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Newly discovered types of neurons in the animals' brain help to compensate for self-motion

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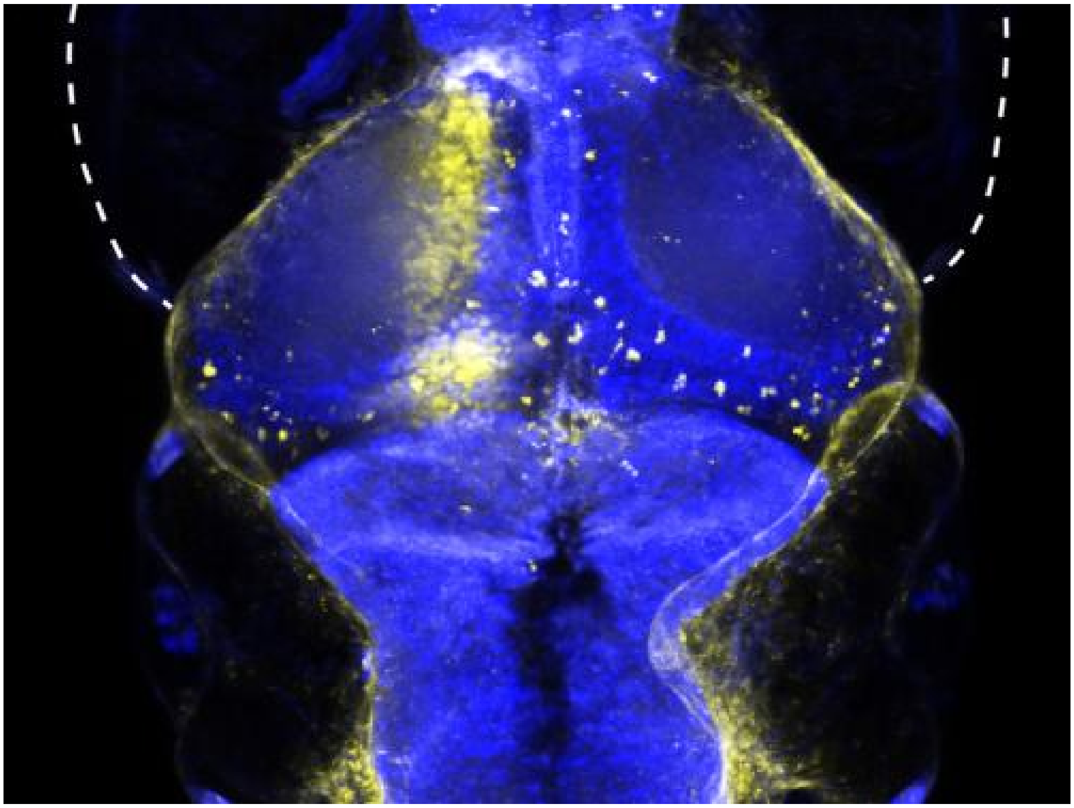

Newly discovered neuron type (yellow) helps zebrafish to coordinate its eye and swimming movements. The image shows the blue-stained brain of a fish larva with the suggested position of the eyes. Credit: Max Planck Institute of Neurobiology/Kubo

Our eyes not only enable us to recognise objects; they also provide us with a continuous stream of information about our own movements. Whether we run, turn around, fall or sit still in a car – the world glides by us and leaves a characteristic motion trace on our retinas. Seemingly without effort, our brain calculates self-motion from this "optic flow". This way, we can maintain a stable position and a steady gaze during our own movements. Together with biologists from the University of Freiburg, scientists from the Max Planck Institute of Neurobiology in Martinsried near Munich have now discovered an array of new types of neurons, which help the brain of zebrafish to perceive, and compensate for, self-motion.

When we jog through a forest, the image of the trees appears to move backwards across our retina. This occurs for both eyes in the same direction. If, however, we turn about our own axis, the trees appear to rotate around us. For one eye, this rotation goes from the outside in, and for the other one it goes from the inside out. Our brain processes such large-scale movements in the visual environment, the "optic flow", so that when jogging, for example, we can estimate our speed correctly and do not constantly stumble.

The human brain is, of course, not unique in being able to perceive optic flow. Fish that live in rivers and streams use this capability, for example, to prevent themselves from drifting in the current. Based on the optic flow, the fish corrects its passive drifting through its own swimming. How and where the fish brain carries out these calculations was not previously known.

"We wanted to know how the compensatory movements are triggered and by which neurons," explains Herwig Baier. Together with his department at the Max Planck Institute of Neurobiology, he searches for and describes the neural networks in the brains of zebrafish larvae that control certain types of behaviour. This is no easy task, as, despite its minuscule size, the brain of a 5-mm-long fish larva consists of several hundred thousand neurons. One advantage, however, is that the brain of the fish larva is almost completely transparent. Neurons can thus be observed directly under the microscope without requiring any surgical dissection.

For their experiments, the scientists placed the fish larvae in circular containers, where they saw black-and-white stripes that moved around them. The animals demonstrated different reactions depending on the movement pattern presented. When the stripes moved from back to front for both eyes, the fish swam straight ahead or tried to turn around. However, when the stripes moved around the fish in a clockwise or counter-clockwise direction, the two eyes followed the perceived direction of rotation. The compensatory movements of the entire body (optomotor behaviour) or of the eyes alone (optokinetic behaviour) should make the motion signal on the retina as small as possible – and keep the fish stable in place.

The neurobiologists wanted to identify the neurons while the brain was processing self-motion and initiating optomotor or optokinetic movements. "It was like looking for a needle in a haystack," explains Fumi Kubo, first author of the study. "This would have been completely inconceivable just a few years ago." For her study, Fumi Kubo, who worked in collaboration with Aristides Arrenberg and Wolfgang Driever from the Institute of Biology I at the University of Freiburg and scientists from the Freiburg Cluster of Excellence BIOSS Centre for Biological Signalling Studies, used a new scientific method: the imaging of the entire brain. Thanks to the latest fluorescent dyes and sophisticated genetic techniques, it has recently become possible to visualise the outlines of all neurons in a fish brain. The special feature of this technique, however, is that the dyes change colour when a neuron becomes active.

During the experiment, the heads of the fish with the labelled nervous system were embedded in a gel. The moving striped patterns on the walls of the container gave the animals the impression of self-motion, similar to the sensation triggered in an IMAX cinema. Depending on whether the stripes drifted forward or rotated, the fish followed the patterns with their eyes or beat their tails. Using a two-photon microscope, the scientists were able to observe which neurons reacted to the direction of the moving stripes.

Four direction-selective cell types had previously been identified in the retina. For a long time, scientists had predicted that these cells somehow carry information about optic flow to downstream neurons in the visual brain, which in turn transmitted the commands to the motor centers that control eye and body movements. The neurobiologists have now succeeded in demonstrating the existence of such comparatively simple neuronal connections. They also discovered seven previously unknown cell types responsible for more complex responses to the inputs from both eyes. For example, one type of cell becomes active when both eyes perceive a forward movement but not a clockwise rotation, which would evoke a turn to the right. This finding is remarkable as in both cases, the left eye should detect a movement from the outside in. "So, not only did we find new cell types, we also discovered a possible explanation as to why the fish's brain distinguishes between translational (that is, forward or backward) and rotational (that is, clockwise or counterclockwise) movements," explains Fumi Kubo.

Once the fish were placed back, swimming freely in their tank, the scientists produced a wiring diagram of the cells based on the recorded tasks for the new neuron types and their locations in the brain. Their findings help to provide a better understanding of the processing of movements in the vertebrate brain. However, Fumi Kubo is already thinking about the next stage in the research: "The next challenge will be to prove the proposed connections in the brain."

More information: Fumi Kubo, Bastian Hablitzel, Marco Dal Maschio, Wolfgang Driever, Herwig Baier und Aristides B Arrenberg. "Functional architecture of an optic flow responsive area that drives horizontal eye movements in zebrafish." *Neuron*, 19 March 2014

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