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Study reveals how the songbird changes its tune

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By Dana Smith | Originally published onUCSF News[1]

A new study from UCSF shows that showed that Bengalese Finches, such as the ones pictured above, switch from generic to specific versions of their songs depending on the situation they are in.

Researchers at UC San Francisco have shown how the Bengalese finch, a domesticated songbird, can learn to tweak its song in specific ways depending on context, which could shed light on how the human brain learns to apply different rules depending on the situation, and have implications for understanding human language and movement disorders.

The study, published November 16, 2017 [2], in *Neuron*, showed that finches switch from generic to specific versions of their songs depending on the situation they are in. What?s more, the researchers identified two distinct areas in the birds? brains dedicated to this learning process: one region that encodes generalizable rules to produce default songs, and another area that can override the default pathway to produce different sounds for different contexts.

This is much like how your own brain learned in infancy the standard arm movement to reach and grab an object, but since then has also learned to adjust the force of your arm and grip of your hand based on the situation ? if, for example, you are picking up a full cup rather than an empty one.

?We wanted to understand how the brain balances the need to generalize learning of movements across many contexts with the need to produce specialized movements in specific contexts,? said Lucas Tian, a PhD student in the Brainard lab at UCSF and lead author on the study. ?This tendency has been shown in humans during movement and speech adaptation, but the neural mechanisms for how this balance is mediated are not known. Songbirds learn to sing in much the same way that humans learn to talk, so we thought the songbird would be a really nice model system to study this process.?

Finches learn to adjust song based on context

Neurobiologists such as UCSF?s Michael Brainard, PhD [3], professor of physiology and psychology and member of the Weill Institute for Neurosciences [4]at UCSF and senior author of the new study, have long studied birdsong for what it can teach us about how the human brain learns complex behaviors such as language, and how the same brain systems fall apart in movement diseases such as Parkinson?s disorder.

Michael Brainard, PhD
[3]

Much like human language, finch song is made up of sequences of ?syllables? ? units of sound similar to musical chords ? and is initially learned by young birds by mimicking adult ?tutors?. As adults, finches sing to attract mates, and can still learn to adjust their songs depending on context ? such as whether they are performing or practicing. Brainard?s lab previously showed [5] where in the brain finches incorporate feedback to improve their songs, but it was still unclear how finches applied these lessons to specific situations.

In the new study, Tian and Brainard wanted to know whether the birds could learn to selectively alter the pitch of specific syllables in their songs depending on context. To train the finches, the researchers played a burst of white noise when the birds sang a particular syllable outside of a pitch range set by the researchers. The birds quickly learned to shift the pitch of that syllable in their song to avoid the unpleasant sound.

The training only occurred when the finches sang the target syllable in a certain song sequence. However, the researchers observed that the birds also began to adjust the pitch of this syllable when it occurred in different parts of their song as well, suggesting they generalized the new rule across contexts. For example, the birds could be trained to raise the pitch of syllable C in the sequence A-B-C-D, but they might also begin singing a higher-pitched syllable C when they sing D-B-C-A as well. How much the birds adjusted their pitch in new contexts depended on how similar the sequence was to the original song.

To understand whether birds could learn different rules for different situations, the researchers next challenged the finches to modify the same syllable in opposite directions depending on the context. Remarkably, the birds learned to distinguish between contexts and varied their responses accordingly. For example, they learned to sing C in a lower pitch when the syllable was preceded by a B but in a higher pitch when it was preceded by an A.

?This type of sophisticated customization of learning to different contexts is very similar to human speech,? said Brainard. ?It?s hard to study what?s going on in the human brain during this process, but we can ask how this context-dependent learning is happening in birds. There is enough similarity in neural structures between birds and mammals to allow us to think that what we learn in the bird might apply more broadly.?

Two brain regions control rule-based and context-dependent learning

There are two brain regions in the finch that are critical for song learning and production: the song motor pathway, which is required to produce the sounds, and the anterior forebrain pathway (AFP), an executive function circuit that is involved in learning and modifying songs.

By chemically blocking the AFP while the birds learned to alter their pitch, the researchers were able to parse out the specific functions of the two regions during learning. They discovered that activation in the AFP was necessary for finches to learn to modify their pitch in a specific context. The AFP recognized when the target syllable occurred in the right sequence and communicated to the motor pathway that it should alter the pitch of the syllable. Without specific instructions, the motor pathway then started to incorporate and generalize this rule to other contexts, sometimes adjusting syllable pitch for other songs. The more feedback the motor pathway received to modify the pitch, the more reliably it did so across contexts.

However, when the birds learned to modify their pitch in two directions for two different contexts, the motor pathway could not deduce and generalize a single rule. Consequently, the AFP had to remain active to tell the motor pathway when and how to modify the pitch.

?This song pathway is a lot smarter and more flexible than we originally thought,? said Tian. ?It?s not just obligatorily producing a syllable. It has access to information about how to modify a task depending on the larger context.?

The study was supported by the Howard Hughes Medical Institute and the National Institutes of Health.

About UCSF Psychiatry

The UCSF Department of Psychiatry [6] and the Langley Porter Psychiatric Institute are among the nation's foremost resources in the fields of child, adolescent, adult, and geriatric mental health. Together they constitute one of the largest departments in the UCSF School of Medicine and the UCSF Weill Institute for Neurosciences, with a mission focused on research (basic, translational, clinical), teaching, patient care and public service.

UCSF Psychiatry conducts its clinical, educational and research efforts at a variety of locations in Northern California, including UCSF campuses at Parnassus Heights, Mission Bay and Laurel Heights, UCSF Medical Center, UCSF Benioff Children's Hospitals, Zuckerberg San Francisco General Hospital and Trauma Center, the San Francisco VA Health Care System and UCSF Fresno.

About the UCSF Weill Institute for Neurosciences

The UCSF Weill Institute for Neurosciences [7], established by the extraordinary generosity of Joan and Sanford I. "Sandy" Weill, brings together world-class researchers with top-ranked physicians to solve some of the most complex challenges in the human brain.

The UCSF Weill Institute leverages UCSF?s unrivaled bench-to-bedside excellence in the neurosciences. It unites three UCSF departments?Neurology, Psychiatry, and Neurological Surgery?that are highly esteemed for both patient care and research, as well as the Neuroscience Graduate Program, a cross-disciplinary alliance of nearly 100 UCSF faculty members from 15 basic-science departments, as well as the UCSF Institute for Neurodegenerative Diseases, a multidisciplinary research center focused on finding effective treatments for Alzheimer?s disease, frontotemporal dementia, Parkinson?s disease, and other neurodegenerative disorders.

About UCSF

UC San Francisco (UCSF) [8] is a leading university dedicated to promoting health worldwide through advanced biomedical research, graduate-level education in the life sciences and health professions, and excellence in patient care. It includes top-ranked graduate schools of dentistry, medicine, nursing and pharmacy; a graduate division with nationally renowned programs in basic, biomedical, translational and population sciences; and a preeminent biomedical research enterprise. It also includes UCSF Health, which comprises top-ranked hospitals ? UCSF Medical Center [9] and UCSF Benioff Children?s Hospitals in San Francisco [10] and Oakland [11] ? and other partner and affiliated hospitals and healthcare providers throughout the Bay Area.

Links
[1] https://www.ucsf.edu/news/2017/11/409031/study-reveals-how-songbird-changes-its-tune
[2] http://dx.doi.org/10.1016/j.neuron.2017.10.019
[3] http://profiles.ucsf.edu/michael.brainard
[4] https://weill.ucsf.edu/
[5] https://www.ucsf.edu/news/2012/05/12049/songbirds-learning-hub-brain-offers-insight-motor-control
[6] https://psychiatry.ucsf.edu/welcome-ucsf-psychiatry
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