Decision-Making and Path Planning for Jumping Rats

Shahin G. Lashkari[1,2], Michael G. Wilkinson[1,2], Bharath Krishnan[3], Gorkem Secer[2], James J. Knierim[4,5], Noah J. Cowan[1,2]

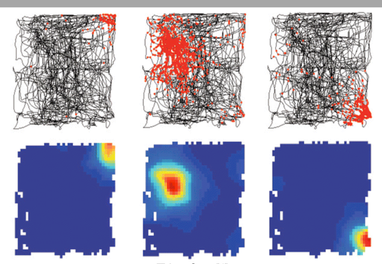
[1]Department of Mechanical Engineering, [2]Laboratory for Computational Sensing and Robotics, [3]Department of Biomedical Engineering, [4]Department of Neuroscience, [5]Zanvyl Krieger Mind/Brain Institute
Johns Hopkins University, Baltimore, MD

Overview

- Analyzing the decision-making and real time path planning processes of terrestrial animals like rats can improve the navigational abilities of robots.
- There are few studies in rats performing complex locomotor behaviors in 3D environments.
- We want to understand how the complex locomotor behavior is influenced by the activity of neurons in the hippocampus.
- Our goal is to analyze the factors that influence rats' navigational decisions.

Background: Place Cells

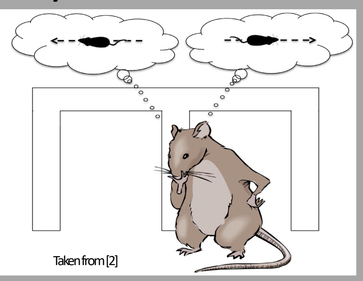
- Place cells of the hippocampus fire when the animal occupies a certain location.
- Example shows three place cells recorded as the animal explored an environment [1]:
  - Top: trajectory of animal (black) and locations where place cells fired (red dots).
  - Bottom: spatial firing rate heat maps of the same place cells.



Taken from [1]

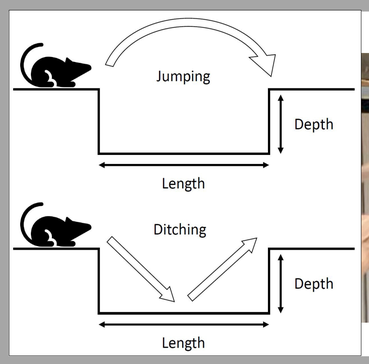
Background: Vicarious Trial and Error (VTE)

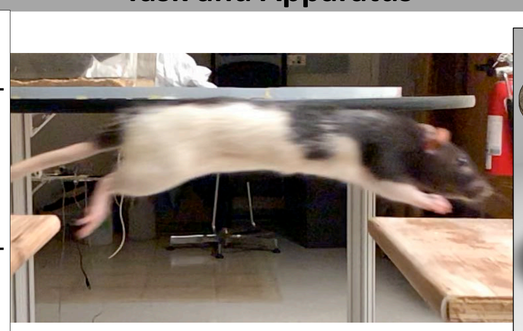
- Exploration of mental possibilities, vicariously trying out alternatives.
- VTE occurs at difficult choice points and eventually disappears as animals automate their behaviors.
- During navigational decision making, VTE correlates with "place cell look ahead" [3,4].
- ***Goal: Study decision making during challenging navigational tasks.***



Taken from [2]

Task and Apparatus





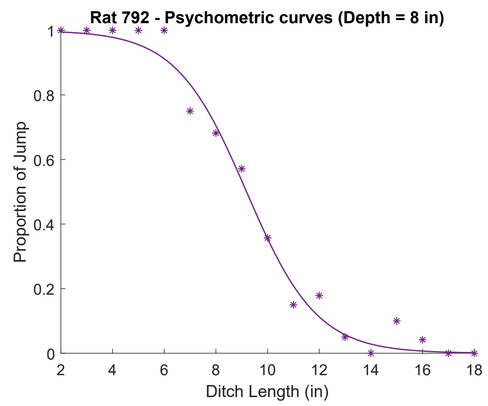
Embed YouTube Videos Here:
https://youtu.be/JE9aaUJOeDgz

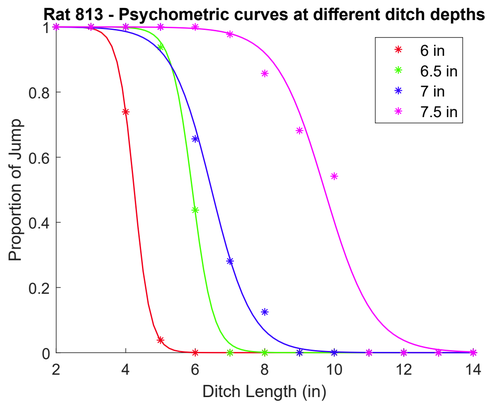
Funding

Army Research Office under the SLICE MURI, award W911NF1810327

Results: Psychometric Tuning with Randomized Ditch Length

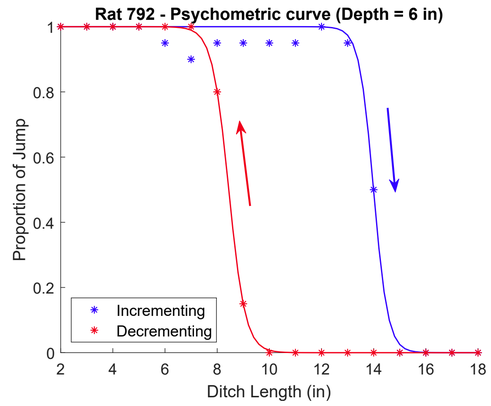
- Each session, depth was kept constant and length was randomly assigned.
- At each length, the fraction of jumps was calculated based on the number of jumps and ditches.
- We fit a sigmoidal psychometric tuning curve to each depth (session).
- The psychometric curve shifts right with increasing depth.

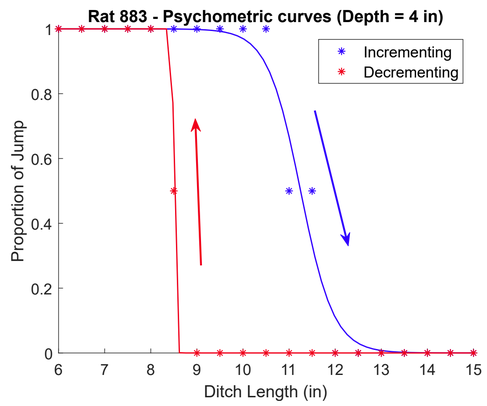




Results: Decision Making is History Dependent

- Each session, depth was kept constant and length was incrementally increased or decreased.
- Hysteretic psychometric tuning demonstrates history dependence.

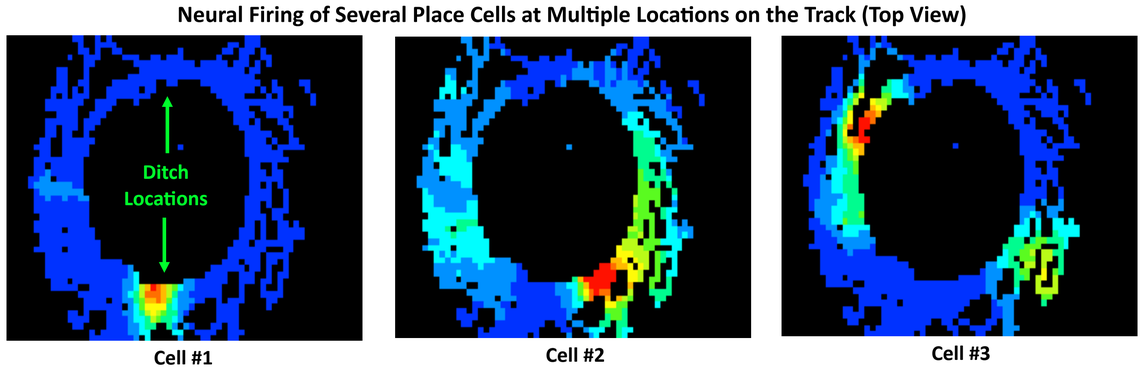




Preliminary Neurophysiological Data from CA1 Region of Hippocampus

- Several place cells fire at the ditch (e.g. cell #1) suggesting a role in decision-making or representation of the ditch.
- Some cells fire after the ditch (e.g. cell #2). We plan to examine whether these cells along with the cells mentioned above exhibit "place cell look ahead" during VTE.
- Some place cells fire at the reward (e.g. cell #3) which is consistent with previous findings that hippocampus preferentially represents reward locations.

Neural Firing of Several Place Cells at Multiple Locations on the Track (Top View)



Cell #1 Cell #2 Cell #3

Discussion

- This behavior presents an opportunity to study navigational decision making in animals.
- We hypothesize that randomization promotes active decision making ⇒ increase in VTE.
- We will examine place cell firing during both VTE and habitual behavior [5] to gain insight into the computations that underly navigational decision making in animals.
- It is hoped that insights into complex navigational decision making in the brain will lead to new ideas for such planning in robotics.

References

[1] Fyhn et al. 2007, [2] Eichenbaum 2013, [3] Johnson and Redish 2007, [4] Redish 2016., [5] Kay et al. 2020