Scientists identify brain circuits tied to the behavior of schooling fish

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A new study by UC San Diego neurobiologists found that glassfish depend on their sense of vision to coordinate social swimming behavior in schools. Credit: Lisanne Schulze, UC San Diego

A flock of migrating geese glides through the summer sky in an unmistakable "V" formation… a thundering herd of bison rumbles across the plains as a formidable group... and a massive school of sardines swims mesmerizingly in unison.

For decades, ecologists and animal behavior specialists have studied these types of group behaviors in a variety of species. Scientists at the University of California San Diego are now looking into their roots from the perspective of the brain. How do groups of animals develop coordinated movements? How can so many individual brains share information to produce a single, coherent behavior?

Published in the journal *Current Biology*, Postdoctoral Scholars David Zada and Lisanne Schulze in Assistant Professor Matthew Lovett-Barron's laboratory in the School of Biological Sciences studied schools of tiny transparent glassfish (Danionella cerebrum) to help uncover intriguing answers to these questions.

"Collective social behaviors, such as fish schooling and bird flocking, are remarkable displays of behavioral complexity in the natural world, but little is known about how these behaviors emerge from the interacting brains of many individuals," said Lovett-Barron, an assistant professor in the Department of Neurobiology. "We don't know very much at all about how neural processes in individual animals produce cooperative behaviors."

Among their new findings, the researchers discovered that glassfish depend on their sense of vision to swim in groups. While some fish species are known to use their sense of water flow to swim together, the glassfish uses sight alone, as the researchers revealed through a series of experiments.

Using machine learning tools to track the movements of fish across different ages, they also discovered that the ability to follow coordinated group movements develops as individuals mature.

Much as newborn humans develop complex social skills as they grow, glassfish refine their ability to move in coordinated social groups as they age. Fish raised in normal social environments avoided other fish at two weeks of age, then gained the ability to aggregate with others after four weeks and finally achieved full social alignment in schools after six weeks.

Since glassfish are highly transparent, the researchers were able to capture images of their brain activity using optical microscopes. They recorded thousands of neurons across the brains of glassfish immersed in a panoramic virtual reality environment, where fish viewed moving fish-like shapes that mimic the experience of schooling.

The researchers identified active circuits by recording images of GCaMP, a fluorescent protein, in neurons. GCaMP glows brighter in the presence of calcium, which comes into cells when neurons are active. These activity recordings showed that glassfish brains respond to the sight of their social partners and that maturity is important for social vision.

While glassfish of all ages could perceive the motion of virtual social partners, only older fish could distinguish between the movement of fish-like shapes and non-fish-like shapes. The researchers believe the development of this visual ability allows glassfish to align their bodies with their social partners in order to properly swim in schools.

Furthering this idea, the researchers studied fish that were raised in isolation. These fish exhibited profoundly impaired schooling behavior and immature visual processing of social stimuli, compared with their counterparts that were raised in groups.

"In nature, we see that large animal groups can move as a cohesive unit, and our laboratory is working to understand how the brains of individuals are able to pay attention to the actions of their social partners to produce this group-level behavior," said Lovett-Barron. "In this study we found that these social abilities emerge progressively over the course of development, as the nervous system matures."

Glassfish, only 10–12 millimeters long as adults (roughly the width of a pencil), have only recently become a model system for biological studies. The closely-related zebrafish is widely studied, but loses its small size and transparency as it ages. Glassfish, on the other hand, remain small and near-transparent their entire lives, providing new opportunities for biologists to observe the brain in action.

More information: David Zada et al, Development of neural circuits for social motion perception in schooling fish, *Current Biology* (2024). DOI: 10.1016/j.cub.2024.06.049

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