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How the fruit fly's brain knows where the fruit fly's going

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Drosophila sp fly. Credit: Muhammad Mahdi Karim / Wikipedia. GNU Free Documentation License, Version 1.2

When we turn our head to one side, the visual field "turns" the other way. When we are on a train, the landscape slides by us. However, we know that we are the ones moving, while the world remains in place. How does the brain avoid being fooled by apparent motion?

A team of neuroscientists from the Champalimaud Foundation in Lisbon, Portugal, discovered in the fruit fly's brain a neural circuit that creates a faithful internal representation of the direction and velocity of the insect's locomotion, allowing it to know where it is going at any given time. Their results, which could also be valid for other animals, including humans, have been published in the journal *Nature Neuroscience*.

In fact, we take this capacity - being able to perceive that our movements are really our own - so much for granted that we end up underestimating the complexity and the fragility of the underlying biological mechanisms. But when we lose this ability, as can be the case in certain mental disorders and due to brain injury, we are no longer able to interact with the world, says Argentinian neuroscientist Eugenia Chiappe. "The precise sense of self-movement is an important part of our sense of self. No sensory experience is possible without movement".

Eugenia Chiappe, who led the new study, wants to understand how, when we go from one place to another, our brain manages to differentiate the apparent motion of the objects around us, generated by our own movements, from an actual physical motion of those objects (as would happen in an earthquake, to give an extreme example).

The team studied a specific type of neurons in the fruit-fly: horizontal system cells, or HS cells, located in a region of the fly's brain called the lobula plate. "We know that HS cells are part of a monitoring system that tells the fly's brain that it was the fly that moved", says Eugenia Chiappe.

This type of cells, generically called "optic-flow processing" cells, also exist in the primate brain. And these neurons receive not only visual information, but also non-visual information related to eye and head movements of the animal. So it would be expected that they also receive non-visual information related to walking movements.

"Until now, this had not been demonstrated", says Eugenia Chiappe, "because it has been very difficult to artificially create the illusion of walking in a monkey." But with the fruit fly, it is much easier to do locomotion experiments: just place the fly on a suspended ball that rolls when the fly walks, and while it is walking you can directly record the activity of HS cells.

To prove the contribution of non-visual signals to the HS cells' activity, the scientists simply turned off the lights. "What we now showed in the fruit fly is that, even in the dark, HS cells continue monitoring body movements through non-visual signals", says Eugenia Chiappe. The authors also showed that these neurons integrate visual and non-visual signals when the lights are back on - that is, when both kinds of signals coexist.

But does this enhance the fly's perception of its own movements?

The answer is yes. "We showed that when the fly can sense self-generated visual feedback, the two kinds of signals, the visual and non-visual, cooperate", says Eugenia Chiappe. More specifically, this cooperation leads to an increase of the activity of HS cells when the visual feedback is expected from the direction of walking. In other words, thanks to the integration of visual and non-visual signals, HS cells can monitor and control the fly's course more faithfully.

To confirm the existence of this visual/non-visual signal cooperation, the team performed a third experiment, where the outside world "reacted" in a totally unnatural way to the fly's walking motion: when the fly turned in a certain direction, the visual field now turned in the same direction!

Under this condition, the HS cells completely lost their sense of orientation, so to speak. "The directional selectivity of the HS cells decreased and they became unable to distinguish one direction from another, failing to tell the fly's brain in which direction the fly was turning", says Eugenia Chiappe.

According to her, a reevaluation of the classical vision of HS cell function is now needed. Up to know, it was thought that in the fruit fly, these cells specifically controlled the flight course.

But one thing remained poorly understood: to a fly which is in the air, the motion of far-away objects appears slower than that of closer objects. In these conditions, how can the fly have an accurate notion of its flight speed, something which is crucial to correctly calculate the distance to its target and land smoothly on it?

Here, another finding the scientists made during the experiments in the dark becomes relevant: the fact that the activity of the HS cells was strongly correlated with the velocity of the fly's body, both when it walks in a straight line and when it turns.

This means, according to Eugenia Chiappe, that "based on the activity of its HS cells, the fly's brain computes its actual physical velocity, both linear and angular". In other words, "it is the combination of visual and non-visual signals that enables the calibration of the visual information, and thus a more faithful representation the fly's locomotive movements", she adds.

In light of these results, HS cells become excellent candidates for the role of self-movement detectors that allow the fly's brain to know, at every moment, where it is headed and to control its course.

"The next step of this research will be to determine what the non-visual signals involved are", says Eugenia Chiappe. These may include our so-called "sixth-sense", proprioception, which enables us to know, at any given instant, the position in space of the different parts of our body.

"Moreover, we also want to understand how these signals combine among themselves in order to supply the relevant information to the brain", says Eugenia Chiappe.

"It is important to understand how motor and visual processes interact with the perception of our own movements. This coordination is at the root of many of our daily activities, and namely of our basic cognitive capabilities", she concludes.

More information: A faithful internal representation of walking movements in the Drosophila visual system, *Nature Neuroscience*, DOI: 10.1038/nn.4435

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