

PRESS RELEASE

How the brain processes the number zero

Researchers from Bonn and Tübingen clarify the neuronal basis of the mathematical concept of "zero"

Bonn, September 24 - Despite its importance for mathematics, the neuronal basis of the number zero in the human brain was previously unknown. Researchers from the University Hospital Bonn (UKB), the University of Bonn and the University of Tübingen have now discovered that individual nerve cells in the medial temporal lobe recognize zero as a numerical value and not as a separate category "nothing". The results have now been published in the journal "Current Biology".

The concept of the number zero has been central to the development of number systems and mathematics and is widely regarded as one of humanity's most important cultural achievements. "Unlike other numbers such as one, two or three, which represent countable quantities, zero means the absence of something countable and at the same time still has a numerical value," says co-corresponding author Prof. Florian Mormann from the Department of Epileptology at the UKB, who is also a member of the Transdisciplinary Research Area (TRA) "Life & Health" at the University of Bonn. In contrast to positive natural numbers, the concept of the number zero only emerged late in human history over the last two millennia. This is also reflected in childhood development, as children are typically only able to understand the concept of zero and associated arithmetic rules at around the age of six.

Neurons signal the number zero

How this concept is represented by nerve cells in the human brain has not yet been investigated. The researchers from Bonn have now joined forces with neurobiologists from the University of Tübingen to get to the bottom of this question. To do this, they showed neurosurgical patients, who had had hair-thin microelectrodes inserted into their temporal lobes at the UKB in preparation for surgery, numerical values from zero to nine. The numerical values were shown as Arabic numerals on the one hand and as sets of dots on the other - including an empty set. "Meanwhile, we were able to measure the activity of individual nerve cells and actually found neurons that signaled zero," says Esther Kutter, who is the first author of the study. "Such neurons responded to either the Arabic numeral zero or the empty set, but not to both."

Number zero is a numerical value for neurons

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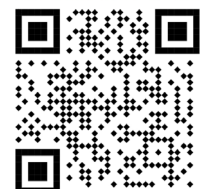
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In both cases, there was a numerical distance effect in which neurons reacted weaker, but measurably, also to the neighboring number one. "So at the neuronal level, the concept of zero is not encoded as a separate category "nothing", but as a numerical value integrated with other, countable numerical values at the lower end of the number line," says Prof. Dr. Andreas Nieder from the Institute of Neurobiology at the University of Tübingen, and Prof. Mormann adds: "Despite this integration, the empty set is encoded differently from other numbers at the neuronal population level, especially in the case of point sets. This could explain why the recognition of the empty set also takes longer at the behavioral level than for other small numbers." For Arabic numerals, however, this effect was not found at either the neural or behavioral level. From this, the researchers recognize the importance of symbolic representations, for example through Arabic numerals, for the integration of the number zero on the number line in the human brain.

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Image material:



Caption: How the brain processes the number zero:

(from left) Prof. Florian Mormann and Esther Kutter, together with Prof. Andreas Nieder from the University of Tübingen, clarify the neuronal basis of the mathematical concept of “zero”.

Picture credits: University Hospital Bonn (UKB) / Alessandro Winkler

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About Bonn University Hospital: The UKB treats around 500,000 patients per year, employs around 9,500 staff and has total assets of 1.8 billion euros. In addition to the 3,500 medical and dental students, 550 people are trained in numerous healthcare professions each year. The UKB is ranked first among university hospitals (UK) in NRW in the Focus Clinic List, had over 100 million third-party funds in research in 2023 and has the second highest case mix index (case severity) in Germany. The F.A.Z. Institute awarded the UKB first place among university hospitals in the category "Germany's Training Champions 2024".