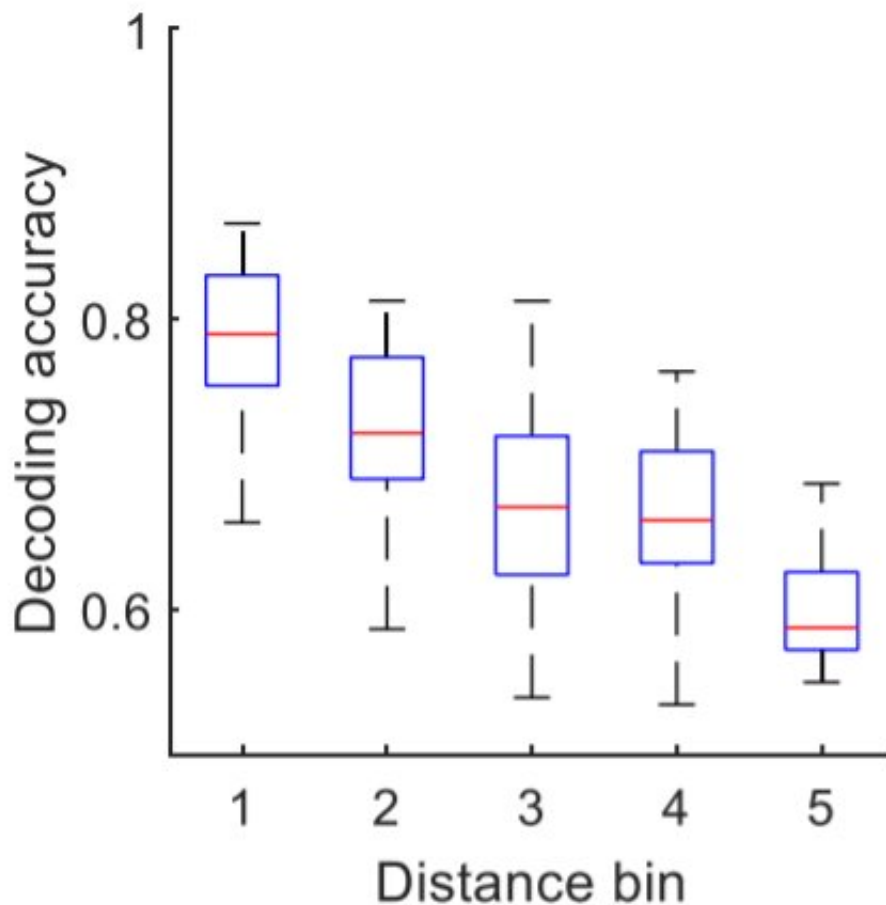# Study determines object-related information is distributed across CA1 neurons in the hippocampus

July 26 2023, by Ingrid Fadelli

The y-axis shows how easy it is to predict whether an object is currently present in the environment, based on neural population activity ("decoding accuracy"). If the score is 1, we can always predict whether the object is present or not; if the score is 0.5, our prediction is not better than tossing a coin. The x-axis shows the

animal's distance from the object. Near the object, prediction accuracy is high; further away from the object, prediction accuracy is low. This shows that patterns in neural population activity are determined by how far the animal is from the object. Credit: Nagelhus, Andersson et al.

The CA1 is a region of the hippocampus known to support the formation, consolidation and retrieval of memories. In recent years, neuroscientists have been trying to better understand how populations of neurons in the CA1 hippocampus encode places and objects.

Researchers at the Kavli Institute for Systems Neuroscience in Norway recently carried out a study exploring how this CA1 area encodes objects and landmarks. Their findings, published in *Neuron*, show that object-related information is represented in the collective activity of CA1 neurons, rather than by individual brain cells.

"Objects can act as landmarks and be crucial for guiding spatial navigation, but what are the mechanisms, in the brain, for object representation during navigation?" Soledad Gonzalo Cogno, one of the researchers who carried out the study, told Medical Xpress. "To answer this question, a few years ago, people from our lab, the Moser lab at Kavli Institute for Systems Neuroscience, discovered that cells in the medial entorhinal cortex (MEC) of mice responded in a very specific manner to the presence of an object in the environment."

In this [previous study](link), researchers at the Kavli Institute for Systems Neuroscience found that cells in the MEC (i.e., a brain region known to support spatial navigation) of mice became active in a location that was linked to a specific object placed in the mice's environment. This location had a fixed distance and orientation relative to the object in question.

"Inspired by this finding, we wondered whether similar responses would be found in the hippocampus, a brain area involved in the formation of memories and that communicates to the medial entorhinal cortex via direct connections," Gonzalo Cogno said.

"The original goal of our study was to determine how individual hippocampal neurons responded to the presence of an object. Recent and exciting technological developments, however, allowed us to also address the more ambitious question of whether, and how, objects are represented in the hippocampal neuronal population (and not only in a few individual neurons)."

To test their hypothesis, Gonzalo Cogno and her colleagues carried out a series of experiments involving adult rats. These rats were individually placed in an arena environment, where they completed four different tasks or trials.

"First, a rat ran in an empty box (which we usually call 'open field arena'), while foraging for cookie crumbles (which they love)," Gonzalo Cogno explained. "In a second trial, we inserted an object in the center of the box—the object was a tall and colorful Duplo tower—and let the rat run in the box once again. The third trial was very similar to the second, but we moved the Duplo tower to another location in the box. In the fourth and last trial, we took the Duplo tower out of the box and let the rat run in it."
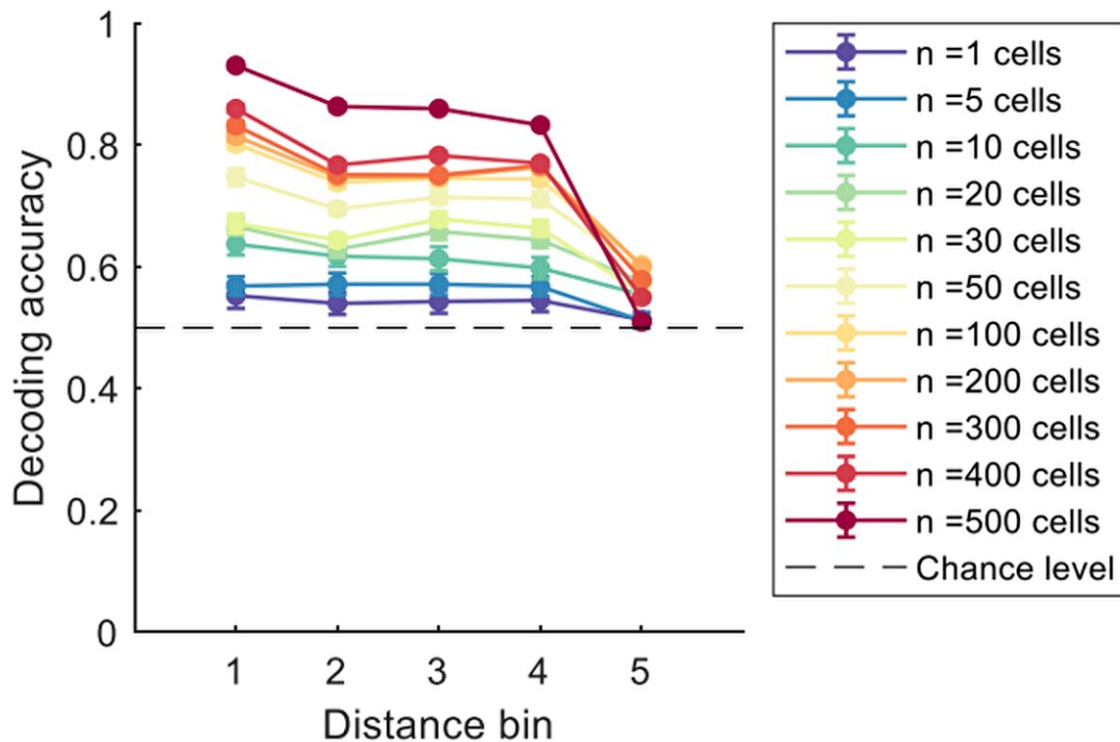
Same as Figure 1, but using different population sizes (ranging from 1 neuron to 500 neurons). The distance-dependent organization of neural population activity (seen as a curve with negative slope) becomes more and more evident with larger population sizes. Credit: Nagelhus, Andersson et al.

Between each of these four trials, the rats were given some time to rest, and throughout the experiment the team recorded neural activity in the hippocampus. Leveraging recent technological advances, they were able to simultaneously record the activity of tens to hundreds of cells, for a maximum of 620 neurons.

The recordings they collected showed that neurons in the hippocampus appeared to organize their activity in unique patterns that varied

depending on where the rat was located in space relative to the object.

"Individual cells didn't show a very clear response to the presence of objects, and those that did so were not abundant in number," Gonzalo Cogno said. "However, information about the presence of the object in the arena, and about the animal distance with respect to the object, were clearly present in the recorded neuronal population. This means that when an object was introduced, the collective activity of the neural population reorganized in a distance-dependent manner."

Interestingly, Gonzalo Cogno and her colleagues found that the reorganization of CA1 neurons could also be observed when neurons that showed a specific selectivity to the object were excluded from their analysis. Overall, their work suggests that information about the presence of an object is distributed across the hippocampal neuronal population.

"Our findings are very much aligned with recent paradigm shifts in the field of neuroscience," Gonzalo Cogno said. "While in the past much attention was put on how single neurons represent, or encode, aspects of the environment and the external world, with the development of new technologies we are now equipped to address the question of how this representation is happening at the neural population level, in which thousands to millions of cells intervene. Can we learn something about the brain by studying neuronal populations, that we could not learn by studying single cells? The answer is yes, and our study is one example of this."

Recent efforts by this team of researchers greatly contribute to the overall understanding of the CA1 hippocampus and how it encodes salient object-related information. In the future, Gonzalo Cogno and her colleagues hope to build on these findings to make exciting new discoveries.

"One interesting question that we could explore in our next studies is how neural representations in general are transformed from the MEC to the hippocampus," Gonzalo Cogno added. "I think this question can be addressed from multiple angles, ranging from pure modeling to pure experimental work. I hope we will be able to address it in the context of object representation, and by adopting an interdisciplinary approach."

More information: Anne Nagelhus et al, Object-centered population coding in CA1 of the hippocampus, *Neuron* (2023). DOI: 10.1016/j.neuron.2023.04.008

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