

Two brain regions interact to help finches know when and how to tailor their songs for specific situations

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Bengalese finches. Credit: Brainard Lab / UCSF

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, 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, professor of physiology and psychology and member of the Weill Institute for

Neurosciences 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.

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](#) 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."

More information: *Neuron* (2017). [DOI: 10.1016/j.neuron.2017.10.019](#)

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