PhD PROJECT PROPOSAL

CENTURI
TURING CENTRE
FOR LIVING SYSTEMS

Title : Formation of cognitive maps during group exploration

Supervisor 1 (with name, email, affiliated laboratory and doctoral school affiliation)
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Abstract (10 lines)*

Spatial cognition permits animals & humans to acquire knowledge about the spatial layout of their environment in order to navigate efficiently to locate food resources, avoid dangerous situations and find their nest. The hippocampal formation is an essential brain hub for spatial cognition and it contains a constellation of spatially modulated cells (neurons that fire preferentially at specific locations in the explored environment) such as place cells in the hippocampus and grid cells in the medial entorhinal cortex. The neurophysiology of space is almost exclusively studied in solitary travelers and how this can be modified by the social environment is largely unstudied. This question is all the more relevant since behavioral studies in rodents & humans have shown that group exploration and navigation patterns are different from those of solitary travelers. The purpose of this project is to study how place and grid cells form during group exploration of a novel environment. To link this signal with dynamics of interactions between individuals in a group, we will use methods from sociophysics and network science. Our goal is to study the links between the formation of the spatial representation in the brain and the dynamics of the socio-spatial network of the group.

Keywords*
Neuroscience, electrophysiology, complex networks, animal behaviour, sociophysics

Scientific question and Objectives (10 lines)*

1. Develop a method based on deep learning to track simultaneously 4 to 10 mice in a novel environment (open field).
2. Explore the dynamic of socio-spatial network during the exploration of a novel environment.
3. Compare solo and group exploration in mice at the behavioral and neurophysiological level.
4. Study whether the socio-spatial network has an influence on the development of the spatial representation of an explorer.

*: Mandatory

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Proposed approach (experimental / theoretical / computational) and research plan (20 lines)*

The aim of the project is to study whether the dynamic of the social network has an influence on the spatial representation formation, as the position and the behavior of other travellers might be used as spatial cues. To do this, we need to get information from two different channels at the same time: individual behavior and neuronal activity. We will thus first record videos of mice performing group explorations of a novel environment, from which we will extract both the animals' trajectories and the interaction events. These trajectories will be analysed with tools from statistical physics to analyse their characteristics, and the interactions events will be used to build temporal networks of contacts. In parallel, we will monitor the neural activity of individuals via electrods, from which the electrophysiological data will be analysed through signal processing methods. This will first allow us to compare the development of place and grid cells in a novel environment between solo travelers and group travelers. Secondly, by aligning information from the temporal network of interactions with the neural activity, we will be able to analyse what impact the presence of other mice, and in particular interaction events, have on the activity of specific brain regions related to navigation.

Interdisciplinarity and Implication of the two labs (15 lines)*
(In this section the collaboration of the two laboratories will be explained in details to explain why the project cannot be conducted by one team alone)

The main topic of this project is to explore the links between neural activity, individual and social behaviour in mice. Its main novelty is the possibility to access simultaneously electrophysiological signals of brain activity, individual trajectories in space and social interactions. As described in the precedent section, to study such data we need to combine methods and concepts from neurosciences, animal behaviour, network science and statistical physics, hence to have an interdisciplinary approach. The project will thus be co-supervised by two researchers from the aforementioned fields: an expert in electrophysiological monitoring of mice performing navigation tasks, and a leading researcher in interdisciplinary work between theoretical physics, complex networks and social sciences.

Specify with whom the person recruited will collaborate and on what aspects *

INMED : Experimental approaches : behavior & electrophysiology
CPT : Analyses

PhD student's expected profile*

- Master's degree in Complex Systems.
- Willingness & Ability to work with animals.
- High proficiency in Python (some knowledge of Matlab could also be useful).
- Interest in neurosciences, animal behaviour, sociophysics are a plus.

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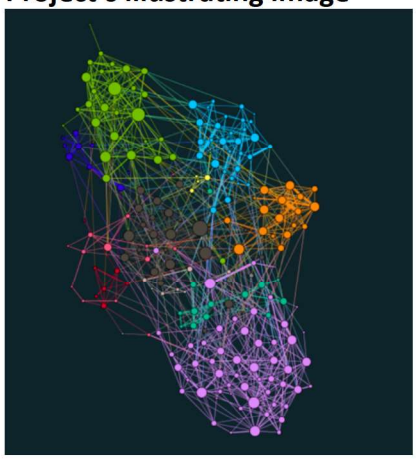
Is this project the continuation of an existing project or an entirely new one?
In the case of an existing project, please explain the links between the two projects (5 lines)*
Entirely new project.

Two to five references related to the project*
Bourboulou et al. (2019). Dynamic control of hippocampal spatial coding resolution by local visual cues. eLife, 8, e44487.
Dorfman et al. (2021). Social spatial cognition. Neuroscience and biobehavioral reviews, 121, 277–290.
Génois et al. (2022) Combining sensors and surveys to study social contexts. Personality Science, in prod.

Two main publications from each PI over the last 5 years*

- Nordlung, Levernier, Trippa, Marti, Bourboulou, Rouault, Monasson, Espztein & Koenig-Gambini (2024) Distinct mechanism for distance versus position coding in the hippocampus (submitted).
- Bourboulou, Marti, Michon, El Feghaly, Nouguier, Robbe, Koenig-Gambini & Epsztein (2019) Dynamic control of hippocampal spatial coding resolution by local visual cues. eLife, 8, e44487.
- Génois, Zens, Oliveira, Lechner, Schaible, Strohmaier. Combining sensors and surveys to study social contexts: Case of scientific conferences. Personality Science, in prod.
- Kobayashi & Génois. The switching mechanisms of social network densification. Scientific Reports (2021) 11:3160.
- Génois & Barrat. Can co-location be used as a proxy for face-to-face contacts? EPJ Data Science (2018) 7:11.

Project's illustrating image



*: Mandatory