Neuroscientists explore the risky business of self-preservation

September 7 2017

A critical survival decision for all animals is when, where and how to escape from a looming threat. A Northwestern University research team using multi-neuron imaging has learned that the escape response for prey is more nuanced than previously thought.

In a study of larval zebrafish, the researchers are the first to find that the animal's innate escape response incorporates the speed of the approaching predator—the urgency of the threat—and not just the proximity of the predator in its calculation of how best to flee.

Prior to the new research, the escape behavior was thought to be driven by a proximity threshold where anything that gets within a certain distance triggers an escape. The Northwestern team, however, found that at slower approach rates by a predator, the larval zebrafish's fastest escape circuit is not deployed; instead, a different circuit produces a more delayed and variable escape behavior.

By attributing prey's neural escape response to the predator's velocity as well as proximity of approach, the research team has uncovered new information that can help scientists understand the neural mechanics that fuel the most elemental self-preservation instincts.

The results will be published online Sept. 7 by the journal *Current Biology*. The study will appear in the Sept. 25 print issue.

"A potential problem with basing the prey's escape decision solely on the predator's proximity is that it does not distinguish between predators approaching rapidly and those approaching slowly," said Malcolm A. MacIver, one of the study's authors. "Our work contributes to understanding a fundamental tradeoff within neural systems: whether to rapidly initiate a canned, inflexible behavior that is more predictable or delay response to compute a more variable behavior that will be harder to predict."

MacIver is professor of biomedical engineering and of mechanical engineering in the McCormick School of Engineering.

To study the neural underpinnings of the escape response, MacIver, professor David L. McLean and biomedical engineering doctoral candidate Kiran Bhattacharyya (first author) chose the larval zebrafish. This animal is transparent, allowing the researchers to image whole groups of neurons and observe the animal's movement at the same time.

"We can watch the brain light up with activity as the animal behaves," said McLean, an associate professor of neurobiology in the Weinberg College of Arts and Sciences and study author. "Studying a model organism such as the zebrafish helps us understand how the brain generates a diversity of behaviors. Gauging an appropriate response to stimuli is a fundamental job of the brain in all animals, including humans, and it is something we want to understand."

McLean and MacIver, whose technical expertise is complementary, have been collaborating for nearly a decade on neuroscience research.

"It seems that the animal is assessing risk, and if the approaching predator's velocity passes a certain level, then the prey gets out of Dodge as fast as it can," MacIver said. "If a predator is coming more slowly, the prey has more options and more time to decide between the options."

Using multi-neuron imaging while simultaneously recording high-speed video of the escape behavior, the researchers have shown that the rate of approach of a threat sets the probability that a special high-speed escape mechanism is deployed (fired by special neurons called Mauthner cells). As the predator's approach rate increases, so too does the probability of deploying this special escape mechanism.

The advantage of the special escape mechanism is that responses occur as fast as possible, but a disadvantage is that the movement is highly predictable, which allows certain predators to "hack" the circuit and trick prey into launching themselves straight into the predator's mouth. At lower approach rates, the special escape circuit is not deployed (Mauthner cells do not fire), and a more variable, although delayed, escape behavior ensues.

"Our findings suggest these simple fish are calibrating their response to the perceived risk of the threat," McLean said. "Our own brain evolved from fish to weigh numerous variables before we act. Now that we know what fish are paying attention to, we can begin to explore the neural computations that govern this fundamental process."

While the special high-speed escape circuit that fish and amphibians deploy for urgent threats disappears in fully terrestrial animals like reptiles, birds and mammals, the alternative high-variability circuit is preserved, MacIver said. As animals emerged from the water and started inhabiting land, their visual range increased dramatically, allowing the expression of more variable behaviors using this alternate circuitry.

The paper is titled "Visual threat assessment and reticulospinal encoding of calibrated responses in larval zebrafish."

Provided by Northwestern University