Statistical Analysis of Naturalistic Long-Duration Mice Foraging Behaviour

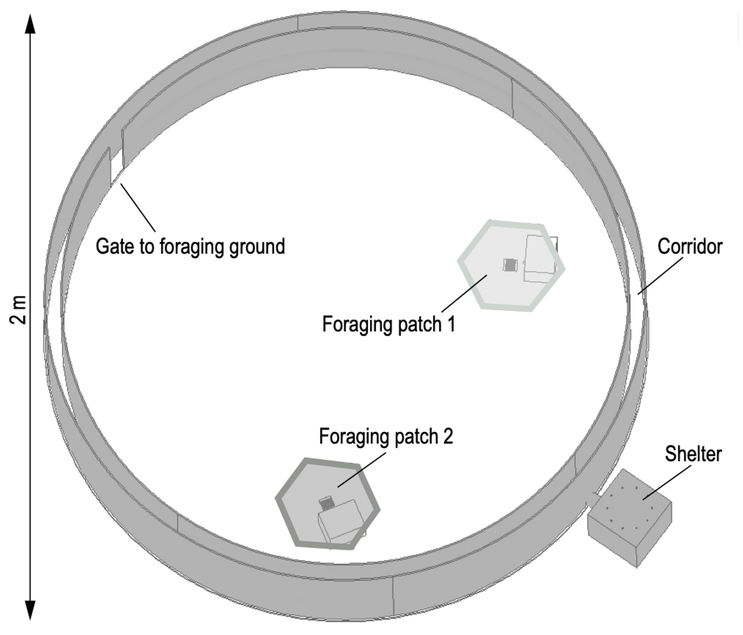
Zimo Li[1], Joaquin Rapela[1], Dario Campagner[1,2], The SWC Foraging Behaviour Working Group[1,2], Maneesh Sahani[1]
[1]Gatsby Computational Neuroscience Unit, University College London, [2]Sainsbury Wellcome Centre, University College London

I. BACKGROUND

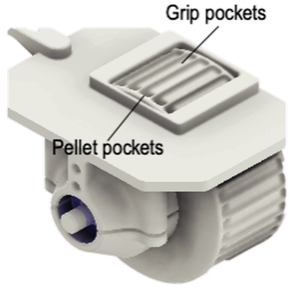
- Foraging behavior has been previously studied using normative theories[1].
- Recent advances in experimentation provide a plethora of foraging data in behavioural and neurophysiological measurements.
- This data might allow statistical modelling to discover aspects of foraging behaviour not captured by normative theories: e.g., internal states[2].
- Here we characterize naturalistic and long-duration mice foraging behaviour[3] using statistical models and present preliminary results.

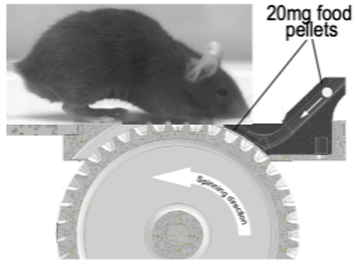
II. BEHAVIOUR MONITORING

- Arena: contain a shelter with water supply and weight recordings. Two foraging patches, each with a delivery machine of the same delivery threshold. Mouse enters the arena through the gate.



- Foraging patch: pellets delivered when the wheel distance moved by the mouse reaches the set threshold (e.g., 1 meter).





Poster Figures Repro

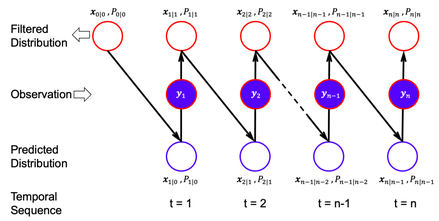
Project Aeon GitHub

III. STATISTICAL ANALYSIS

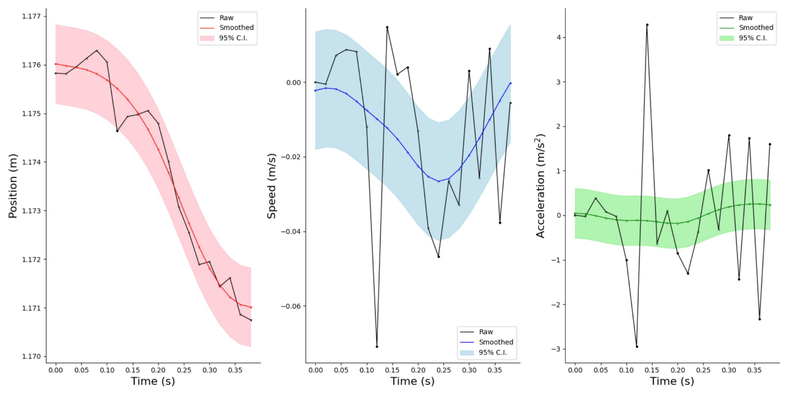
1. Kinematics Inference

- Used a Gaussian Linear Dynamical System (LDS) model and the Kalman filter algorithm to infer mouse kinematics (position, velocity, and acceleration) from noisy position measurements.
- Inferred and smoothed kinematics are less noisy than finite difference estimation.

Kalman Filter Algorithm



Raw and Processed Data of Mouse Kinematics on the X-Axis

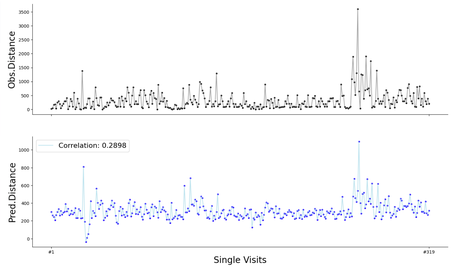


2. Foraging Bout Duration Prediction

- Use Gaussian-Generalized Linear Model (GLM) to predict the wheel distance moved by the mouse in each visit to the foraging patch.
- Pellets consumed in the last visit to the same patch is significantly influencing mouse foraging during the current visit.

Observations and Predictions From the Gaussian-GLM Model

Parameter	Coefficient	Significance: p-value
Speed	59.16	0.15
Acceleration	-33.55	0.41
Pellets in Last Visit: Same Patch	*92.82*	*0.00*
Pellets in Last Visit: Different Patch	-36.46	0.06
Duration: since Last Visit	13.51	0.49
Duration: since Arena Entrance	3.67	0.87

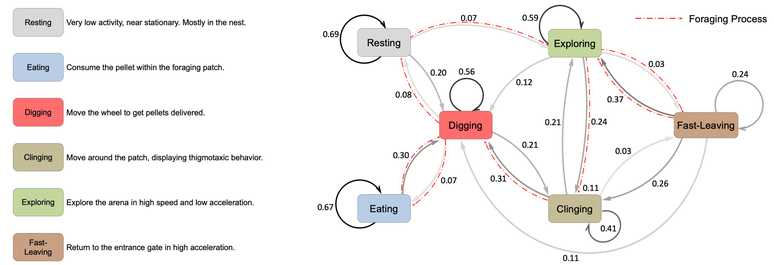


[1] Charnov, Eric L (1976). Optimal foraging, the marginal value theorem. *Theoretical population biology*, 9(2), pp.129-136.
[2] Marques, João C., Li, Meng, Schaak, Diane, Robson, Drew N., Li, Jennifer M. (2020). Internal state dynamics shape brainwide activity and foraging behaviour. *Nature*, 577(7789), pp.239-243.
[3] Sainsbury Wellcome Centre Foraging Behaviour Working Group. (2023). Aeon: An open-source platform to study the neural basis of ethological behaviours over naturalistic timescales, https://doi.org/10.5281/zenodo.8413142

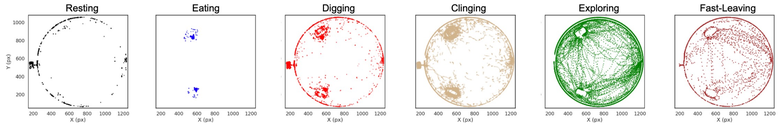
3. Behavioural Syllable Characterization

- Used a Hidden Markov Model (HMM) with a multivariate Gaussian emission model to infer discrete behavioral states from kinematics (speed and acceleration) extracted by the LDS model.
- Interpreted the characterized states by combining with foraging information: pellets delivery, mouse position, mouse moving direction, etc..
- Some states (e.g., fast-leaving) reflects mouse motivation during the task.

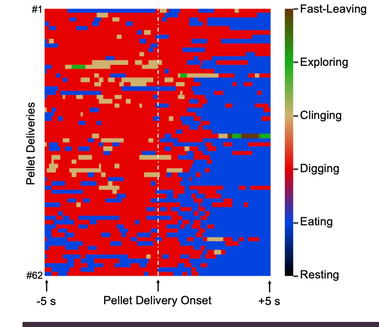
Transition Diagram of Characterized Mouse Syllables



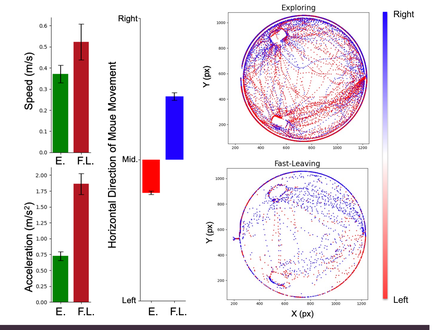
Mouse Positions in Different Syllables



Digging / Eating



Exploring (E.) / Fast-Leaving (F.L.)



IV. SUMMARY & FUTURE ASPECTS

- We developed a new assay to study naturalistic foraging behaviour in mice
- We applied a Linear Dynamical Systems model of infer kinematics from position measurements.
- We used a regression analysis to discover behavioral variables that are predictive of foraging-bout duration.
- We applied an HMM to infer foraging behavioral states (i.e., syllables) from kinematic variables obtained in the LDS analysis, potentially mapping onto distinct foraging and defensive actions.
- In the future we will apply this approach to analyze weeks long recordings and establish how foraging strategies evolves over naturalistic timescales.