A Wide Range of Hearing

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COMING IN LOUD AND CLEAR

A recent study by scientists working in Panama may afford a new appreciation of our limited auditory range. If human ears could detect the ultrasonic frequencies bats use to echolocate, then going outdoors at night when bats are foraging for insects might well cause us pain. The ultrahigh frequencies (20,000 to 70,000 hertz) bats use to search for food attenuate, or fall off, rapidly over short distances. To compensate, bats emit extremely loud signals starting at around 115 to 120 decibels (dB)—the same level as a rock concert and approaching the human threshold of pain—and reaching as high as 140 dB.

Using an array of microphones to record emitted signals and stereophotography to determine distance and direction of flying bats, Annemarie Surlykke, of the University of Southern Denmark, and Elisabeth Kalko, of the University of Ulm, Germany, measured the intensity of calls in 11 bat species. Published in the April issue of *PLoS ONE,* this is the first study to estimate and compare source levels (i.e., the sound pressure level 10 centimeters from a bat's mouth) and detection ranges among bats that use different foraging methods.

All the bats studied emitted search calls that were most intense when bats were some distance away from the microphone array and surrounding surfaces, roughly 5 to 10 meters; calls decreased in intensity as the bats came closer than 5 meters to the microphones. Of the 11 species representing 5 families, 1 forages for flying insects in open space, 8 forage for similar prey in edge space, and 2 trawl for insects over water. The open and edge space foragers had similarly intense source levels of 122 to 134 dB, whereas the trawlers averaged 137 dB.

Yet despite variations in frequency and intensity among calls and differences in body size, the bats all exhibit similar detection ranges. In detecting prey, the bats with higher frequencies emit higher-intensity calls, whereas bats using lower frequencies emit signals that are less intense.

PICKING UP LOW FREQUENCIES

What determines the different auditory ranges of mammalian species? Early models of auditory mechanics couldn't account for the most characteristic feature of mammalian cochleas: their spiral shape. Vanderbilt mathematician Daphne Manoussaki and colleagues Richard Chadwick and Emilios Dimitriadis reexamined the prevailing views of cochlear function and proposed a new idea two years ago—namely, that the coiling of the cochlea plays a role in its sensitivity to low-frequency sound. More recently, with the help of several more colleagues, they published evidence that strongly supports this hypothesis. The study appears in the 22 April issue of *Proceedings of the National Academy of Sciences.*

Located in the inner ear and sculpted of bone, the fluid-filled cochlea is the acoustic interface between the movable bones of the middle ear and the nervous system. Sound waves vibrate the ear drum, the three middle-ear bones transmit the vibrations to the cochlear fluid, and the oscillations travel various frequency-dependent distances up the spiraling coil, causing sensory hair cells in the cochlea to fire.

The basilar membrane splits the spiral canal into two tapering tubes; oscillations in these two fluid-filled chambers displace this membrane, producing electrical signals in the hair cells. The basilar membrane is quite stiff at the base, or entrance, of the cochlea, where the higher frequencies of an animal's range register, and it becomes more flexible toward the apex, where lower frequencies register.

Until 2006, this was as far as the explanation went, with researchers concluding that it didn't matter whether cochleas, which have a species-specific number of turns, were straight or coiled. Manoussaki and colleagues took their model a step further, showing that the spiral shape works like the curved walls of a whispering gallery to enhance sound, focusing wave energy toward the outer wall of the chamber, particularly in the tighter curves where low frequencies peak.

The scientists measured cochlear curvature in 15 mammalian species, both terrestrial and aquatic, and found that the ratio of the radius of curvature at the base to the radius of curvature at the apex strongly correlates with an animal's ability to hear low frequencies. Cows, for example, with a basilar membrane length of 38 millimeters, have a ratio of 8.8 and can hear sounds as low as 23 hertz, whereas dolphins, with a basilar membrane of similar length but a ratio of 4.3, cannot hear frequencies below 150 hertz.

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