Scientists identify brain area that determines distance from which sound originates

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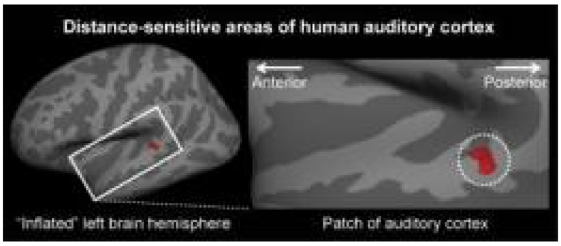

This is an image of human cerebral cortex, digitally "inflated" to smooth out normal folds and ridges, showing in red the portion of auditory cortex that responds to the distance from which sounds arrive. Credit: Jyrki Ahveninen, Ph.D., Martinos Center for Biomedical Imaging, Massachusetts General Hospital

Researchers at the Martinos Center for Biomedical Imaging at Massachusetts General Hospital have identified a portion of the brain responsible for determining how far away a sound originates, a process that does not rely solely on how loud the sound is. The investigators' report, which will appear in the early edition of *Proceeding of the National Academy of Sciences*, is receiving early online release this week.

"Although sounds get louder when the source approaches us, humans are able to discriminate between loud sounds that come from far away and softer sound from a closer source, suggesting that our brains use distance cues independent of loudness," says Jyrki Ahveninen, PhD, of the Martinos Center, senior author of the PNAS report. "Using functional MRI we found a group of neurons in the auditory cortex sensitive to the distance of sound sources and different from those that process changes in loudness. In addition to providing basic scientific information, our results could help future studies of hearing disorders."

The human brain has distinct areas for processing sensory information - signals responsible for vision, hearing, taste etc. Studies of the visual cortex, located at the back of the brain, have produced detailed maps of areas handling particular portions of the visual field. But understanding of the auditory cortex, located on the side of the head above and behind the ear, is quite limited. While it is known that the portion of the auditory cortex extending toward the back of the head determines where a sound comes from, exactly how the brain translates complex auditory signals to determine both the location and distance from which a sound originates is not yet known.

In their search for auditory neurons that process sound distance, the research team faced some particular challenges. In research laboratories that study hearing, sounds must be delivered to study participants through headphones, which means the acoustical "space" in which a sound is generated must be simulated. This must be done with exquisite accuracy, since environmental aspects causing sound to reverberate probably contribute to distance perception. Since the MRI equipment itself generates a loud noise, the researchers scanned participants' brains once every 12 seconds to measure responses to sounds presented during intervening quiet periods.

In the first experiment, study participants - 12 adults with normal hearing - listened to a series of paired sounds of varying degrees of loudness and at simulated distances ranging from 15 to 100 cm and were asked to indicate whether the second sound was closer or farther away than the first. Although the differences in loudness varied randomly, participants were quite accurate in distinguishing the simulated distances of the sounds. Acoustical analysis of the particular sound cues presented indicated that the reverberations produced by a sound, which are more pronounced in a closed environment and for sounds traveling farther, may be more important distance cues than are the differences between sounds perceived by a participant's two ears.

After the first experiment confirmed the accuracy of the simulated acoustical environment, functional MR images taken while participants listened to another series of paired sounds recorded how activity in the auditory cortex changed in response to sounds of varying loudness and direction as well as during sound of constant levels and silence. The images produced identified a small area that appears to be sensitive to cues indicating distance but not loudness. As far as the investigators know, this is the first time neurons sensitive to sound-source distances have been discovered.

"The identified area is located near other auditory cortical areas that process spatial information," says corresponding author Norbert Kopco, PhD. "This is consistent with a general model of perceptual processing in the brain, suggesting that in hearing, as in vision and other senses, spatial information is processed separately from information about the object's identity or characteristics such as the musical pitch of sound. Our study also illustrates how important it is to combine expertise from different fields - in our case imaging/physiology, psychology, and computational neuroscience - to advance our understanding of such a complex system as the human brain."

Provided by Massachusetts General Hospital