Mapping Brain Networks

Neuromatch Academy Project - July 2020

The Neuromatch Academy[6] was a summer school that happened in the summer of 2020. In the midst of a pandemic, the school emerged on an online platform reaching out to everyone across the world. The academy served the purpose of training neuroscientists to learn computational tools, make connections to real world neuroscience problems, and promote networking with researchers.

The academy also provided an opportunity for the students to carry out their own mini-project that would last three weeks. Several datasets were provided for exploration. Our group Les Souris Grises, from the pod 063-Gay-Ladybug have decided to go with the Steinmetz data set. Below us is a description of the Steinmetz data set that we chose.

Dataset chosen:

The dataset used for this purpose was the dataset procured by Steinmetz et al. 2019[1].

The Steinmetz dataset is an **electrophysiological** recording from multiple regions of the mouse brain during a 2-Alternative Forced Choice Task paradigm. **Neuropixel** probes were used to record from approx. **30,000 neurons** from **42 regions**, while the mouse performed a visual discrimination task. In each trial (multiple trials conducted over each session; and a total of 39 sessions), a mouse was placed on a wheel with its **head fixed**, surrounded by 3 screens (left, right and in front). Images of differential contrast were presented to either the left, right or both the screens and the mouse had to turn the wheel in the correct direction in order to bring the greater-contrast image to the front-screen. If there was no image presented on either side, the correct response was to hold the wheel steady for 1.5s. Neural activity was continuously recorded for the entire duration of the task.

The locations in the dataset have been mapped according to the Allen Mouse Brain Atlas[4]

Code for the analysis was written in **Python**, with the help of scientific packages; **Numpy, Scipy, Sklearn**

To load the data into our notebooks for further analysis, we used some code[2] provided by **Dr. Marius Pachitariu.**

For a detailed description of the dataset see this[7] document by Dr. Nick Steinmetz and this[8] writeup by us.

Questions:

During a decision making task like the one in the Steinmetz experiment, a number of different **brain regions** are involved in the processing of sensory information to decision making to motor action. These regions act together in particular **networks**. We're aware of the anatomical organisation of these regions but the **dynamical interactions** among them, is not well established.

How do the different brain regions interact with one another in terms of **functional connectivity**? Can we attribute behaviour to large-scale **brain wide circuits**? Are different networks involved in different tasks? What can the neural activity from distinct regions reveal about their interaction on a temporal scale? These are some broad questions that we set out to answer.

Our questions were inspired by some of the original questions from some exemplary projects[3].

Scope:

Upon discussion with our mentor, Dr. John Butler, we came to the conclusion that for the short time span, our original question was **too ambitious**. So, we narrowed down our question to looking at only **two regions** and trying to establish how these two interact with each other, in terms of similarities or dissimilarities in their temporal activity.

We decided to focus on one rodent's data, from one session (Session no. 11). Our chosen regions were the **primary visual area** (VISp) and the **secondary motor area** (MOs). These two are **anatomically and functionally distinct**, hence they were our best shot at investigating differences in activity.

We believe that the dataset has enough potential, and given enough time we can build **better models** to represent the **temporal activations** of regions. However for the time being we shall settle on the simpler task.

Approaching the problem:

Dataset exploration and explanation:

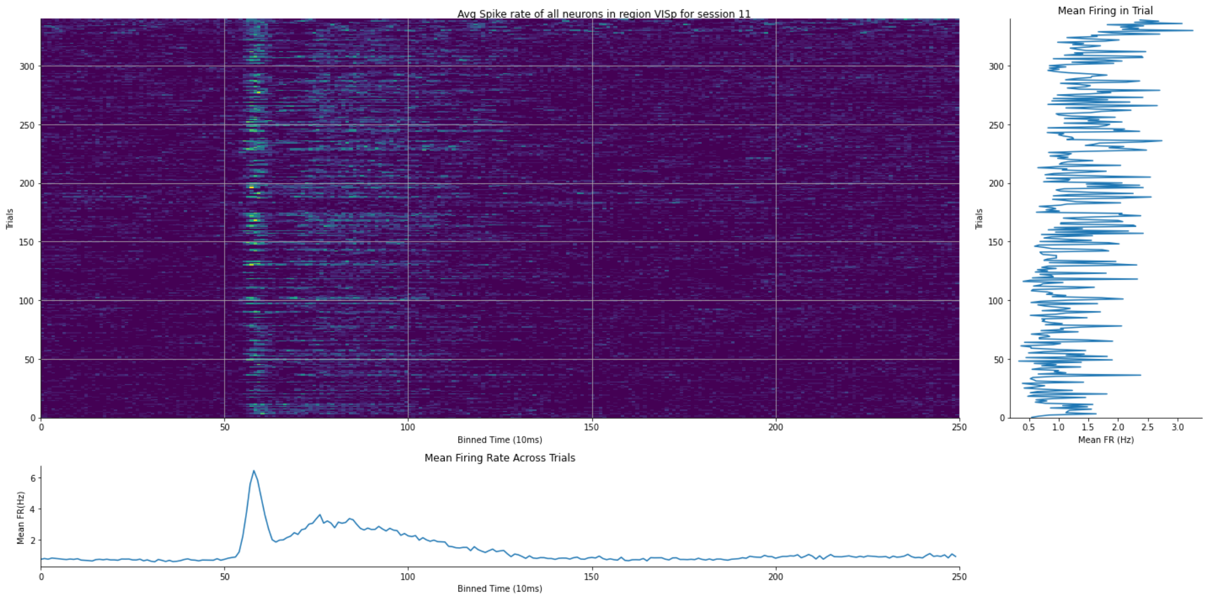
The neural data we had was a time series data of **spike waveforms** for all the neurons from each of the 42 regions. Since we wanted to look at the activity of a population of neurons from 2 regions, we needed to obtain the average activity of all neurons.

Analysis Pipeline:

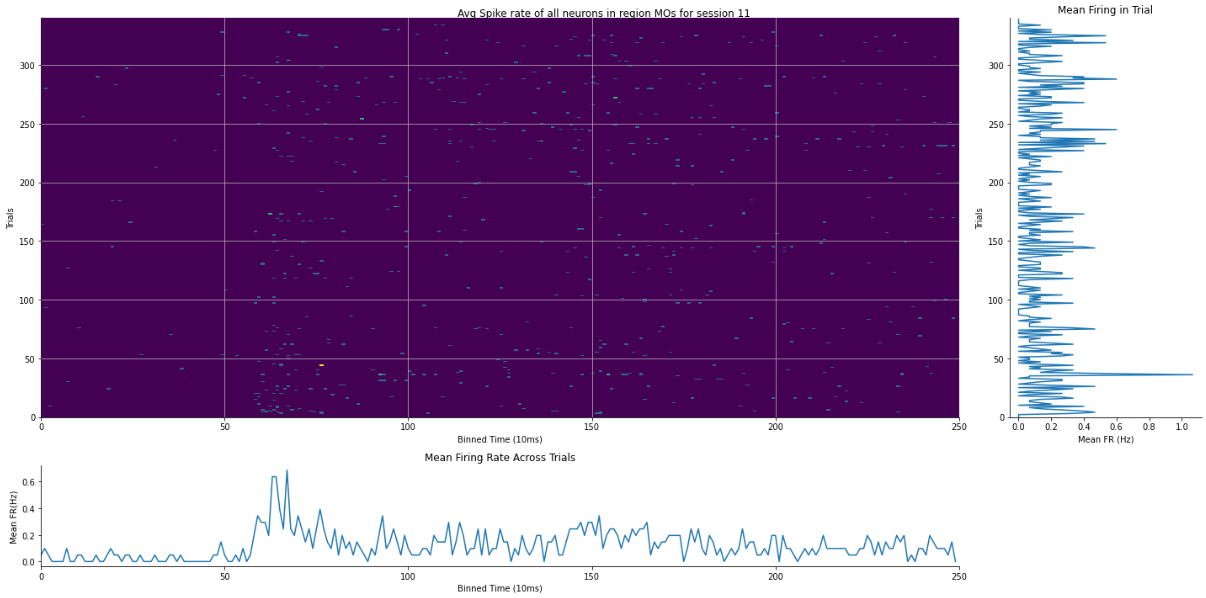
- Obtaining the **raster plots** showing the time course of the average activity of the 2 regions of our interest.
- **Binning** the data into 10ms bins and plotting the average activation over time
- Plotting averages of the bins across time.
- **Normalizing** the bins and finding the corresponding regions of excitatory / inhibitory activation, via **visual inspection**.

Results:

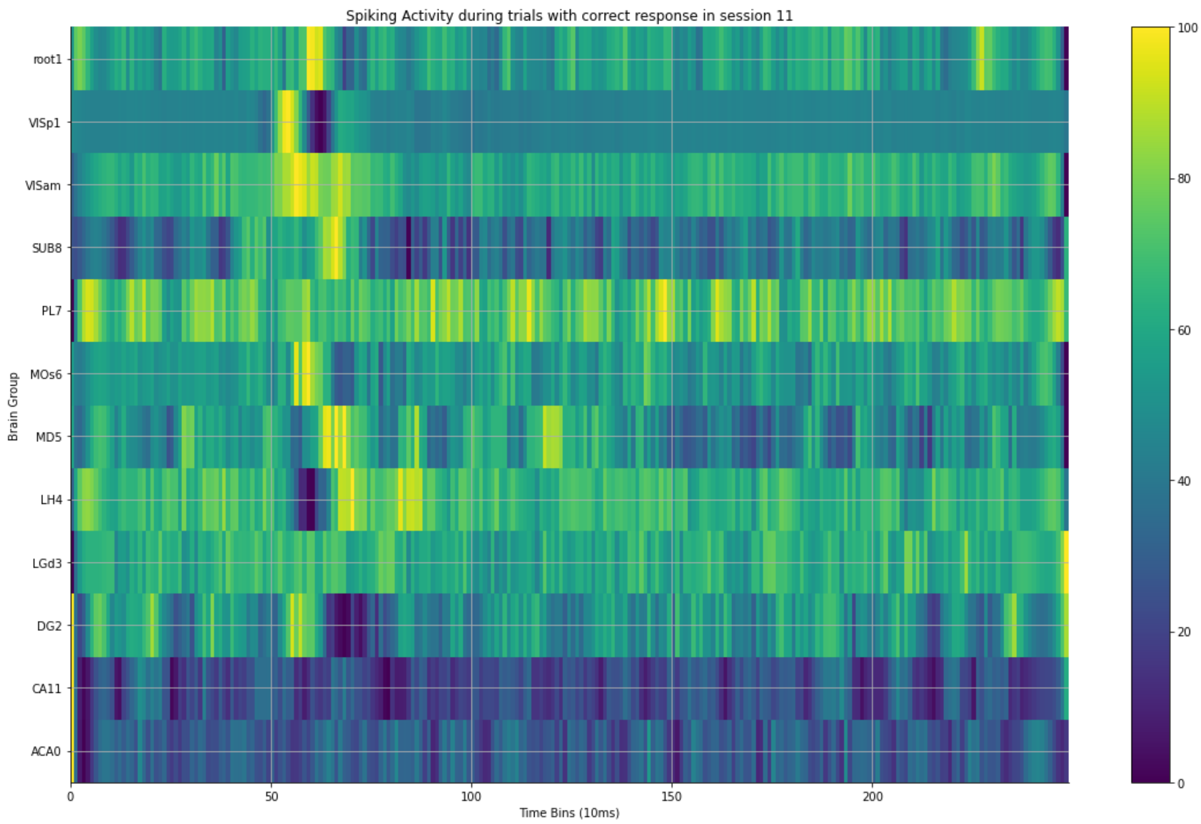
All our results and processes involved can be found in our GitHub repo[5]
Our initial tasks were to extract the data into a more interpretable form. We successfully did that with some help from some helper code.

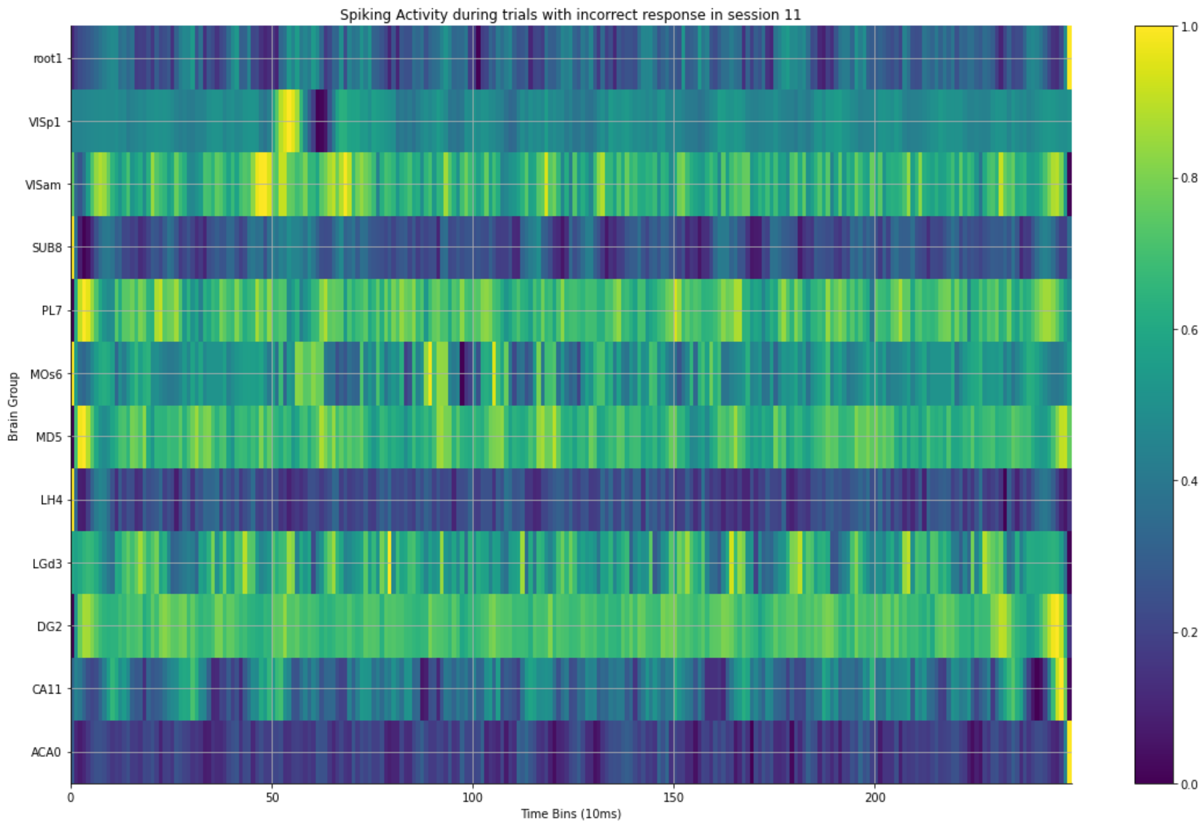


The above is one of our plots that we got. On the Y axis we have labeled the trials for a particular session and on the X axis we have the time bins (binned at 10ms width). The activity of all neurons from a particular region (in this case the **VISp** or the **Primary Visual Cortex** have been averaged across a trial and produced in this pseudocolor plot. Below we have another similar plot but from the **MOs** i.e. the **Secondary Motor Region**.



Apart from the other graphs we also decided to plot an average plot for a particular region over all correct trials / incorrect trials in a region. This plot is presented below.





It can be seen from the above two plots that there is quite a varied **difference** between the responses in general from the regions during the two different outcomes. We can see the activation of each region through time. Also we have to mention that the stimulus was presented at 50ms, and then activations follow. In this way we can see how information travels through brain regions in order to complete a certain motor task.

Upon close inspection one will also be able to make out the fact that the timing responses of the VISp and the MOs are different. This is exactly what we wanted to see. However we were **yet to quantify** this result.

Discussion and Further steps:

- Our two chosen regions were expected to show temporal difference in activity. Our results verified the same.
- Although we haven't statistically quantified the differences, we could visually interpret that there is a sequential activation in these two regions, signifying that the VISp is responsible for processing visual sensory information, LH of the thalamus plays a role in decision making, MO shows activation during motor action.
- Hence after this, we can look for the cascade of activation by analysing the activity from all 42 regions.

Our further tasks would be to first try to develop a classification model that could organize the raw data into these different trials. This will allow us to verify the data.

After which, we can proceed to use cross-correlation, RDMs or CCA to compare areas.

People:

- John Butler (Mentor)
- Arun Garimella (TA)
- Anna Marinou
- Anwesha Das
- Debaditya Bhattacharya

Resources:

1. Dataset:
   https://figshare.com/articles/steinmetz/9598406
2. Code by Dr. Pachitariu:
   https://github.com/MouseLand/steinmetz2019_NMA
3. Example Projects PPT:
   https://docs.google.com/presentation/d/1WAHfJcBPM4rmwwvreAAS92sRYtltJRwklxH-82NzCYo/preview?pru=AAABc3cRwPE*S0Y87T5BNFvf9wvSREdLUQ&slide=id.p
4. Allen Brain Atlas:

5. GitHub Repository:
https://github.com/Debu922/NMA_Mapping_Brain_Networks_2020
6. Neuromatch Academy
https://www.neuromatchacademy.org/
7. Nick’s Explanation of the data.
https://github.com/nsteinme/steinmetz-et-al-2019/wiki/data-files
8. Our explanation of the data.
https://docs.google.com/document/d/15YZOHIa6rZ8kx1bcIEH5j7-j-pj0GzmjLoevHVT1LIg/edit
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