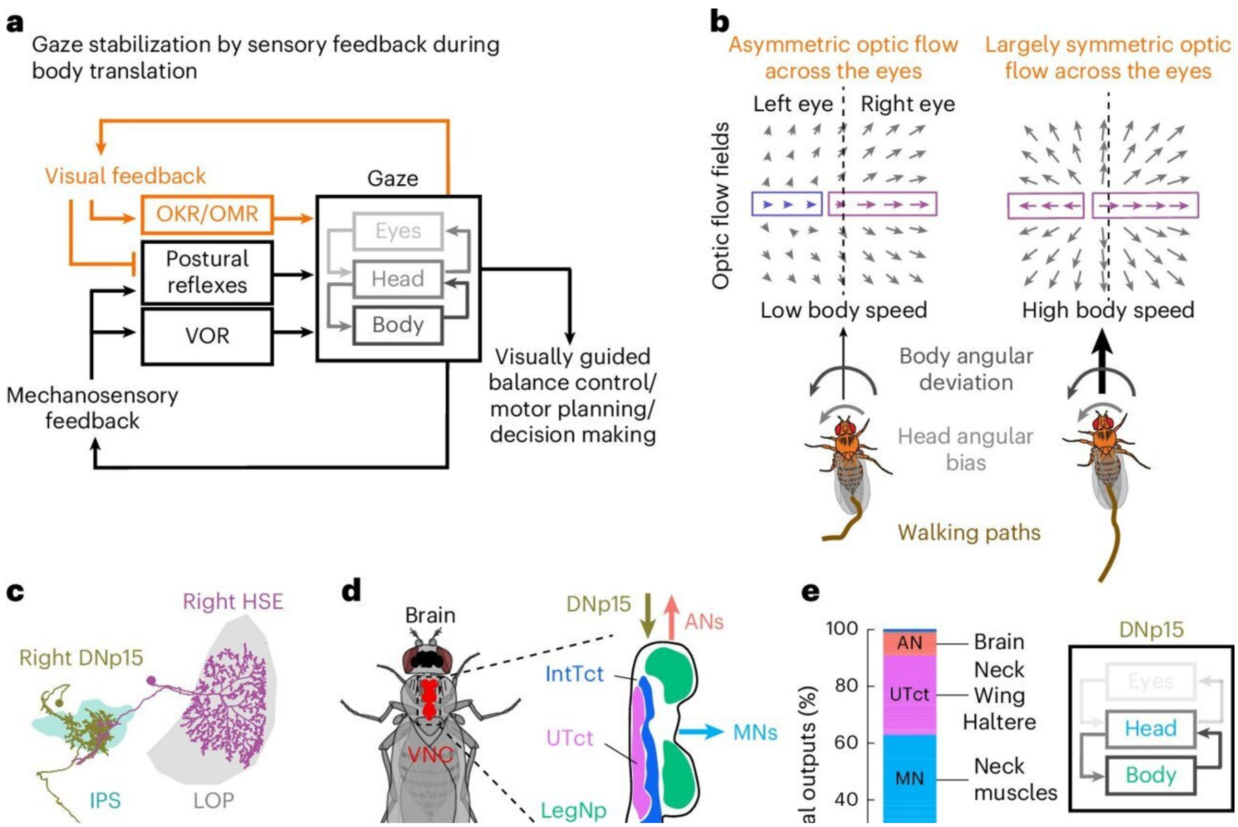
How fruit flies' neurons spot tiny visual errors to keep them flying straight

May 1 2025



Examining optic flow processing for gaze stabilization during locomotion. Credit: *Nature Neuroscience* (2025). DOI: 10.1038/s41593-025-01948-9

When a fruit fly is navigating straight forward at high speed, why does it know that it's not straying off course? Because as long as the fly moves directly forward, the visual scene shifts from front to back in a near-perfect mirror image across both retinas—generating, in other words, a symmetrical visual motion pattern. This pattern, known as "optic flow," provides a powerful cue for detecting self-motion and maintaining direction.

Moreover, at high speeds, as soon as the fly starts deviating from its straight-ahead course even slightly, the optic flow becomes less symmetrical. But the high level of translational symmetry due to the fly's high-speed forward motion could mask smaller binocular asymmetries caused by slight rotational inflections in its trajectory.

Therefore, detecting such "errors" and correcting them at the motor level is not trivial and must happen very quickly. Only then will the fly ensure it continues to move straight forward, as intended.

In a study published in *Nature Neuroscience*, scientists reveal how the fruit fly, Drosophila melanogaster, achieves this remarkable feat. The retina alone cannot distinguish whether motion is symmetric or not; it requires additional processing from other brain regions.

There's a simple reason for that.

"If you are only receiving visual information from one eye, you will never know whether you are in a symmetric or an asymmetric condition. You are missing half the picture, because you don't have the information from the other eye," explains Eugenia Chiappe, principal investigator at the Sensorimotor Integration Lab of the Champalimaud Foundation, in Lisbon, and one of the senior authors of the new study.

The researchers—from Germany, Portugal and the US, in collaboration with Chiappe's team—have now identified a compact but complete neural network that integrates visual input from both eyes to detect even minor optic flow asymmetries. They have also mapped the full circuit responsible for this visual computation and revealed how it guides the fly's steering behavior.

A critical subtraction

First, they took a closer look at a well-known class of neurons, called "horizontal system" cells, or HS cells, which were already known to be involved in motion vision and course control. These cells process optic flow and are sensitive to horizontal motion across the retina.

They then focused on a pair of descending [downstream] neurons known as DNp15, which receive input from HS cells and send signals to the fly's motor system via the ventral nerve cord (VNC)—insects' equivalent of the vertebrate spinal cord. Using so-called two-photon microscopy, the researchers showed that, unlike HS cells, DNp15 neurons are less sensitive to symmetric optic flow. Instead, they selectively respond to asymmetries.

"Our idea was that DNp15 neurons integrate information from the two sides of the head—receiving ipsilateral [same-side] input from HS cells and contralateral input from another motion-sensitive population, H2 cells," says Chiappe.

However, the scientists found that DNp15 neurons are not simply integrating—adding up—visual inputs. "Instead, these neurons perform a subtractive computation, actively removing the symmetric component of the optic flow to extract the asymmetric signal," Chiappe points out.

These results could not be explained by looking only at the DNp15 neurons and their inputs: there had to be other neurons involved. To find them, the team used a recently completed electron microscopy-based wiring diagram of the fruit fly's brain that allowed them to trace and identify neurons.

"The information provided by this dataset was a game-changer," says Chiappe—and has become even more so since artificial intelligence came to the rescue, enabling automatic (instead of manual) segmentation and tracking.

When the team studied the primary downstream neural projections from HS and H2 neurons, they first found that many connections are to descending neurons targeting areas of the VNC responsible for controlling the neck, haltere, wing and legs. This confirmed that these visual motion-sensitive neurons directly influence motor output.

More importantly, they also identified a network of 16 additional neurons that feed back into HS, H2 and DNp15 neurons, modulating their activity. Among them, a class of inhibitory neurons, called bIPS cells, plays a pivotal role in subtracting symmetrical components of the visual input.

These neurons respond strongly to symmetric optic flow and appear to suppress it at the level of DNp15 output—likely enhancing the latter's sensitivity to even small asymmetries.

"In fact, bIPS cells help DNp15 neurons focus on what matters—the asymmetrical optic flow component signaling deviations from a straight path. The sensitivity to small asymmetries then emerges from both the visual input and the recurrent signals from the broader network," Chiappe explains.

Steering back on course

The study shows that, even at high speeds, when optic flow is largely symmetrical, this compact circuit extracts subtle deviations that indicate a need for course correction. DNp15 neurons compute the residual asymmetry and pass that information on to motor neurons in the fly's VNC, triggering precise changes in body posture to put the fly back on track.

"This fine-tuned optic flow processing transforms binocular asymmetries into categorical steering commands for course and gaze control," the authors sum up in their paper.

In essence, the fruit fly's ability to fly or walk straight isn't just due to keen vision—it is the result of a sophisticated neural computation.

"Critically based on recurrent inhibition and lateral competition that compares inputs from both eyes, this suppresses irrelevant symmetry and emphasizes what matters most: when and how to steer," Chiappe concludes.

More information: Mert Erginkaya et al, A competitive disinhibitory network for robust optic flow processing in Drosophila, *Nature Neuroscience* (2025). DOI: 10.1038/s41593-025-01948-9

Provided by Champalimaud Centre for the Unknown

Citation: How fruit flies' neurons spot tiny visual errors to keep them flying straight (2025, May 1) retrieved 4 October 2025 from
https://phys.org/news/2025-05-fruit-flies-neurons-tiny-visual.html

This document is subject to copyright. Apart from any fair dealing for the purpose of private study or research, no part may be reproduced without the written permission. The content is provided for information purposes only.