Zebrafish yield clues to how we process visual information

Lawrence Berkeley National Laboratory

To a hungry fish on the prowl, the split-second neural processing required to see, track, and gobble up a darting flash of prey is a matter of survival.

To scientists, it’s a window into how our brain coordinates the eye motions that enable us to hit a baseball, sidestep an errant skateboarder, and otherwise make our way in a world full of danger and opportunity.

This process is now better understood, thanks to a team of scientists that imaged the activity of individual neurons in a part of a zebrafish’s brain called the optic tectum. The optic tectum receives signals from the retina, filters them, then sends the signals to other parts of the brain that control motion.

They found that when the fish saw something that resembles prey zipping by, the output neurons in the optic tectum are strongly activated. These output neurons send signals to the rest of the brain — a jolt to spark the fish into action and give chase.

But when the fish saw large flashes of light and dark, the equivalent of a bland world devoid of potential prey, the output neurons in the optic tectum are weakly activated.

“We can see, for the first time, how neurons in the fish’s optic tectum take visual information and convert it into an output that drives action,” says Ehud Isacoff, a biophysicist who holds joint appointments with Lawrence Berkeley National Laboratory’s Physical Biosciences and Materials Sciences Divisions and UC Berkeley’s Department of Molecular and Cell Biology.

Isacoff conducted the research with a team of scientists that includes Claire Wyart, a scientist in his UC Berkeley lab; Filippo Del Bene of Herwig Baier’s University of California at San Francisco lab; and Loren Looger of the Janelia Farm Research Institute in Virginia.

They report their research in the October 29 issue of the journal *Science.*

Their work could shed light on how we process visual information. The optic tectum in fish is related to the superior colliculus in the human brain, which coordinates eye motion.

“We are particularly sensitive to high-contrast, moving objects that fill only a small portion of our visual field,” says Isacoff. “When you stand next to a busy road and track cars going by, the coordination of the motor control in the eyes that allows

you to visually track cars is very important."

To learn more about this flow of visual information, the scientists used a state-of-the-art combination of fluorescent imaging and microscopy. Fish were genetically developed in which specifically targeted neurons in their optic tectum expressed a gene encoding an engineered fluorescent protein. The protein lights up whenever calcium enters the cell during electrical activity. Using fast microscopy to observe this fluorescence, the scientists watched individual neurons blink on and off as they transmit signals.

When the fish were shown movies that blanketed much of their visual field with stimuli, the neurons in the output portion of the optic tectum sent a weak signal to the rest of the brain. No food, no action.

But when the fish watched a movie of thin, moving black bars that mimic the size and speed of swimming prey, such as paramecia, the output portion of the optic tectum lit up.

"We identified a difference in the optic tectum's output between visual information that covers the whole visual field versus a small object moving across it," says Isacoff.

The scientists next set out to determine what happens inside the optic tectum to cause this difference. How does the optic tectum take visual information from the retina that indicates potential prey, and translate it into a call to action on the output side?

They found that a movie that stimulates the entire visual field activates a wide swath of neurons in the input portion of the optic tectum, including many inhibitory neurons. These inhibitory neurons conspire to drown out the signal as it travels deeper through the optic tectum. By the time the signal arrives at the output portion of the optic tectum, it's very faint.

"The inhibition is so dominant that it kills the signal," says Isacoff.

But when a tiny object moves across the visual field, a much smaller number of inhibitory neurons are excited. This allows a tiny sliver of signal to travel through the optic tectum and arrive at the output portion largely uninhibited.

The scientists tested the role of inhibitory neurons by blocking the neurons' function and observing how this impairment affected the zebrafish's ability to catch prey.

"We know that the inhibitory neurons are the key to this process because if we interfere with their function the animal loses the ability to hunt," says Isacoff.

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