How elephantnose fish switch between electrical and visual sense

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The elephantnose fish explores objects in its surroundings by using its eyes or its electrical sense – sometimes both together. Zoologists at the University of Bonn and a colleague from Oxford have now found out how complex the processing of these sensory impressions is. With its tiny brain, the fish achieves performance comparable to that of humans or mammals. The advance results have been published online in the *Proceedings of the National Academy of Sciences* of the United States of America (*PNAS*). The print issue will appear soon.

The elephantnose fish (Gnathonemus petersii) is widespread in the flowing waters of West Africa and hunts insect larva at dawn and dusk. It is helped by an electrical organ in its tail, which emits electrical impulses. The skin contains numerous sensor organs that perceive objects in the water by means of the changed electrical field. "This is a case of active electrolocation, in principle the same as the active echolocation of bats, which use ultrasound to perceive a three-dimensional image of their environment", says Professor Dr. Gerhard von der Emde at the Institute of Zoology at the University of Bonn. Furthermore, the elephantnose fish can also orient using its eyes.

Professor von der Emde, along with his doctoral candidate Sarah Schumacher and Dr. Theresa Burt de Perera of Oxford University, have now investigated how the unusual fish processes the information from the various sensory channels. Ms. Schumacher summarizes the results: "The animals normally use both senses. If necessary, for example because one of the two senses provides no information or the

information of the two senses differs greatly, however, the fish can switch back and forth between their visual and electrical senses". The scientists were surprised by the manner in which the fish use these two senses to get the best perception of their environment: When the animals became familiar with an object in the aquarium, for example with the visual sense, they were also able to recognize it again using the electrical sense, although they had never perceived it electrically before.

Fish give precedence to the most reliable sensory information

In addition, the fish demonstrated a previously unexpected ability: Their brain gave more weight to the information it thought was more reliable. When the two senses delivered different information in the close range of up to two centimeters, the fish trusted only the electrical information and were then "blind" to the visual stimuli. In contrast, for more distant objects, the animals relied above all on their eyes. They perceived the environment best by using their visual and electrical senses in combination. "A transfer between the different senses was previously known only for certain highly developed mammals, such as monkeys, dolphins, rats, and humans", says Professor von der Emde. An example: In a dark, unfamiliar apartment, people feel their way forward to avoid stumbling. When the light goes on, the obstacles felt are recognized by the eye without any problem. Mammals process such information with their cerebral cortex. The elephantnose fish, however, has just a relatively small brain and no cerebral cortex at all – but nevertheless switches back and forth between the senses.

Clever experimental setup

The scientists came up with a very clever test setup: The elephantnose fish was in an aquarium. Separated from it were two different chambers,

between which the animal could choose. Behind openings to the chambers there were differently shaped objects: a sphere or a cuboid. The fish learned to steer toward one of these objects by being rewarded with insect larvae. Subsequently, it searched for this object again, to obtain the reward again.

When does the fish use a particular sense? In order to answer this question, the researchers repeated the experiments in absolute darkness. Now the fish could rely only on its electrical sense. As shown by images taken with an infrared camera, it was able to recognize the object only at short distances. With the light on the fish was most successful, because it was able to use its eyes and the electrical sense for the different distances. In order to find out when the fish used its eyes alone, the researchers made the objects invisible to the electrical sense. Now, the sphere and cuboid to be discriminated had the same electrical characteristics as the water.

Many repetitions of the individual experiments were necessary in order to apply statistical analyses to reach conclusions about the sensory processing of the elephantnose fish. The scientists worked with a total of ten animals, working more or less in shifts. "The behavior of the different individuals was nearly identical", says Professor von der Emde. For that reason the scientists are certain that this enormous sensory performance is achieved not only by a particulary talented specimen but by all elephantnose fish.

More information: Sarah Schumacher et al. Cross-modal object recognition and dynamic weighting of sensory inputs in a fish, *Proceedings of the National Academy of Sciences* (2016). DOI: 10.1073/pnas.1603120113

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