

In order to recognize spatial structures, bat echolocation uses similar cues as our sense of sight

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The scientists recreated 3D "stills" of water waves and had bats distinguish the flat disk in the middle from each one of the other disks in the dark. They found that the bats have an easier time doing so when the discs carry many and high waves - just as humans would if they had to solve a corresponding visual task. Credit: © Klemen Koselj

The sonar system of bats exploits spatial information in a way similar to our sense of sight, despite the different anatomy of eyes and ears. In a new study, scientists at the Max Planck Institute for Ornithology in Seewiesen and the Ludwig Maximilians University Munich have now shown that echoes contain information that allows bats to distinguish differently structured surfaces. On a turbulent water surface for example, a fidgety prey item acoustically stands out even against the clutter of the background waves.

Echolocating bats have turned night into day. They ensonify their environment with loud ultrasonic calls and listen for reflected echoes. Over a thousand species of bats occupy all imaginable food niches, from mosquito-hunters to nectar-lickers to so-called trawling bats. Usually, when bats hunt close to a background, they need to find the prey [echo](#) amidst a multitude of background echoes—the needle in the haystack. But hunting close to a [water surface](#)—as for example water and pond bats do—is advantageous, explains Holger Goerlitz, Head of the Acoustical and Functional Ecology research group at the Max Planck Institute for Ornithology: "A smooth water surface acts like a mirror, also acoustically: at the same angle as the sound hits the surface, it is also reflected. In our case, mainly away from the bat, because it calls diagonally downwards and forwards. A floating insect, on the other hand, reflects sound directly back to the bat: a single conspicuous prey echo against silence." But what if the [water surface](#) is not as smooth as a mirror? After all, bats do hunt in wind and rain or over flowing waters.

Many aquatic predators such as leeches, spiders or amphibians can perceive the three-dimensional structure of water waves and thus distinguish them from prey. Lutz Wiegrebe from the Biocenter of the Ludwig Maximilians University was curious as to whether echolocating bats can also achieve this with their sense of hearing. This is quite the challenge, because any information about where a sound arriving at the eardrum originally came from must be calculated, namely by comparing

the incoming signals at left and right ear. "When a sound comes from the left, it arrives at the left ear both earlier and louder than at the right ear" says Leonie Baier, first author of the study. "And when a sound comes from the front, it sounds a little bit different than coming from the back—this is because of our outer [ears](#)." She goes on to explain that bats also calculate distance: "The more time elapses between sending the call and receiving the echo, the farther away the target is."

Wave perception

Getting to the bottom of the perception of spatial structure, Baier trained her bats to distinguish a smooth surface from a rippled surface—in the dark, so only with the help of echolocation. It turned out that the bats were much better at detecting structured surfaces when those had a high spatial frequency, i. e. many waves closely together. The bats could even perceive such ripples of only one to two millimeters height. However, when the spatial frequency was very low, i.e. with only a few widespread waves, the bats could not tell the difference between the smooth and structured surfaces; not even when the ripples were 32 millimeters high. Comparing this to natural patterns, the scientists interpret their results in such a way that gentle background waves caused by wind are virtually invisible to the bats, while the waves of bobbing prey catch the bats' eye—or rather their ear.

"Comparing the sensitivity of [echolocation](#) for spatial frequencies with that of human vision produces astonishing parallels," says Lutz Wiegrebe. But the anatomy of eye and ear are fundamentally different, so the researchers went on in search of the mechanism behind the [bats'](#) performance. On the computer, they simulated the neuronal activity as found in the bat's auditory nerve and showed that the echoes actually contain a lot of information to distinguish structured surfaces from one another. Holger Goerlitz summarizes: "We were able to show that mere physical properties of surface structures provide the auditory system

with information that the visual system uses to process [spatial information](#). A beautiful example of convergent evolution."

More information: A. Leonie Baier et al. Echo-Imaging Exploits an Environmental High-Pass Filter to Access Spatial Information with a Non-Spatial Sensor, *iScience* (2019). [DOI: 10.1016/j.isci.2019.03.029](https://doi.org/10.1016/j.isci.2019.03.029)

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