Flies in a VR world reveal how vision affects locomotion

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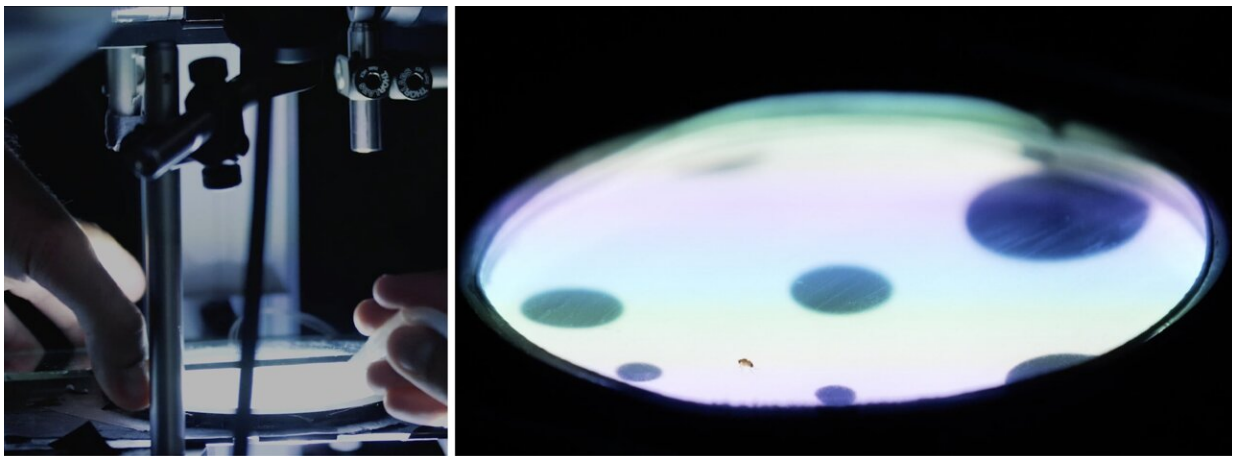

Fruit flies placed in a virtual reality world help scientists understand how vision affects locomotion. Credit: Alexandre Azinheira, Champalimaud Foundation

Eugenia Chiappe, principal investigator of the Sensorimotor Integration Research Group at the Champalimaud Centre for the Unknown, Lisbon, Portugal is standing in her office. There is a door, maybe three meters away, and the floor is flat and clear. Eugenia, who intends to walk in a straight line to the door, takes a second to measure the distance and the terrain. She closes her eyes, walks four steps forward, and bumps into a chair to her right.

This may not surprise you. It seems very obvious that vision is linked to the ability to move effectively, so obviously you can't walk in a straight line with your eyes closed. But, why not? These are movements that we have perfected over many years, and yet we struggle to manage more than a few steps without eyesight. In a study published today, in the scientific magazine *Current Biology*, scientists show how visual control affects locomotion in flies.

The brain-body-eye connection

This paper, results from the Ph.D.-thesis research of Tomás Cruz and examines the myriad ways in which locomotion is stabilized, and how these are affected by vision. This research is based on work with the Drosophila melanogaster fruit-fly, although both Tomás and Eugenia believe that the results are translatable to large-brained animals, including humans.

This research challenges an accepted model of how vision influences locomotion. Eugenia Chiappe explains that "the long-standing view is that of reactive compensatory rotations, either via head-body coordination or directly on body rotations. What we found is that that's not the case. What vision is doing to maintain gaze stability is to influence body movements by tuning postural adjustments as a preventative measure."

In other words, scientists believed that visual feedback generated reactive rotations: once you deviate from the course, vision triggers a compensatory rotation. This paper, however, suggests that these rotations happen far too quickly for this to be the case, and that they are actually preventing erroneous movements, rather than reacting to them, which was not a commonly held hypothesis.

Tomás Cruz believes that the real novelty of the findings is exactly this, that "the effect of vision must take place much closer to the limb control than previously thought, in the fly's equivalent of the spinal cord."

Eugenia says that "Tomás is showing that, inevitably when there is no vision, the limb control systems are responding to balance and posture perturbations. Whereas when vision is available, the behavioral goal of walking straight takes precedence over those little postural adjustments."

Without vision, your body is still receiving some information to help make postural adjustments. If you are standing on a slope, your ankles will angle up or down to maintain your body in an upright position so you won't fall over. If you step forward with your left leg, the next step with your right will follow the path of least resistance—the easiest movement to maintain balance, but not necessarily in a straight line. However, if you have a behavioral goal—to walk straight ahead, for example—vision tunes down the required postural adjustments to a minimum in order to achieve this effectively.

How does the animal, whether insect or human, decide which model to follow? "There is a little tension between what the animal is willing to do and what the physical properties of the world impose in terms of postural control. Vision skews the model in favor of behavioral goals. When vision is not available, the preferred model relates to posture and balance. This idea is largely applicable to humans, too," asserted Eugenia.

Fly goals?

When discussing a fruit-fly's behavior and intentions, one obvious question is raised: how can you know if it is acting in a goal-oriented way, given that you don't know the goals of the fly? Eugenia gives full credit to Tomás for this, explaining that "this is the other intelligent aspect of this paper! It was very difficult to test, because we're dealing with an internal signal that is very difficult to extract from outside observation."

Tomás used the FlyVRena, a state-of-the-art virtual reality system to perform the experiments. In his own words, "we immerse the fly in virtual reality so we can measure, in high resolution, how the fly moves in this environment and control what gets into the fly's retina. With humans, this would be done with VR goggles, but with the fly we built a small space with a floor that used virtual reality technology to allow us to manipulate precisely whatever the fly is seeing from below. The walls and ceiling of the space are kept static and blank to minimize the visual stimuli 'noise'. With this method, we tested hypotheses like 'Is vision important for head-body movement coordination?'"

Eugenia explains how the team could ascertain if the fly was acting in a goal-oriented or more random way: "This was also very smart from Tomás, who created a situation in the world, such that the animal displays a very structured regular behavior. In this way, we could be safe to assume that any deviation from this would be unintentional, or not goal-related. To do this, we heated the walls, meaning that the fly would always walk in a given area of the space, turning as it got too close to one of the walls and heading in a predictable direction." Then it was just a case of seeing how the fly organized movement across the body under different visual conditions, including complete darkness.

Applying knowledge to larger brains

With this new information, what are the next steps for this research? Eugenia says that "the preventive effect of visual feedback we have observed strongly suggests the presence of bidirectional interactions between spinal cord signals and visual circuits in the brain, so the next step for us is to understand their bidirectional interaction across different behaviors. More generally, these interconnected streams of information between the body and the brain not only affect the control of movement corrections but also create perception, commission, and a sense of self. For example, in certain psychiatric conditions, like when a patient can't recognize their own limbs, there are particular states in which these bidirectional interactions have been fragmented."

The final word should go to Tomás, who is preparing to defend his thesis on this research. He explains that "the next steps would be to identify the exact circuits in which these sources of information converge and investigate how they interact to guide the animal's behavior."

More information: Fast tuning of posture control by visual feedback underlies gaze stabilization in walking Drosophila, *Current Biology* (2021). DOI: 10.1016/j.cub.2021.08.041

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