University: Sharif University of Technology

Department: Electrical Engineering

Course Name: Advanced Neuroscience

Homework 3 Report

Noise Correlation

Student Name: Ali Shahbazi

Student ID: 98101866

Instructor: Prof. Ali Ghazizadeh

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Question 1

Before using the data, by running `script_mean_firing_rates_gratings.m`[1], we delete neurons with SNR lower than 1.5dB or firing rate lower than 1 spike/sec.

In Figure 1, PSTHs of three monkeys are plotted for each stimulus. As we can see, there is somehow a sinusoidal structure in the PSTH indicating the on and off in presenting gratings in the experiment. Also, we can see a soft drop in all PSTHs over time. Although 1000ms is not considered long, neurons do adapt and the firing rate would decrease over time.

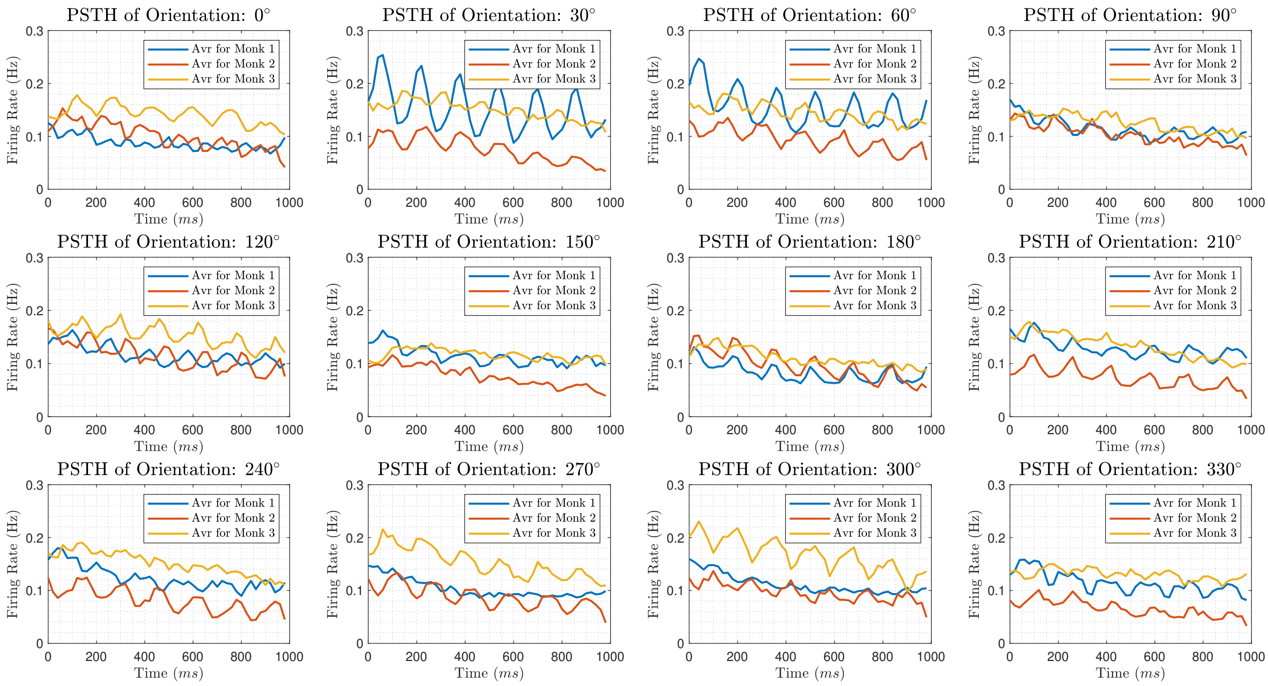

Figure 1: Average PSTH for Different Stimuli

In Figure 2 tuning curve for the top three active neurons in each monkey is plotted. As we can see almost all these neurons that are sensitive to a direction, are also sensitive to that direction with +180°. It means that they code the orientation. The average response to each stimulus is also plotted to compare firing rates.

[1]this code and all data are provided by [2]

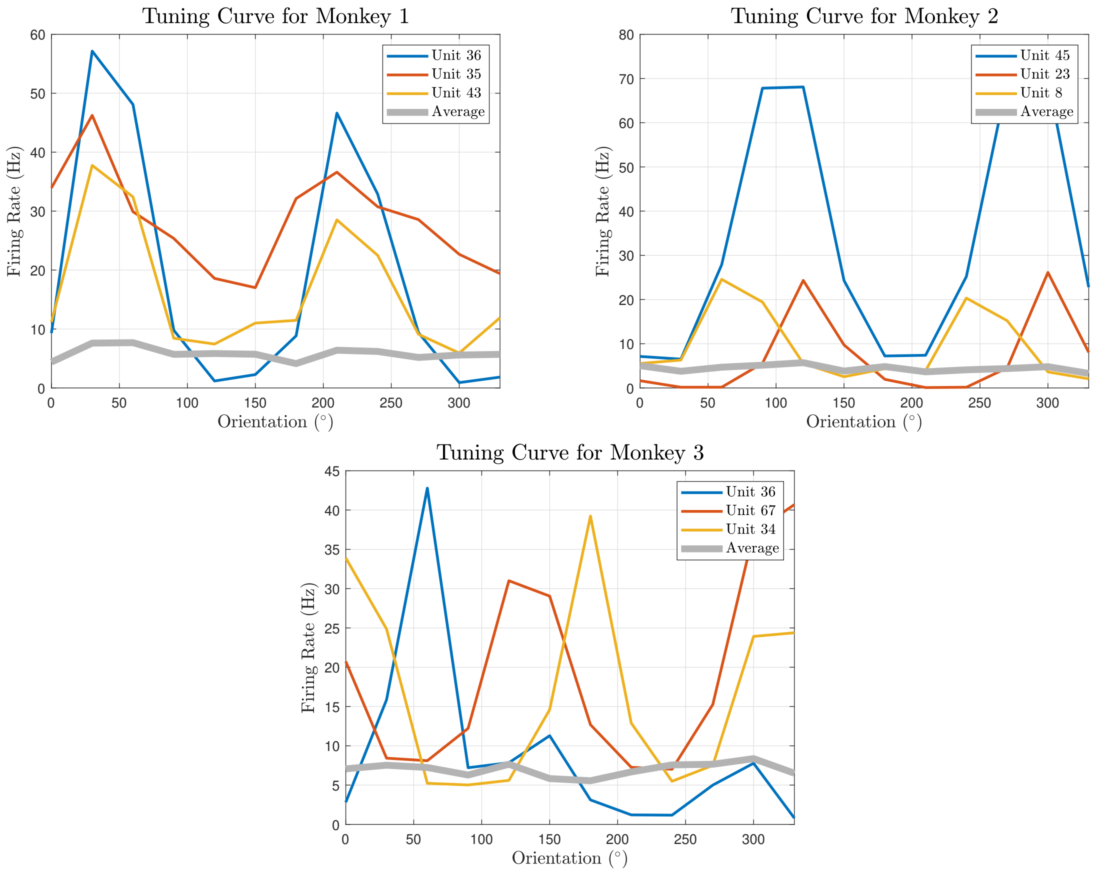

Figure 2: Tuning Curves for Most Active Neurons

Question 2

By comparing the firing rates in each stimulus, we can find which stimulus each neuron responds to. Note that $0°$ and $180°$ are same here. White blocks are NaN caused by deleted neurons (omitted because of bad SNR or low firing rate). For channels with more than one neuron, the average preferred orientation is considered.

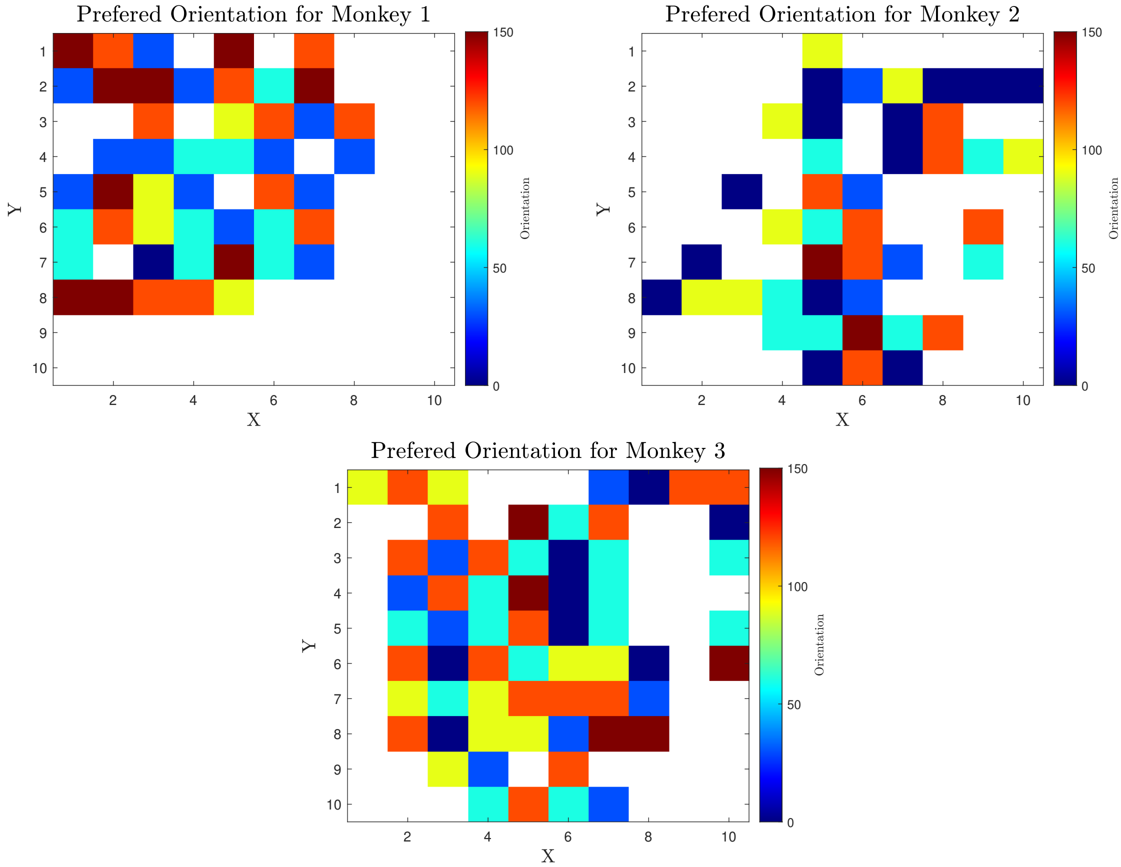

Figure 3: Preferred Orientation in Array

As we can see in Figure 3, there is no obvious pinwheel organization. One reason is undefined blocks and the other reason might be the distance between adjacent electrodes. As mentioned in their paper [3], the minimum distance between electrodes is $400\mu m$, therefor we have much low spatial resolution, and recognizing pinwheels is hard.

Question 3

In Figure 4, Figure 5 and Figure 6 the dependence of r_{sc} on distance and tuning similarity is investigated.

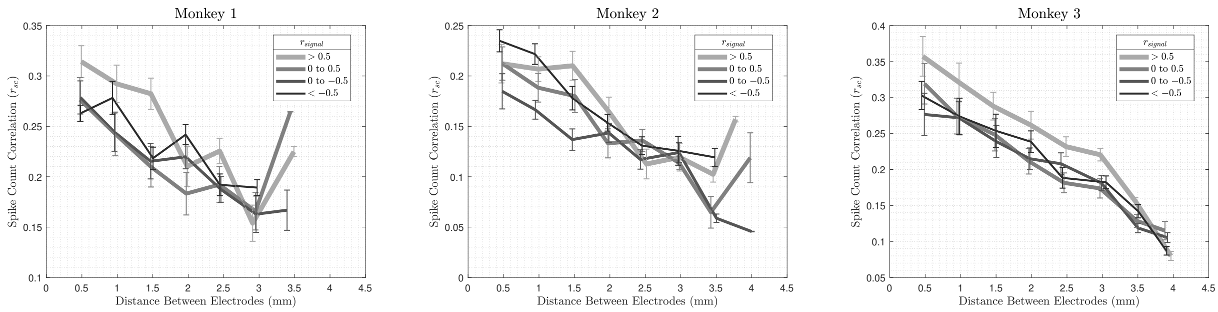

Figure 4: The dependence of r_{sc} on distance for pairs grouped based on their orientation tuning similarity (r_{signal})

Spike count correlation (noise correlation) decreases with the increase of distance between electrodes, and neurons with higher orientation tuning similarity are found to have higher noise correlation.

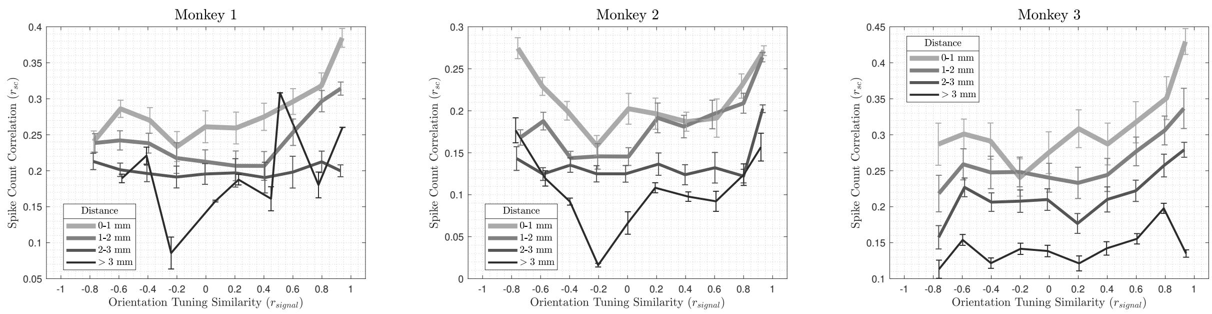

Figure 5: The dependence of r_{sc} on r_{signal} for pairs grouped by their separation

Spike count correlation (noise correlation) increases with the increase of orientation tuning similarity and neurons that are closer to each other, have higher noise correlation.

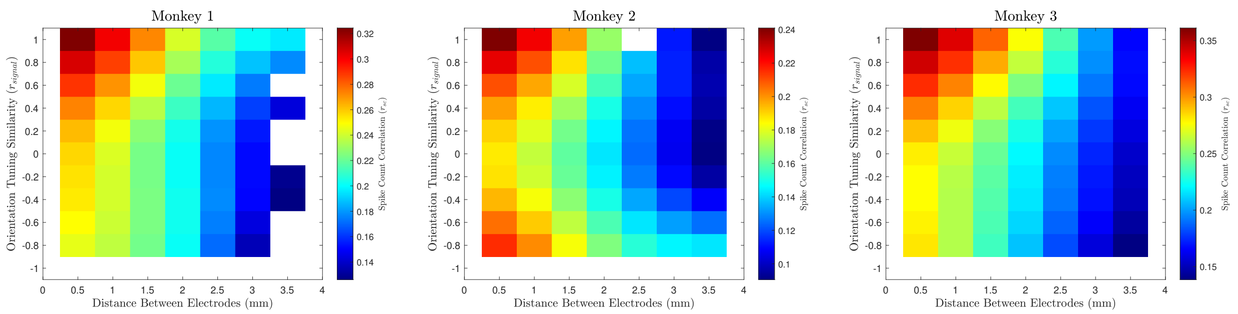

Figure 6: The dependence of r_{sc} on both distance and tuning similarity

Neurons that are close to each other and have high orientation tuning similarity, are found to have high spike count correlation as well.

Note that Figure 6 is achieved by applying a 2D Gaussian filter as discussed in the caption in paper [3].

Question 4

In spontaneous periods, neurons tend to work randomly due to a noise input, resulting in notable variability in firing rate and high Fano Factor and noise correlation. But when an input is applied, some neurons respond and fire and excite others and also inhibit another group of neurons. Therefore, excited neurons converge to their final firing rates in each trial and inhibit the activity of others. Inhibited neurons also reach their determined firing rates and because of low variability, Fano Factor decreases and causes a decrease in noise correlation. Figure 7 shows a simple *winner take-all* model which can explain decrease in Fano Factor.

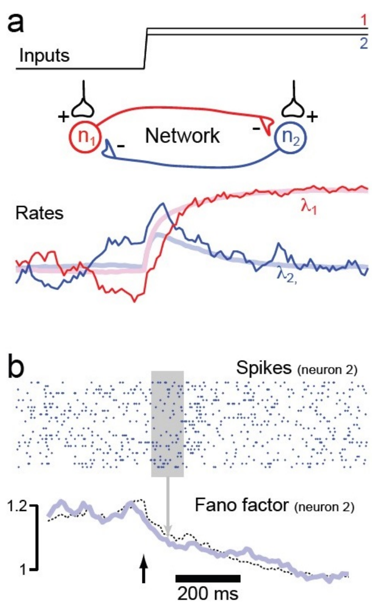

Figure 7: Winner Take-All Model, from [1]

Question 5

We found that neurons with similar orientation tuning are highly correlated with each other (Figure 5). So one way is to get the correlation of neurons in spontaneous periods and guess that those neurons with high spike count correlation, are likely to code the same orientation and would have similar orientation tuning. Note that we can not find the orientation which is being coded, but can guess the population which is coding it.

References

[1] Mark M Churchland et al. “Stimulus onset quenches neural variability: a widespread cortical phenomenon”. In: *Nature neuroscience* 13.3 (2010), pp. 369–378.

[2] Adam Kohn and Matthew A Smith. “Utah array extracellular recordings of spontaneous and visually evoked activity from anesthetized macaque primary visual cortex (V1)”. In: *CRCNS. org* 10 (2016), K0NC5Z4X.

[3] Matthew A Smith and Adam Kohn. “Spatial and temporal scales of neuronal correlation in primary visual cortex”. In: *Journal of Neuroscience* 28.48 (2008), pp. 12591–12603.