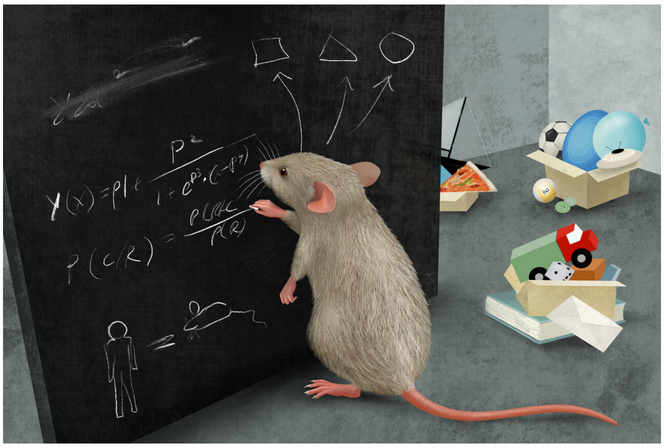
Mice master complex thinking with a remarkable capacity for abstraction

21 April 2021



Mice form categories to simplify their world. Showing that, researchers identified neurons that encode learned categories. Credit: MPI of Neurobiology/ Kuhl

Categorization is the brain's tool to organize sensory inputs. Grouping information into categories simplifies the complex world and helps people to react quickly and effectively to new experiences. Scientists at the Max Planck Institute of Neurobiology have now shown that also mice categorize surprisingly well. The researchers identified neurons encoding learned categories and thereby demonstrated how abstract information is represented at the neuronal level.

A toddler is looking at a new picture book, points to an illustration and shouts 'chair." The kid made the right call, but that does not seem particularly noteworthy. People can recognize all kinds of chairs as 'chair' without any difficulty. For a toddler, however, this is an enormous learning process. It must associate the chair pictured in the book with the chairs it already knows—even though they may have different shapes or colors. How does the child do that?

The answer is categorization, a fundamental element of thinking. Sandra Reinert, first author of the study explains: "Every time a child encounters a chair, it stores the experience. Based on similarities between the chairs, the child's brain will abstract the properties and functions of chairs by forming the category 'chair." This allows the child to later quickly link new chairs to the category and the knowledge it contains."

Our brain categorizes continuously, not only chairs during childhood, but any information at any given age. What advantage does that give us? Pieter Goltstein, senior author of the study says: "Our brain is trying to find a way to simplify and organize our world. Without categorization, we would not be able to interact with our environment as efficiently as we do." In other words: We would have to learn for every new chair we encounter that we can sit on it. Categorizing sensory input is therefore essential for us, but the underlying processes in the brain are largely unknown.

Mice categorize surprisingly well

Sandra Reinert and Pieter Goltstein, together with Mark Hübener and Tobias Bonhoeffer, group leader and director at the Max Planck Institute of Neurobiology, studied how the brain stores abstract information like learned categories. Since this is difficult to investigate in humans, the scientists tested whether mice categorize in a way similar to us. To do so, they showed mice different pictures of stripe patterns and gave them a sorting rule. One animal group had to sort the pictures into two categories based on the thickness of the stripes, the other group based on their orientation. The mice were able to learn the respective rule and reliably sorted the patterns into the correct category. After this initial training phase, they even assigned patterns of stripes they had not seen before into the correct categories—just like the child with the new book.

And not only that: When the researchers switched the sorting rules, the mice ignored what they had learned before and re-sorted the pictures according to the new rule—something we humans do all the time while learning new things. Therefore, the study demonstrates for the first time to what extent and with which precision mice categorize and thereby approach our capacity for abstraction.

Neurons gradually develop a category representation

With this insight, the researchers were now able to investigate the basis of categorization in the mouse brain. They focused on the prefrontal cortex, a brain region which in humans is involved in complex thought processes. The investigations revealed that certain neurons in this area become active when the animals sort the striped patterns into categories. Interestingly, different groups of neurons reacted selectively to individual categories.

Tobias Bonhoeffer explains: "The discovery of category-selective neurons in the mouse brain was a key point. It allowed us for the first time to observe the activity of such neurons from the beginning to the end of category learning. This showed that the neurons don't acquire their selectivity immediately, but only gradually develop it during the learning process."

Category-selective neurons are part of long-term memory

The scientists argue that the category-selective neurons in prefrontal cortex only play a role once the acquired knowledge has been shifted from short-term to long-term memory. There, the cells store the categories as part of semantic memory—the collection of all factual knowledge. In this context, we should keep in mind that the categories we learn are the brain's way to make our world simpler. However, that also means that those categories are not necessarily 'right' or correctly reflect reality.

By investigating category learning in the mouse, the study adds important details to the neuronal basis of abstract thinking and reminds us that complex thoughts are not only reserved for us humans.

The study is published in *Nature*.

More information: Mouse prefrontal cortex represents learned rules for categorization, *Nature* (2021). DOI: 10.1038/s41586-021-03452-z

Provided by Max Planck Society