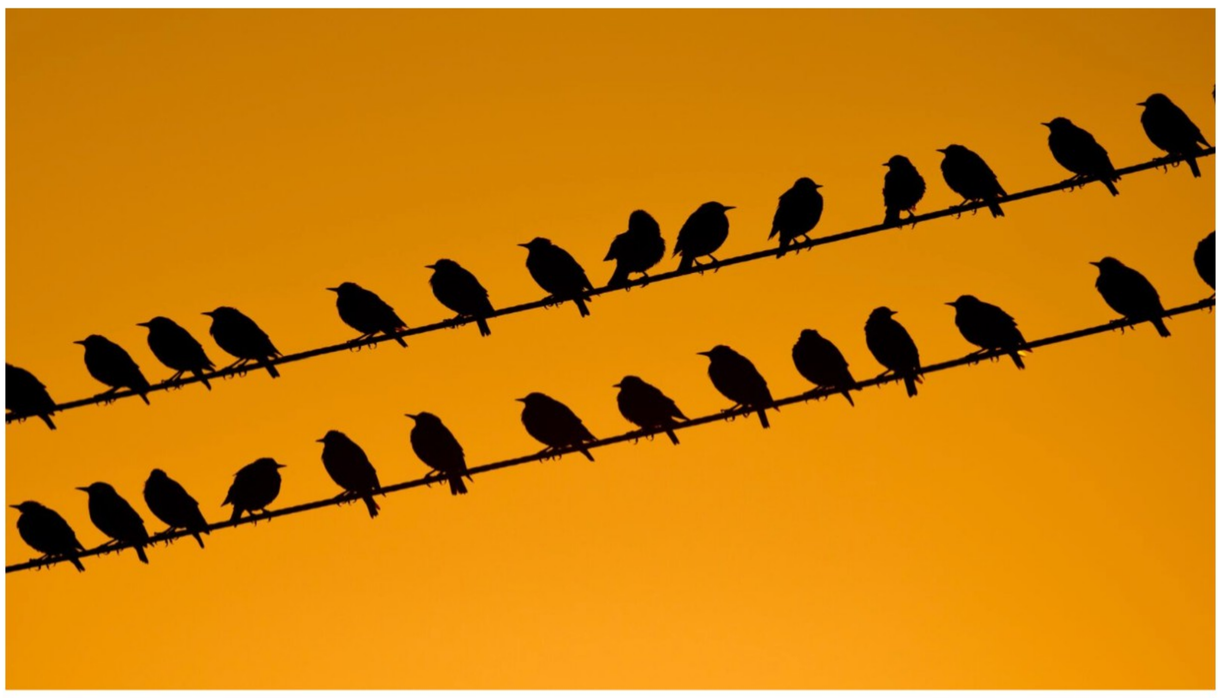
IN THE LAB

Q&A: What the brains of songbirds can teach us about human stuttering with neurobiologist Erich Jarvis

By Nicholas St. Fleur March 15, 2024

Reprints



Starlings perch on a power line in the morning sun.
PATRICK PLEUL/DPA/AFP VIA GETTY IMAGES

A symphony of synapses fires every time a songbird sings. For Erich Jarvis, a neurobiologist at Rockefeller University, the neural pathways he finds particularly interesting inside a bird's brain are those that enable the bird to make new sounds from listening to its environment. This is an ability known as vocal learning, and is perhaps most notably exhibited when a parrot mimics a person's speech (or profanity). Humans too have the capacity for vocal learning — it's a foundation of human language. As do elephants, who scientists discovered can imitate the sounds of passing trucks.

Jarvis, who is also a scientific investigator with the Howard Hughes Medical Institute, studies the molecular and genetic processes involved in how certain species of birds copy, modify, and produce new sounds. He sat down with STAT to discuss how uncovering the secrets behind these behaviors in the avian brain can help scientists better understand the intricacies of our own brains, and potentially find treatments for vocal disorders like stuttering. The conversation has been edited for clarity and length.

Rockefeller University neuroscientist Erich Jarvis
FRANK VERONSKY/THE ROCKEFELLER UNIVERSITY

Back in 2014 you had published a special issue in Science about avian genomics. It made a lot of buzz among the scientists I followed on Twitter and I remember one tweeting something along the lines of "Dr. Erich Jarvis just pulled a Beyoncé!" Tell me a bit about publishing that research and how you got interested in birds in the first place.

I got interested in avian genomics from the perspective of trying to find genes involved in the ability to imitate sounds, vocal learning, which is an important component of spoken language. There are three groups of birds that have it: hummingbirds, parrots and songbirds. I needed to determine whether or not those three groups of species inherited their behavior and their brain

pathway from a common ancestor, and that's why they're all similar, or was it independent? Were they along different branches of the family tree?

We needed a whole bunch of genomes to correctly infer what the family tree of birds were like. …So we did that for birds, which was a huge task by itself, just sequencing all those genomes and inferring the tree. And since we had all of those genomes, there are so many other papers that were published at the time as well, using those genes.

I'll just finish off here by saying that once we got to that point where we had, I think it was like eight articles in Science, of which I was an author on seven of those, I asked the editor, "Has anybody ever done this before?" And they said, "Never." I was like, "Wow, the first one?" Imposter syndrome rubbed off on me, because I had been used to being the first African American to do X, Y, and Z in science. But now it's the first human to lead-author or co-author on seven publications in a special issue in Science.

You dropped the mic.

That was the Beyoncé moment, yes.

You have one of the more colorful backgrounds as a scientist. From my understanding, you're quite an accomplished dancer. So what led you to pursue science?

A lot of my family was into the arts. We were going to be singers, dancers and so forth. I couldn't sing as well as my brothers and sister, so, I went into dance and started winning dance contests when I was in junior high school. That took me to the High School of Performing Arts in New York City and Joffrey Ballet School and Alvin Ailey Dance School. I was on my path to become a professional dancer. But something clicked in me that my mother always said: "Do something that has a positive impact on society."

I liked to do science as well, and I felt I could do that better as a scientist than I could as a dancer. So at the end of high school, I switched to going into science. I went to Hunter College here in the city. I found that being trained as a dancer trained me to become a scientist because they both require a lot of discipline, hard work, creativity, and a lot of failure before you have success. Having that combination of skills learned as a dancer, I think, made me a better scientist.

How does art meld itself into the work you do looking at bird songs, behavior and neural pathways?

There's an aesthetic part of it. Something beautiful. Something that really attracts your attention. Lots of these vocal-learning species of birds, they like to produce various melodies or complex sequences of vocalizations which keep the attention of others of their own species. Sometimes, unfortunately, it keeps the attention of predators. This is why I think vocal learning doesn't evolve as often as it could, because predators are selecting against evolution of language, so to speak. But nevertheless, I do think it is an artistic form of expression.

What exactly is vocal learning?

Vocal learning is the ability to imitate sounds that you hear that you're not naturally born with. In a more strict definition, it's sounds that are produced with the vocal organ, the larynx. You can get some species to learn how to — "pbbbt" — smack their lips like some chimpanzees. They call that raspberry. Because they have voluntary control over their lips. Even with their tongue, you can get them to do some clicking sounds. But you can't get them to voluntarily modulate the muscles of the larynx. Only vocal-learning species can do that.

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Of all of the animals that have vocal learning, why study birds?

Well besides us and a few other mammals, like dolphins and bats, amongst the other vertebrate lineages, only birds have species that evolved vocal learning. Including some that are kind of advanced, like parrots who can imitate our human speech sounds and even understand what they mean when they imitate those sounds. That's the main reason. And even though their forebrain or the cortex of the brain is organized differently than ours as mammals, they came up with a solution that's similar in terms of how the neurons are connected in the network to control the vocal organs.

Is there a particular bird that captures your imagination more so than any other?

Cockatoos catch my imagination a lot. Because getting back to the dance, it turns out that only species that learn how to imitate vocalizations are the ones that can learn how to dance, to synchronize their body movements to sound, in a rhythmic way. Cockatoos are a type of parrot species and they're really good dancers. They're good vocal imitators as well, so they have both going for them.

From the neurobiological perspective, what is so fascinating to you about vocal learning in birds?

There are three things that are fascinating about the brains of these vocal learning species, including us humans and these birds. We have an extra brain pathway that controls our vocal organs and oral facial musculature for sound production that you do not find in other mammals or other birds like chickens.

Further, that extra brain pathway looks like it evolved out of an existing motor pathway that controls body movement. So spoken language is really a body movement pathway controlling the muscles of the larynx, producing all these interesting cognitive sounds and thoughts and so forth.

Thirdly, once these new brain pathways evolved out of surrounding motor pathways, it created new specializations in genes that control its connections, the interactions between cells in that brain pathway, and how fast that brain pathway can work. Because laryngeal muscles in us humans and syrinx muscles in birds are the fastest firing muscles in the entire body, you need fast firing neurons to control fast firing muscles, and this happened all similarly in birds and in humans.

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Where is that translation between studying bird brains and studying human brains?

What's remarkable is that, even though the vocal learning birds and humans came at a similar solution independently, the genes that are making them specialize also changed in a similar way independently. What we find is that mutations in those genes that cause speech deficits in humans will also cause vocal learning deficits in the songbirds. What it means is that convergent evolution also leads to convergent health-related disorders. That means we can use these vocal learning birds as animal models for human speech.

Can you provide some examples? What are some of the disorders this research can help provide insight into?

One example is the FOXP2 gene. It's a transcription factor that regulates up or down the activity of other genes in the brain. It's been found that when FOXP2 has a mutation in humans, it affects speech more than any other function in the body. Humans have special changes in their FOXP2 that's different from other species. … If you manipulate that gene in the vocal-learning bird in the same brain region, to make it like what these humans have, you will also find vocal learning deficits.

Second example is stuttering. There is a part of the brain called the basal ganglia that in both songbirds and humans is being used for learning, including learning how to imitate sounds. We find that if that part of the brain is damaged in both humans and in songbirds, then it causes stuttering. We call that neurogenic stuttering, and it can happen in childhood.

What's interesting about these birds is that they undergo neurogenesis, new neurons. My former Ph.D. adviser, Fernando Nottebohm, found that. Birds can regenerate neurons in their brains in places where humans can't. After the neural repair occurs, the stuttering is gone. So the question is, can we figure out how the birds did that in their brain, and then induce new neuron formation in human brains in the same way to repair neurogenic stuttering.

Wait, let me take a step back here. Birds can stutter?

Vocal-learning birds can stutter, that's right. They will stutter with brain lesions in certain areas where the lesions in humans also cause stuttering.

How would you tell that the bird is stuttering?

You have the bird's song before the brain lesion. Then you have it afterwards. The bird starts to sing and goes "eh—eh—eh—eh—eh." And then he gets stuck and it's "eh-eh-eh-eh-eh-eh-eh-eh-eh-eh-eh-eh-eh." He just keeps repeating the same syllable over again. Especially when he's trying to sing to a female. He's very nervous. He stutters more when the lesion bird sings to a female.

Audio of a male zebra finch "stuttering"

What would some potential future next steps be? Would it be developing a drug?

Yeah. In a far off future, because we would have to figure out how the birds are inducing this neurogenesis in the brain. Then try to induce that process in a human brain with some drug injections.

Does your research potentially translate into other human diseases?

We did some studies where we try to create Parkinsonian-like conditions in birds and looked at their songs. In Parkinson's patients, it's not just the tremors in the hands and the walking, but the voice also has a tremor-like quality to it. We were looking at the mechanisms of what's going on there in terms of the same brain region that has the dopaminergic neurons in humans, lesioning them in songbirds and seeing whether we can repair those neurons or not, and the mechanism. And there's a lot of overlap.

[Also] autism, especially verbal-related deficits in autism. I mentioned earlier about the genes that are specialized, they're higher in their activity or lower in their activity in speech areas of the brain and in vocal learning equivalent areas of songbirds. Well, it turns out some of these same genes, when they have substitutions and mutations in them, are associated with autism deficits in children. We think that's not a coincidence, because one common theme of autism is communication deficits through vocal communication. … I've been applying for autism grants with our bird work, but it's hard to convince funders that we can actually really use birds to do this.

For people who might now be inspired to listen more intently to birds chirping, is there a songbird you'd recommend?

I like starlings. Starlings have lots of variety.

About the Author

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