Scientists uncover evidence for a new form of collective sensing in electric elephantnose fish

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Weakly electric fish like these, Gnathonemus petersii, may be tapping into sensory information garnered by nearby fish. Credit: Sawtell lab/Columbia's Zuckerman Institute

It would be a game-changer if all members of a basketball team could see out of each other's eyes in addition to their own. A research duo at Columbia's Zuckerman Institute has found evidence that this kind of collective sensing occurs in close-knit groups of African weakly electric fish, also known as elephantnose fish. This instantaneous sharing of sensory intelligence could help the fish locate food, friends and foes.

"In engineering, it is common that groups of emitters and receivers work together to improve sensing, for example in sonar and radar. We showed that something similar may be happening in groups of fish that sense their environment using electrical pulses. These fish seem to 'see' much better in small groups," said Nathaniel Sawtell, Ph.D., a principal investigator at Columbia's Zuckerman Institute and a professor of neuroscience at Columbia's Vagelos College of Physicians and Surgeons.

In a paper published in *Nature*, Dr. Sawtell and postdoctoral research associate Federico Pedraja, Ph.D., combine multiple lines of evidence to argue that the species of electric fish they study, Gnathonemus petersii, pull off a lightning-fast feat of collective sensing never before documented in biology.

Scientists have long known that electric fish sense changes in the electric fields they project into their waterscapes, much like the acoustic signals that bats and dolphins deploy. The fish rely on specialized organs in their skin that emit and sense electric fields to communicate. They also use them for an electric version of echolocation to detect, track and distinguish various objects in their watery environments.

G. petersii electric fish dwell in African river habitats that are dark and murky, where the fishes' eyes are of limited value. In thinking about that challenge with an engineering mindset, Drs. Pedraja and Sawtell conjectured that the fish might have evolved sensory abilities akin to networked radar and sonar systems, whose multiple units can collaborate to detect objects further out and in more detail than can lone unconnected units.

To test if this principle of collective sensing applied to electric fish, the researchers first developed a computer model in which they could simulate the fishes' electrical environment. They analyzed whether individual electric fish were better at detecting objects by tapping into signals emitted by nearby fish.

"Think of these external signals as electric images of the objects that nearby electric fish automatically produce and beam to nearby fish at the speed of light," said Dr. Pedraja. "Our work suggests that three fish in a group would each receive three different 'electrical views' of the same scene at virtually the same time," added Dr. Sawtell.

Among the most telling results of the simulation study, Dr. Sawtell noted, is that collective sensing could extend the electro-location range of the electric fish up to three times. The researchers say that such a large sensory enhancement would almost certainly confer survival benefits.

The researchers then went in search of an actual neural basis for such an ability in G. petersii. Recordings in a part of the brain devoted to the electrosensory system showed that the fish respond to both their own electric discharges and to external electrical signals from, say, other electric fish or lab-generated mimics of the signals. Particularly exciting to the scientists was how the patterns of brain activity closely matched what the simulation studies suggested the researchers might see in neural recordings.

Behavioral observations added more evidence that the fish really do engage in collective sensing. In the tanks, the fish assumed in-line and right-angle formations that the computer model showed are favorable for collective sensing. Also, recordings of a kind of electrical dialog between fish featured highly precise turn-taking in which the fish emitted their electrical discharges in strict alternation. The authors speculate that this behavior, previously termed the "echo response," might play a key role in coordinating collective sensing.

As the researchers have uncovered a new sensory capability, more fascinating questions have emerged for them.

"These fish have some of the biggest brain-to-body mass ratios of any animal on the planet," said Dr. Sawtell. "Perhaps these enormous brains are needed for rapid and highly sophisticated social sensing and collective behavior."

The researchers noted that learning more about the brain mechanisms involved could provide leads for artificial sensing technologies for applications including underwater autonomous vehicles and medical imaging.

More information: Nathaniel Sawtell, Collective sensing in electric fish, *Nature* (2024). DOI: 10.1038/s41586-024-07157-x. www.nature.com/articles/s41586-024-07157-x

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