

How do we find the way?

Brain mechanisms of spatial orientation

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The ability to find one's way depends on the brain's ability to integrate information about location, direction and distance. This integration is implemented in a widespread brain network of hippocampal and neocortical areas interfaced by the medial entorhinal cortex (MEC). I will show that the MEC contains the brain's own coordinate system, a two-dimensional metric map representing the animal's changing location in the environment. A key component of this map is the 'grid' cell. Grid cells fire selectively at regularly spaced positions in the environment such that, for each cell, activity is observed at places that define a repeating triangular pattern tiling the entire environment covered by the animal, almost like the cross points of graph paper, but with an equilateral triangle as the unit of the grid. Grids of neighboring cells are offset relative to each other, such that all potential positions of the environment are covered by any local ensemble of grid cells. The neural map in the MEC is multilayered, containing cells that integrate directional information with position and distance information. Collectively, the firing of grid cells with different spacing and different directional sensitivities mediates precise information about where the animal is in the environment. In contrast to the multiple environment-specific representations coded by place cells in the hippocampus, local ensembles of grid cells maintain a constant phase structure across environments, allowing position to be represented and updated by the same translation mechanism in all environments encountered by the animal. I will conclude by showing that the nature of the hippocampal population response is determined by lateral shifts and rotations in the entorhinal spatial representation. Whereas rate-based changes in hippocampal representations are associated with stable activity in grid cells, remapping in hippocampal place cells is invariably associated with a realignment of the firing vertices of the grid cells. Coordinate shifts in the grid cell system are thus determinants of a fundamental property of hippocampal neuronal networks, namely pattern separation, or their ability to decorrelate overlapping input patterns before information is stored.