

Language of a fly proves surprising

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A group of researchers has developed a novel way to view the world through the eyes of a common fly and partially decode the insect's reactions to changes in the world around it. The research fundamentally alters earlier beliefs about how neural networks function and could provide the basis for intelligent computers that mimic biological processes.

In an article published in the *Public Library of Science Computational Biology Journal*, Los Alamos physicist Ilya Nemenman joins Geoffrey Lewen, William Bialek and Rob de Ruyter van Steveninck of the Hun School of Princeton, Princeton University and Indiana University, respectively, in describing the research.

The team used tiny electrodes to tap into motion-sensitive neurons in the visual system of a common blowfly. Neurons are nerve cells that emit tiny electric spikes when stimulated. The electrodes detected pulses from the motion-sensitive neurons in the fly. The fly uses the neurons to estimate, and subsequently control, how it moves through the world.

The team harnessed the wired fly into an elaborate turntable-like mechanism that mimics the kind of acrobatic flight a fly might undergo while evading a predator or chasing another fly. The mechanism can spin extremely fast and change velocities quickly. A fly in the mechanism sees changes in the world around it and its motion-sensitive neurons react much in the same way as they would if the insect were actually flying.

Under complex flight scenarios, the fly's neurons fired very quickly. The researchers looked at the firing patterns and mapped them with a binary code of ones and zeroes, much like computer instructions, or binary messages in digital phone communications.

The team found that the impulses were like a primitive, but very regular "language"—with the neuron firing at precise times depending on what the fly's visual sensors were trying to tell the rest of the fly about the visual stimulus. When they examined this language, it spoke volumes about how the harnessed fly reacted to its world.

"In this system, the motion-sensitive neurons emit spikes very often and very precisely," said Nemenman. "Historically, people have observed a lot more random spike intervals. This research is a departure from the traditional understanding in that we see that the precision of spike timing that carries information about the fly's rotation is a factor of ten higher than even the most daring previous estimates."

Similar-though-much-simpler experiments on different subjects, including flies, and going back to the seminal work of E. D. Adrian and Yngve Zotterman in 1926, seemed to show that sensory neurons would fire a certain number of impulses during a given period, but that the precise timing of the impulses was largely irrelevant. Nemenman and his team believe the timing of the spikes was not as crucial during those early experiments largely because the artificial stimulation was in some sense unnatural, bordering on the monotonous and predictable.

"Biological organisms have an interest in conserving energy," Nemenman said. "Fly eyes account for about one-tenth of the fly's energy consumption. The fly wants to be very efficient, but it costs energy and molecular resources to emit many precise spikes in the neurons."

“If you are presenting simple stimuli where little changes with time, then the most efficient way to encode them may be to generate few randomly positioned spikes, which would be sufficient to convey whatever small changes, if any, happened. Similarly, if the stimulus is unnaturally fast, the neurons may not be able to encode it well.

“However, if you put an organism in an environment with fast and naturally changing velocity profiles, the fly starts using all the bandwidth available to it,” Nemenman said. “The motion-sensitive neuron adjusts its coding strategy and it uses the precise positioning of the spikes to tell the rest of the fly exactly what is happening.”

In addition to the complex motions possible with the team’s apparatus, they conducted their experiment in a wooded setting similar to the fly’s natural environment, adding to the complexity and realism of the experiment.

Nemenman and his colleagues’ research is significant because it re-examines fundamental assumptions that became the basis of neuromimetic approaches to artificial intelligence, such as artificial neural networks. These assumptions have developed networks based on reacting to a number of impulses within a given time period rather than the precise timing of those impulses.

“This may be one of the main reasons why artificial neural networks do not perform anywhere comparable to a mammalian visual brain,” said Nemenman, who is a member of Los Alamos’ Computer, Computational and Statistical Sciences Division. “In fact, the National Science Foundation has recognized the importance of this distinction and has recently funded a project, led by Garrett Kenyon of the Laboratory’s Physics Division, to enable creation of large, next-generation neural networks.”

New understanding of neural function in the design of computers could assist in analyses of satellite images and facial-pattern recognition in high-security environments, and could help solve other national and global security problems.

Source: Los Alamos National Laboratory

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