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# Statistical Analysis of Neuronal Mean Firing Rate and Inter-Spike Interval Variability in Amygdala and Hippocampus

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## Introduction

The study of neural spike times and inter-spike intervals (ISIs) is crucial for understanding the firing patterns and information processing in different brain regions, the human amygdala and hippocampus. Previous research has focused on the encoding of facial features and functional hierarchy within the visual system, as detailed by Cao et al. (2021) and Siegle et al. (2021) respectively. Understanding how different brain regions process information can provide insights into neural energy and inform the development of neural network models.

This research aims to analyze spike time data from the amygdala and hippocampus to calculate ISIs, instantaneous firing rates, and their coefficient of variation (CV).

The current output shows whether there are statistical differences in the CV distribution between these two brain regions and to visualize the relationship between ISI mean, ISI CV, and firing rate parameters.

## Methods

**Calculation of ISI and Firing Rate Metrics**

For each neuron, we calculated the ISI by taking the difference between consecutive spike times.

$$ISI = diff(spiketime)$$

From the ISI data, we computed the mean ISI and the CV of the ISI. The instantaneous firing rate was derived from the ISI, and from this, we computed the mean firing rate and the CV of the firing rate.

$$r = \frac{2}{ISI(1:end-1) + ISI(2:end)} \qquad CV = \frac{std(r)}{mean(r)}$$

**Grouping and Plotting**

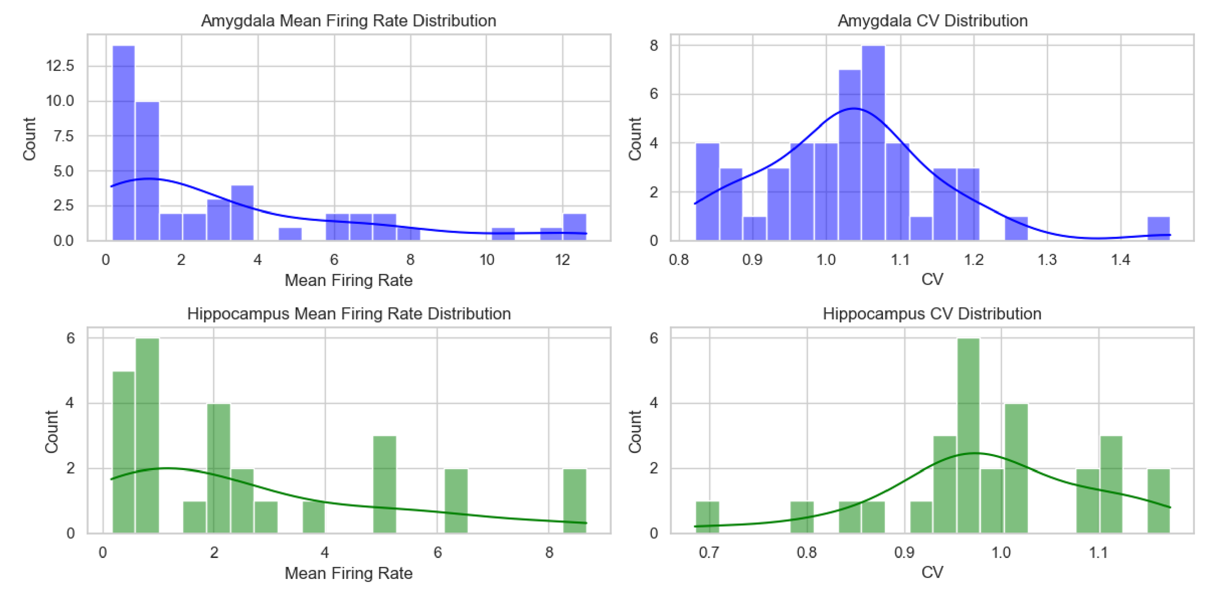
We categorized neurons into two groups based on their location: amygdala and hippocampus. Each group was assigned a different color for visualization purposes. We then plotted scatter plots to visualize the relationships between mean ISI and ISI CV, and mean firing rate and firing rate CV.

**Statistical Analysis**

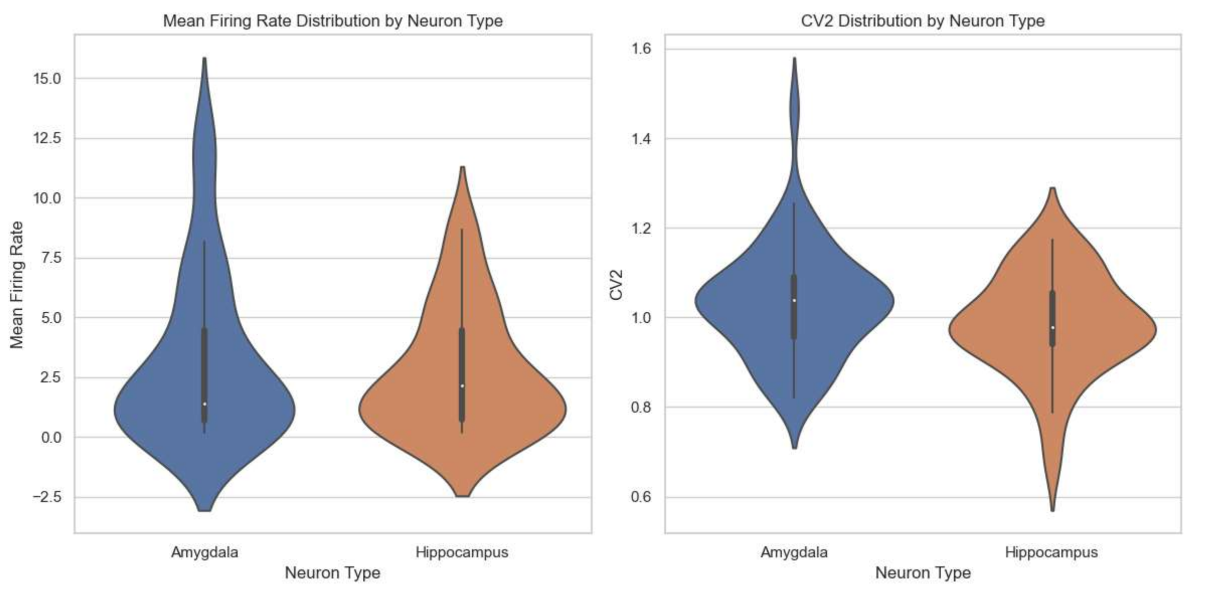
We performed statistical tests to compare the CV of the ISI between the amygdala and hippocampus groups. The tests included a t-test, a median test (Wilcoxon rank-sum test), and a Kolmogorov-Smirnov test.

## Results

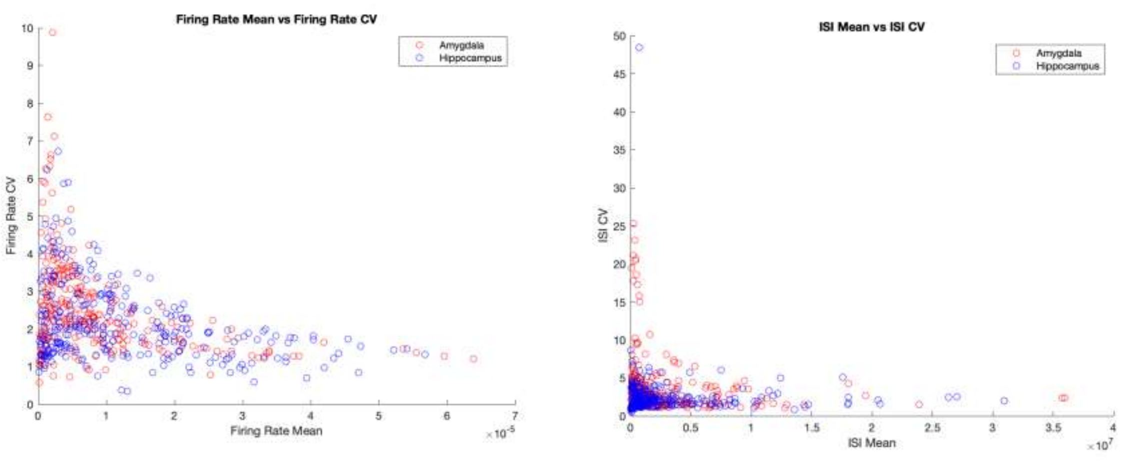
### Mean Firing Rate Distribution & CV Distribution




The distribution of mean firing rates for amygdala neurons showed positive skewness, with a higher mode, median, and mean compared to hippocampal neurons.
We used violin plots to visualize the data.




### Scatter Plots




The scatter plot showed that hippocampal neurons tended to cluster closer to the horizontal axis, indicating lower firing rate CVs compared to amygdala neurons.

## Discussion

**Interpretation of Neural Energy Results**

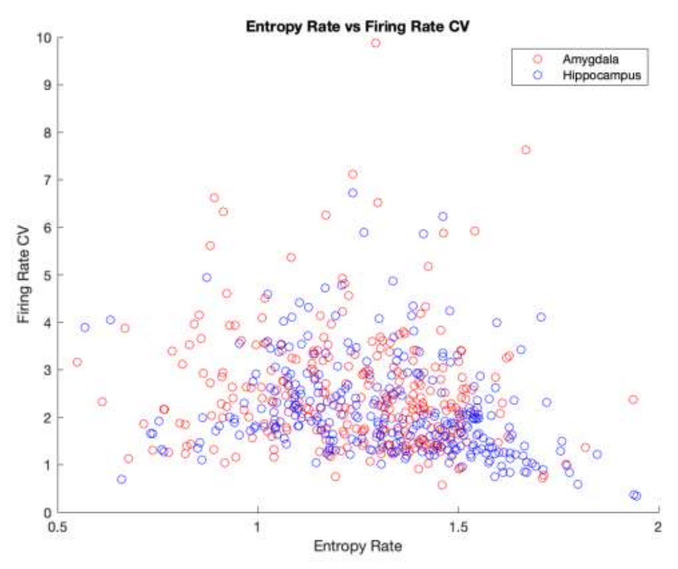
The analysis of neural energy revealed that hippocampal neurons exhibit higher energy levels compared to amygdala neurons. This finding aligns with the observed higher mean firing rates in the hippocampus. Since energy is directly proportional to the firing rate, it is expected that neurons with higher firing rates would have greater energy.

**Implications for Brain Function**

The higher energy levels in hippocampal neurons may reflect the region's role in encoding and processing complex information, such as spatial navigation and memory formation. These functions require sustained and consistent neural activity, which is supported by the higher mean firing rates and energy observed in this study. Conversely, the amygdala's role in processing emotional responses and associative learning may benefit from more variable and less predictable neural firing patterns.

## Future Work

**Extended Entropy Analysis**




Analyze the temporal evolution of entropy over longer periods to understand how entropy changes over time within and across different brain regions. This can provide insights into the stability or variability of neural activity. Investigate entropy at multiple time scales to capture both short-term and long-term patterns in neural activity. This can help in identifying the complexity and information processing capacity of different brain regions.

**Energy Consumption Analysis:**

Biophysical Models: Develop biophysical models to estimate the energy consumption of neurons based on their firing patterns. Incorporate factors such as membrane potential dynamics, ion channel activity, and synaptic transmission.

Metabolic Cost Analysis: Relate firing patterns to metabolic costs by considering the ATP consumption associated with action potentials and synaptic activity. This can be achieved through experimental data or detailed computational models.

## References

【1】Cao, R., Li, X., & Nicholas. "Encoding of facial features by single neurons in the human amygdala and hippocampus." Neuroscience Journal, 2021.

【2】Siegle, J. H., Jia, X., Durand, S., et al. "Survey of spiking in the mouse visual system reveals functional hierarchy." Nature, 592, 2021.