Zebrafish vision in its natural context: from natural scenes through retinal and central processing to behaviour.

Berichterstattung

Projektinformationen

NeuroVisEco

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Projektwebsite

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Periodic Reporting for period 4 - NeuroVisEco (Zebrafish vision in its natural context: from natural scenes through retinal and central processing to behaviour.)

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Zusammenfassung vom Kontext und den Gesamtzielen des Projekts

The project seeks to address how sensory systems of animals are adapted to best process the specific information required for survival and procreation. Focussing on the sense of sight and using the shallow freshwater fish Danio rerio (commonly known as zebrafish) as a model, we ask how this animal's eyes and nerve cells therein are suited to support navigation of their underwater world. This requires looking at several stages of vision, beginning from studying what visual information is actually present and important in the zebrafish natural world, to studying the structure and function of the eye's optics and retina, to ultimately relate these aspects to how the animal behaves when presented with different types of stimuli.

The importance of this work may be understood from a point of view of "efficient sampling". Simply put, in nature the physical and chemical information detectable by animal's senses, (e.g. light, sounds, odorants etc.) differs between different environments that animals live in. For any animal to efficiently use its specific set of senses, it should specifically invest in circuits and mechanisms that are best at picking up and processing the type of information that is likely to occur in their natural world, or that is of particular importance for survival and reproduction. A better understanding of how evolution can balance the specific tuning and complexity of an animal's sensory complement may lead to the design "smart-sensors" for our own technological applications. Moreover, it will help us understand the fundamental mechanisms and strategies that neuronal networks use to compute information.

Arbeit, die ab Beginn des Projekts bis zum Ende des durch den Bericht erfassten Berichtszeitraums geleistet wurde, und die wichtigsten bis dahin erzielten Ergebnisse

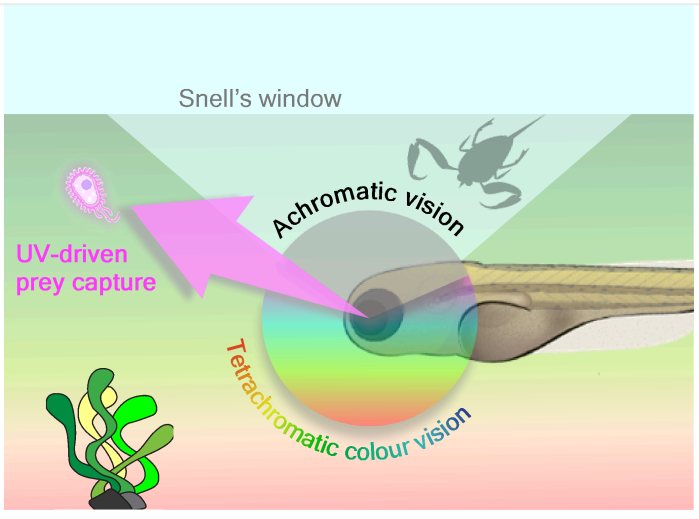
We began by studying the zebrafish natural habitat. Zebrafish live in shallow freshwaters, typically in low-current side-pockets on the side of streams across the Indian subcontinent. We visited several field sites and took video footage of the habitat. In addition, we used a custom device capable of collecting accurate spectral information, from ultraviolet to infrared. This is key to understanding how zebrafish may see colour. From this work we find that different parts of the visual field contain different important information for these animals. The world below the fish tends to be red-dominated and is rich in spatial detail. The horizon is very colourful but lacks spatial detail. Next, the world above the animal is first a ground-reflection on the underside of the water surface, and beyond this, in a region called Snell's window, the fish see the world above the water surface. The latter part of visual space is largely devoid of structure and colour. Together, these findings laid out a series of predictions how the visual system of zebrafish should be organised for efficient function. For example, it predicted that the lower part of the eye, which surveys the upper part of visual space, should not invest in circuits that support in colour vision, as there is little colour in this part of visual space. Conversely, the upper part of the eye, which surveys the ground beneath the zebrafish, should invest in colour-sensitive circuits to make best use of colour information on the ground.

Turning to functional recordings in the eye by way of laser-scanning microscopy combined with

genetically encoded reporters of neuronal activity, this is exactly what we found. Looking at different sets of nerve cells in the zebrafish eye, in different parts of the retina, we found that the lower eye of larval zebrafish is all but colour-blind, while the upper part of the eye supports rich colour vision. In this work, we also stumbled across another key feature of these animal's eyes. The part of the retina that looks just above the horizon in front of the fish is extremely UV-light sensitive. Further work revealed that this is probably a specific adaptation of small underwater animals to support prey-capture. While this first part of our project is published (Zimmermann, Nevala, Yoshimatsu et al. 2018), we now follow up on these points using further functional recordings in different populations of neurons both in the retina, and in the brain.

Fortschritte, die über den aktuellen Stand der Technik hinausgehen und voraussichtliche potenzielle Auswirkungen (einschließlich der bis dato erzielten sozioökonomischen Auswirkungen und weiter gefassten gesellschaftlichen Auswirkungen des Projekts)

We have made some headway in understanding how zebrafish colour vision is matched to the specific distribution of colours in their natural habitat. From here, we can speculate that also other aspects of these animal's vision are tuned to their natural visual world. For example, not just colour, but also spatial detail varies systematically across their visual space. How is this reflected in their visual circuits? Similarly, we will further study at which point of the visual system specific adaptation are implemented. For example, we might expect that adaptations pertaining to colour vision (which are comparatively "simple") are implemented early, while adaptations to more complex visual aspects such as motion might be implemented at a later stage. A better understanding of these types of questions promises to lead to a richer appreciation of how sensory systems can efficiently process information in a more general setting, and in turn lead to new insights in how we could be designing our own algorithms (e.g. in computational image processing) and physical sensors (e.g. smart cameras).



Zebrafish colour vision varies with visual elevation

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