# New model for the origin of grid cells

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Ludwig Maximilian University of Munich neurobiologists present a new theory for the origin of the grid cells required for spatial orientation in the mammalian brain, which assigns a vital role to the timing of trains of signals they receive from neurons called place cells.

Nerve cells in the brain known as place cells and grid cells, respectively, play a crucial role in spatial navigation in mammals. Individual place cells in the hippocampus respond to only a few spatial locations. The grid cells in the entorhinal complex, on the other hand, fire at multiple positions in the environment, such that specific sets are consecutively activated as an animal traverses its habitat. These activation patterns give rise to a virtual map, made up of a hexagonal arrangement of grid cells that reflect the relative distances between particular landmarks in the real world. The brain is therefore capable of constructing a virtual map which encodes its own position in space.

The Nobel Prize for Medicine and Physiology 2015 went to the discoverers of this system, which has been referred to as the brain's GPS. However, the developmental relationship between place cells and grid cells, as well as the mechanism of origin of grid cells and their disposition in hexagonal lattices remain unclear. Now LMU neurobiologists Professor Christian Leibold and his coworker Mauro Miguel Monsalve Mercado have proposed a new theoretical model, which for the first time provides a plausible model based on known biological processes. The model implies that the development of grid cells and their response fields depend on synaptic input from place cells. The new findings are described in the journal *Physical Review Letters*.

The authors of the new paper assign a central role in their model to correlations in the timing of the neuronal response sequences generated by different place cells. The members of these groups become active when the animal reaches certain locations in space, and they transmit nerve impulses in precisely coordinated temporal sequences, which follow a particular rhythmic patterns, and thereby encode relative spatial distances. Leibold and Monsalve Mercado have used a classical neuronal learning rule, known as Hebb's rule, to analyze the temporal correlations between the firing patterns of place cells and the organization of the grid cells. Hebb's rule states that repeated activation of two functionally coupled neurons in quick succession progressively enhances the efficiency of synaptic transmission between them. By applying this concept of activity-dependent synaptic plasticity to the correlated temporal firing patterns of place cells, the authors can account for the formation of the hexagonal dispositions of grid cells observed in freely navigating mammals.

"The models so far proposed to explain the development of grid cells on the basis of input from place cells were unspecific about the precises underlying biological mechanisms. We have now, for the first time, been able to construct a coherent model for the origin of grid cells which makes use of known biological mechanisms," says Christian Leibold. The new model implies that grid cells are generated by a neuronal learning process. This process exploits synaptic plasticity to transform temporal coordinated signaling between place cells into the hexagonal patterns of grid-cells reponses observed in the entorhinal complex. The model therefore predicts that the grid cells should first arise in the deep layers of the entorhinal cortex.

**More information:** Mauro M. Monsalve-Mercado et al. Hippocampal Spike-Timing Correlations Lead to Hexagonal Grid Fields, *Physical Review Letters* (2017). DOI: 10.1103/PhysRevLett.119.038101

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