to see if the male mating song can be permanently altered by LMAN stimulation and whether females prefer the stable or variable song version.