

Schooling Fish May Have Just One Influencer

By studying a real fish swimming among virtual fish, researchers uncover the rules that a fish follows when schooling.

By **Michael Schirber**

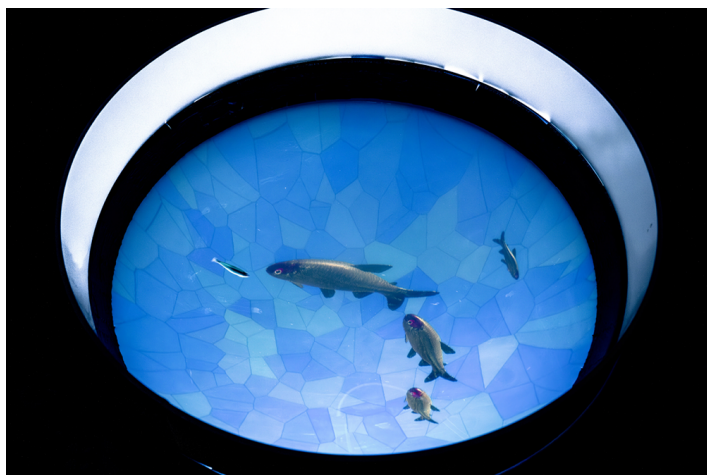
Fish schools can contain hundreds of individuals, all swimming in concert. To understand how these animals coordinate their behavior, scientists try to imagine what a fish perceives—putting themselves in the fish’s proverbial shoes, or rather, fins. Guy Theraulaz and his colleagues at the National Center for Scientific Research (CNRS) and the University of Toulouse in France have taken this process one step further by building a virtual-reality environment that recreates the schooling experience for one real fish [1]. The team programmed four virtual fish with different interaction rules and observed the response of the real fish in each case. The results suggest that schooling fish focus on a single

influential neighbor, filtering out the behavioral cues from other fish in the school.

As it swims in a school, a fish continuously observes its closest neighbors, presumably registering information about their relative distance, speed, and direction. The fish uses these environmental inputs to adjust its course and stay in-line with the group. Researchers have proposed several models for how fish process this information, but verifying which model is correct is challenging. “We don’t know what’s happening in the head of the fish,” Theraulaz says. But reading an animal’s mind may not be necessary if researchers can control the behavioral cues that the animal receives (see [Research News: Desert Locusts Follow Unexpected Motion Rules](#)).

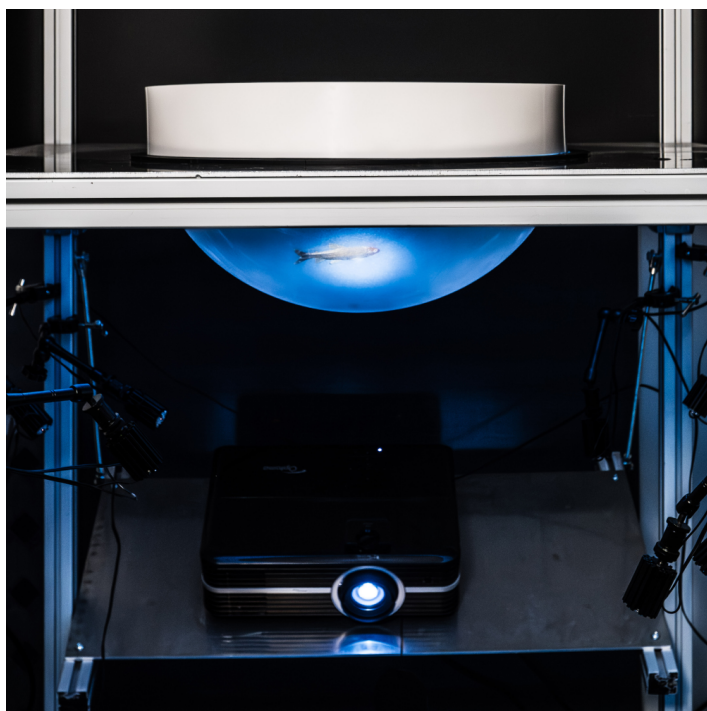
Theraulaz and his team have demonstrated this control in a virtual-reality setup, consisting of a 50-cm-wide bowl filled with water. The walls of the bowl are made of a special plastic material that acts like an underwater movie screen. When a fish is placed in the bowl, images of virtual fish are projected from below, giving the real fish the impression that it is surrounded by a school.

Since the real fish is moving, Theraulaz and colleagues have to constantly adapt the projections to the current position of the real fish. The researchers track the real fish with a 3D camera placed above the bowl, using that information to adjust both the location and the size of the virtual-fish projections. If, for example, the real fish is on the left side of the bowl, and the researchers want a virtual fish to appear up close on the right, then a large image needs to be projected on the far side of the bowl.



A single, real fish (left) swims in a virtual-reality bowl, where virtual fish are projected onto the walls. The sizes of the virtual fish are enlarged to make them appear closer to the real fish.

Credit: Z. Kang *et al.* [1]



This side view of the virtual-reality experiment shows the projector located beneath the bowl.

Credit: G. Theraulaz/University of Toulouse

This study is not the first in which fish have been plopped into a virtual-reality environment, but previous experiments used smaller bowls, so they were limited to studying the 2D movements of relatively small fish. The bowl of the Toulouse team is large enough to accommodate the 3D movements of the rummy-nose tetra (*Hemigrammus rhodostomus*), a 3-cm-long South American fish that exhibits strong schooling behavior.

The researchers placed a single tetra in their bowl with four virtual fish programmed to obey a set of interaction rules. These rules were based on the team's earlier observations of pairs of real tetras swimming together, which revealed the influence that one fish (the "focal" fish) feels from a neighbor [2]. Influence is a variable determined by how much the focal fish adjusts its motion to be in-line with its neighbor. The team found that influence depends on the relative positions of the fish, with the highest influence occurring when the neighbor swims in front of the focal fish at a distance of about 5 cm.

The question then becomes: how to extend these two-fish interaction rules to a multifish scenario. Theraulaz and

colleagues investigate three different schooling strategies. The first assumes that a fish follows only one neighbor—the one considered most influential on the basis of its relative position. This most-influential neighbor is not fixed but can change as the fish jockey around each other. The second strategy assumes that a fish follows two neighbors: the most-influential and the second-most-influential. The focal fish effectively averages the effect of the two neighbors and adjusts its heading accordingly. The third strategy extends averaging to all four neighbors.

In separate trials, the researchers programmed the virtual fish to behave according to one of the three strategies and observed how the real fish responded. Comparing the data with simulations, they found that a model based on the first strategy best matched the observations. The implication is that the real fish is primarily following its single-most-influential neighbor rather than averaging cues from the entire group.

"The experiment does a good job of creating a schooling-like environment for the focal fish," says biologist Liang Li from the Max Planck Institute of Animal Behavior in Germany. He says the real fish clearly responds to the virtual fish, changing its behavior when the programmed rules change. "This reaction suggests that the real fish is genuinely interacting with the virtual group." Li adds that the findings raise interesting questions about how a fish chooses which neighbor is the most influential. "The virtual-reality approach developed here could be a powerful way to explore these questions."

The virtual experience is not the same as reality—for one, the virtual fish do not make hydrodynamic wakes, which may affect schooling behavior. Still, the researchers think that their results show how selective fish are about the information they collect. "A fish does not pay attention to all its neighbors," Theraulaz says. He says that other social animals, such as ants, exhibit similar information filtering as a low-cost strategy for group organization. "If an organism selects the right information, it can coordinate with other individuals while minimizing its cognitive load." We humans likely perform similar filtering when we "swim" through a busy crowd, he says.

Michael Schirber is the Deputy Editor of *Physics Magazine*.

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