Student Name: Mohammad Mohammad Beigi
Student ID: 99102189
Subject: Neural Encoding

Advanced Topics in Neuroscience - Dr. Ali Ghazizadeh
Assignment 2

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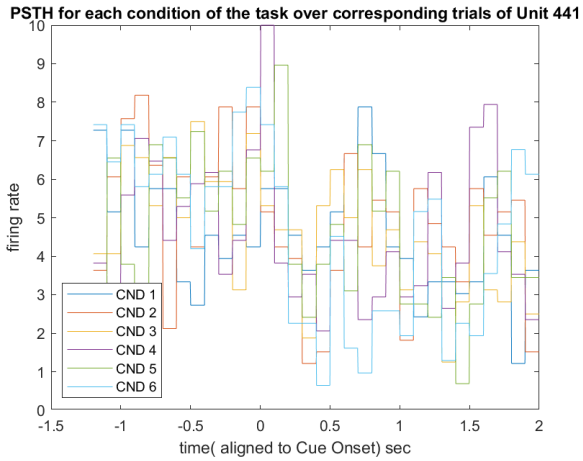
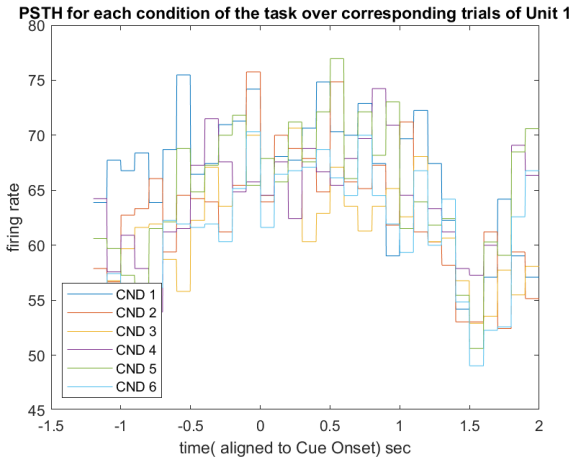
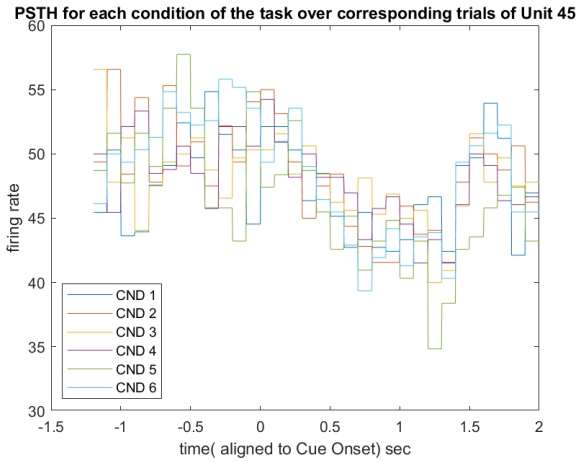
1. Calculate the PSTH for the units and plot the average PSTH for each condition of the task.

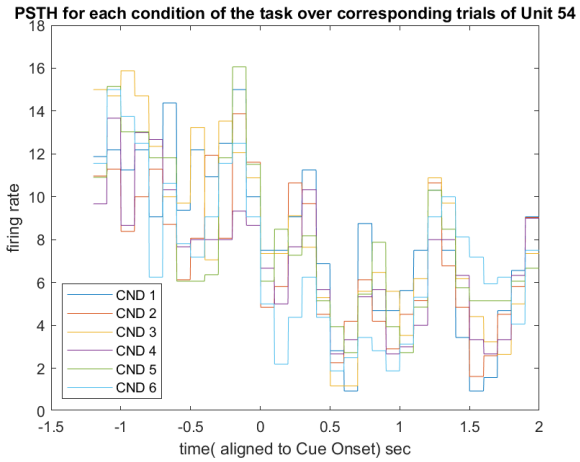
Answer:

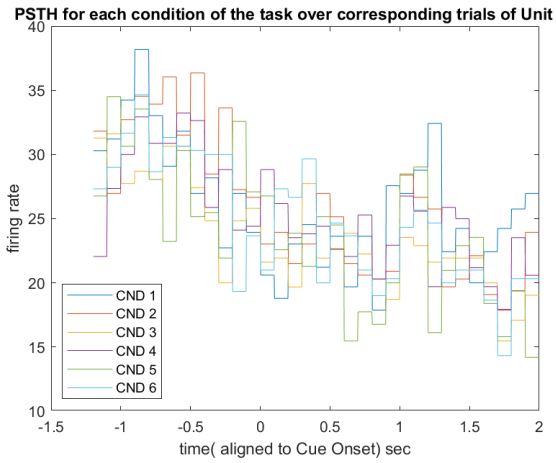
PSTH for different units in different conditions:

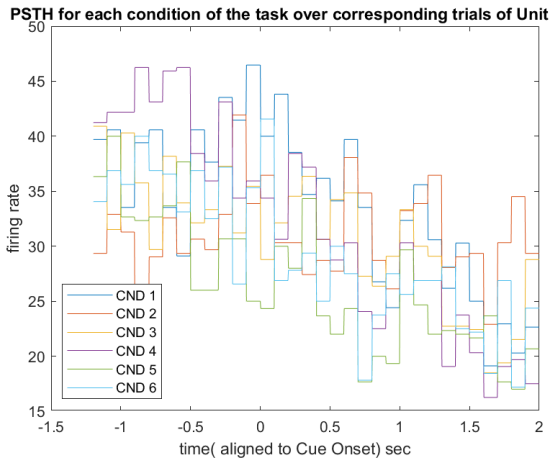


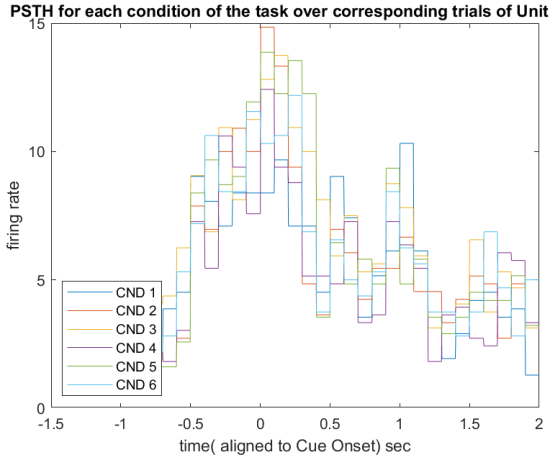


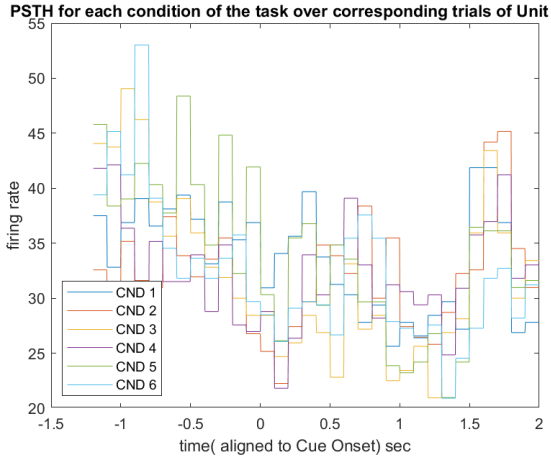


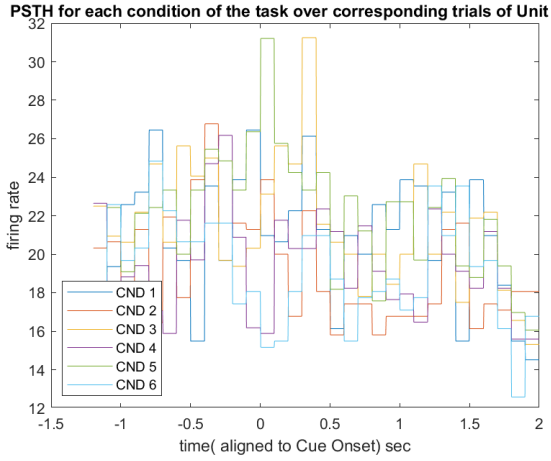


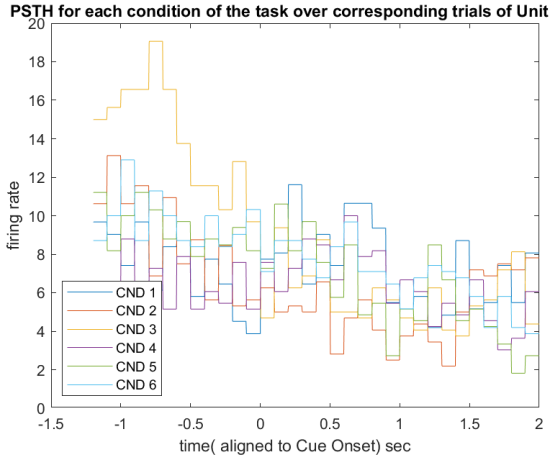

PSTH for each condition of the task over corresponding trials of Unit 89
firing rate
time(aligned to Cue Onset) sec
CND 1
CND 2
CND 3
CND 4
CND 5
CND 6

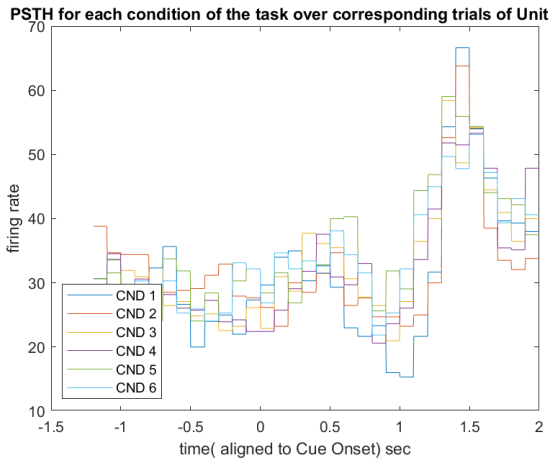

PSTH for each condition of the task over corresponding trials of Unit 133
firing rate
time(aligned to Cue Onset) sec
CND 1
CND 2
CND 3
CND 4
CND 5
CND 6

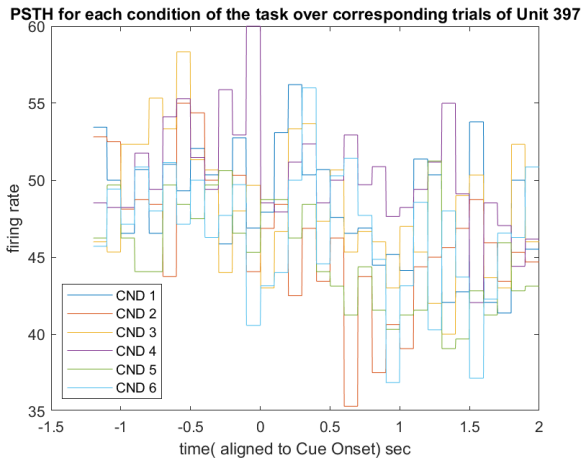

PSTH for each condition of the task over corresponding trials of Unit 177
firing rate
time(aligned to Cue Onset) sec
CND 1
CND 2
CND 3
CND 4
CND 5
CND 6


PSTH for each condition of the task over corresponding trials of Unit 221
firing rate
time(aligned to Cue Onset) sec
CND 1
CND 2
CND 3
CND 4
CND 5
CND 6

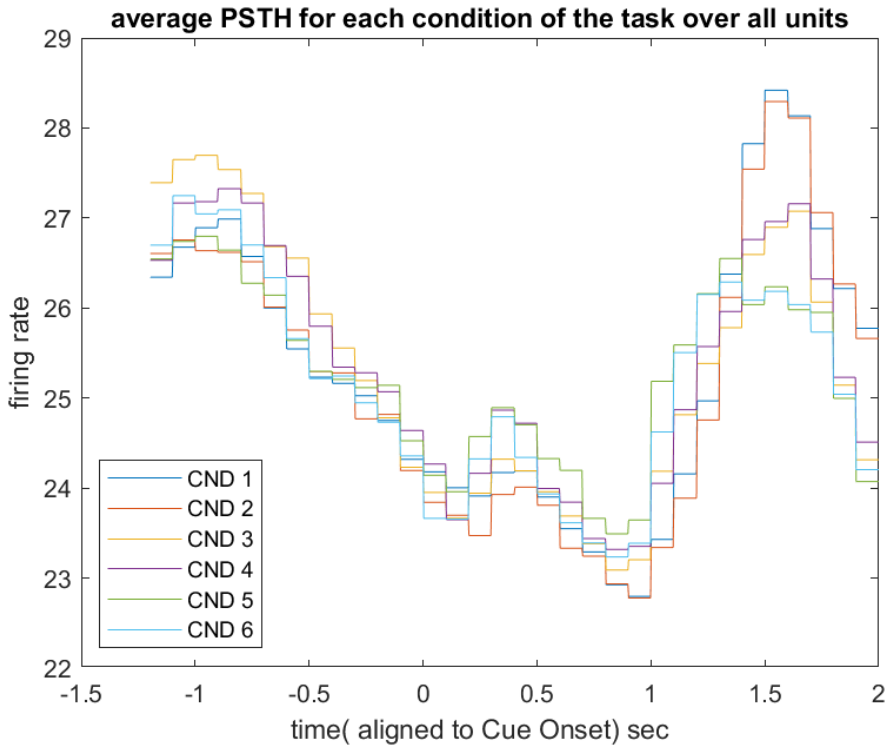

PSTH for each condition of the task over corresponding trials of Unit 265
firing rate
time(aligned to Cue Onset) sec
CND 1
CND 2
CND 3
CND 4
CND 5
CND 6


PSTH for each condition of the task over corresponding trials of Unit 309
firing rate
time(aligned to Cue Onset) sec
CND 1
CND 2
CND 3
CND 4
CND 5
CND 6





Average PSTH for each condition of the task over all units and their corresponding trials:



(a) Are the PSTH of different units act in the same way?

Answer: No; As we see in the figures above, PSTH varies from one unit to another.

(b) Could you infer the encoding of task parameters from the average PSTH?

Answer: From last figure we can conclude that we can not infer the encoding of task parameters from the average PSTH.(Because the average PSTHs in different conditions are so close to each other)

2. Single unit analysis using GLM: Use GLM analysis to find out which units significantly encode the task conditions which includes reward expected value and cue location (i.e. regress neural responses against these two parameters)

Answer:

To answer this part, first we consider the interval 300ms to 1300ms after cue onset. Then we calculate mean of firing rate for each unit and its conditions separately(Now we have a 6×1 array for each unit). Then we will regress neural responses against reward expected value and cue location. We also calculate CV for each 6×1 array.

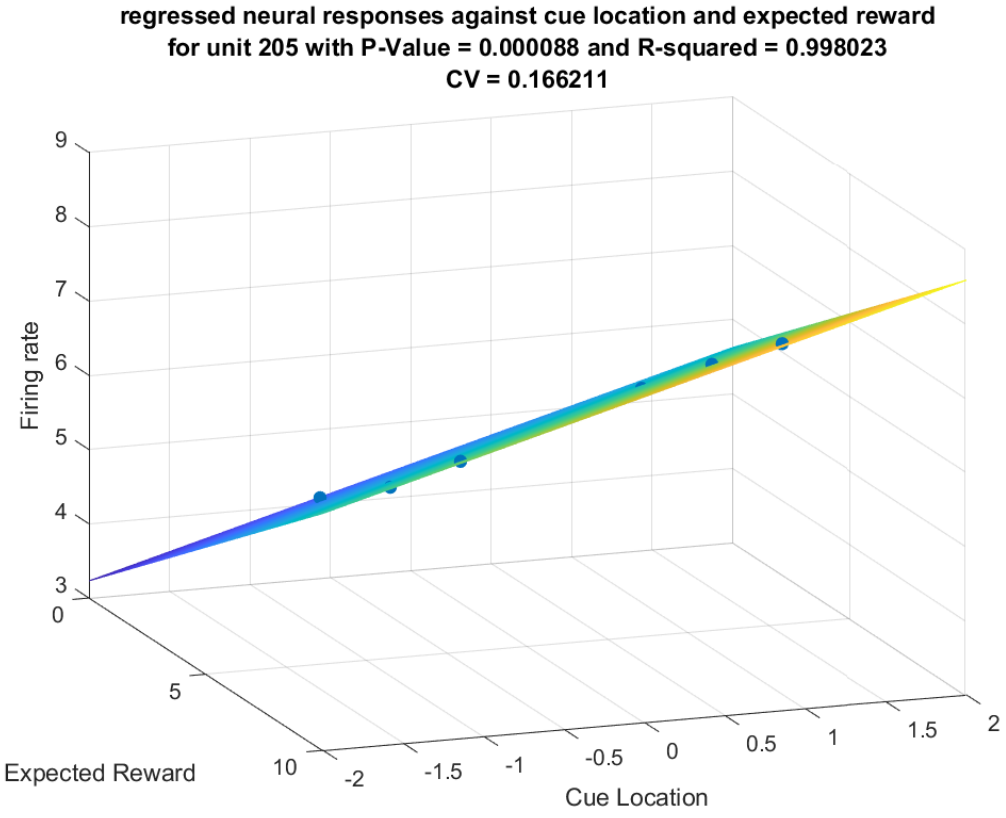
Note: In the context of regression analysis, a P-value is a statistical measure that helps determine the significance of the relationship between the predictor variables (independent variables) and the response variable (dependent variable).

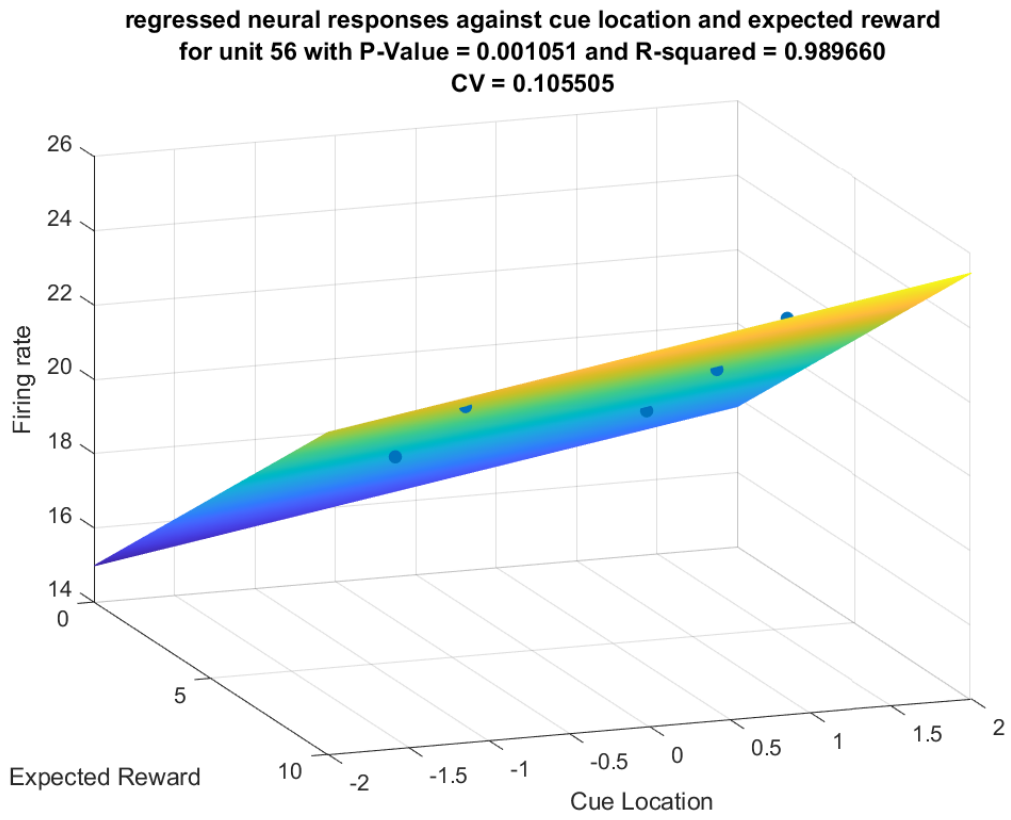
The P-value is used to test the null hypothesis, which assumes that there is no significant relationship between the predictor and response variables. A low P-value (usually less than 0.05) indicates that the null hypothesis can be rejected, meaning that there is a significant relationship between the predictor and response variables.

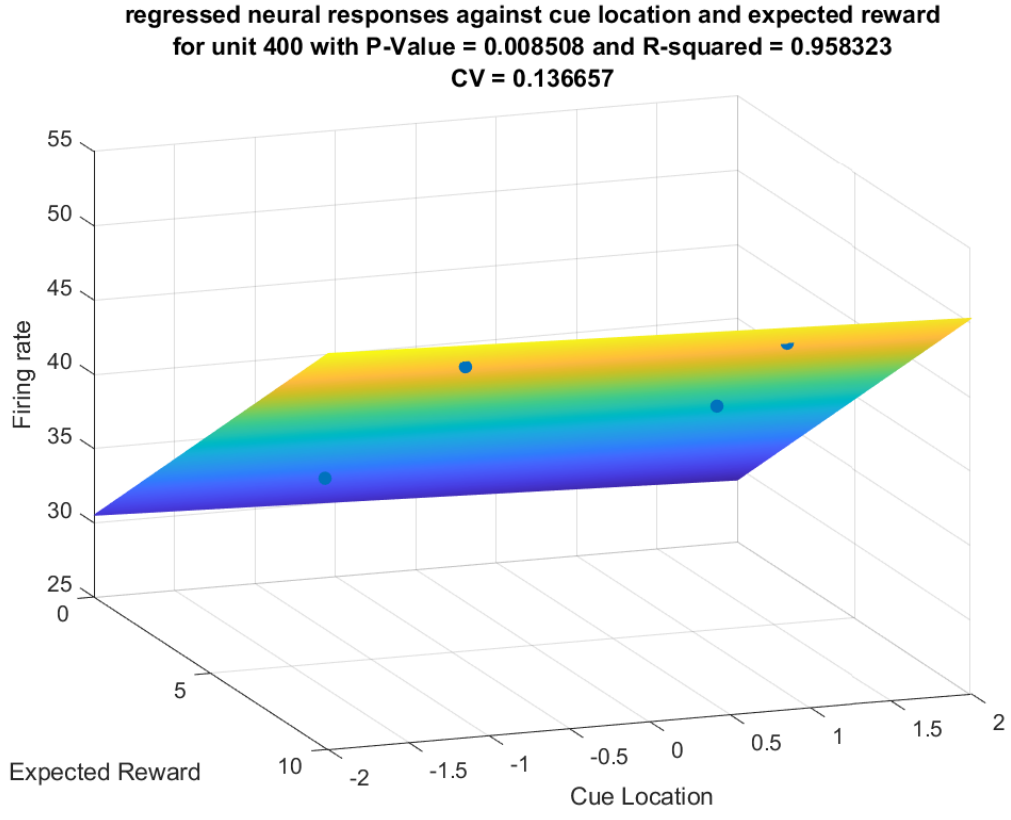
Specifically, the P-value represents the probability of observing a correlation as extreme as the one estimated from the sample, assuming the null hypothesis is true.

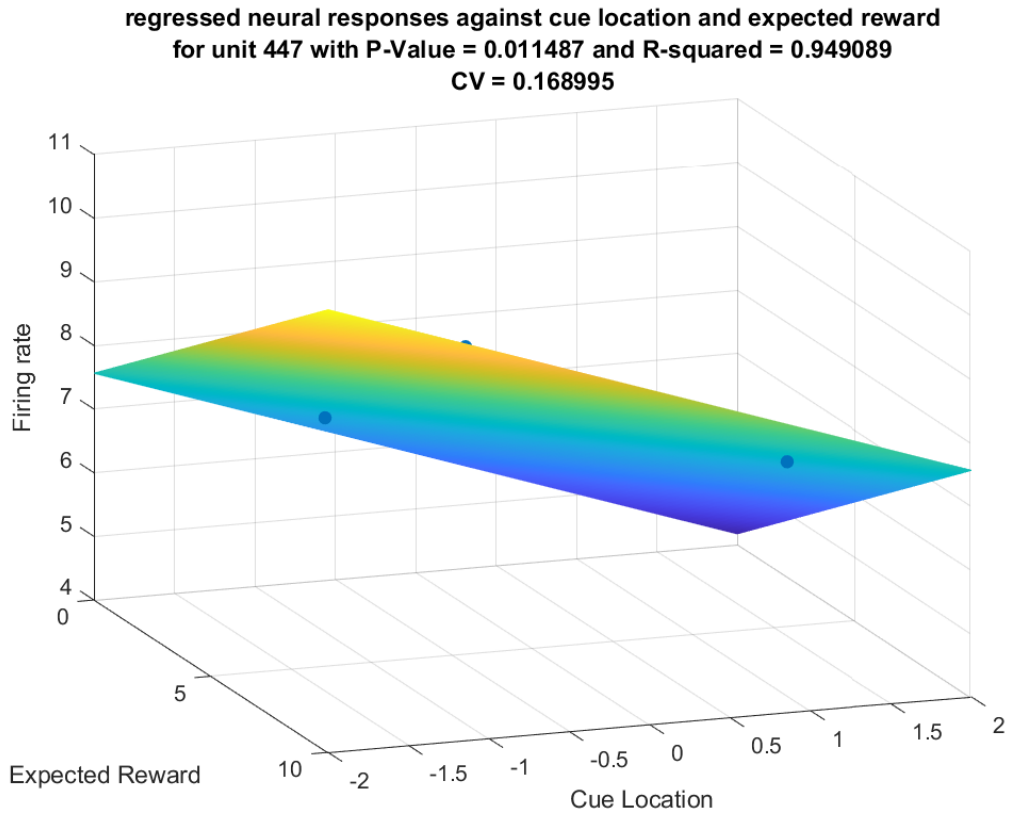
The P-value is commonly reported in regression output along with the estimated coefficients, standard errors, and confidence intervals. It is a crucial measure in statistical analysis and helps researchers draw conclusions about their data.

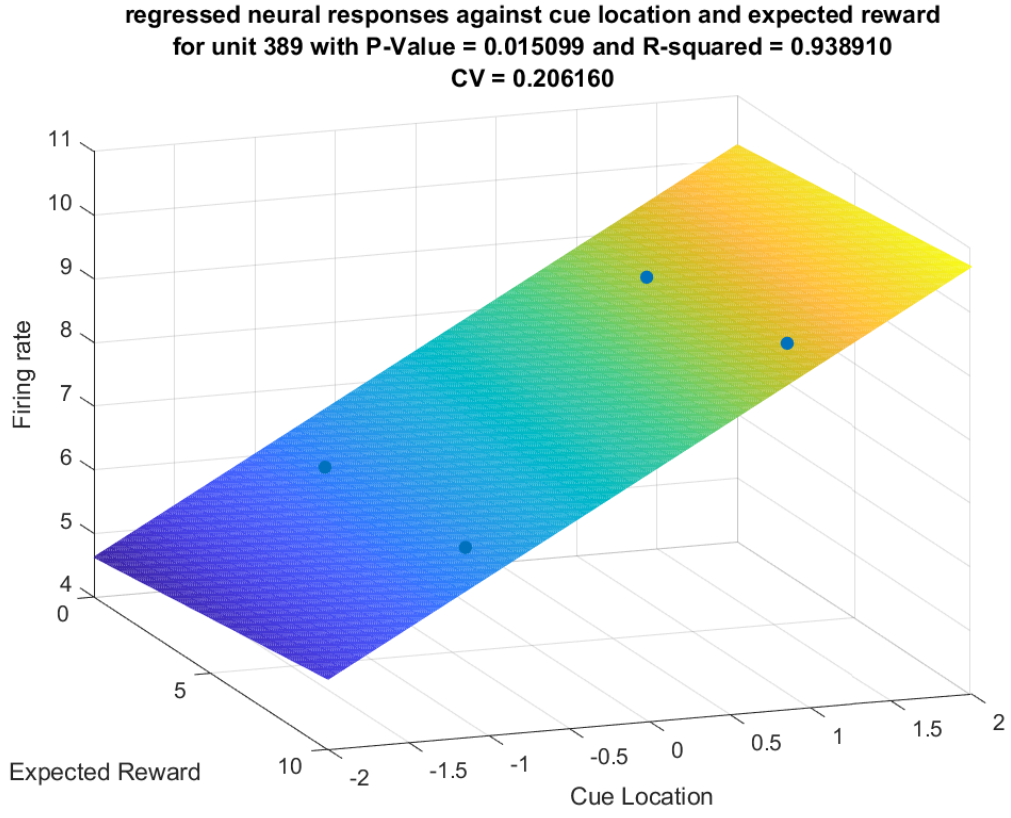
Now we consider the 150 higher CVs and the corresponding units. some of the results are the following figures:

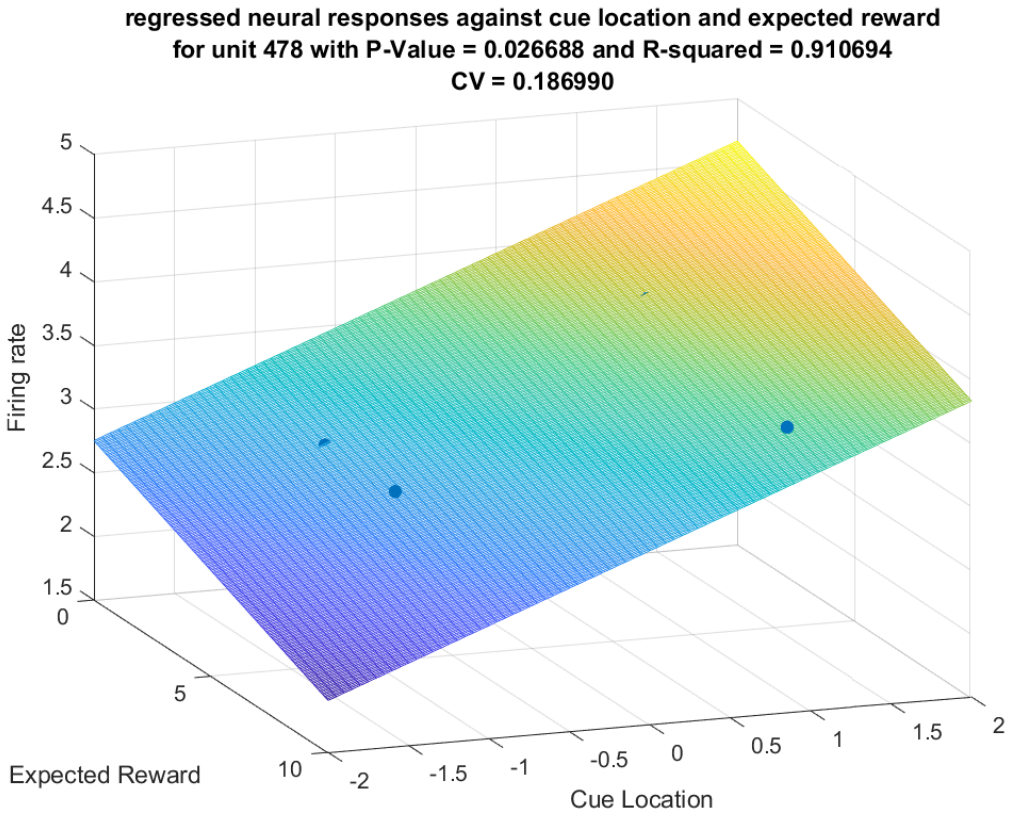


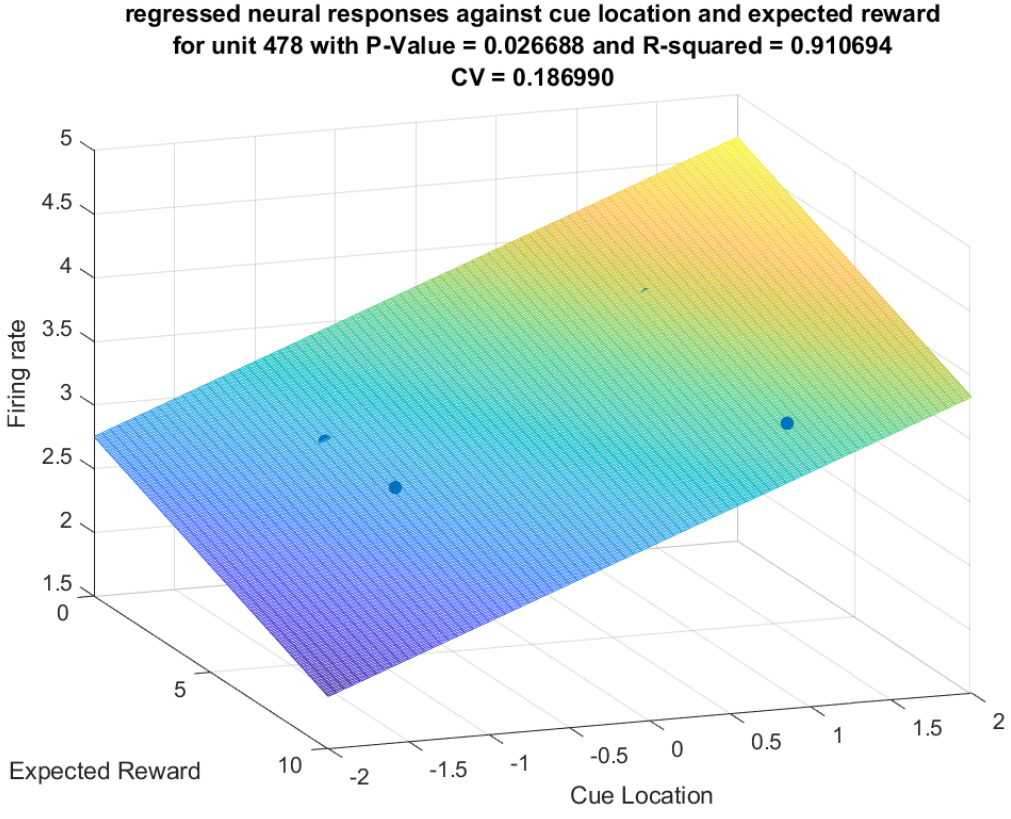

regressed neural responses against cue location and expected reward
for unit 56 with P-Value = 0.001051 and R-squared = 0.989660
CV = 0.105505
Firing rate
26
24
22
20
18
16
14
0
5
10
Expected Reward
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
Cue Location

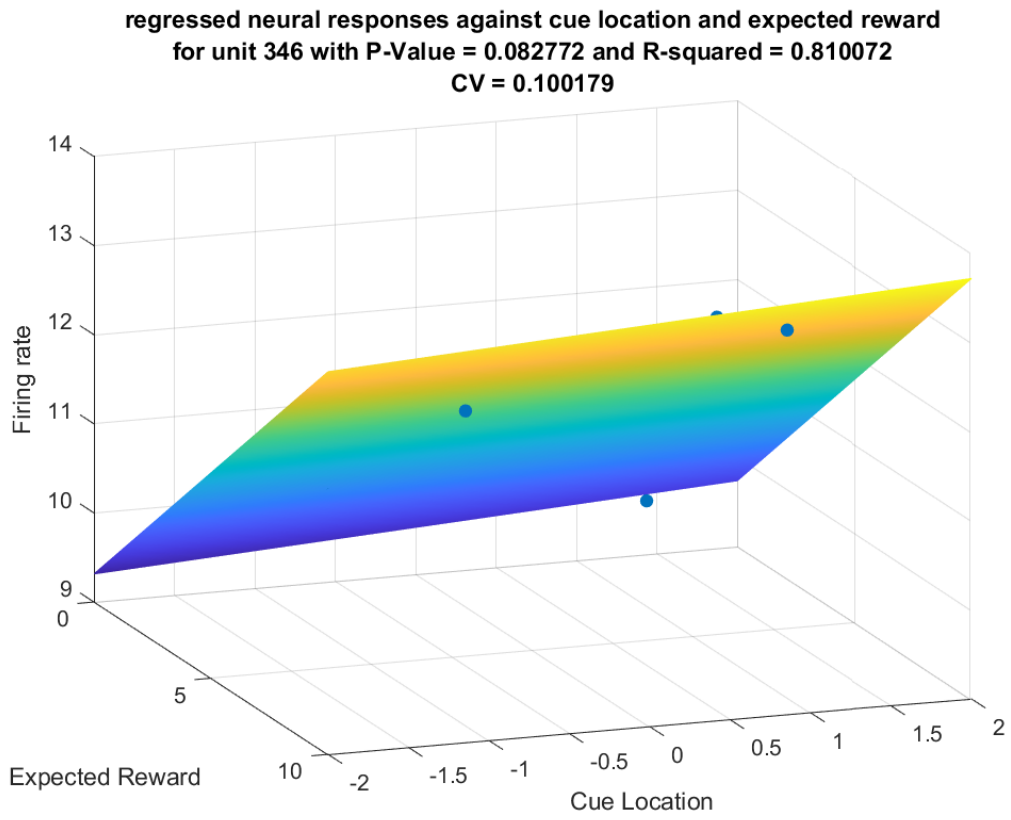

regressed neural responses against cue location and expected reward
for unit 400 with P-Value = 0.008508 and R-squared = 0.958323
CV = 0.136657
Firing rate
55
50
45
40
35
30
25
0
5
10
Expected Reward
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
Cue Location

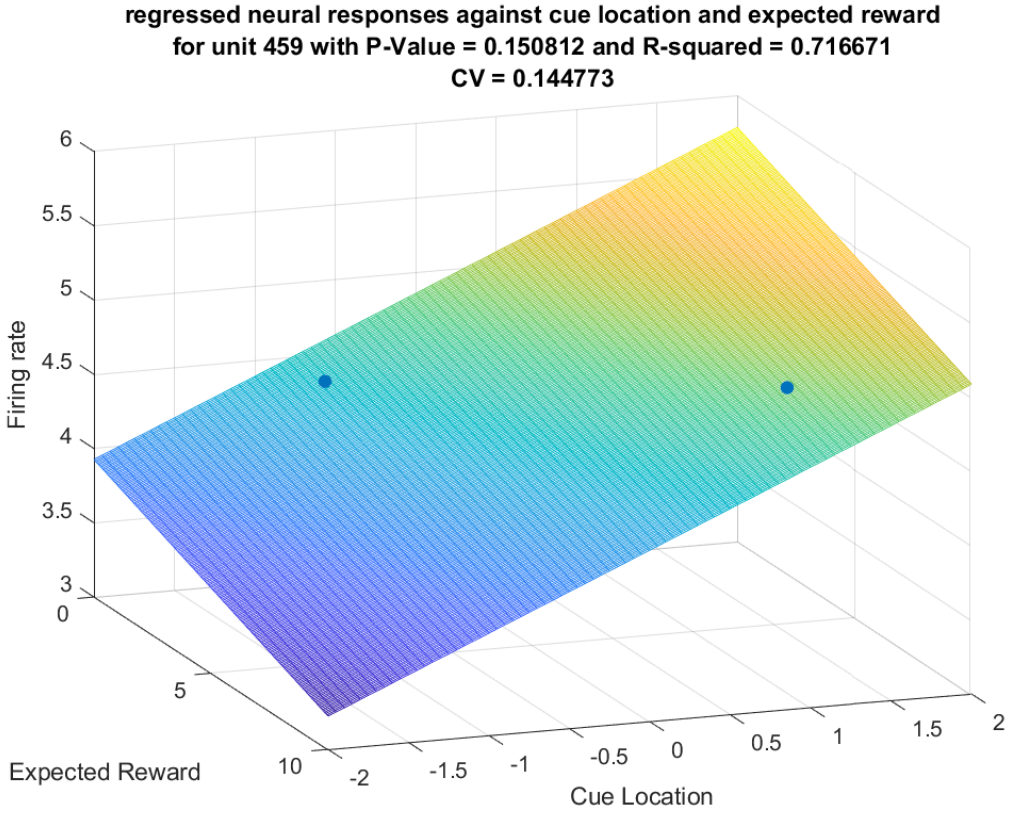

regressed neural responses against cue location and expected reward
for unit 447 with P-Value = 0.011487 and R-squared = 0.949089
CV = 0.168995
Firing rate
11
10
9
8
7
6
5
4
0
5
10
Expected Reward
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
Cue Location

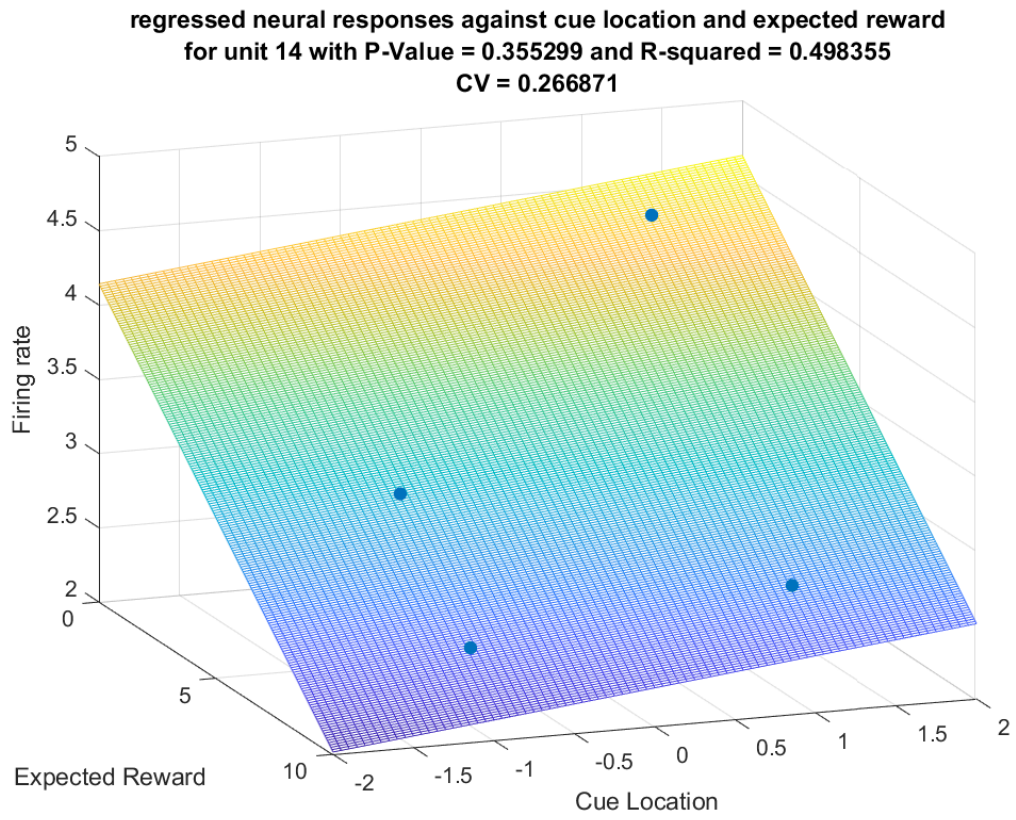

regressed neural responses against cue location and expected reward
for unit 389 with P-Value = 0.015099 and R-squared = 0.938910
CV = 0.206160
Firing rate
11
10
9
8
7
6
5
4
0
5
10
Expected Reward
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
Cue Location

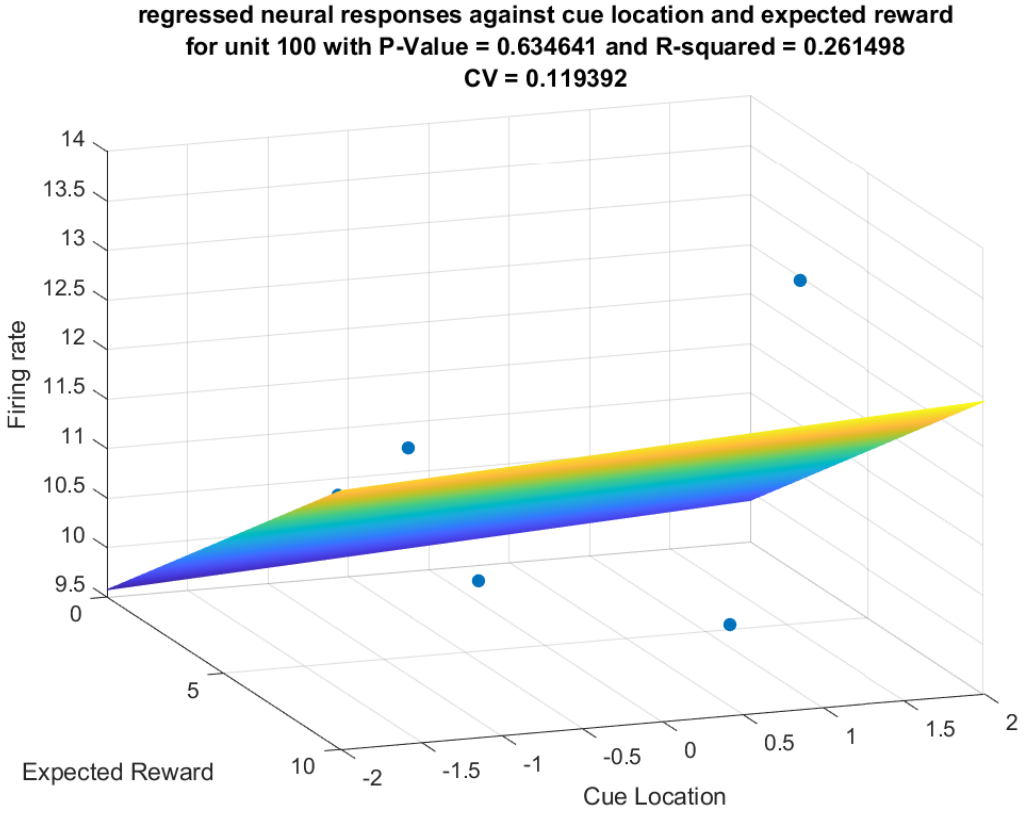

regressed neural responses against cue location and expected reward
for unit 478 with P-Value = 0.026688 and R-squared = 0.910694
CV = 0.186990
Firing rate
5
4.5
4
3.5
3
2.5
2
1.5
Expected Reward
0
5
10
Cue Location
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2


regressed neural responses against cue location and expected reward
for unit 478 with P-Value = 0.026688 and R-squared = 0.910694
CV = 0.186990
Firing rate
5
4.5
4
3.5
3
2.5
2
1.5
Expected Reward
0
5
10
Cue Location
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2


regressed neural responses against cue location and expected reward
for unit 346 with P-Value = 0.082772 and R-squared = 0.810072
CV = 0.100179
Firing rate
14
13
12
11
10
9
Expected Reward
0
5
10
Cue Location
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2

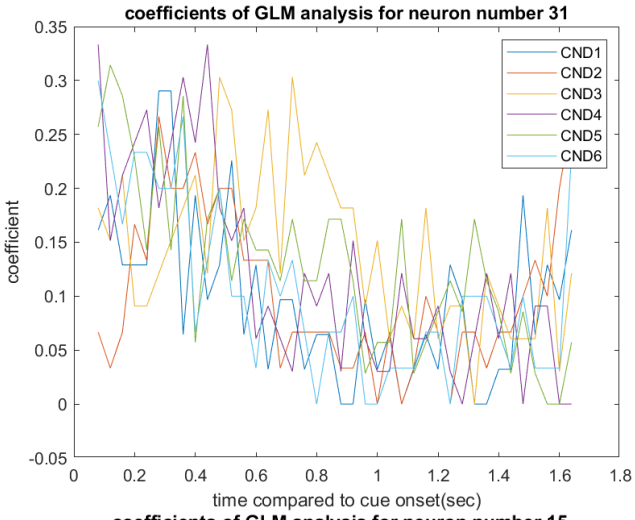

regressed neural responses against cue location and expected reward
for unit 459 with P-Value = 0.150812 and R-squared = 0.716671
CV = 0.144773
Firing rate
6
5.5
5
4.5
4
3.5
3
Expected Reward
0
5
10
Cue Location
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2

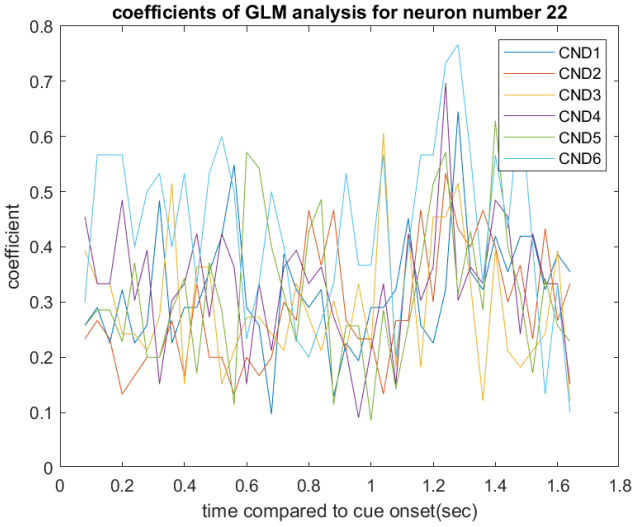

regressed neural responses against cue location and expected reward
for unit 14 with P-Value = 0.355299 and R-squared = 0.498355
CV = 0.266871
Firing rate
5
4.5
4
3.5
3
2.5
2
Expected Reward
0
5
10
Cue Location
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2

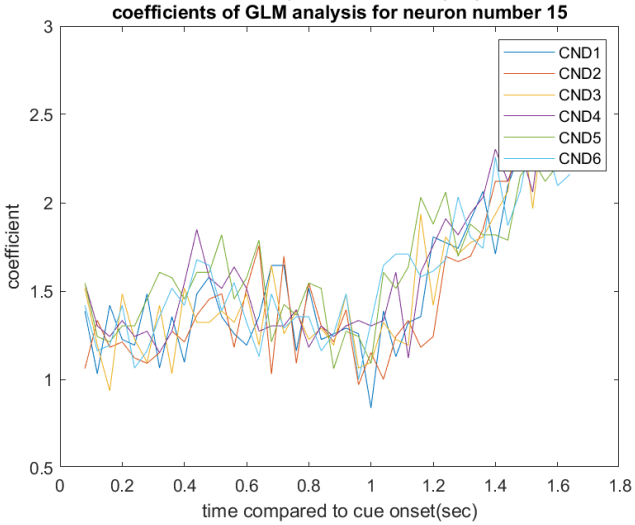

regressed neural responses against cue location and expected reward
for unit 100 with P-Value = 0.634641 and R-squared = 0.261498
CV = 0.119392
Firing rate
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
Expected Reward
0
5
10
Cue Location
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2

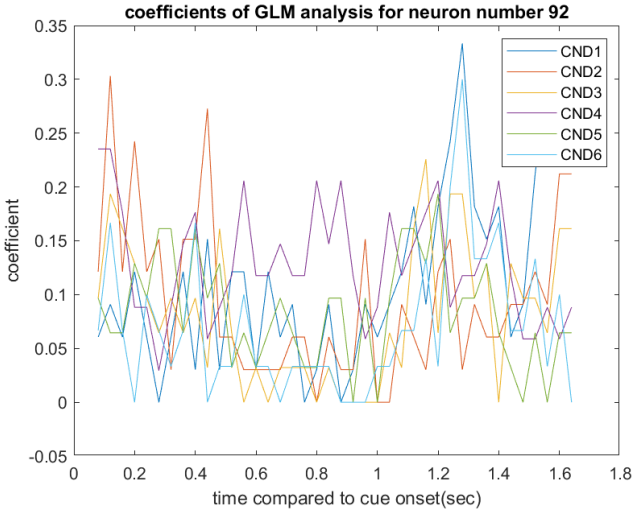
An other answer: We will consider each condition as a flag And for each bin per each neuron we will consider 6 coefficients which encode firing frequency in that bin.

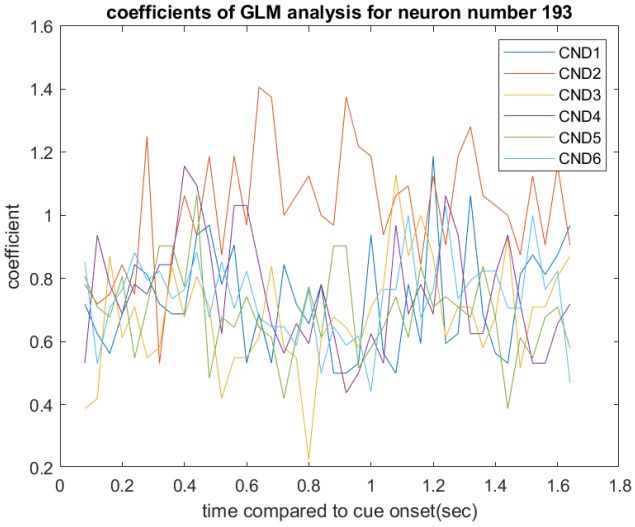
So for each bin if the ith coefficient is bigger, then the condition number i is more important than other conditions. For some of the neurons the resulting plots are as below:

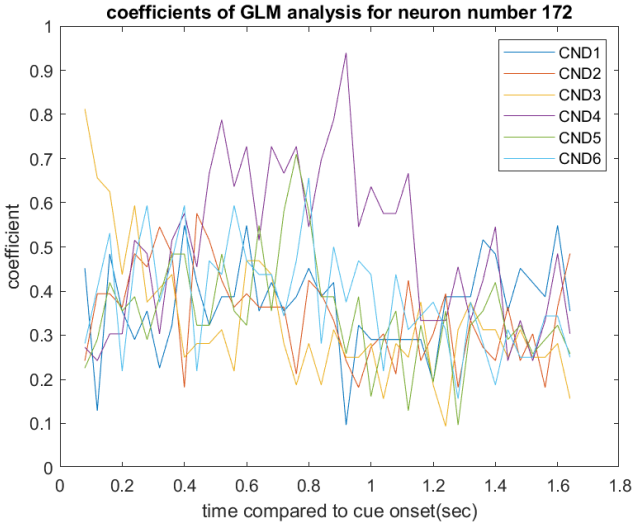




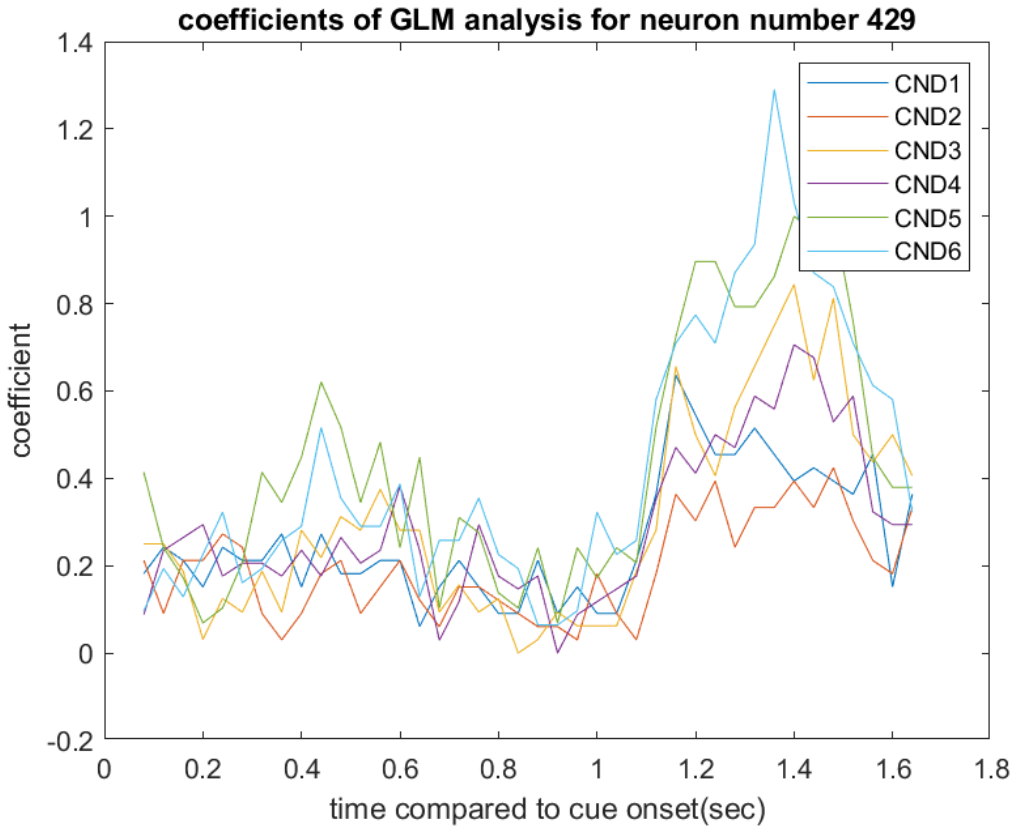


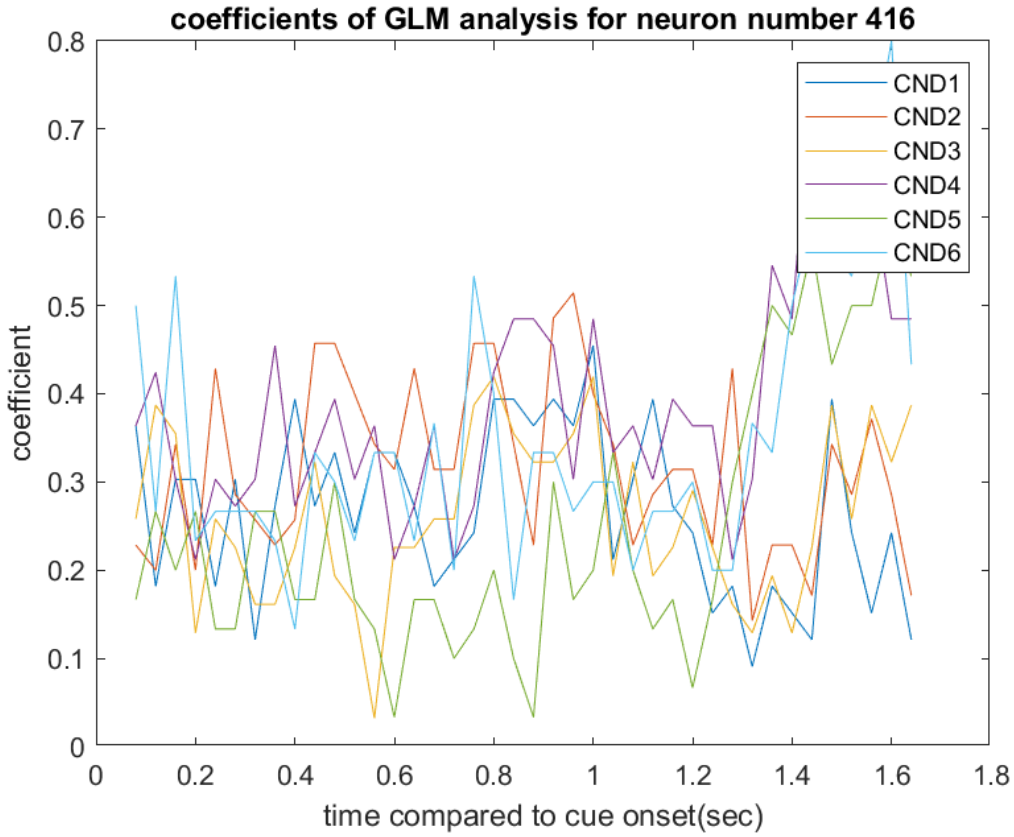




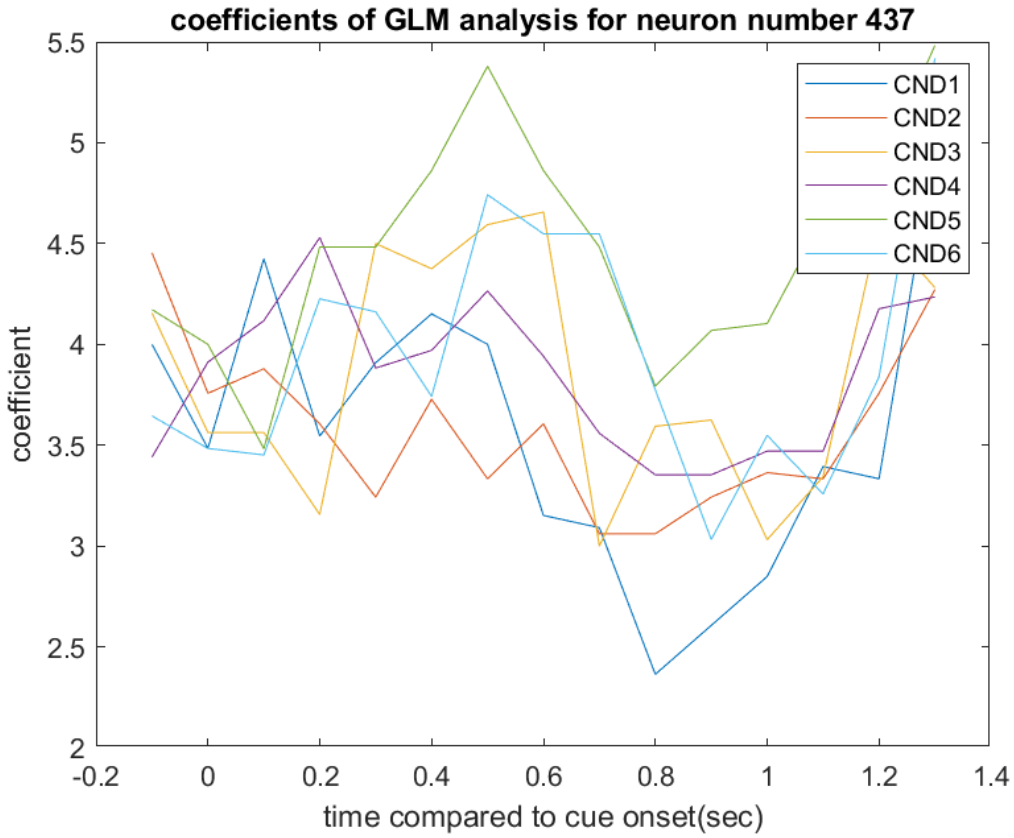


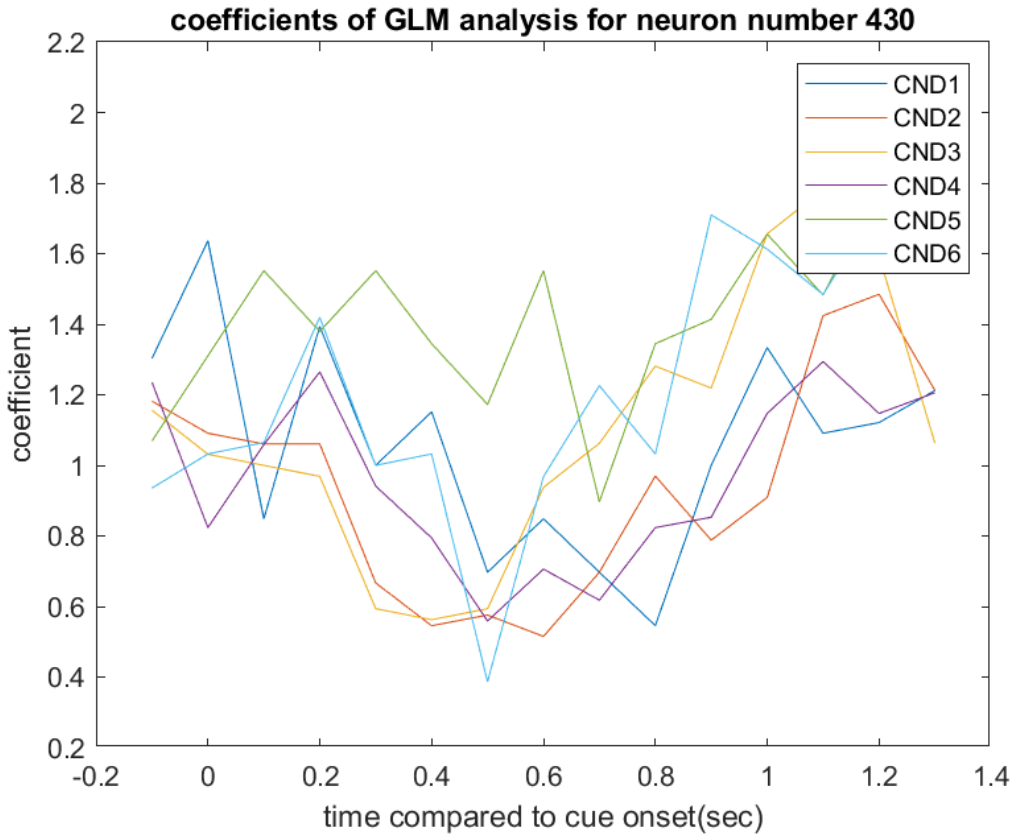
Best neurons(by considering P-Values) which can separate conditions:

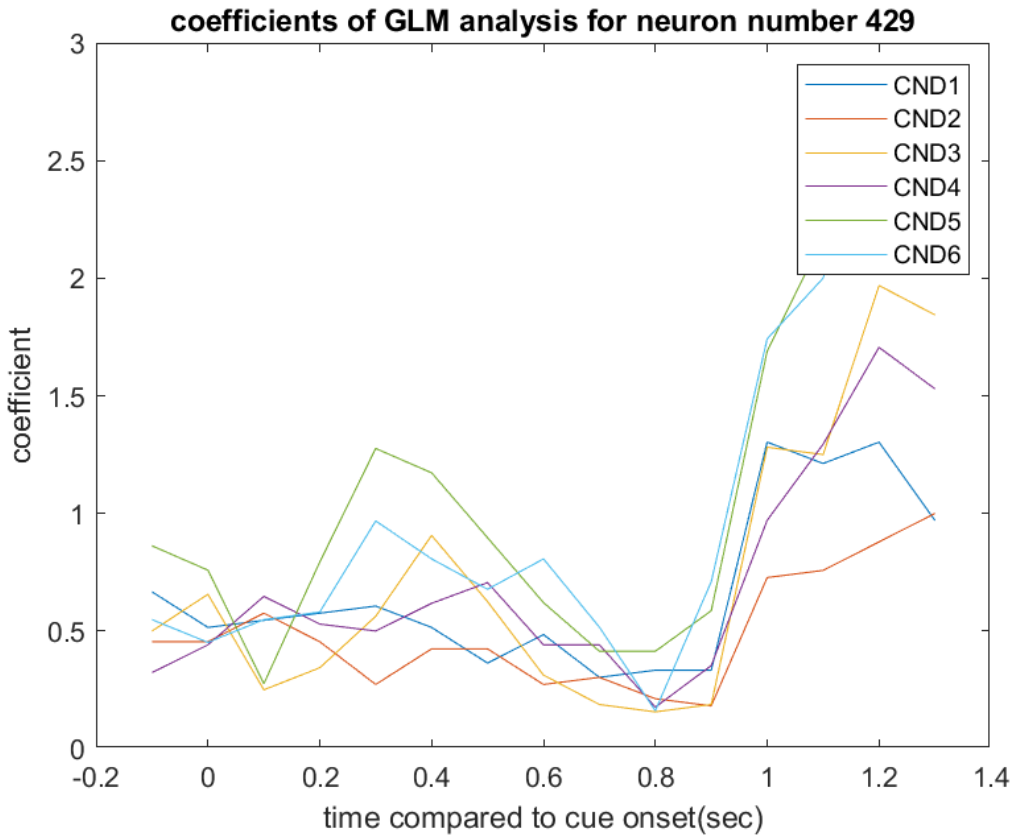


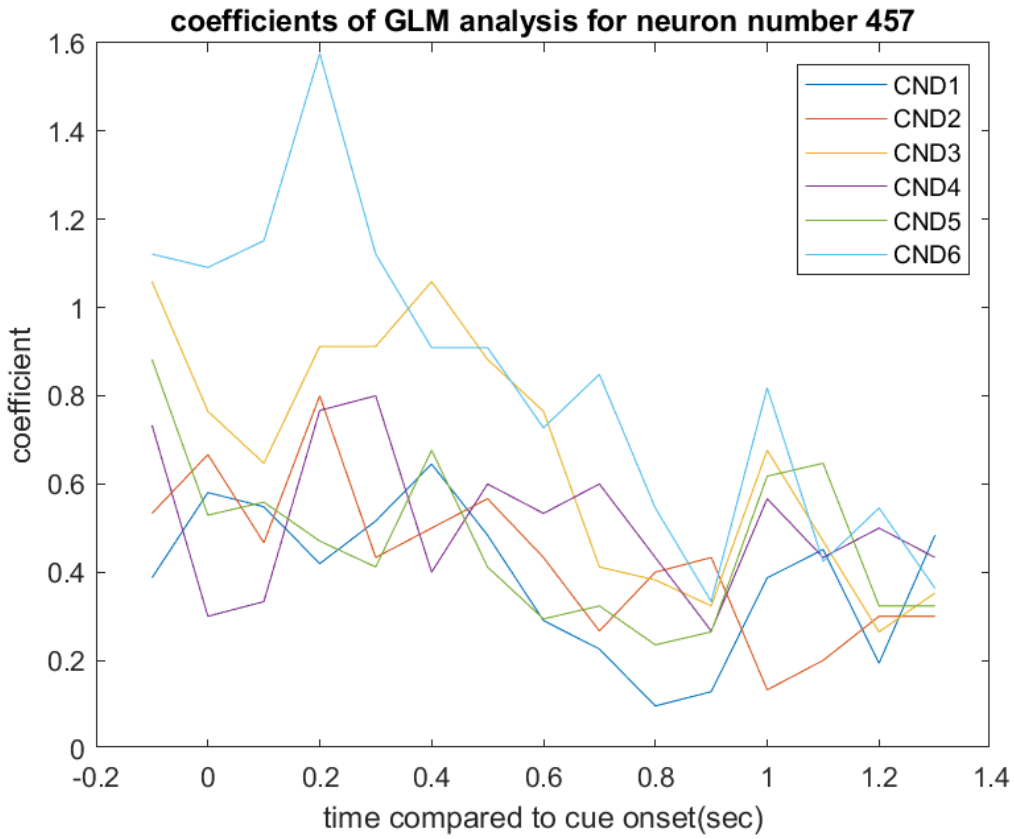


When we have 32 Bins for each trial(100ms each bin), best results are as below:






coefficients of GLM analysis for neuron number 429
CND1
CND2
CND3
CND4
CND5
CND6
coefficient
time compared to cue onset(sec)
0
0.5
1
1.5
2
2.5
3
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4

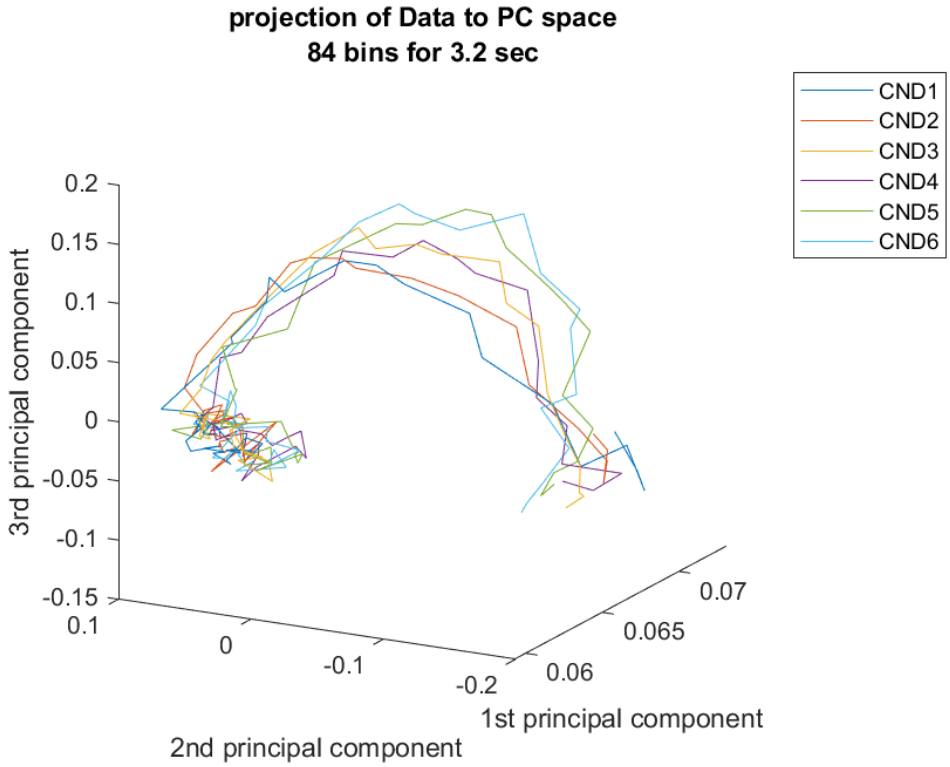

coefficients of GLM analysis for neuron number 457
CND1
CND2
CND3
CND4
CND5
CND6
coefficient
time compared to cue onset(sec)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4

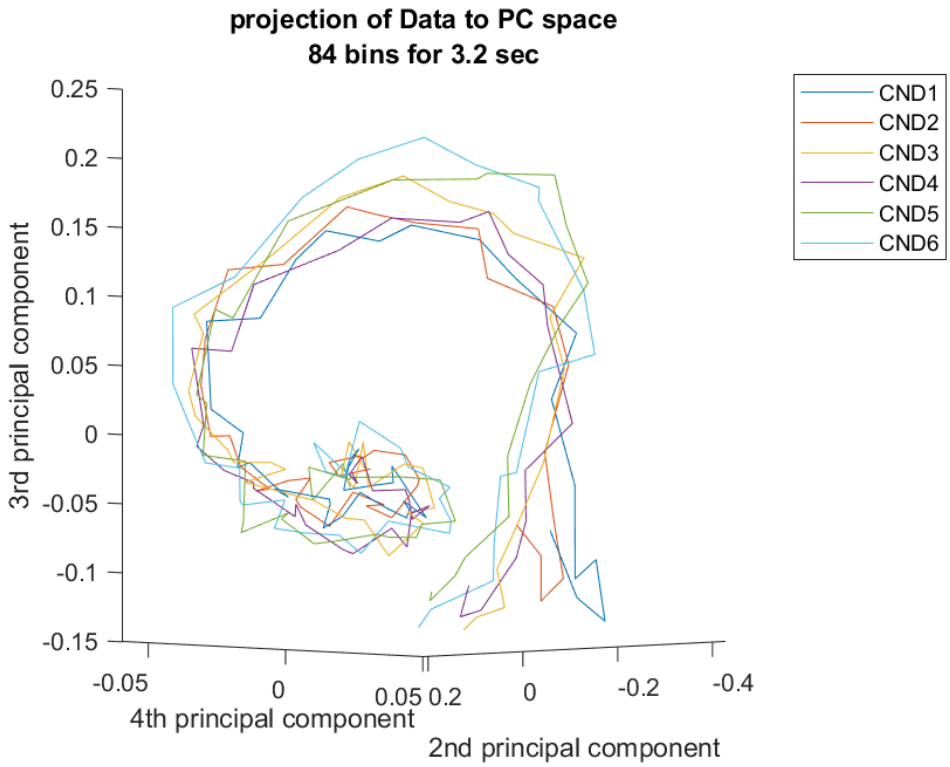
3. Plot the population activity in lower dimension (2 or 3) by using suitable dimension reduction algorithm.

Answer:

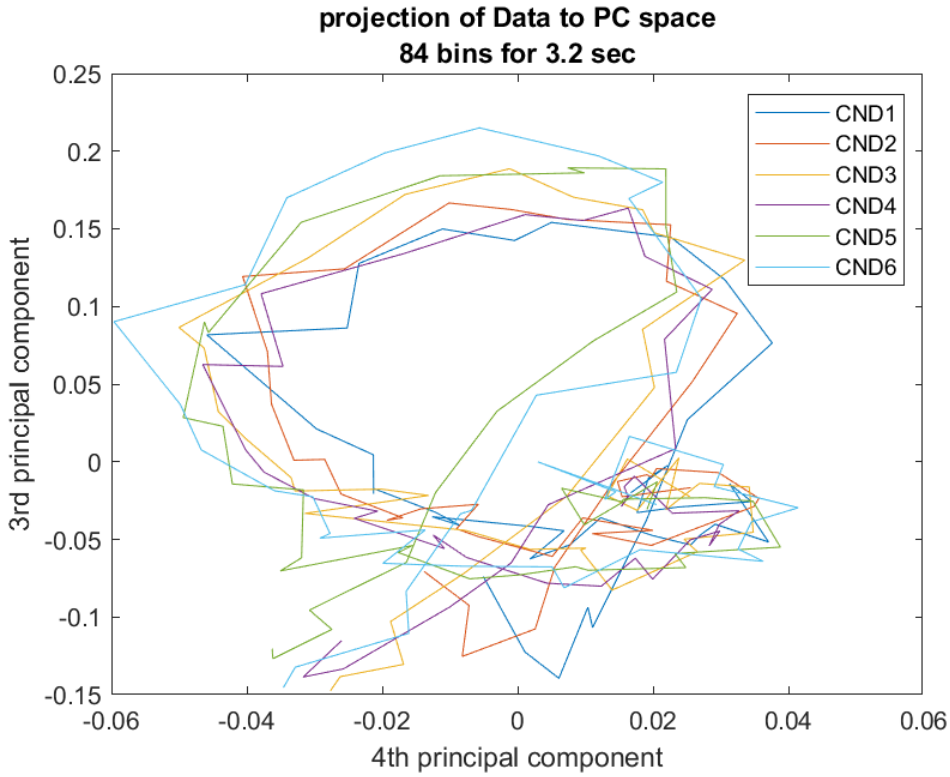
We will apply PCA as a dimension reduction algorithm. the results in 2 dimension are the following figures:

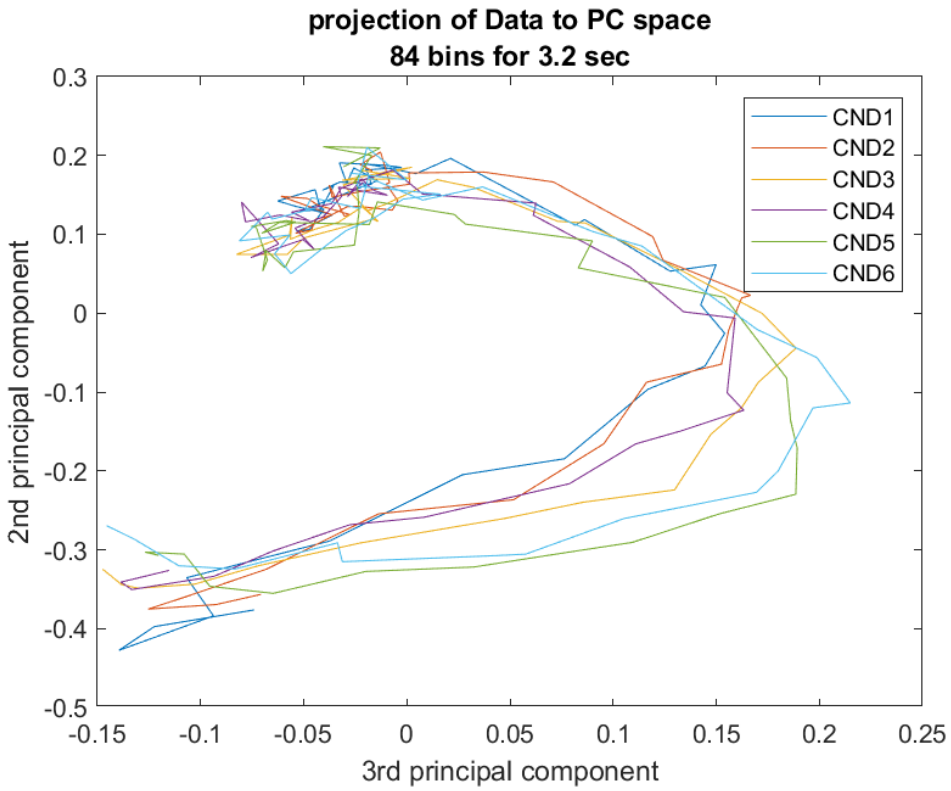
Results in 3 dimensions:

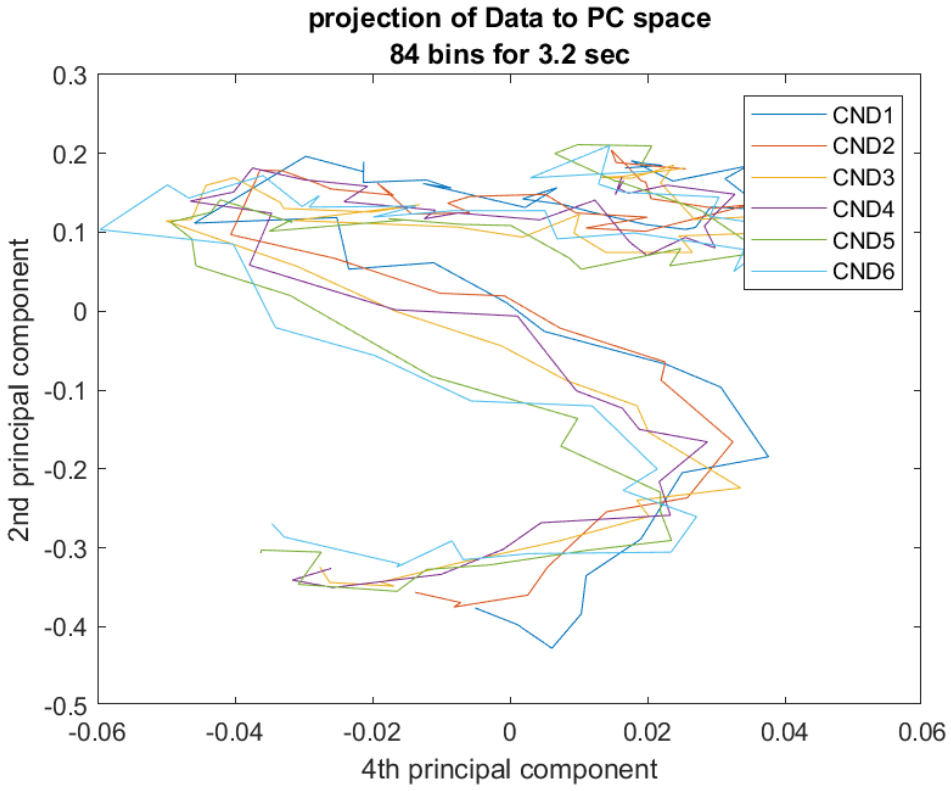




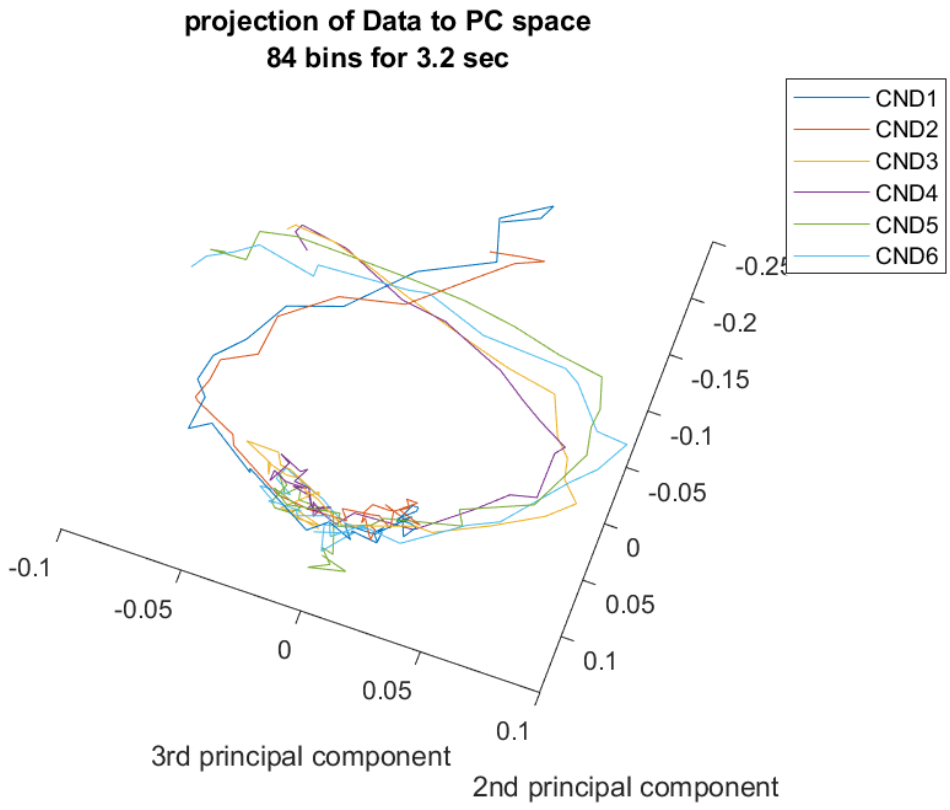
Results in 2 dimensions:



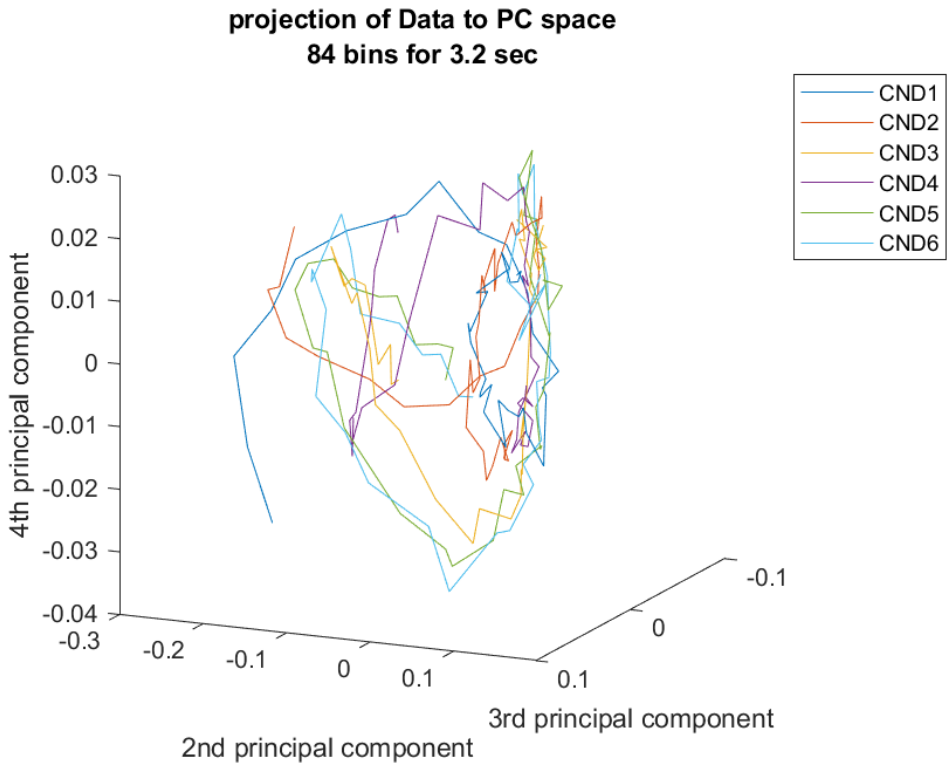

projection of Data to PC space
84 bins for 3.2 sec
CND1
CND2
CND3
CND4
CND5
CND6
2nd principal component
3rd principal component
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.15
-0.1
-0.05
0
0.05
0.1
0.15
0.2
0.25


projection of Data to PC space
84 bins for 3.2 sec
CND1
CND2
CND3
CND4
CND5
CND6
2nd principal component
4th principal component
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.06
-0.04
-0.02
0
0.02
0.04
0.06

result for separate PCA on conditions:



By looking at the figure above we can conclude that conditions 1 and 2 have been separated from other conditions.



By looking at the figure above we can conclude that conditions 4 has been separated from other conditions.

4. Until now, we checked the encoding of reward expected value in single units and population space. But in order to verify the structure we see, we have to do some shuffling tests. Elsayed and Cunninghum proposed a method for shuffling and statistical testing that whether the activity of population is the byproduct of single units. Based on your shuffling does the population data teach us more than what is expected from single unit analysis?

Answer:

Simple shuffling(shuffling labels) gave me the same result: