Brain has natural noise-cancelling circuit

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To ensure that a mouse hears the sounds of an approaching cat better than it hears the sounds its own footsteps make, the mouse's brain has a built-in noise-cancelling circuit.

It's a direct connection from the motor cortex of the brain to the auditory cortex that says essentially, "we're running now, pay no attention to the sound of my footsteps."

"What's special about this cancellation process is that the brain learns to turn off responses to predictable self-generated sounds," said Richard Mooney, the George Barth Geller professor of neurobiology. "You can watch as these responses disappear as a function of time and experience."

The findings, which appear early online Wednesday in *Nature*, come from an array of difficult experiments, including a "mouse virtual reality" setup.

This brain circuitry works differently than noise-cancelling headphones, but the results are similar. The headphones monitor ambient noise around the listener and then produce sounds that are mirror images of those soundwaves to cancel them out. Similarly, the brain's auditory cortex receives a signal directly from the motor cortex that tells its inhibitory neurons to selectively cancel out the sounds it has learned will come from a particular motion.

For this system to work, it cannot depend solely on input from the ears, Mooney said, "because by the time the auditory signal from the ear is processed by the brain, it's old news."

In fact, the motor cortex sends the cancellation signal to the auditory cortex in parallel with commanding a movement, a process so fast that cancellation in the auditory cortex is actually predictive. "The sound of the first footstep isn't heard," said David Schneider, a former Duke postdoctoral researcher in Mooney's lab who is now an assistant professor at New York University.

"We would have a hard time operating in the natural world, if we couldn't predict the sensory consequences of moving around in it," said

Mooney, who has also studied the connection between the auditory cortex and the motor cortex as birds learn to sing.

To monitor the circuit, Schneider and Duke graduate student Janani Sundararajan trained mice to associate an artificial tone with their foot-falls. As the mice walked or ran on a treadmill in this "virtual reality" experiment, the tone's tempo matched each pitter-pat.

"We decided to make the sound as artificial as possible to push the mouse's brain beyond what it was evolved to do," Schneider said.

Schneider and Sundararajan watched the mouse's brain as synapses that the motor cortex makes in the auditory cortex changed as it learned to cancel a predictable movement-related noise. They were able to identify the inhibitory neurons that responded to the artificial tone to cancel out its signal, "exactly like noise cancelling," Schneider said.

To confirm what they were seeing, Sundararajan then did a series of behavioral experiments in which mice were taught to seek a reward after hearing two different tones. Then she trained them on the treadmill as before to associate one of those tones with walking. After training, the mice detected the non-associated tone better than the 'walking' tone when they were actually walking, even though they detected both tones equally well when they were standing still.

"The brain would rather be more sensitive to noises other than the ones we make," Sundararajan said. For a mouse being stalked by a nearby cat, it would be a matter of survival.

More information: David M. Schneider et al, A cortical filter that learns to suppress the acoustic consequences of movement, *Nature* (2018). DOI: 10.1038/s41586-018-0520-5