EBERHARD KARLS
UNIVERSITÄT
TÜBINGEN

Public Relations Department

Dr. Karl Guido Rijkhoek
Director

Janna Eberhardt
Research reporter

Phone +49 7071 29-76788
+49 7071 29-77853
Fax +49 7071 29-5566
karl.rijkhoek[at]uni-tuebingen.de
janna.eberhardt[at]uni-tuebingen.de

www.uni-tuebingen.de/aktuell

Press Release

How the brain learns to come up with nothing

Tübingen neuroscientists discover brain processes which lead to the concept of “zero” on the number line

Tübingen, 21 April 2016

Zero is a magic number. It stands for emptiness, for nothing – and yet it is considered one of the greatest cultural achievements of humankind, making the breakthrough for science and mathematics. It took a long stretch of human history for zero to be recognized and appreciated.

Even children understand that zero itself is a number only after they have learned to count other numbers. It is not easy for human beings to comprehend an empty set as an abstract numerical value. University of Tübingen neuroscience researchers headed by Professor Andreas Nieder now have some answers as to how and where brain cells depict a zero amount as a part of the number line.

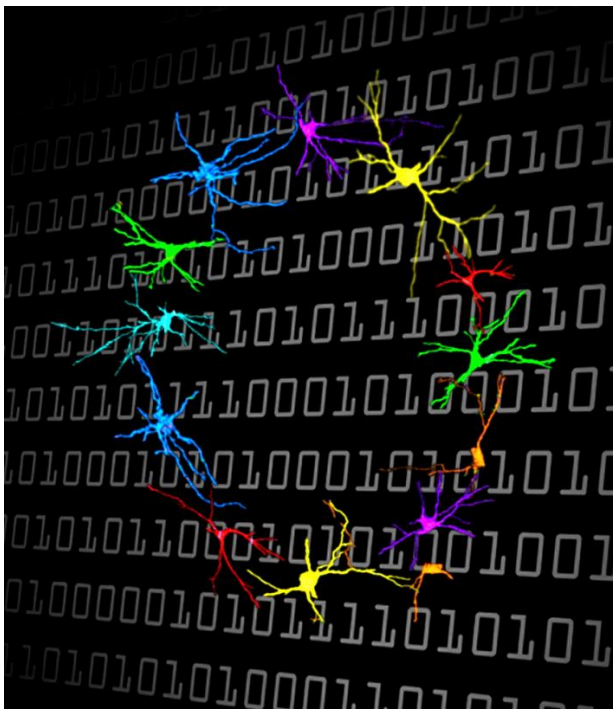
The researchers trained two rhesus monkeys to assess the number of dots on a computer screen from zero to four. In the test, the monkeys judged “no dots” as the number closest to one, thereby giving it quantitative significance at the start of the number line.

While this was happening, the researchers measured the activity in two parts of the monkeys’ brains, the parietal lobe and the frontal lobe, which is the next place neural signals are sent. The researchers had shown in the past that these two regions play a key role in the processing of quantities. “A comparison of the two brain regions showed an initial amazing transformation in the way empty sets are portrayed by neurons,” says Andreas Nieder.

Nerve cells in the parietal lobe registered the lack of countable dots as a missing visual stimulus, without quantitative significance and therefore fundamentally different from numbers. But at the next level at which processing takes place, the frontal lobe, the neurons treated the absence of elements as an empty set among other countable sets, with the greatest similarity to the number one. “Not until it gets to the frontal lobe

does the empty set become abstracted as a value on the number line, analogously with the behavior of the animals," says Nieder.

The new findings provide information on how and just where the brain actively translates an absence of countable stimuli into a numerical category. "For a brain which has evolved to process sensory stimuli, conceiving of empty sets is an extraordinary achievement," Nieder says. "This is the first sign of the ability to formulate concepts independently of experience and beyond what is perceived, just as required for a complex number theory." That the nerves in the prefrontal cortex are capable of making that step confirms the tremendous significance of this area of the brain for abstract thought – which is frequently disrupted in neuropsychiatric disorders.



The discovery of the number zero is considered one of humankind's greatest cultural achievements. Tübingen neurology researchers can now report how and where brain cells depict an empty set as a part of the number line. Image: Andreas Nieder

Publication:
Araceli Ramirez-Cardenas, Maria Moskaleva & Andreas Nieder: Neuronal representation of numerosity zero in the primate parieto-frontal number network. *Current Biology.*
Online: 21 April 2016, DOI: http://dx.doi.org/10.1016/j.cub.2016.03.052

Contact:
Professor Andreas Nieder
University of Tübingen
Institute of Neurobiology – Animal Physiology
Phone: + 49 7071 29-75347
andreas.nieder[at]uni-tuebingen.de