Time-shifted inhibition helps electric fish ignore their own signals

August 12 2020, by Talia Ogliore

African fish called mormyrids communicate using pulses of electricity. To distinguish their own signal from those of neighboring fish, their brains inhibit sensory responses using a corollary discharge, which is an internal copy of their own motor command. New research from biologists in Arts & Sciences shows that this corollary discharge has co-evolved with large and rapid changes in these signals across species. Credit: Tsunehiko Kohashi

Electric fish generate electric pulses to communicate with other fish and sense their surroundings. Some species broadcast shorter electric pulses, while others send out long ones. But all that zip-zapping in the water can get confusing. The fish need to filter out their own pulses so they can identify external messages and only respond to those signals.

A solution to this problem is a brain function called a corollary discharge . It's sort of like a negative copy of the original message—something that tells the fish: Ignore this.

But an animal's brain doesn't have to block sensory inputs during the entire message to effectively ignore its own signal, according to new research from biologists at Washington University in St. Louis.

Instead, the inhibitory signal—that call to ignore—is delayed in fish that communicate using longer electric pulses, versus those using shorter pulses.

"In fish that communicate with longer pulses, sensory responses to their own pulse are delayed," said Bruce Carlson, professor of biology in Arts & Sciences. "Thus, a delayed corollary discharge optimally blocks electrosensory responses to the fish's own signal."

Carlson and Matasaburo Fukutomi, a postdoctoral fellow in his laboratory, published their new research on African mormyrid weakly electric fish in the *Journal of Neuroscience*.

A brief, well-defined period of inhibition keeps electric fish from missing out on other important external signals, Carlson said.

Corollary discharge helps electric fish filter out their own pulses. Credit: Matasaburo Fukutomi

Time-shifted tune-out

Scientists have known about corollary discharges since the 1950s. In the decades since, corollary discharges have been found in many different species and sensory systems, but it remained unknown how corollary discharges were modified as communication signals evolved.

Previous work on corollary discharge in electric fish had been done with species that communicate using short-duration electric pulses, those lasting less than 1 millisecond.

For their new study, Carlson and Fukutomi included these fish and five additional species that communicate using electrical pulses ranging in duration from 0.1 to 10 milliseconds.

"We found the sensory neurons respond with spikes in a narrow time window regardless of pulse duration," Fukutomi said. "These spikes occurred in a specific part of the self-generated pulse, the first peak of the pulse. In addition, we compared the time courses between the corollary discharge inhibition and the pulse and found that the time-shifted inhibition overlapped the first peak of the electric pulse.

"Time-shifted inhibition is a reasonable change because longer-lasting inhibition would result in an unnecessarily long insensitive period," he said. "I am impressed that there is a solution that makes more sense in real organisms than we might have expected."

The new findings have broader implications for understanding the evolution of brains.

"Despite the complexity of sensory and motor systems working together to deal with the problem of separating self-generated from external signals, it seems like the principle is very simple," Carlson said. "The systems talk to each other. Somehow, they adjust to even widespread, dramatic changes in signals over short periods of evolutionary time."

As part of continuing research, Carlson and Fukutomi are working to pinpoint the place in the brain circuit where the delay is adjusted, and how that adjustment is made. They are also investigating how the inhibition delay changes over the individual lifetime of a fish.

The researchers also recently co-authored a new review paper on the contributions of electric fish to the study of corollary discharge in *Frontiers in Integrative Neuroscience*.

Even though humans aren't able to generate electric fields, research on corollary discharge in electric fish has provided insights that are important in medical science as well as basic science. Dysfunction of corollary discharge may be related to psychiatric diseases such as schizophrenia in humans, for example.

"I love strange creatures, including electric fish," Fukutomi said. "We can only feel electricity as pain, but we never sense electricity as the fish does.

"Surprisingly, electrosensory systems share a lot of general features with other sensory systems," he said. "I am very excited to be studying these fish."

More information: Matasaburo Fukutomi et al, Signal diversification is associated with corollary discharge evolution in weakly electric fish, *The Journal of Neuroscience* (2020). DOI: 10.1523/JNEUROSCI.0875-20.2020

Provided by Washington University in St. Louis