Deciphering the role of grid cells in local modulations of spatial coding resolution

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Abstract (10 lines)
Humans, like other mammals, can flexibly navigate familiar environments. Spatial navigation relies on an internal “cognitive map” and engages interconnected cerebral structures notably the hippocampus and medial entorhinal cortex (MEC). Hippocampal neurons (the place cells) fire when an animal is in a specific location in its environment while neurons in MEC (grid cells) fire when an animal is at the crossings of a hexagonal grid covering the whole environment. The factors controlling spatial coding resolution are poorly understood. To address this question, we recently developed high density extracellular recordings in head-fixed mice navigating virtual reality environments. Using this paradigm, we observed a strong influence of local visual cues on hippocampal spatial coding resolution. In this project we want to decipher at the biological and computational levels if the local modulation of place cells’ spatial coding resolution could be inherited from upstream grid cells. An important aim of the current project is to develop new models of grid cells that can accommodate local inhomogeneities such as local variations in resolution.

Keywords Medial entorhinal cortex, Grid cells, Navigation, Virtual reality, Spatial coding resolution, Automata networks

Objectives (5 lines)
Grid cells’ discharge pattern forms a hexagonal grid covering the whole environment. The scale of this grid (distance between grid fields) could determine the scale of place cells. Our objective is to directly test this hypothesis by recording grid cells while animals explore a 2D virtual reality environment enriched with local visual cues. Our hypothesis is that grid scale will locally shrink around these cues. Current models of grid cells based on attractor networks are unable to account for local grid deformations. The second aim of the project is to explore new models of grid cell generation based on automata networks and assess their possible local deformation.
**Proposed approach (experimental / theoretical / computational)** (10 lines)

We will use high density silicon probe to record grid cells in mice exploring 2D virtual environments with local visual cues unevenly distributed and decipher their impact on grid cells’ scale and coding precision. Specific cue manipulation will be used to assess the dynamics of resolution adaptation. In parallel we will build an automata network model of MEC based on known connectivity and test its parameter space to reproduce the grid pattern and test possible local deformations. The performance of this network and local modulation will be compared to existing networks based on attractor dynamics.

**Interdisciplinarity** (10 lines)

This project lies at the interface between neuroscience and computer science. Large-scale neuronal recordings as performed in the Epsztein lab using multi-shank electrodes (up to 128 recording sites) make now possible to record the simultaneous activity of hundreds of neurons simultaneously, a pre-requisite to study grid cells activity. The development of 2D virtual reality will benefit from the mechatronic platform of Centuri. The data generated will be used to assess the validity of a newly developed model of grid cell activity based on automata networks developed in the Perrot lab. This model partly based on known connectivity of the MEC network where grid cells are found will explore alternative mechanisms of the grid pattern generation able to accommodate local deformations of the grid.

**Expected profile** (5 lines)

We seek to recruit a highly motivated and versatile PhD student with a background in experimental biology but willing to learn computer modeling. The candidate should be interest in network dynamics and have good programming skills. Some knowledge in spatial cognition and computational neuroscience would be a plus.

**Is this project the continuation of an existing project or an entirely new one?**

In the case of an existing project, please explain the links between the two projects (5 lines)

This is an entirely new project that follows the recent observation of increased spatial coding resolution of hippocampal place cells near local visual cues in mice during virtual navigation in the team (Bourboulou et al., 2019).
2 to 5 references related to the project


2. The spatial periodicity of grid cells is not sustained during reduced theta oscillations. Koenig J, Linder AN, Leutgeb JK, Leutgeb S. Science. 2011


3 main publications from each PI over the last 5 years

**Julie Koenig-Gambini**


  * equal contribution

**Kevin Perrot**


2. On the emergence of regularities on one-dimensional decreasing sandpiles. **Perrot K** and Rémila E. Theoretical Computer Science, 2020


**Jérôme Epsztein**


  * equal contribution