'Odometer neurons' encode distance traveled and elapsed time

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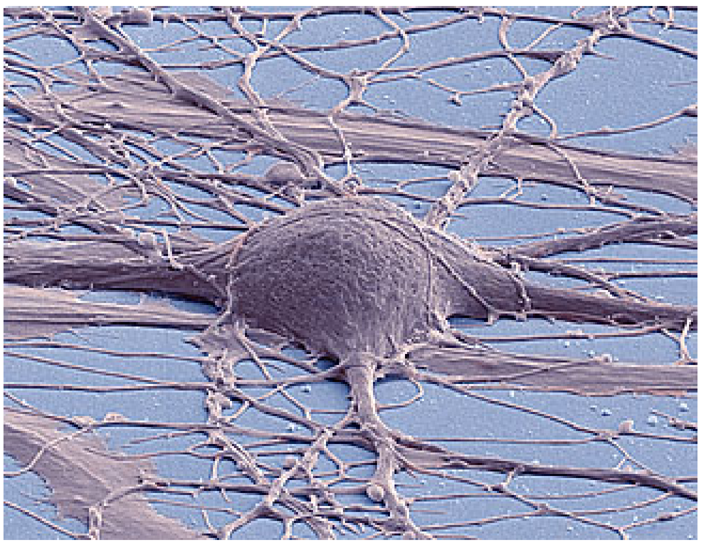

This is a scanning electron micrograph (false color) of a human induced pluripotent stem cell-derived neuron. Credit: Thomas Deerinck, UC San Diego

Animals navigate by calculating their current position based on how long and how far they have traveled and a new study on treadmill-running rats reveals how: neurons called grid cells integrate information about time and distance to support memory and spatial navigation, even in the absence of visual landmarks. The findings, published November 4 in the journal *Neuron*, challenge currently held views of the role of grid cells in the brain.

"Space and time are ever-present dimensions by which events can be organized in memory," says senior study author Howard Eichenbaum, a psychologist and neuroscientist at Boston University. "These findings support the view that memory evolved as a common function in mammals using circuits that organize events in space, time, and potentially many other dimensions of experience."

Past research has shown that grid cells receive information from other cells about the direction traveled. But until now, there was no direct evidence showing that grid cells signal distance or time, leaving its role in path integration merely speculative. In the new study, Eichenbaum and first author Benjamin Kraus of Boston University addressed this question by placing rats on treadmills while recording the activity of grid cells. The researchers kept either the run duration or distance fixed while varying the speed to disentangle the influence of these factors on cell firing.

During treadmill running, 92% of grid cells fired at specific moments or distances while the rats ran in place. For example, one cell would fire 8 seconds into the run, regardless of the speed or distance, while another cell would fire after the rat ran 400 centimeters, regardless of the speed or duration. About half of the cells were influenced by time, another half by distance, and 41% were affected by both time and distance.

"The major current view is that grid cells are dedicated to coding locations in space," Eichenbaum says. "Our findings reflect the discovery that, when location is held constant, grid cells also encode time and distance, suggesting a much broader role for the medial entorhinal cortex than solely mapping space."

In particular, the findings suggest that grid cells are capable of supporting path integration, even without visual cues such as landmarks and optic flow. However, the cells' grid patterns were larger and further spaced during treadmill running compared with foraging in an open field with a stable visual landmark. This observation suggests that visual information may help to calibrate the activity of grid cells to improve the accuracy of animals' spatial representation of their environment. Moreover, the same time- and distance-keeping mechanism could be important for organizing the temporal flow of experiences in memory as well as that in spatial routes.

Eichenbaum believes the studies so far are just the beginning of explorations about how time information is represented in the memory system. "We need to understand how the hippocampus and entorhinal cortex interact to support memory for the flow of events. We need to know the sources of temporal information to this system. And we need to know how sequential events are linked to the representation of time," he says. "We believe that knowledge about the brain circuits that support memory will eventually lead to new directions for treatment or prevention of memory and cognitive disorders."

More information: *Neuron*, Kraus et al.: "During running in place, grid cells integrate elapsed time and distance run" dx.doi.org/10.1016/j.neuron.2015.09.031

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