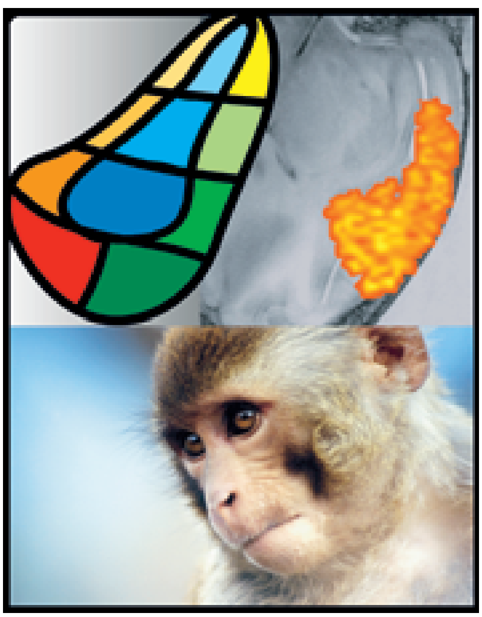
NEUROPHYSIOLOGY

A Mosaic of Tones

The brain filters what we hear. One of the reasons it is able to do this is because particular groups of neurons react only to specific sound frequencies. Neurobiologists at the Max Planck Institute for Biological Cybernetics in Tübingen used high-resolution functional magnetic resonance imaging (fMRI) of non-human primates to create a frequency map for 11 exceptionally small auditory fields in the brain. They did this by identifying neuronal fields that are activated either by single frequencies (tones) or by combinations of frequencies. Many of the findings will now aid in human imaging, which for more than a decade has had difficulty doing such a large-scale mapping as was accomplished here in some of our closest primate relatives. (PLoS Biology, June 20, 2006)



The brain area that primates use to process sound resembles a mosaic of individual fields. Max Planck researchers have used functional magnetic resonance imaging to describe how the spectrum of frequencies is distributed over each individual field.

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Whether we are in a factory surrounded by rattling machines or at a party where loud music and voices compete: when we are conversing with someone, we are still able to filter out the voice of the person we are talking to from the surrounding cacophony of sound. This is because our brain decides what is heard; oftentimes, the brain can stabilize a sound that we are interested in even during disruptions. We still do not fully understand how this happens, but we think it has something to do with the mosaics of tone responses that we observe so prominently on the brain. These responses reflect how the cochlea, a hearing organ within the inner ear, is stimulated, much the same way that visual areas in the brain can show a topography of how the retina is stimulated. For the cochlea, this means that different frequencies activate certain groups of neurons in the auditory cortex in the brain. It is presumed that the brain is thus able to interpret the structure in the sounds it hears. This seems like an important first step in how sounds are identified and separated from others.

Until now, the main way of finding out in detail which areas of the brain were responsive to certain frequencies was through electrophysiological studies in animals. Now researchers have non-invasively scanned the brains of primates using high-resolution functional imaging, in the same way that people are often scanned. "Such scans were not previously possible, making comparisons to human imaging very difficult. Now we have closed that gap," explains Christopher Petkov, who headed the research at the Max Planck institute in Tübingen. Since the brain structure of primates is generally similar, many of the findings could hold for humans.

The researchers created what is known as a frequency map of the primates' auditory cortex and were thus able to identify where certain frequencies are processed in given areas of the auditory cortex. The auditory cortex is divided into individual neighboring fields, four of which the Max Planck scientists were able to map for the first time. A total of 11 fields are now known that are arranged like a mosaic on the surface of the brain.

This mosaic is organized in a periodic pattern: every field has a region that responds best to specific sound frequencies. In certain neighboring fields, the response to a frequency is the exact opposite, like a mirror image, so that there is a rise and fall of tone responses throughout the auditory cortex. "The different fields almost certainly have different tasks," says Christopher Petkov, "but we are only beginning to understand what those differences are." They likely have much to do with how sounds are identified and heard in our typically noisy listening environments.

The neurophysiologists in Tübingen also divided the fields into two groups. Three of these fields, which together form a sort of core or center of the auditory cortex, react to simple sounds like tones with single frequencies. The other eight, including the four newly described ones, respond better to sounds that are a mixture of different frequencies. These fields encircle the three core fields like a belt and clearly prefer more complex sounds.

Thanks to this research and the new frequency maps, the Max Planck researchers think further advances will soon be made in human imaging. These maps can also be used to evaluate how well they represent sound frequencies in noisy environments, or as a tool to evaluate hearing loss in individuals, or how resistant their auditory cortex is to environmental noise.

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