PhD PROJECT PROPOSAL

CENTURI
TURING CENTRE
FOR LIVING SYSTEMS

Title of the project

What role for effort and time in decision-making and motor control during foraging?

Lead supervisor: David Robbe, INMED david.robbe@inserm.fr
Co-supervisor 1: Eloy Christophe, IRPHE christophe.eloy@irphe.univ-mrs.fr
Co-supervisor 2: Ahmed El Hady, Center for the advanced study of collective behavior ahady@ab.mpg.de

Abstract

Imagine that you need to catch a bus to return home after work. Will you decide to run as fast as possible to catch the first incoming bus? Or will you walk slowly to save your energy after an exhausting day, at the risk of missing this first bus and arriving late at home? This example illustrates that our daily decisions and actions involve some kind of economic computation in which we adjust effort to obtain reward (here arriving comfortably at home) sooner than later. While the impact of reward on decision making and its underlying neural bases have been extensively studied, much less is known regarding how effort and time affect reward-related decisions and movements. The goal of this proposal is to take advantage of a new naturalistic foraging task in freely moving mice and foraging theories to understand how individual sensitivities to time and effort drive variability in the strategy of rodents facing an explore vs exploit dilemma. Such knowledge may help to understand what conditions favor seemingly irrational or non optimal usage of resources.

Keywords

decision making | motor control | foraging | vigor | theoretical neuroscience | exploration |optima control theory

Objectives

A first objective will be to quantify precisely the behavior of rodents engaged in a foraging task in which the effort and time of exploration and exploitation can be manipulated. Then taking advantage of optimal control and foraging theories, we will attempt to model the individual variability in foraging strategy in term of time and effort sensitivities. Those models will serve to generate new experimental predictions regarding the determinants of decision (explore or exploit) and movement speed, at the behavioral and neural levels.

Proposed approach (experimental / theoretical / computational)

We have recently developed a new task in which mice must forage for drops of water by deciding whether to keep harvesting from a rewarding source that is progressively delivering less frequent rewards (exploitation) or to travel toward a new source of water (exploration). Exploring takes time and requires effort (exploration costs). Exploiting a depleting patch also requires effort to collect the rewards and, as the reward rate decreases, animal must evaluate if it is worth keeping spending time and effort without much return (exploitations costs). Exploitation duration and the speed of movements during both exploration and exploitation will be analyzed in the frameworks of marginal value theorem and optimal control theory. Following a first round of theoretically-driven behavioral experiments and model-based analyses (model-fitting of behavioral data), the role of specific circuits in the basal ganglia in controlling effort and/or time sensitivities will be examined using circuit-specific manipulations.

Interdisciplinarity

The question of the mechanisms generating adaptive decisions and movements is often addressed from the angle of their neuronal bases. However, the principles governing behavior might be more efficiently discovered through theoretical approaches, by considering behavior control from the point of view of physical sciences, economics and in terms of optimality. Such approach requires careful observation of the bio-mechanics of the body and the decision taken by subject (explore vs exploit) under various and well-controlled experimental conditions, and their abstraction in mathematical models. Once the main determinants of behavior have been determined and included in a model, then it is fruitful to test the model robustness in different experimental conditions (new version of the task) and, finally, examine its implementation in the brain. Thus, this proposal will require interaction between behavioral sciences, physics, mathematics and experimental neuroscience.

PhD student's expected profile

We are looking for a candidate with a strong quantitative background, capable to developing numerical simulation/model (i.e. strong programing skills) and with a strong taste for animal behavior and cognition

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

The project is in continuation with those Thomas Morvan (Centuri PhD student defending in December 2023) and Maud Schaffhauser (2nd year ANR-funded PhD student) in which we studied effort and time sensitivities in rodents and the exploration/exploitation dilemma. Those two projects are funded with two ANR grants. Some nice behavioral observations have been made. In this project we are extending the behavioral paradigm with an original exploration/exploitation paradigm to be able to directly probe debated aspect of foraging theories. We also hope to be able to address neuronal mechanisms.

Two to five references related to the project

[1] Shadmehr R, Reppert TR, Summerside EM, Yoon T, Ahmed AA (2019) Movement Vigor as a Reflection of Subjective Economic Utility. Trends Neurosci.
[2] Carland MA, Thura D, Cisek P (2019) The Urge to Decide and Act : Implications for Brain Function and Dysfunction. The Neuroscientist.
[3] Yoon T, Geary RB, Ahmed AA, Shadmehr R (2018) Control of movement vigor and decision making during foraging. Proc Natl Acad Sci.
4] Mazzoni P, Hristova A, Krakauer JW (2007) Why don't we move faster? Parkinson's disease, movement vigor, and implicit motivation. J Neurosci.

Two main publications from each PI over the last 5 years

[1] Jurado-Parras M-T, Safaie M, Sarno S, Louis J, Karoutchi C, Berret B, **Robbe D** (2020) The Dorsal Striatum Energizes Motor Routines. Curr Biol.

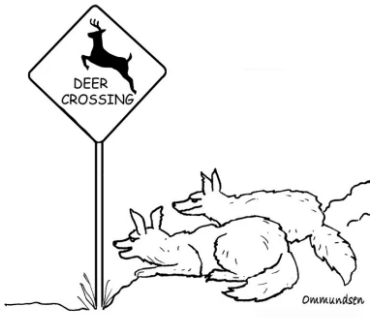
[2] Safaie M, Jurado-Parras M-T, Sarno S, Louis J, Karoutchi C, Petit LF, Pasquet MO, **Eloy C**, **Robbe D** (2020) Turning the body into a clock: accurate timing is facilitated by simple stereotyped interactions with the environment. Proc Natl Acad Sci USA.

[3]Loisy A, **Eloy C**. (2022) Searching for a source without gradients: how good is infotaxis and how to beat it. Proceedings of the Royal Society A..

[4] Davidson JD, **El Hady A**. (2019) Foraging as an evidence accumulation process. PLoS computational biology.

[5] Kilpatrick ZP, Davidson JD, **El Hady A**. 2021. Uncertainty drives deviations in normative foraging decision strategies. Journal of the Royal Society Interface.

Project's illustrating image



"I think we finally mastered foraging theory."