Stop and listen: Study shows how movement affects hearing

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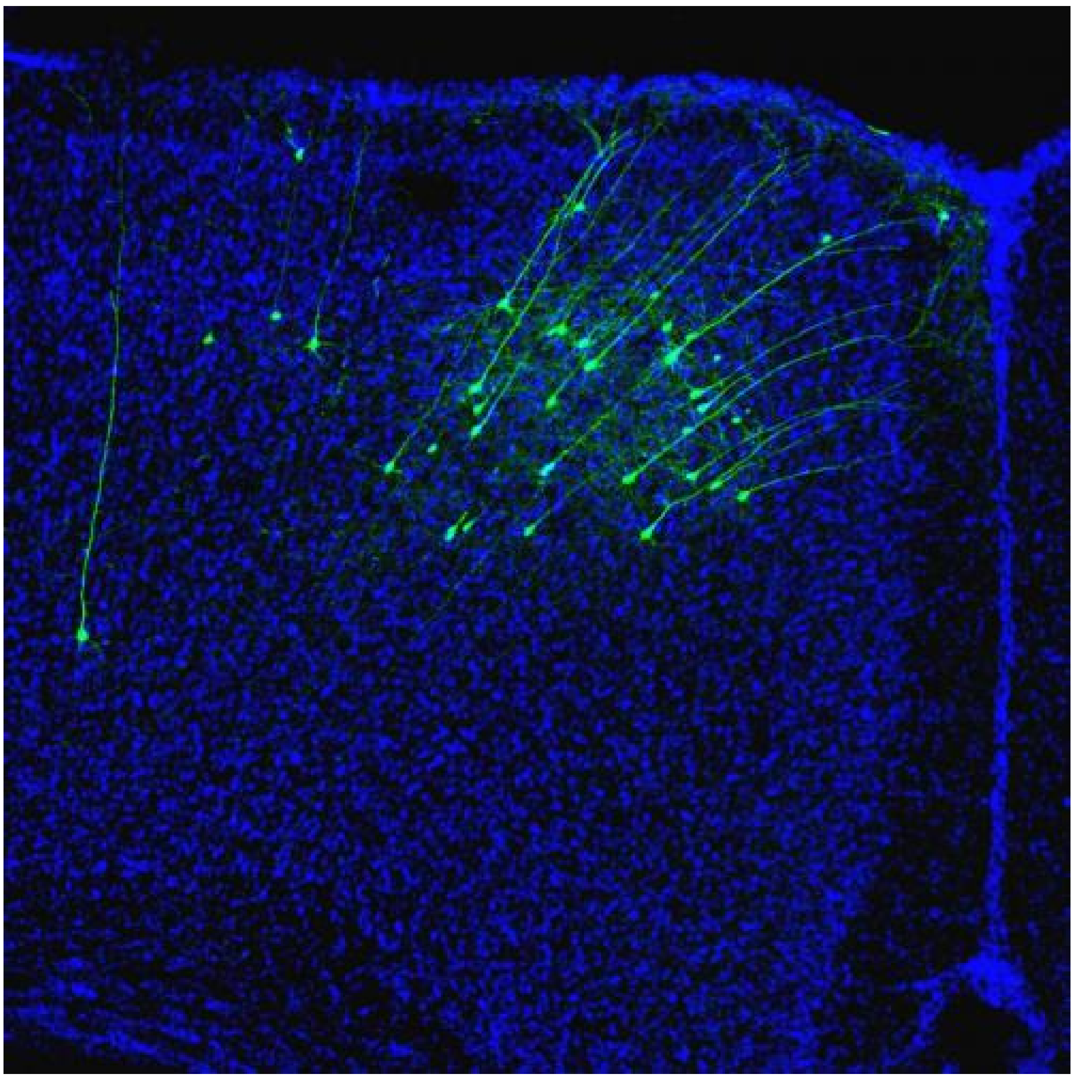

Neurons in the mouse motor cortex (green) project to the auditory cortex. As the mouse moves, these neurons suppress activity in the auditory cortex. Credit: Anders Nelson, Duke University

When we want to listen carefully to someone, the first thing we do is stop talking. The second thing we do is stop moving altogether. This strategy helps us hear better by preventing unwanted sounds generated by our own movements.

This interplay between movement and hearing also has a counterpart deep in the brain. Indeed, indirect evidence has long suggested that the brain's motor cortex, which controls movement, somehow influences the auditory cortex, which gives rise to our conscious perception of sound.

A new Duke study, appearing online August 27 in *Nature*, combines cutting-edge methods in electrophysiology, optogenetics and behavioral analysis to reveal exactly how the motor cortex, seemingly in anticipation of movement, can tweak the volume control in the auditory cortex.

The new lab methods allowed the group to "get beyond a century's worth of very powerful but largely correlative observations, and develop a new, and really a harder, causality-driven view of how the brain works," said the study's senior author Richard Mooney Ph.D., a professor of neurobiology at Duke University School of Medicine, and a member of the Duke Institute for Brain Sciences.

The findings contribute to the basic knowledge of how communication between the brain's motor and auditory cortexes might affect hearing during speech or musical performance. Disruptions to the same circuitry may give rise to auditory hallucinations in people with schizophrenia.

In 2013, researchers led by Mooney first characterized the connections between motor and auditory areas in mouse brain slices as well as in anesthetized mice. The new study answers the critical question of how those connections operate in an awake, moving mouse.

"This is a major step forward in that we've now interrogated the system in an animal that's freely behaving," said David Schneider, a postdoctoral associate in Mooney's lab.

Mooney suspects that the motor cortex learns how to mute responses in the auditory cortex to sounds that are expected to arise from one's own movements while heightening sensitivity to other, unexpected sounds. The group is testing this idea.

"Our first step will be to start making more realistic situations where the animal needs to ignore the sounds that its movements are making in order to detect things that are happening in the world," Schneider said.

In the latest study, the team recorded electrical activity of individual neurons in the brain's auditory cortex. Whenever the mice moved—walking, grooming, or making high-pitched squeaks—neurons in their auditory cortex were dampened in response to tones played to the animals, compared to when they were at rest.

To find out whether movement was directly influencing the auditory cortex, researchers conducted a series of experiments in awake animals using optogenetics, a powerful method that uses light to control the activity of select populations of neurons that have been genetically sensitized to light. Like the game of telephone, sounds that enter the ear pass through six or more relays in the brain before reaching the auditory cortex.

"Optogenetics can be used to activate a specific relay in the network, in this case the penultimate node that relays signals to the auditory cortex," Mooney said.

About half of the suppression during movement was found to originate within the auditory cortex itself. "That says a lot of modulation is going on in the auditory cortex, and not just at earlier relays in the auditory system" Mooney said.

More specifically, the team found that movement stimulates inhibitory neurons that in turn suppress the response of the auditory cortex to tones.

The researchers then wondered what turns on the inhibitory neurons. The suspects were many. "The auditory cortex is like this giant switching station where all these different inputs come through and say, 'Okay, I want to have access to these interneurons,' " Mooney said. "The question we wanted to answer is who gets access to them during movement?"

The team knew from previous experiments that neuronal projections from the secondary motor cortex (M2) modulate the auditory cortex. But to isolate M2's relative contribution—something not possible with traditional electrophysiology—the researchers again used optogenetics, this time to switch on and off the M2's inputs to the inhibitory neurons.

Turning on M2 inputs reproduced a sense of movement in the auditory cortex, even in mice that were resting, the group found. "We were sending a 'Hey I'm moving' signal to the auditory cortex," Schneider said. Then the effect of playing a tone on the auditory cortex was much the same as if the animal had actually been moving—a result that confirmed the importance of M2 in modulating the auditory cortex. On the other hand, turning off M2 simulated rest in the auditory cortex, even when the animals were still moving.

"I couldn't contain my excitement when we first saw that result," said Anders Nelson, a neurobiology graduate student in Mooney's group.

More information: "A synaptic and circuit basis for corollary discharge in the auditory cortex," David M. Schneider, Anders Nelson, Richard Mooney. *Nature*, August 27, 2014. DOI: 10.1038/nature13724

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