Making the best of sparse information

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New findings reported by LMU researchers challenge a generally accepted model of echolocation in bats. They demonstrate that bats require far less spatial information than previously thought to navigate effectively.

Bats find their way in the dark by emitting ultrasonic signals and analyzing the echoes generated when these signals impinge on, and are reflected by, objects in their environment. Experiments carried out by LMU researchers now refute a central postulate of the conventional model of echolocation. "Up to now, it has been assumed that the echoes provide a kind of acoustic image of the environment, which allows bats not only to detect objects but also to perceive the gaps between them. This notion turns out to be wrong. Our experiments show that bats have very little ability to spatially resolve objects. Their navigational system makes do with a surprisingly small amount of spatial information, and its mode of operation differs fundamentally from our conventional picture of echolocation," says Lutz Wiegrebe, a professor in the Neurobiology Division. The new findings appear in the latest issue of the journal *Current Biology*.

In their study, Wiegrebe and colleagues used bats that had been trained to emit ultrasonic signals when they detected the acoustic reflections of objects in their environment. In the experimental set-up, the bats emitted signals which were reflected from a target placed directly in front of them, but were also exposed to reflections originating from sources to the left and right of the target of interest. The latter therefore served as cluttering targets which were displaced from the target of interest by angular distances that were varied from experiment to experiment. "The bats were extremely irritated by the virtual reflections, and were able to detect the target of interest only when the virtual targets were placed relatively far away from it."

This paradigm used to measure the spatial resolution of the bat echolocation system is analogous to that used to measure the spatial resolution of the visual system. In the mammalian retina, the anatomical organization of the photoreceptor cells itself provides the basis for high spatial resolution. "But echolocation works in an entirely different way," Wiegrebe explains. "The sensory cells in the inner ear do not encode axes in space, they encode time and frequency. Spatial information must be secondarily derived from these inputs by neuronal processing. Our experiments demonstrate that the spatial resolution of the bat echolocation system is approximately three orders of magnitude worse than that of the human visual system. In other words, bats navigating by echolocation receive an extremely fuzzy picture of their environment. A visually simple task like 'how many fingers am I holding up' is extremely difficult to solve with biosonar. Nevertheless, bats can navigate very effectively." The authors of the new study believe that the animals compensate for the deficit in spatial resolution by constantly updating the incoming information relating to the distance and direction of objects, and concentrating on determining the relative positions of the objects that are closest to them.

The results may well have implications for manmade navigation systems. "The navigational systems used in e.g. autonomous vehicles use a camera to capture a continuous stream of information. It is conceivable that much of this information is redundant. Bats use a much simpler

scheme that does not depend on the acquisition of a 3-D image of their environment, such as that provided by the visual system. Yet they can navigate quite effectively."

In a paper recently published in the journal *iScience*, Leonie Baier (a member of Lutz Wiegrebe's research group) and Dr. Holger Goerlitz of the Max Planck Institute for Ornithology showed that some bat species are preferentially sensitive to surface-wave patterns with high spatial frequencies, which allows them to gauge depth, i.e. differentiate between foreground and background. This ability enables them to detect an insect on the surface of a pond, for instance. "Our work has now shown that bats cannot resolve this information spatially," says Wiegrebe. If the water surface is covered with vegetation, a foraging bat can no longer localize the insect.

More information: Cornelia Geberl et al. The Spatial Resolution of Bat Biosonar Quantified with a Visual-Resolution Paradigm, *Current Biology* (2019). DOI: 10.1016/j.cub.2019.04.046

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

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