Exploratory Analysis on Allen Institute Visual Cortex Recordings

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ABSTRACT

This project aims to explore and investigate neuronal recordings of mouse visual cortex dataset from Allen institute via different data analysis methods.

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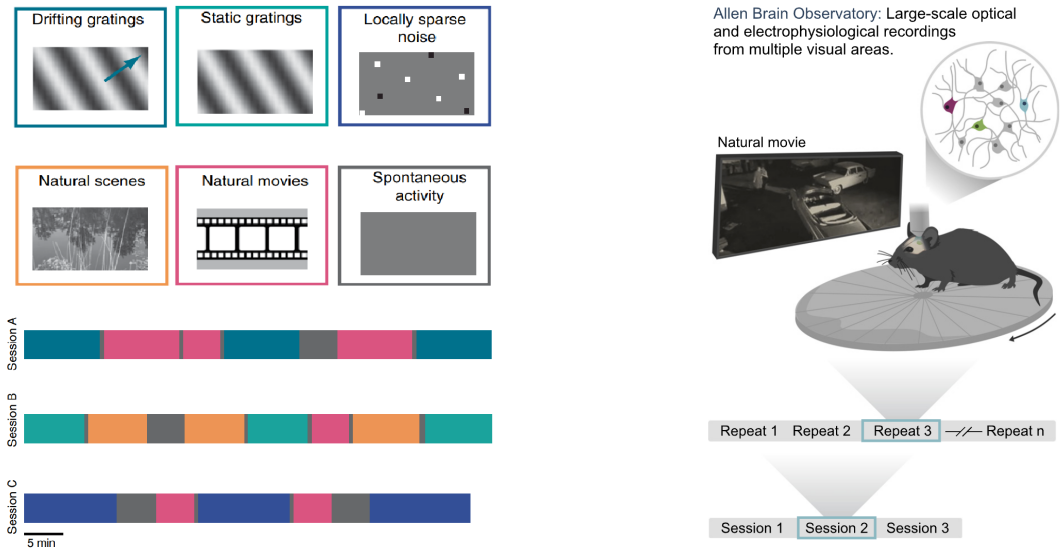
I. INTRODUCTION & BACKGROUND

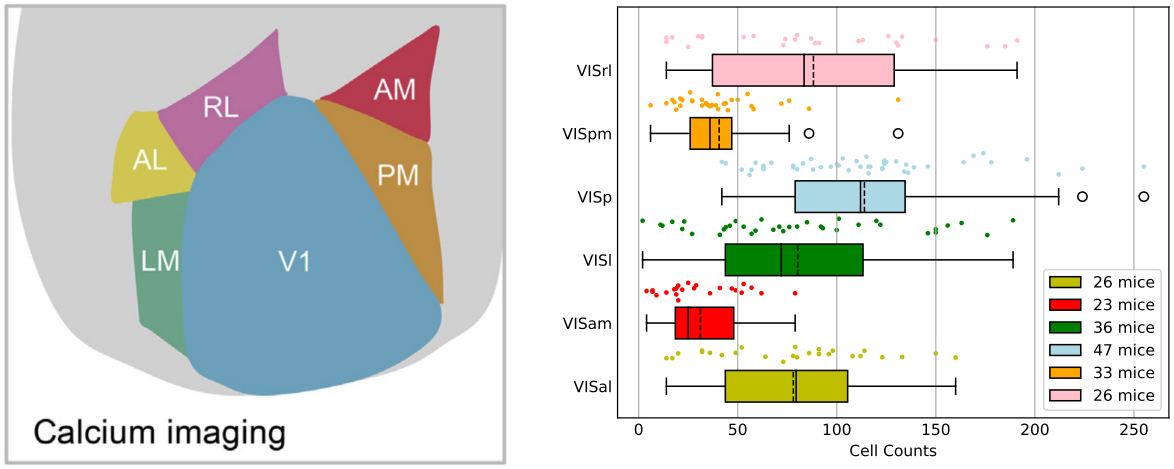
This project aims to explore and investigate neuronal recordings of mouse visual cortex dataset from Allen institute via different data analysis methods. The data analysis component involves working with Allen Institute recordings. These recordings has observations of neuronal population of the mouse brain's visual cortex under various visual stimuli conditions (Fig. 1a) with resolution of detecting single cells activity across time. The two used measurement techniques are Neuropixels and two-photon $Ca2^{+}$ imaging which have different structures. The data we chose to work with is two-photon imaging data-set [1].



(a) (b)

FIG. 1: **(a)** Mice experienced six distinct stimulus blocks, divided into three separate imaging sessions labeled as session A,B and C, conducted across different days[1] **(b)** Schematic structure of experiments setup for selected stimulus (natural movie) [2]

In order to investigate my research's problem statement which relates to dynamics of brain across time, we needed an experiment which were repeated across different days and the only repeated stimulus in this experimental setup was natural movie (Fig. 1a). Natural movie stimulus which is 30 seconds long has been shown to the animal for 3 different days (session 1, 2, and 3) and each day has been repeated 10 times (Fig. 1b). Each mouse is imaged just for one cortical area (Fig. 2a) and the measurement contains calcium fluorescence signals for each neuron within that area (Fig. 2b).



(a) (b)

FIG. 2: **(a)** Visual cortex areas map : V1 (primary visual area), LM (lateral-medial visual area), AL (anterolateral visual area), PM (posteromedial visual area), RL (rostrolateral visual area), and AM (anteromedial visual area)[2] **(b)** distribution of experiments across different brain areas with different observed neurons (solid line : median, dashed line: mean)

In Figure 3, we present three instances of neurons that exhibit consistent and strong responses when exposed to the natural movie across 30 trials. These neurons seem to encode distinct time frames, capturing various features and information from the movie. Although there are also other neurons that do not consistently maintain their robustness across different trials. These neurons might be involved in more complex information processing or not responsive to the movie at all.

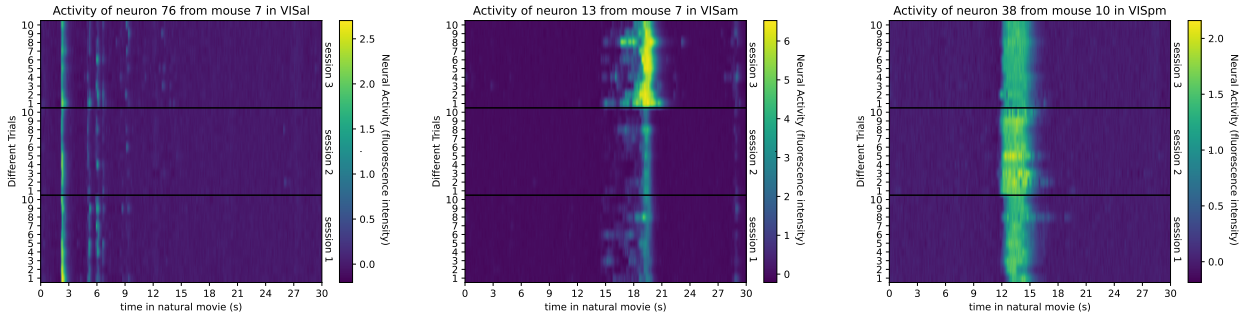


FIG. 3: Three example neurons which have reliable response to the natural movie stimulus.

II. METHOD

In this section, I will detail the data collection process and outline the methods used for analyzing these brain signals.

A. Data Retrieval and Cleaning

For collecting raw data from Allen institute there is an API which I used in python []. I downloaded all experiments available for two-photon calcium imaging and filtered them by the stimulus we are interested in (natural movie one). I created a general class of mouse which includes attributes: id, signals (Called dff traces) and etc. Then I created different instances of mouse class and write data from API to the attributes and finally stored them as .npz (from numpy package) files to begin analysis.

B. Data Statistics & Visualization

To get some primary insight of the dataset, I plotted a boxplot for the variability of cell counts per mouse in different brain regions (see Fig.2b) by reading the cleaned dataset and using matplotlib and numpy packages. I explored neuronal signals of different neurons by plotting imageshow (see Fig.3) and saw different responses across neurons. To find well behaved neurons, I calculated average correlation of each neuron with itself (see Fig.5) and picked the most correlated neurons$(\text{Correlation} > \text{threshold}\,;\text{threshold} = 0.8)$.

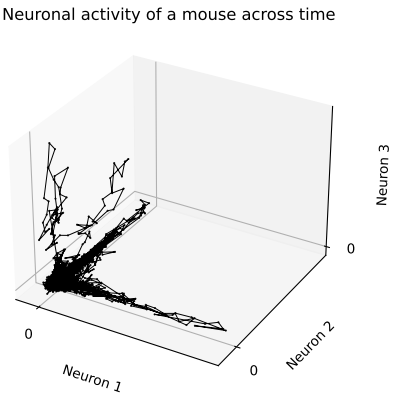


FIG. 4: Activity of a single mouse in high dimensional space

C. PCA Analysis

You can think of the activity of all neurons (for a single animal) as a trajectory in a high dimensional space (Fig. 4) where each point corresponds to a time frame of movie with N (total number of neurons) components in a sense that i^{th} component shows activity of i^{th} neuron at time t. Ideally this trajectory should contain the information regarding the movie and one might think of reducing this trajectory into an smaller subspace. The first approach that comes to mind is PCA (principal component analysis)[3]. I performed PCA on each mouse using sklearn.decomposition

module and categorized them into different brain areas, then plotted the explained variance ratio for each area (see Fig. 6).

III. RESULTS & DISCUSSION

Statistics of cells : According to the method for selecting robust cells (II B) we obtain a scatter plot of correlations of all cells of all mice in different brain regions, for instance I only presented the VISp (V1) area (see Fig. 5). By choosing a threshold and selecting highly correlated cells you can pick robust cells. Population mean (across mice) of correlations is between 0.078 and 0.105 for VISp with 95% confidence interval.

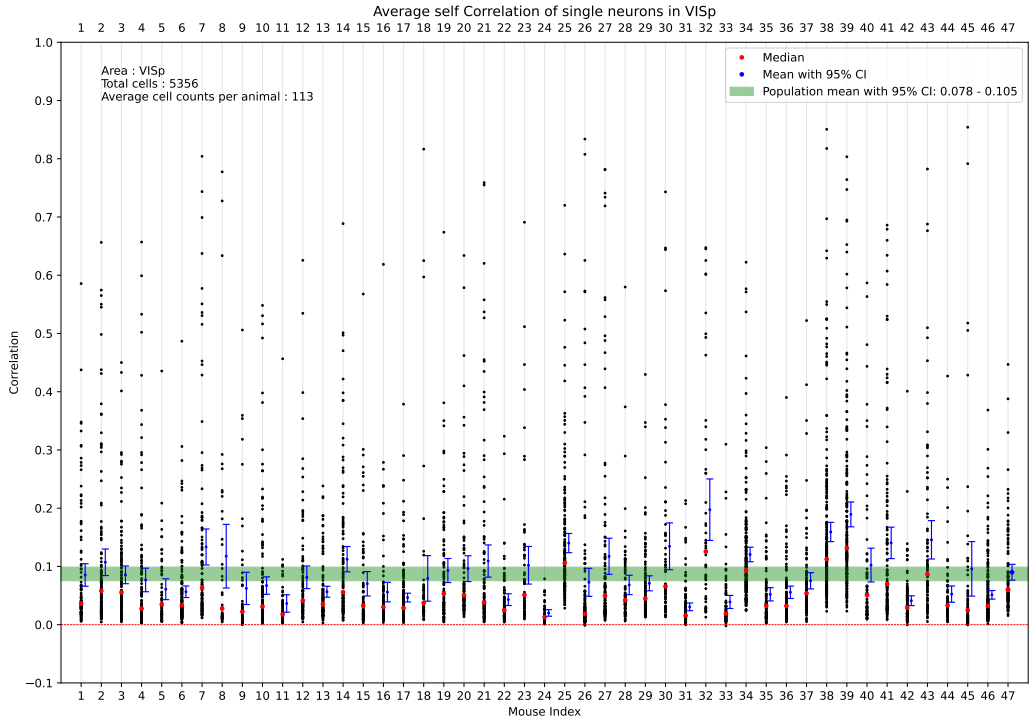


FIG. 5: cell correlation with itself. Each point corresponds to a neuron and higher correlation means more robustness in acticity for the cell

PCA results:

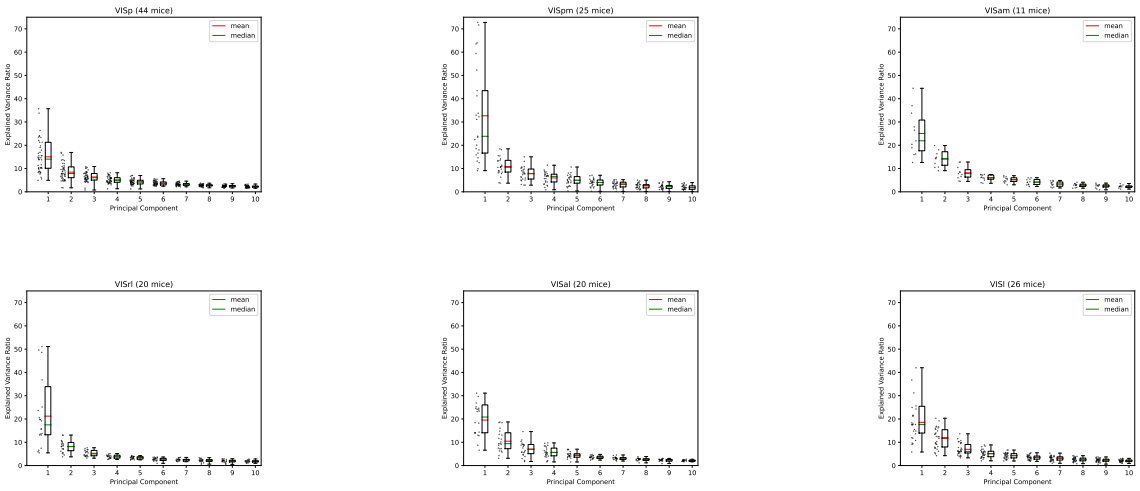


FIG. 6: Six subfigures arranged in a 2 by 3 grid

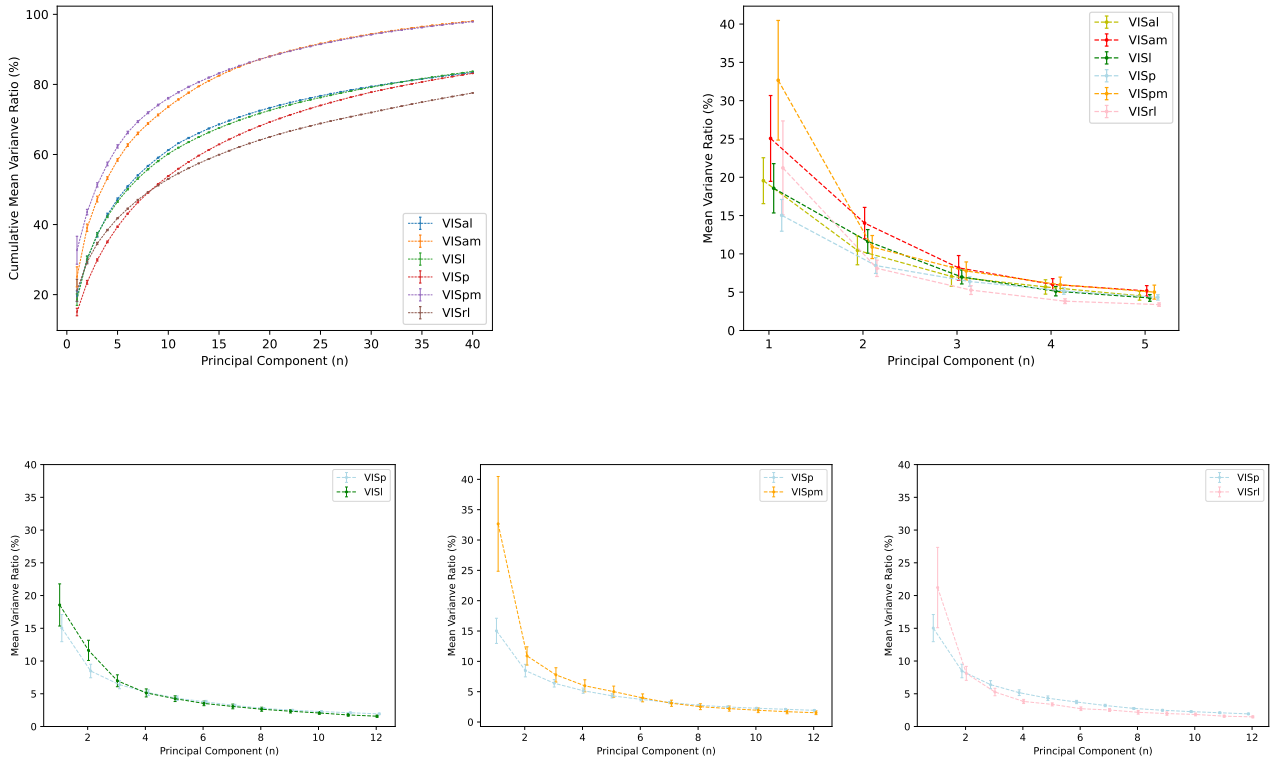


FIG. 7: Six subfigures arranged in a 2 by 3 grid

IV. CONCLUSION

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[1] S. E. de Vries, J. A. Lecoq, M. A. Buice, P. A. Groblewski, G. K. Ocker, M. Oliver, D. Feng, N. Cain, P. Ledochowitsch, D. Millman, *et al.*, A large-scale standardized physiological survey reveals functional organization of the mouse visual cortex, Nature neuroscience **23**, 138 (2020).

[2] D. Deitch, A. Rubin, and Y. Ziv, Representational drift in the mouse visual cortex, Current biology **31**, 4327 (2021).

[3] https://en.wikipedia.org/wiki/Principal$_c omponent_a nalysis$.