What the mouse eye tells the mouse brain

January 7 2016

The retina sends information to the brain via some 40 different channels. Credit: CIN/Tübingen University

Tübingen researchers have shown that image processing in the eye is more extensive than previously thought. They investigated the channels that transmit information from the eye to the brain. In the course of this investigation, they not only identified numerous new cell types: they also found that the retina seems to possess some 40 different channels into the brain, twice as many as previously assumed. The results of their study are published in the latest edition of *Nature*.

"What the frog's eye tells the frog's brain" was the title that cognition scientist Jerome Lettvin gave to a seminal paper published in 1959. He assumed that the eye not only sees, but also processes images – even before they are transmitted to the brain for further processing. Lettvin was able to show that the eye neither simply takes pictures like a camera, nor does it send them to the brain without filtering. Instead, the eye itself extracts valuable information from what it sees. In the case of the frog, for example, it might 'tell' the brain: "There is something small and dark there, possibly a fly." For his revolutionary hypotheses, Lettvin was at first laughed off stage at conferences. In the meantime, though, his oft-quoted paper is considered a milestone. The questions raised in Lettvin's time are still pursued by scientists today.

A Tübingen-based team of researchers has now tackled these questions anew, led by Prof. Thomas Euler and Prof. Matthias Bethge (Werner Reichardt Centre for Integrative Neuroscience, Bernstein Center for Computational Neuroscience, and Institute for Ophthalmic Research). The neuroscientists wanted to find out which kinds of information about the world the retina transmits to the brain. To this end, they undertook a study on an unheard-of scale, investigating more than 11,000 individual

retinal cells in mice - far bigger than the largest similar study to date, which had been content with investigating approx. 450 individual cells.

Combining state-of-the-art experimental methods, the researchers studied retinal ganglion cells (RGCs). They made use of electroporation, a staining technique which makes whole populations of nerve cells visible under the microscope. This enabled the researchers to watch individual cells at work in real time. The vast amounts of data were analyzed using advanced machine learning techniques. The scientists were most interested in the diverse functions of these cells: different ganglion cells respond to different properties of images, and send this information to the brain via different channels, each specialized in either contrast, color, direction and movement, edges etc. From these information channels, the brain assembles our image of the world surrounding us. The scientists tested for the response behavior of the ganglion cells to various simple images and moving optical stimuli.

Based on this functional differentiation, the team was able to identify up to 40 types of ganglion cells in the retina, very likely representing as many information channels. This is far more than the at most 20 types which had been heretofore assumed. While the results from the mouse model cannot be applied directly to humans, the retina is similar in all mammals. This brings an analogous classification in humans within reach.

The large number of different information channels suggests that the retina does not simply transform received light signals into nerve cell signals. Instead, it also interprets the signals in fundamental ways. Their work in basic research has brought the Tübingen neuroscientists a large step closer to understanding how images are interpreted in the brain. Since many diseases of the eye only affect certain retinal cell types and channels, these insights can also help in developing more specific treatments. In Tübingen, research on prosthetic technology to restore

sight to blind people (retina implants) has been going strong for many years. This research stands to profit massively from the new results: current models still stimulate the retina relatively unspecifically. New insights provided by the study at hand might help future versions to feed visual information directly into suitable channels.

More information: Tom Baden et al. The functional diversity of retinal ganglion cells in the mouse, *Nature* (2016). DOI: 10.1038/nature16468

Provided by Universitaet Tübingen