

Project Templates

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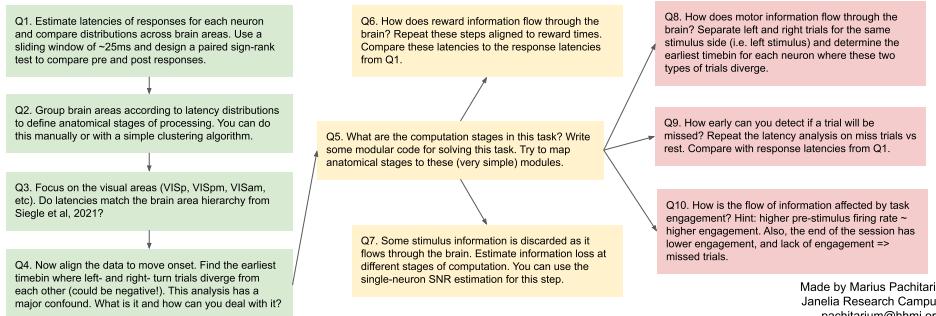
Click on each image below to see a full browser version!

Flow of information through the brain during a sensorimotor task

Background: New technologies like the Neuropixels probes are giving us exquisite access to neural computations simultaneously across the entire brain (Steinmetz et al. 2019; Allen et al. 2019; Siegle et al. 2021). One of the simplest such computations is sensory-guided behavior, for example instructing an animal to provide a left/right response to a left/right stimulus. Even such simple tasks can reveal a great deal about the collective behavior of neurons distributed across diverse brain areas (NMA: W1D4). Here you will take advantage of the precise temporal resolution of electrophysiology to calculate single neuron latencies to various task variables. You will combine this information with anatomical information and with a model of sensory processing. This project is suitable for beginners as it requires no advanced methods.

Project setup: We provide data wrangling code: extracting neural activity binned and aligned to various events, for specific trial types ([link to google colab](#)).

Project map: The project core is covered by Q1-5, subsequent questions can be taken in any order. Certain patterns should emerge, leading you to more specific hypotheses about the flow of information during brain-wide computations.



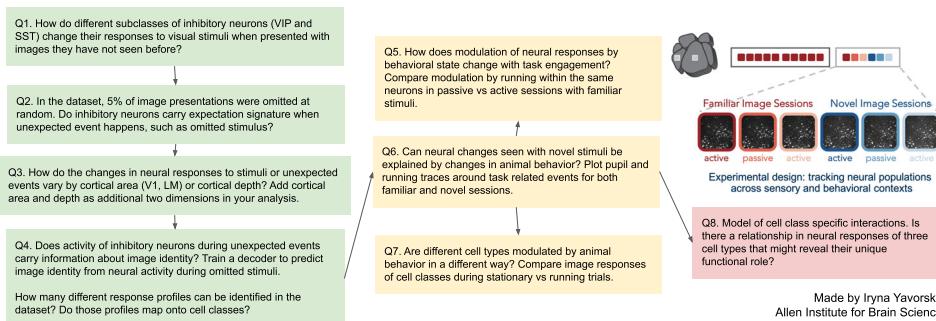
Made by Marius Pachitariu
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Effects of stimulus context and behavior state on visual representations

Background: Processing of visual information by cortical areas is influenced by animal's past experiences (Poort et al., 2015; Khan et al., 2018) and modulated by the behavioral state of the animal (Niell & Stryker, 2010). While experience can lead to sparseness in neural encoding that persists over multiple days, behaviors like running, whisking, and overall animal's alertness can modulate activity in visual cortex on a second-to-second basis (Stringer et al., 2019; Musali et al., 2019). The cellular mechanisms that enable flexible neural coding over different timescales are still not well understood. The Allen Institute's Visual Behavior 2P dataset includes 2-photon calcium imaging data from excitatory and two subclasses of inhibitory neurons (SST and VIP) collected over six days under different experimental conditions: passive viewing vs active change detection task performance, with images that mice were trained on vs novel images they had no prior experience with.

Project setup: To get started, you can download a subset of data from only inhibitory cells ([example 1](#)) or access the full dataset using the [Allen SDK](#) ([example 2](#)).

Project map: Project ideas in green can be answered using pre-saved data file from example 1, while questions in yellow and red will require you to access data using AllenSDK, reformat it according to questions needs.



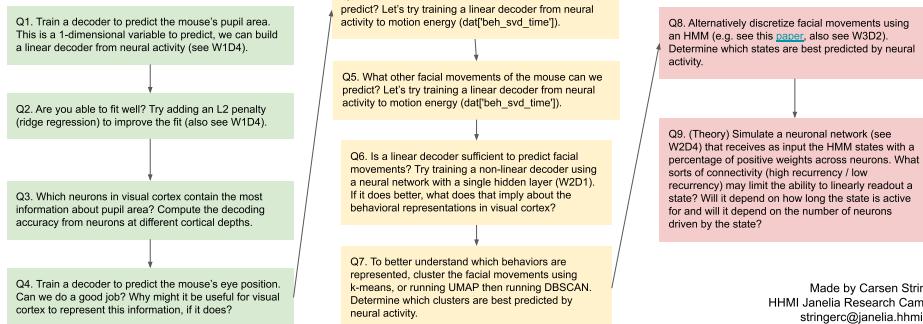
Made by Iryna Yavorska
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Behavioral representations in mouse visual cortex

Background: Mice move their whiskers, groom, and run while we record their neural activity. These behaviors are represented in neurons across the brain, not just in motor areas. In particular, we will be analyzing neural activity in the visual cortex. You can see more details about this dataset in the [intro](#) video and in the associated [paper](#). There are ~10,000 neurons recorded simultaneously across multiple cortical depths, along with the facial behaviors of the mouse, represented using the principal components of the motion energy. We want to understand what types of behaviors are represented by the neurons, and how they are represented. This may give us clues as to how these signals might be used for computations such as learning associations between behaviors and visual stimuli. To do this, we can build various models to decode behavior from neural activity.

Project setup: This project will use this data [loader](#).

Project map: description of the suggested questions and how they relate to each other and to the project. The tree structure can and should be customized as necessary for each project.



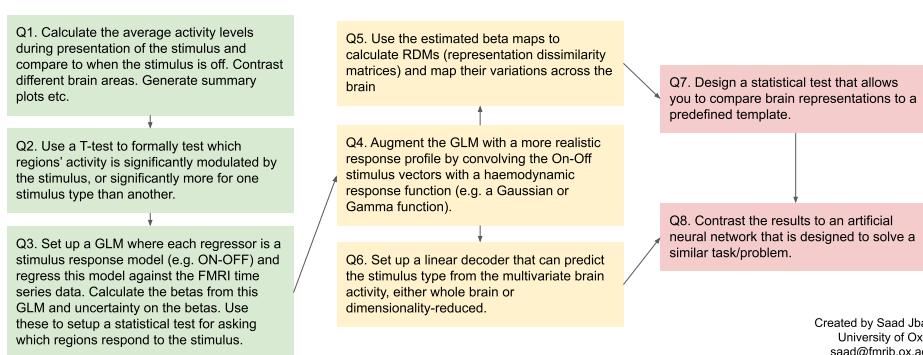
Made by Carsen Stringer
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Mapping brain activation and representation with FMRI

Background: Stimulus-evoked activity can be measured with FMRI through haemodynamics: changes in blood flow, volume, and oxygenation in response to neuronal activity changes.

Project setup: Here we start from time series data. Using the HCP task data, where different stimuli are either ON or OFF, we will create increasingly sophisticated models of brain activity. We will then use these models to ask statistical questions on localisation of brain function and on information representation.

Project map: The project core is covered by Q1-4; subsequent questions can be taken in any order. If using data sets that have beta maps, you can start from Q5-6



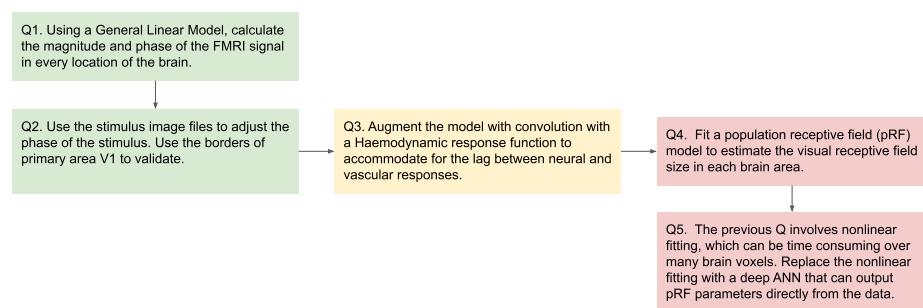
Created by Saad Jbabdi
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Retinotopic mapping with FMRI

Background: Multiple brain areas in the visual cortex contain a map of the visual/retinal space. FMRI is routinely used to estimate this mapping in order to delineate different subdivisions of the visual cortex and study their properties.

Project setup: This project is set to utilise a retinotopic mapping experiment, for which the Human Connectome Project data is used (see data [loader](#) and [Benson et al.](#) for a detailed description of the data/experiment)

Project map: The project core is covered by Q1-3; For Q4 see [Dumoulin 2008](#).



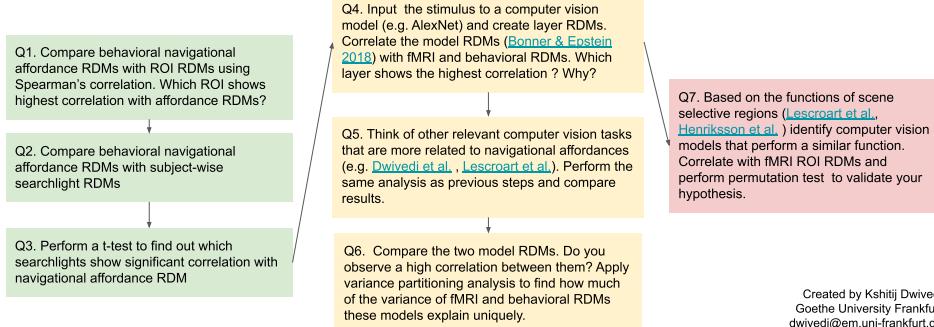
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Computational modeling of navigational affordances & scene selective cortical responses

Background: As we move about the world, we use vision to determine where we can go in our local environment and where our path is blocked. In this project, our first goal is to identify which brain regions encode the structure of navigable space in visual scenes using behavioral and fMRI data from [Bonner and Epstein](#). The next goal is to identify a computational model of navigational affordances and underlying cortical responses

Project setup: Consider fMRI response to indoor images in the form of ROI specific and searchlight representational dissimilarity matrices (RDMs). Find which ROIs/searchlights show significant correlation with navigational affordances behavioral RDM. Identify relevant computer vision models to explain navigational affordance behavioral and scene selective fMRI responses

Project map: The project core is covered by Q1-4; subsequent questions explore potential models to explain behavioral and scene-selective fMRI responses

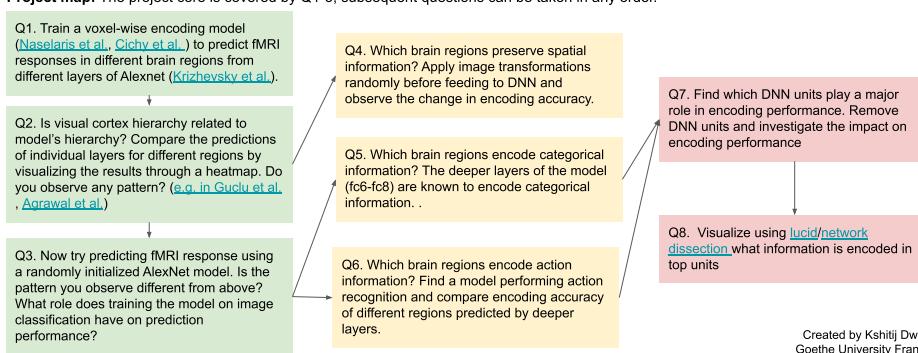


Investigating the visual information in different brain regions

Background: Stimulus-evoked activity can be measured with fMRI through haemodynamics: changes in blood flow, volume, and oxygenation in response to neuronal activity changes. fMRI recordings allows recording responses from multiple brain regions simultaneously with high spatial resolution. In this project we look at the human fMRI response to visual stimulation and investigate which brain regions encode which type of visual information by predicting fMRI responses from artificial vision models.

Project setup: Consider fMRI response to visual stimulation (images/ videos) and a basic computer vision model (AlexNet) performing image classification. For images you can use [Kay & Gallant dataloader](#), for videos you can use [Algoauts dataloader](#).

Project map: The project core is covered by Q1-3; subsequent questions can be taken in any order.

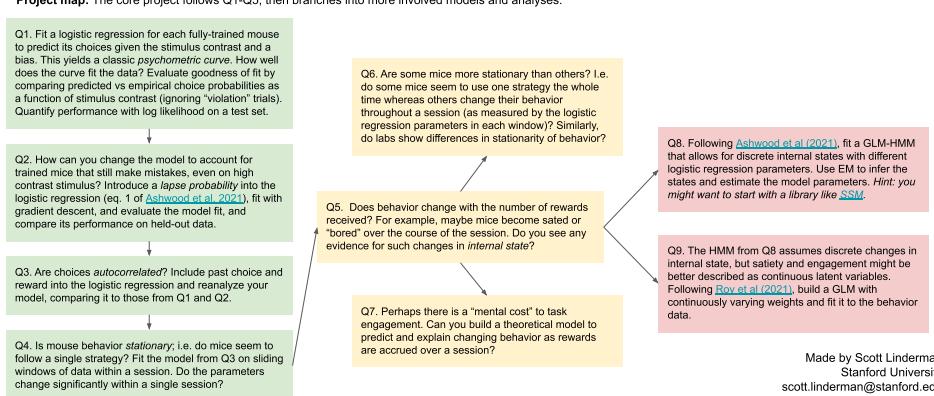


Investigating state-dependent decision-making in mice performing a 2AFC task

Background: The International Brain Laboratory studies perceptual decision-making in mice. They have collected millions of trials of mice making a binary choice based on a visual stimulus. Formally, this is called a two alternative forced choice (2AFC) task. While the mice learn to perform the task well, they still make many mistakes. This project will study these "lapses" in judgement to look for evidence of time-varying internal states, following recent work of [Ashwood et al \(2021\)](#) and [Roy et al \(2021\)](#).

Project setup: This project will use the IBL behavior dataset ([intro](#), [loader1](#), [loader2](#), [loader3](#))

Project map: The core project follows Q1-Q5, then branches into more involved models and analyses.

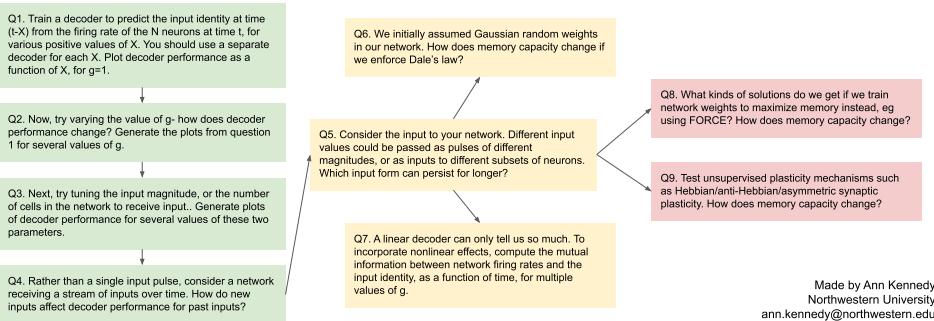


Investigating the working memory capacity of recurrent neural network models

Background: To hold information in working memory or integrate sensory inputs over time, the brain must be able to maintain representations of past sensory inputs for several seconds for future computation (NMA: [W3D2](#); [Barak and Tsydkiws, 2014](#)). Recurrently connected networks of neurons have been shown to be capable of producing stimulus-evoked firing rate fluctuations on timescales many orders of magnitude longer than that of the membrane time constant of individual neurons ([Toyoizumi and Abbott, 2011](#)). In this project, we ask: what strategies might recurrently connected populations in the brain employ to preserve temporally structured information over time?

Project setup: [Link to Colab notebook](#)

Project map: The project core is covered by Q1-5; subsequent questions can be taken in any order.

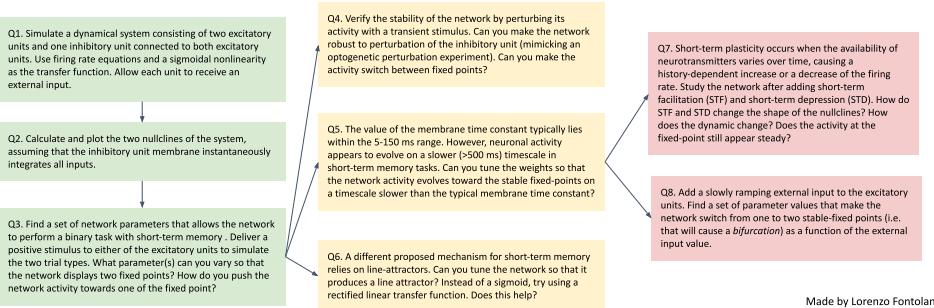


Attractor models of short-term memory

Background: Persistent, stimulus-dependent neuronal activity has been observed in some brain areas during tasks (that require) requiring the temporary maintenance of information. This function is called short-term memory. Neurons representing the information can remain active for several seconds after the original input has been removed. In this project you will build a simple, population-based, dynamical system model of a short-term memory task (NMA: [W2D4](#)). You will study how even a simple model can generate different behaviors. This project requires basic proficiency in the mathematics of dynamical systems.

Project setup: <link to a google colab>

Project map: Q1-5 cover the core part of this project. Additional questions may emerge while tackling Q1-5. Explorations are encouraged.

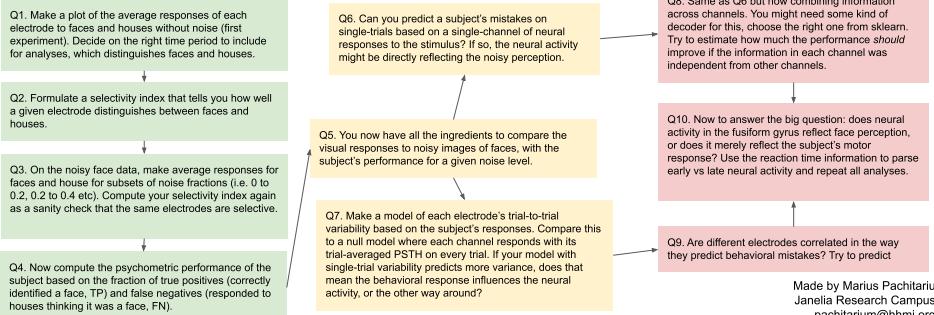


Does neural activity reflect face perception?

Background: It is all too easy to find a neuron in the brain representing sensory features of the external world. This especially applies to visual cortex, where it has been shown that neurons in the mouse brain encode stimulus orientation to an average precision of 0.3 deg, which is 100x better than the mouse's behavioral performance (see Stringer orientations dataset, [Stringer et al. 2021](#)). However, just because a population of neurons encodes a stimulus does not mean that the subject has conscious access to this information. When a subject is aware of a stimulus feature, we say that the subject has formed a "percept". Can we find areas of the brain where neural activity correlates with perception, measured psychometrically by the subject's performance in a task? In this project, you will answer this question for the Faces/Houses ECoG dataset ([Miller et al. 2017](#)), which contains stimuli with different noise levels as well as psychometric performance of the subjects viewing these stimuli.

Project setup: Use the [data loader](#) to investigate the ECoG responses.

Project map:

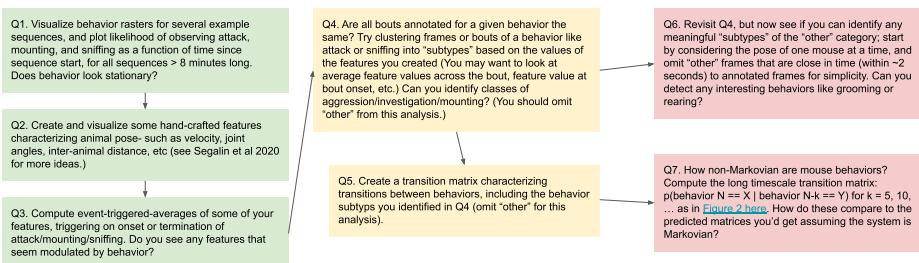


Analyzing the structure of mouse social behavior

Background: Animals engaged in social behavior make continuous decisions of how to interact with a member of their species. In the field of ethology, we study the structure of animal behavior to gain insight into the neural algorithms by which that behavior is controlled (see eg [Anderson and Perona 2014: WDD3](#)). In this project, you'll explore mouse behavior in a resident-intruder assay, in which a male mouse in its home cage is presented with a male or female intruder, and the animals are allowed to freely interact. Can you determine from tracking data what cues shape animals' behavior? What timescales of behavior can you identify in the data?

Project setup: Use the CaIM21 dataset ([Sun et al 2021](#)) to study the structure of mouse social behavior. The poses of both animals have been tracked using a computer vision pipeline ([Segalin et al 2020](#)), and three social behaviors of interest (attack, mount, and sniffing) are manually annotated. Code to load and explore the dataset is provided [here](#).

Project map: An example project exploring timescales of behavior is outlined below- however feel free to get creative and follow other lines of investigation!



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By Neuromatch

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