Genetically tailored instruction improves songbird learning

September 18 2019

Credit: Brainard lab / UCSF

Some recent research suggests that educational achievement can be predicted based on differences in our genes. But does this really mean that genes set limits on an individual's academic potential? Or do these findings just reflect how standardized educational systems reward certain inborn learning styles and aptitudes at the expense of others?

A new UC San Francisco study conducted in songbirds supports the second interpretation, showing that what at first appear to be genetic constraints on birds' song learning abilities could be largely eliminated by tailoring instruction to better match the birds' inborn predispositions.

Education researchers have long advocated for tailoring classroom instruction to the specific learning styles of different students. However, carefully controlled studies showing the benefits of this approach have been inconclusive.

"Untangling the influences of genes and experience on educational achievement in humans is extremely challenging," said Michael Brainard, Ph.D., a professor of physiology and psychiatry and Howard Hughes Medical Institute investigator in the UCSF Center for Integrative Neuroscience. "The advantage of studying this kind of learning in songbirds is that in our experiments we can carefully control both the genetic background of individual birds and the instruction that they receive."

Male Bengalese finches learn to sing early in life by mimicking their fathers' songs. This results in unique family variants of the species' song being passed down generation-to-generation from fathers to sons. For example, some bird families tend to be slower-than-average crooners while others prefer jauntier up-tempo melodies. Brainard and other researchers have long studied this apparent "cultural learning" as a model of how human children learn language and other complex behaviors from their parents.

When David Mets, Ph.D., joined Brainard's lab after completing a doctorate in genetics, he wanted to ask a different kind of question: How do genetic predispositions and early life experiences combine to generate an individual's behavior?

In a 2018 study, Mets and Brainard had shown that differences in song tempo between Bengalese finch nests is at least partly genetic: young birds tend to sing at the same tempo as their fathers, even if they have never heard their fathers' song. In their new study, published September 10, 2019 in *eLife*, Brainard and Mets turned to the question of learning aptitude. They observed that some young birds easily pick up the song of an adult "tutor," while others struggle to match the structure of the songs they hear. Were these apparent differences in learning aptitude also genetic, or was there something more subtle going on?

"Having discovered that there were genetically determined biases in song tempo that differ across families and are heritable, we became interested in the idea that if we could understand these biases, we might be able to harness them to influence learning outcomes," Mets said.

To answer this question, the researchers exposed young birds, which had never heard their father's song, to a computerized tutoring program that played a synthetic, experimentally controllable, version of the species' typical song.

The researchers first had the computerized tutoring program present all the birds with a "one-size-fits-all" tutor song that captured the average song structure and tempo found in the Brainard lab's finch colony. They found that only birds from families that had long preferred to sing at this average, intermediate tempo were able to learn this "standardized" song effectively, while birds with a family history of singing faster or slower songs weren't able to pick it up accurately.

In contrast, when the researchers presented birds with a synthesized tutor song tailored to their genetic background—slower-tempo songs for birds from slow-singing nests, medium tempo for birds from medium-singing nests, and higher tempo for birds from fast-singing nests—all the birds proved capable of accurately learning the song.

Strikingly, birds from slow-song families, who had performed the worst at picking up the structure of the colony's average-tempo song, did just as well as average-tempo birds—and better than fast-tempo birds—when the groups were presented with songs that matched their family histories.

The results suggest that much of what initially seemed like genetically driven differences in learning ability were actually explained by mismatches between birds' genetic predispositions and their early life experiences: Birds who appeared to be worse learners when they were tutored with the average song of the colony turned out to be fully capable of learning well when presented with a stimulus tailored to their family background.

"In this study, we were able to demonstrate the importance of matching instruction to genetics using the simple songs of birds," Mets said. "We think that similar interactions between genetic predispositions and early life experience are likely to be equally important for complex human behaviors."

Brainard, also a member of the UCSF Weill Institute for Neurosciences and the Kavli Institute for Fundamental Neuroscience, added, "Almost everyone agrees that complex traits like learning ability are shaped by both genes and experience, but what's not very widely appreciated is that nature and nurture don't just add up independently—they interact. We see this in our songbirds where it's the right match between inborn predispositions and early life experience that determines learning outcomes. Understanding the impact of these gene-experience interactions is critical to avoid misinterpretations of human genetic studies."

Mets and Brainard are now pursuing the specific genetic variants that drive differences in finch families' predisposition to learn faster or slower songs, as part of the lab's overarching goal to understand how genes and experience together shape the brain circuits underlying complex behaviors, which ultimately underlie an animal's individuality.

Authors: Mets and Brainard are the sole authors, and co-corresponding authors on the new study.

Provided by University of California, San Francisco