IMPACT PROFILE
RESEARCH AT THE UNIVERSITY OF MARYLAND

SHIHAB SHAMMA

Hearing and the Brain

Sound may seem a straightforward physical phenomenon, whose waves can be recorded, charted and parsed. But no machines can do what the human brain does—understand a wide variety of speakers, distinguish a single voice in a crowd, or readily switch between enjoying the musical performance of a whole orchestra or attending to the sound of one instrument in it.

Shihab Shamma, professor of electrical and computer engineering and member of the Institute for Systems Research, studies how the brain performs these feats. "We study the auditory system to understand how neural processing works throughout the brain," Shamma says. Among other things, he and his research team study how the brain learns and recalls sounds, how attention and expectation affect what we hear, and the plasticity of the brain's response.

One of the major findings from Shamma's lab is that the adult brain is extremely plastic. For example, in a conversation, a person's brain rapidly adapts to the other person's voice, language and speech patterns, and filters out background noise. Shamma, research scientist Jonathan Fritz, and

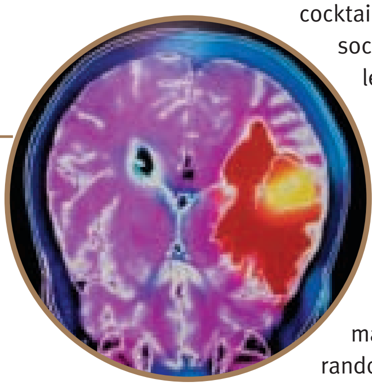
Neuroplasticity and Hearing

their team have developed experimental techniques and methods of data analysis revealing that neurons in the auditory cortex fire differently depending on whether a person or an animal is listening passively or is engaged in a specific task and listening for a particular sound. Within seconds, cortical neurons in the brain become attuned to an attended sound. These neural changes can become permanent if a sound continues to be important. The researchers have also discovered that areas of the brain that respond to sound encode meanings and not simply the physical energy of a sound.

To study the brain, Shamma's lab uses methods ranging from electrical engineering, physics and computer science to cellular and molecular neuroscience. The lab maintains a colony of ferrets for behavioral and neurophysiological experiments. Shamma's students have a wide range of backgrounds, and the lab collaborates with faculty in the departments of biology, psychology and linguistics, among others.

The tuning of the brain by experience or the demands of a specific task isn't limited to hearing, Shamma notes. Visual tasks have analogous effects. In some areas of the brain, his group has found, neurons respond to the meaning of a sensory stimulus independent of whether information is obtained visually or through sound. Cells in the cortex may respond, for example, to either the face or voice of a friend, or to the sound or sight of a siren.

One long-standing question among neuroscientists is how people are able to attend to one speaker in a crowd, picking out one voice amid a great deal of noise—the "cocktail party problem." "Although you can't take a ferret to a cocktail party," Shamma jokes, "many social animals face a similar problem of identifying and following a voice in a crowd." Together with assistant professor of electrical and computer engineering Jonathan Simon and post-doctoral fellow Mounya Elhilali, Shamma simulated the cocktail party problem by presenting animals with a dizzying sequence of random tones spanning a wide range of frequencies. If, while listening to this complex soundscape, the ferret is anticipating a specific tone, the response of neurons in the brain changes dramatically, becoming sensitized to the tone and synchronized to its timing. "These changes occur within seconds. Your brain is constantly changing," says Shamma.



In addition to providing fundamental insights about the brain, Shamma's work on hearing has many applications. For example, government agencies are interested in signal processing algorithms that automatically distinguish intelligible speech from other sounds on recordings. The algorithms Shamma's team has developed to discriminate between human speech and other sounds were superior to anything else currently available according to independent tests conducted by a government agency. The Air Force has tested the same kind of algorithms, tuned differently, to detect and classify birds in air space. The algorithms can also be trained to recognize the distinctive acoustic signatures of foot steps, and efforts are being made to distinguish underwater sounds made by animals, submarines and ships.

A better understanding of sound processing also can be used to predict the quality of acoustics in a concert or lecture hall. The ability to separate and distinguish sounds—again, the "cocktail-party problem"—can have great benefits when applied to hearing aids. Shamma and one of his students work with researchers at Walter Reed Army Medical Center to enable hearing aids to automatically choose settings in tune with a user's different needs at different times—whether that is listening to music, conversing with someone, listening to a lecture, or navigating a busy sidewalk.

An outsider may be surprised to find an electrical engineer so deeply involved in trying to understand the brain, but Shamma says matter-of-factly, "Although the brain is incredible, the information processing that allows us to perceive the world is not magic." *—Karin Jegalian*

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