Spatial Information Encoding – Part 2

Last assignment we got measurements of 6 neurons, and we were supposed to classify them as head-direction cells or not.

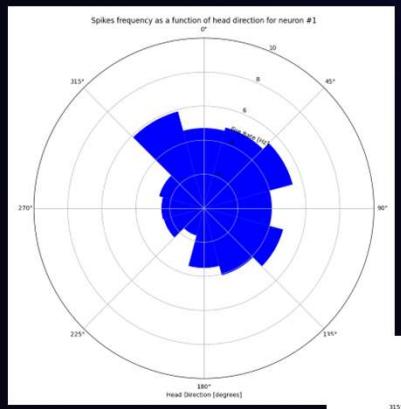
This time I'm working with the same data, but we got more options now: place cell, head-direction cell, grid cell or none of those.

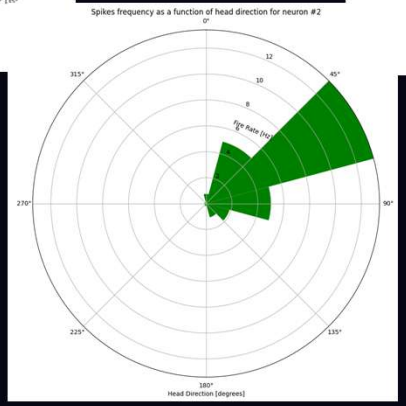
I'll continue my investigation of those neurons and try to decide how to more properly classify them as.

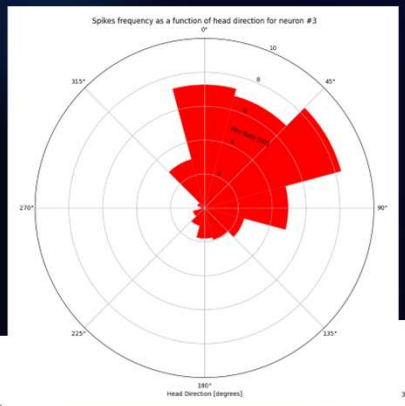
by Anton Pasternak

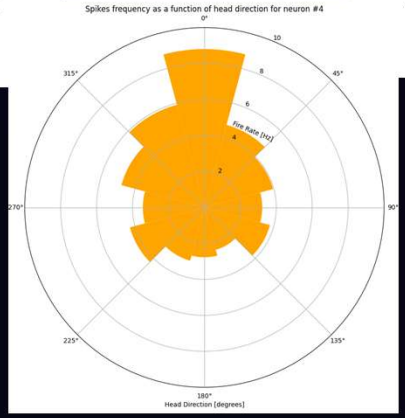
Neurons Firing Rate as a Function of Head Direction

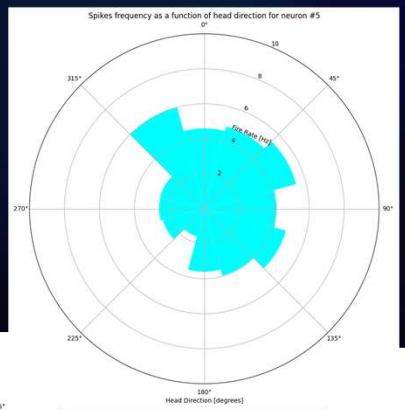
These are the original polar graphs from the previous assignment, where I showed how the neurons firing rate looked like when the head of the rat was at different degrees.

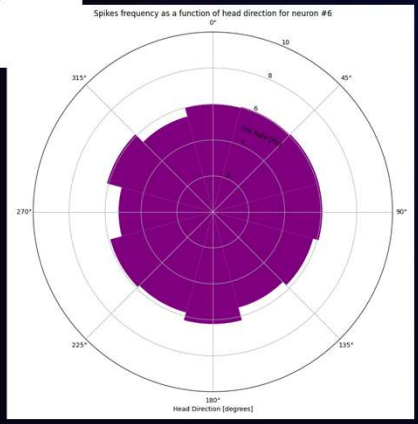






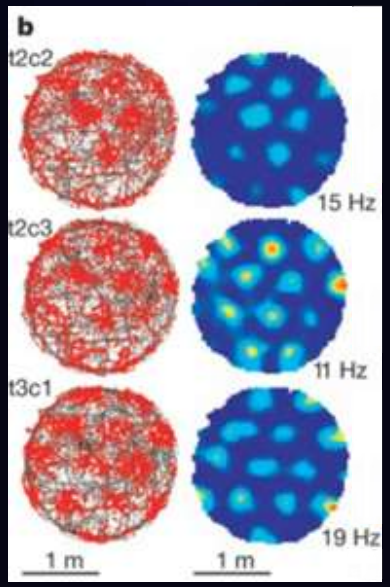






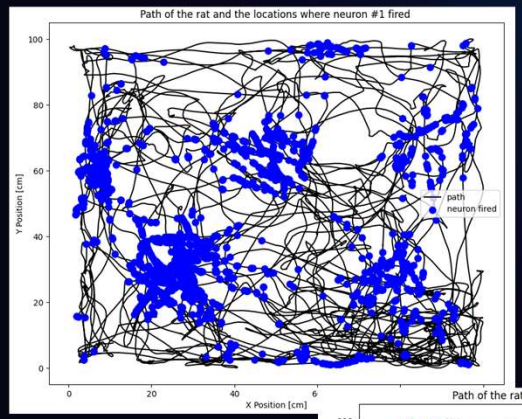
Continuation of the Investigation

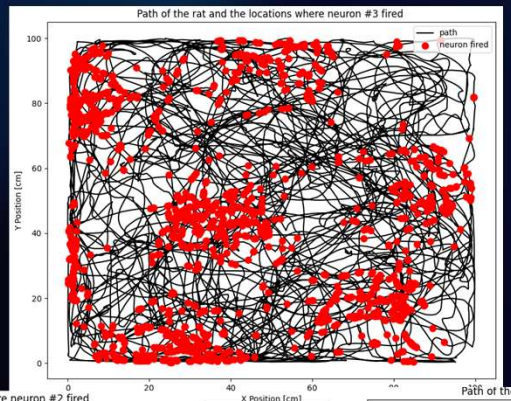
Now I'm going to continue the investigation in a different way and I'll try to recreate these graphs from the original paper by Hafting:

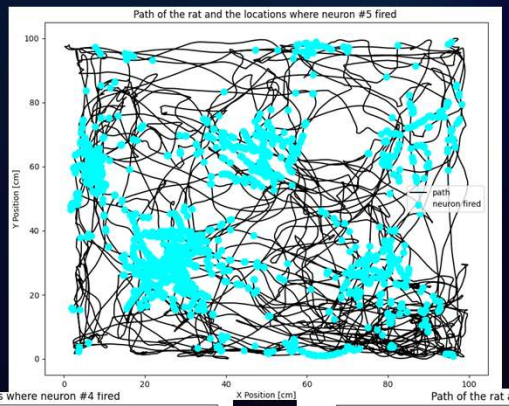


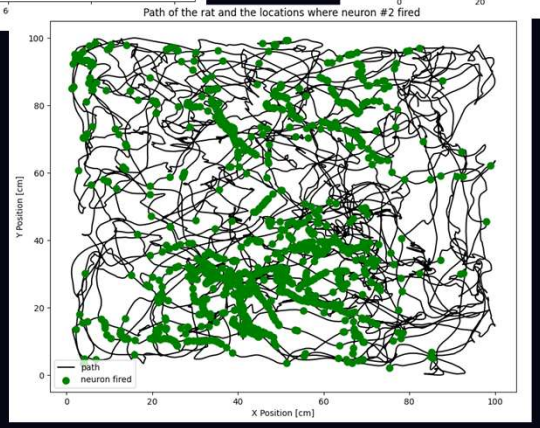
Neural Activity (spikes) VS the Path of the Rat

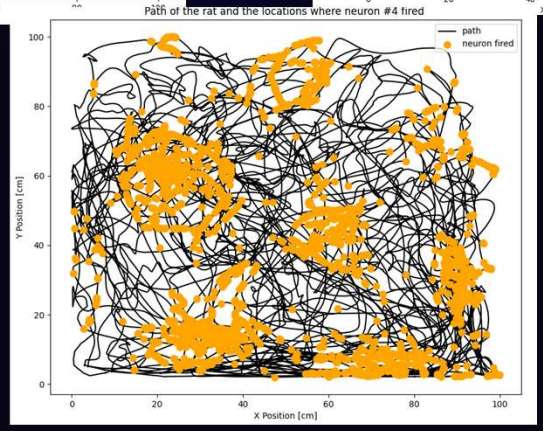
Here I've worked with the data of the position of the rat as well. In black I drew the physical path the rat walked through in the squared arena that it was in and on top of it are the places where this neuron fired (size of the area is 100cm^2).

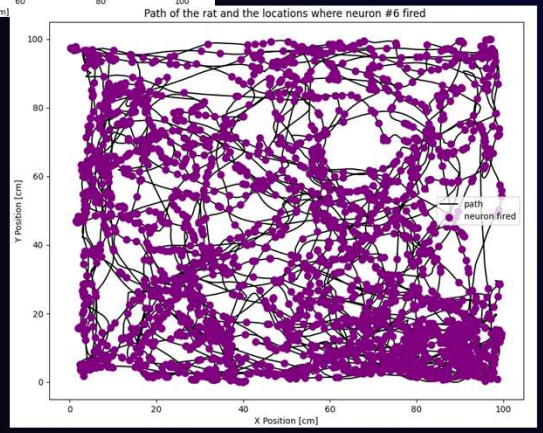






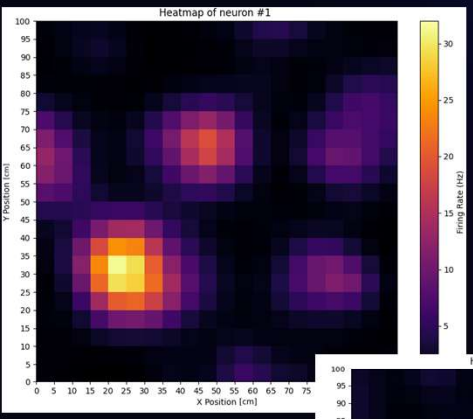


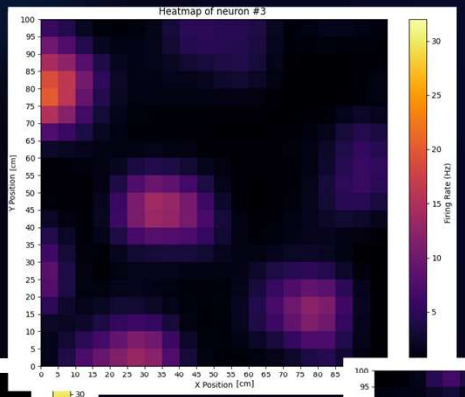


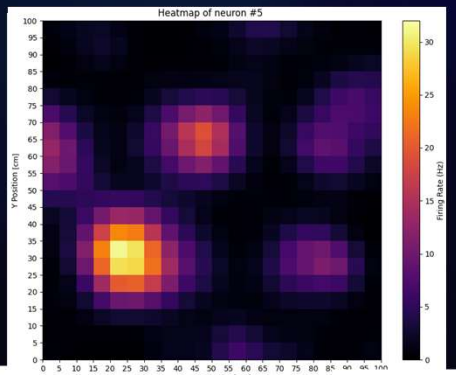


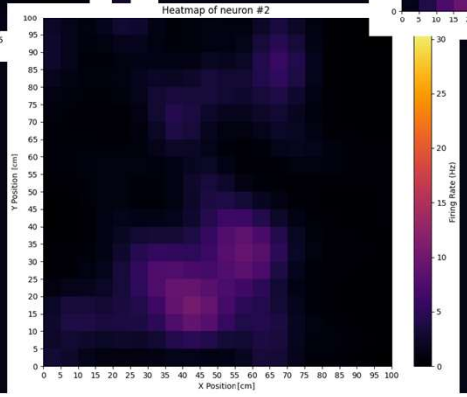
Heatmap of the Neural Activity (Firing Rate)

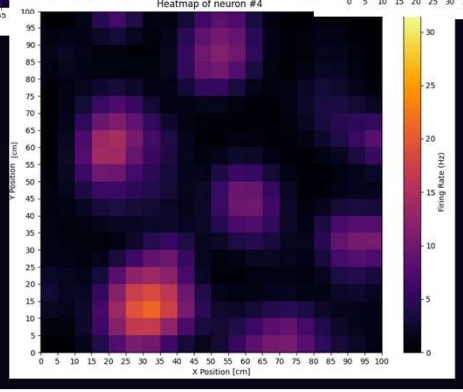
And here I show a heatmap of the neurons firing rate and how it changes based on the places that the rat passed through in the arena which is divided into cells of 5cm^2, a choice made while considering the average head length of a rat (about 45mm) . Also, I added a minimum of 1 visit in each of the cells to make it prettier and avoid the blank spaces in the heatmap like Hafting had, and make it look more like the last one here (Figure 6a, from the same paper by Hafting):

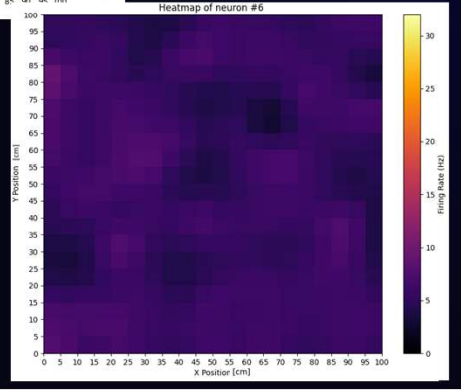






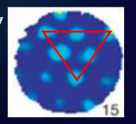




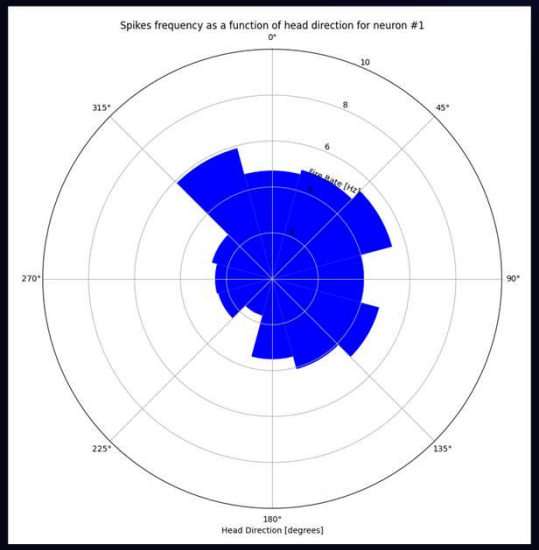


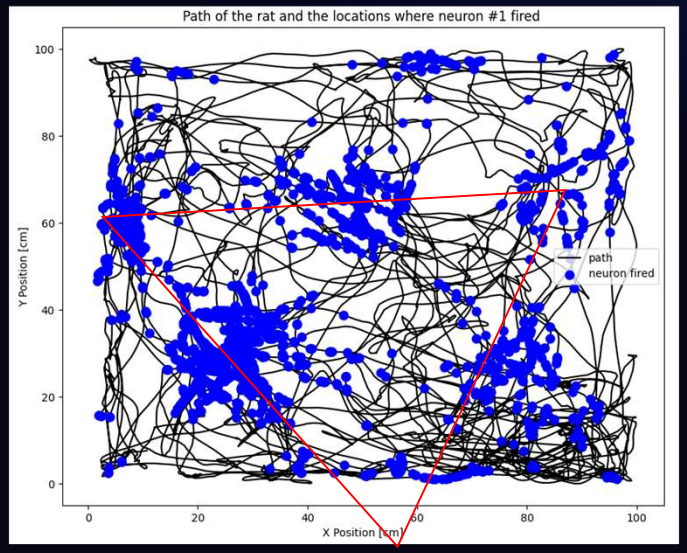
Final Classifications – Neuron #1

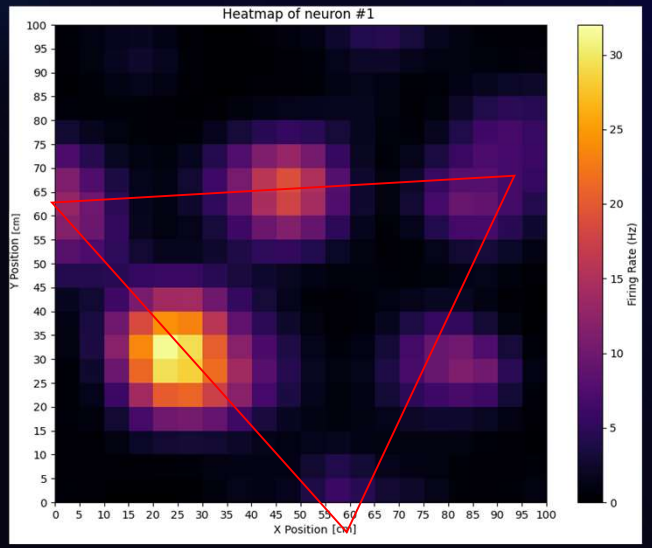
Previously I classified this neuron as not head-direction cell because I didn't see the attributes head-direction cells should show.
And now I believe that this is a **grid cell** because of the shape that is seen in the heatmap, it holds a close resemblance to the grid cells that were shown in the original paper by Hafting, and as he worded it: "In every isolated principal neuron, the firing field formed a grid of regularly tessellating triangles spanning the whole recording surface (Fig. 1b, left and middle columns)"



Also, I believe that this neuron is functioning as a **place cell** as well because there is a "preference" of the neuron to a specific area and it fires there more then in the other places that form the grid, the place of the maximum firing rate is around (±5cm) y=30, x=25

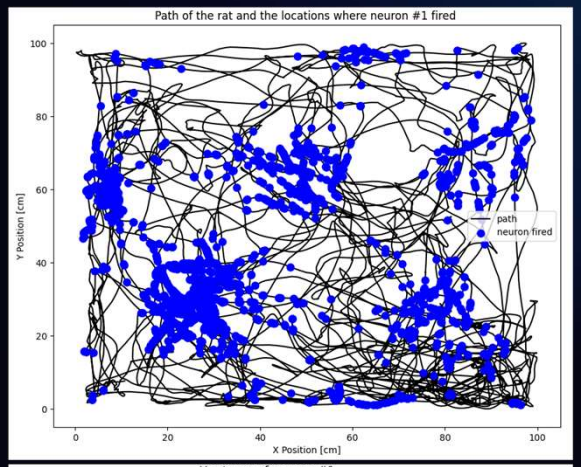


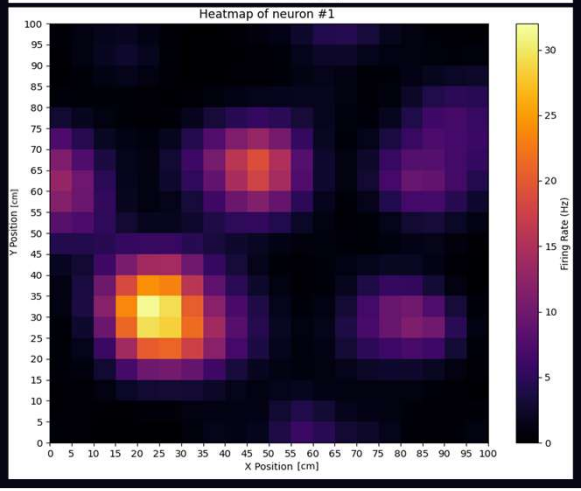


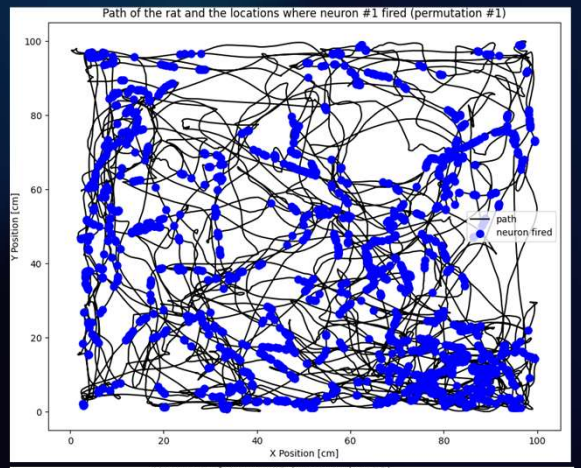


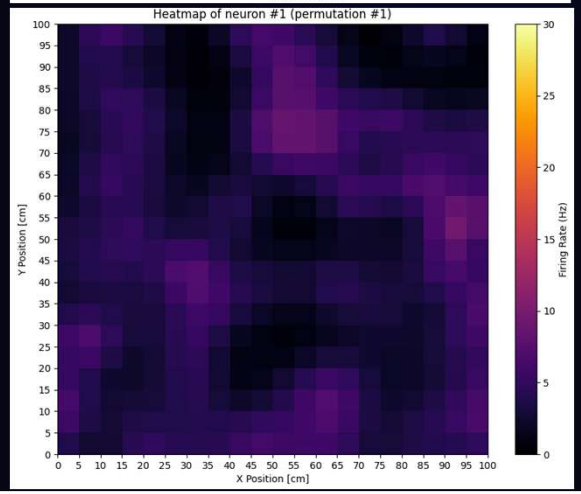
Neuron #1 Permutations

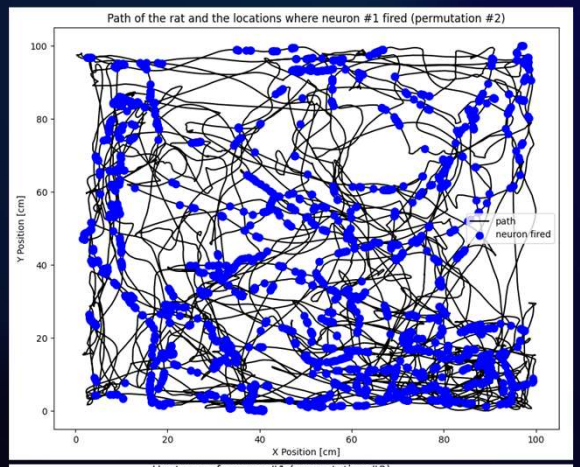
In order to eliminate the possibility of random artifact making these patterns appear as grid cells here are 2 permutations (center and right) of the new graphs compered to the originals (left):

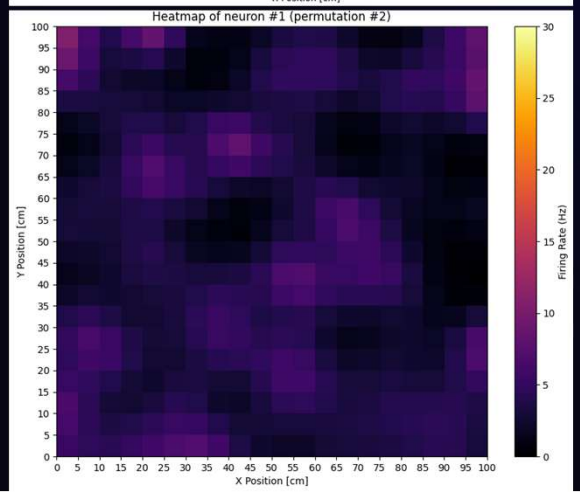






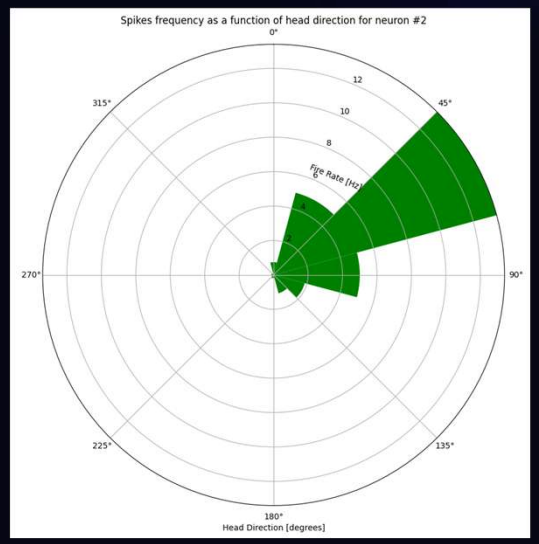


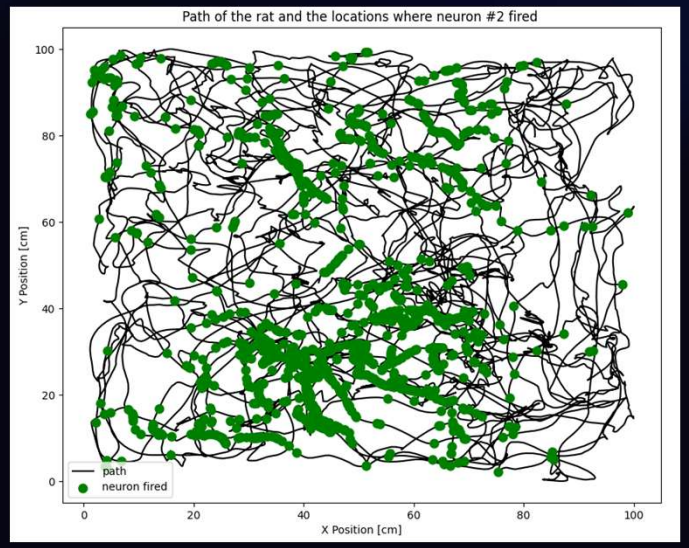


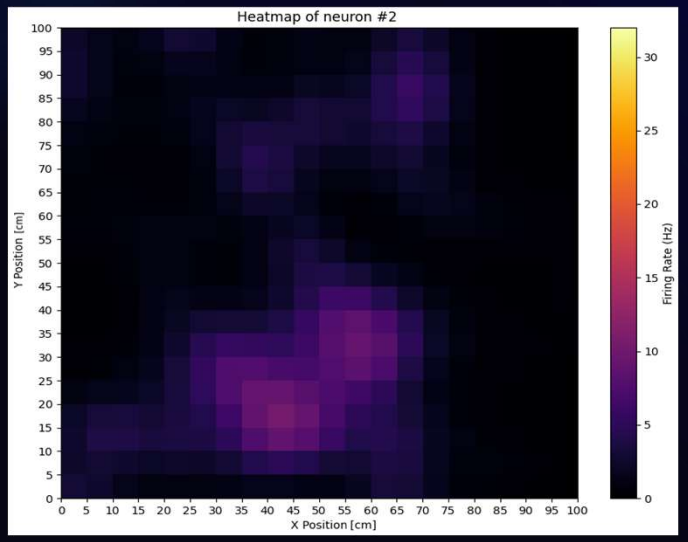


Final Classifications – Neuron #2

For the second neuron I stay with my original decision of it being a **head-direction cell**, because the highest fire rates accrued when the rat was looking at around (±15deg) 60 degrees. But I also believe that this neuron could also functions as a place cell as well.
To determine that I'll continue next the investigation further.

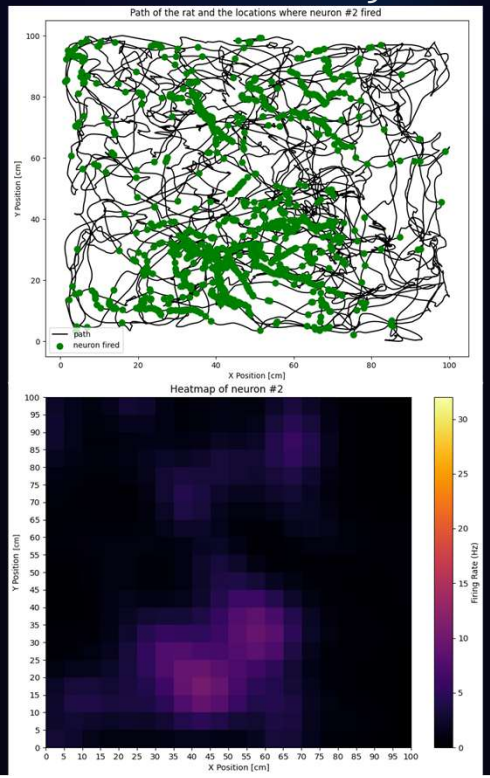


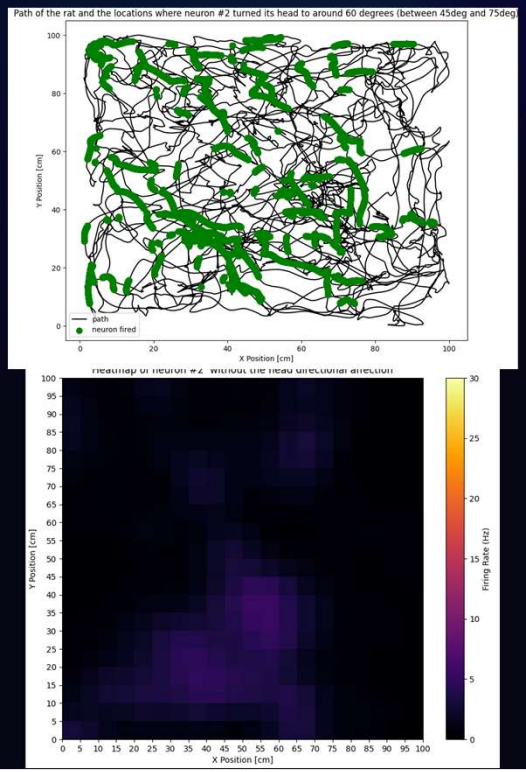




Neuron #2 – Continue the Investigation

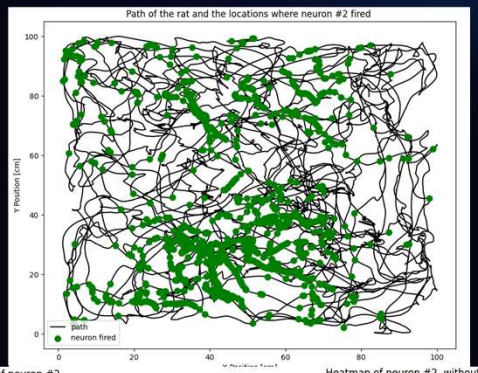
Here I added a comparison between the original new graphs (left) and the places where the head of the rat was at this neurons preferred direction in order to see if the spot on the lower half of the heatmap is because the rat turned its head to this direction mainly there, and it looks that this is not the case. I also added a heatmap of the same neuron but this time in a way that eliminated the affect of the head-direction (where the head is at the preferred degree, I put a zero in the spikes array) and we can see that it looks like there is a preferred zone of a maximum firing rate of 5.45 Hz, so this neuron could act as a **place cell** as well.

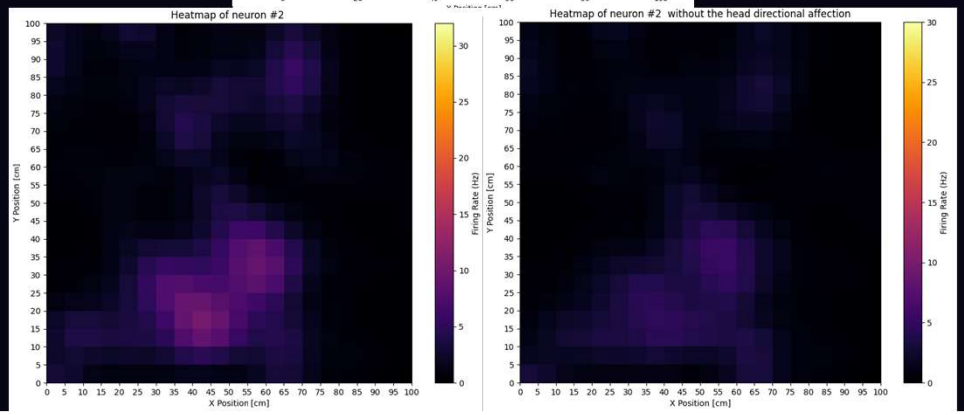


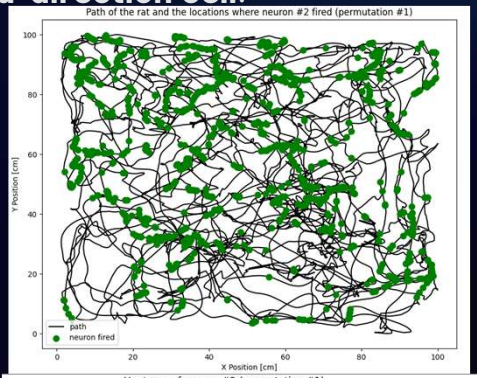


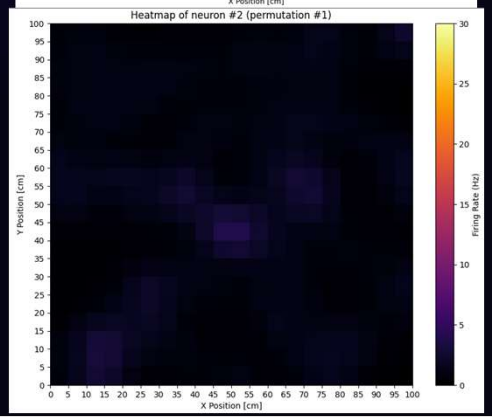
Neuron #2 – Permutations

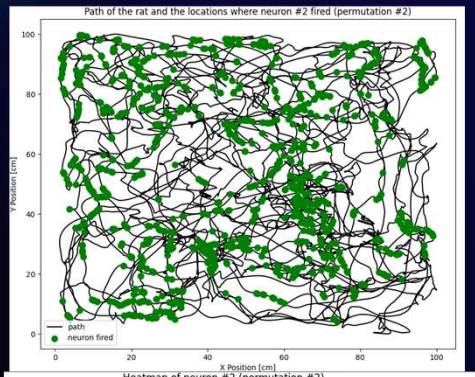
Now I'm using the permutations to make the final classification for this neuron, and we can see a comparison between the original new graphs (left) + the heatmap without the directional effects. As you can see from the permutations on the right, the path graph looks as random as the original one but the graph of the permutated data (without the direction effect) we see a peak of around 6.4Hz so we can assume the previous suspicions about the neuron being a place cell as well, are unbased and it looks like that resulting from a randomized artifact. So finally, the second neuron is only a **head-direction cell**.

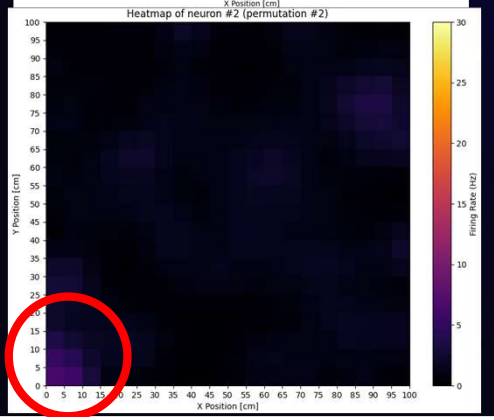








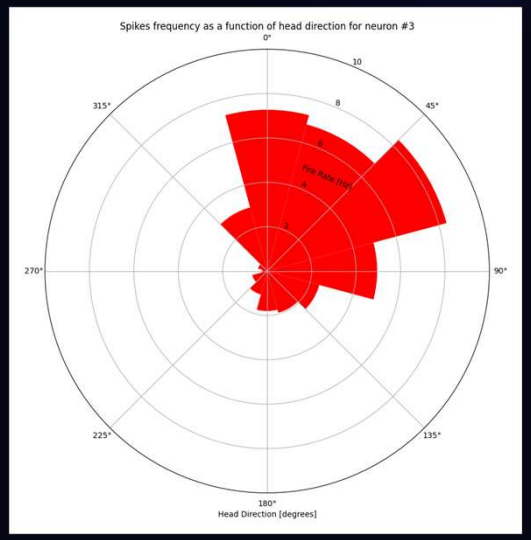


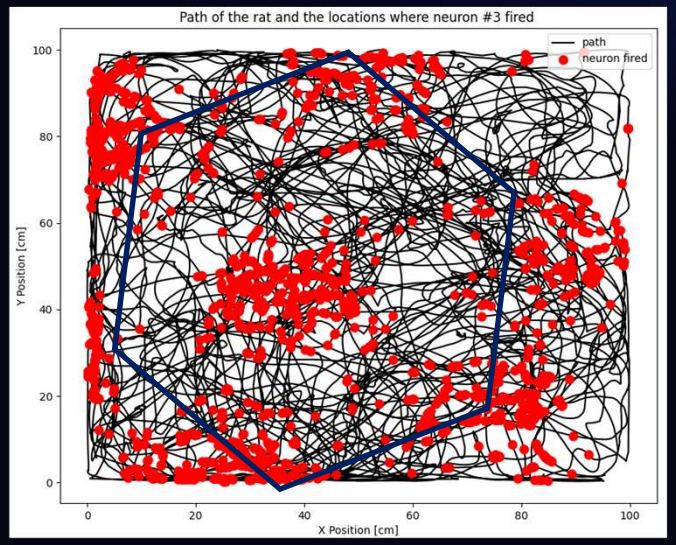


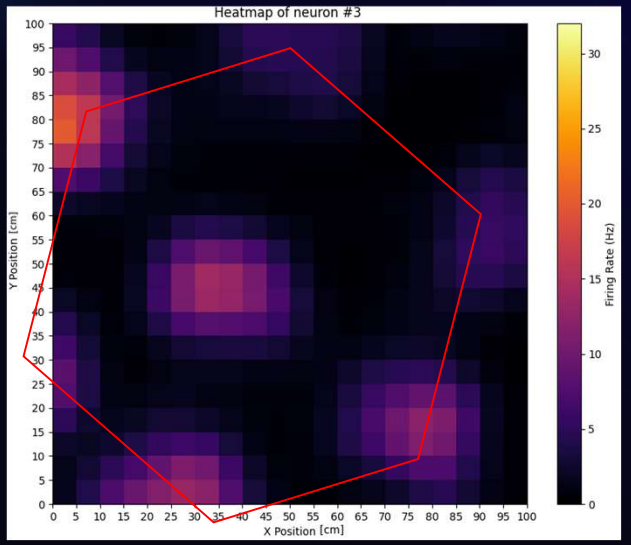
Final Classifications – Neuron #3

Originally, I classified this neuron as a bi-directional head-direction cell but now I see that the new graphs show that the neuron actually behaves more like a **grid cell**. Although it's harder to see the triangles its easier to see the hexagonal shape of the grid.

Here the firing rates are pretty homogenous, that's why I believe this neuron functions as a **grid cell** only.

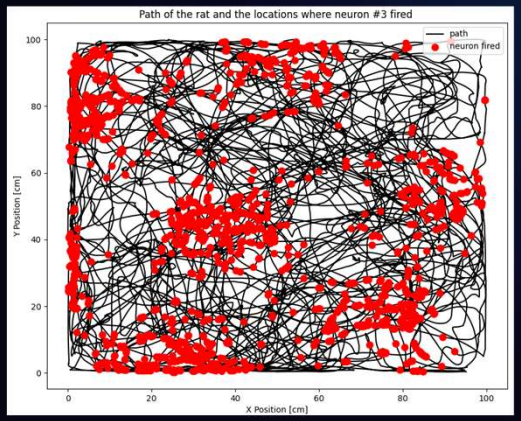


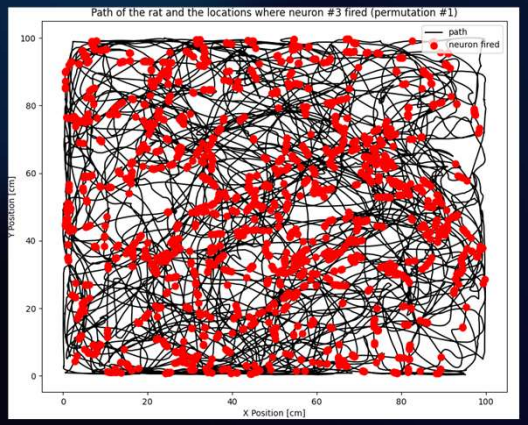


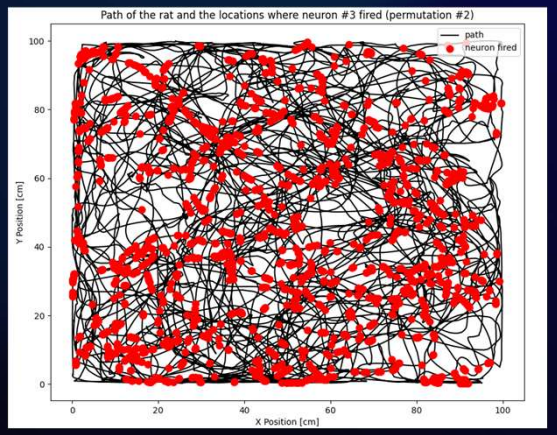


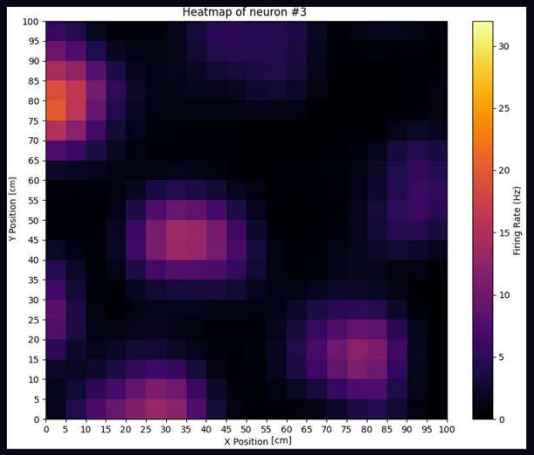
Neuron #3 Permutations

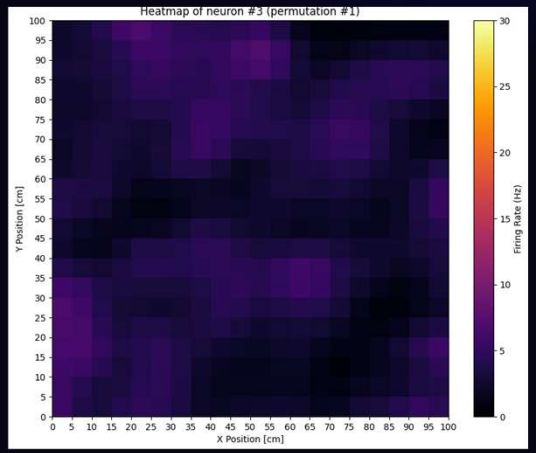
In order to eliminate the possibility of random artifact making these patterns appear as grid cells here are 2 permutations (center and right) of the new graphs compered to the originals (left):

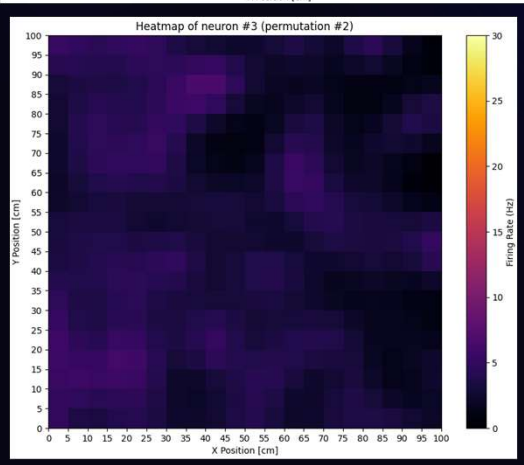








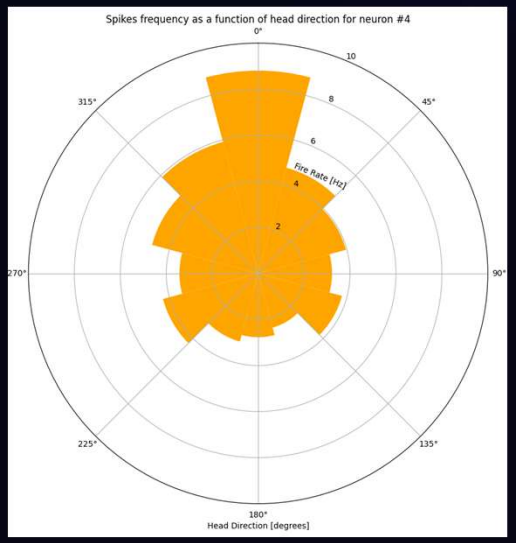


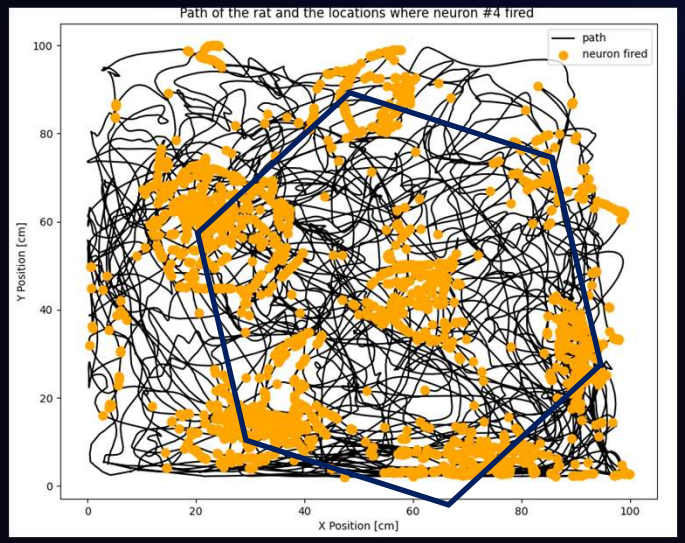


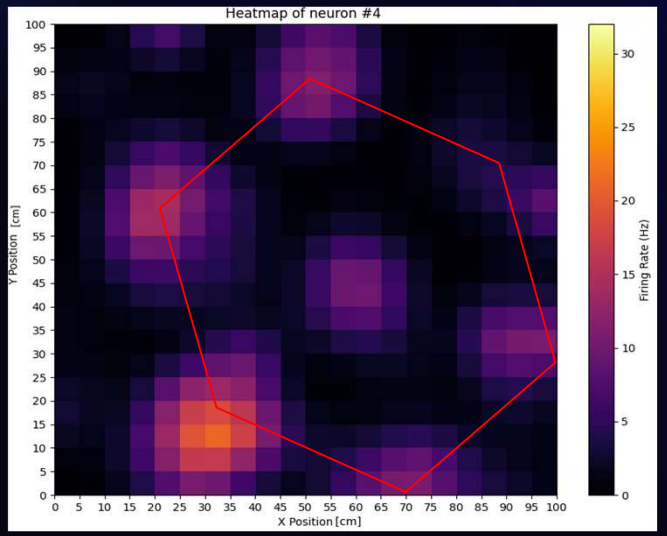
Final Classifications – Neuron #4

Originally, I classified this neuron as a head-direction cell but now I see that here as well, the new graphs show that the neuron behaves more like a **grid cell**. And again, it's harder to see the triangles its easier to see the hexagonal shape of the grid.

Here the firing rates are pretty homogenous as well, that's why I believe this neuron functions as a **grid cell** only.

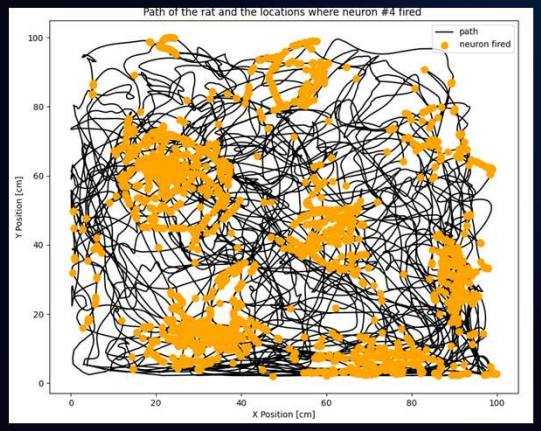


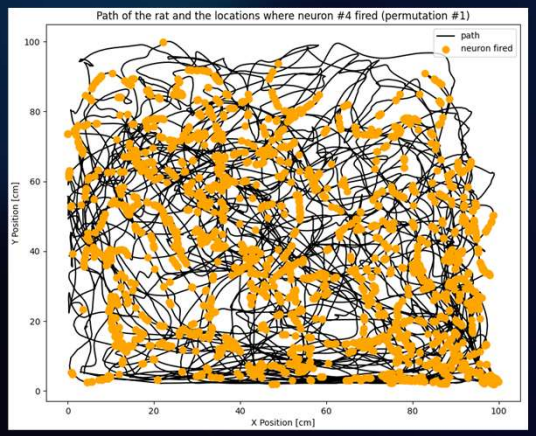


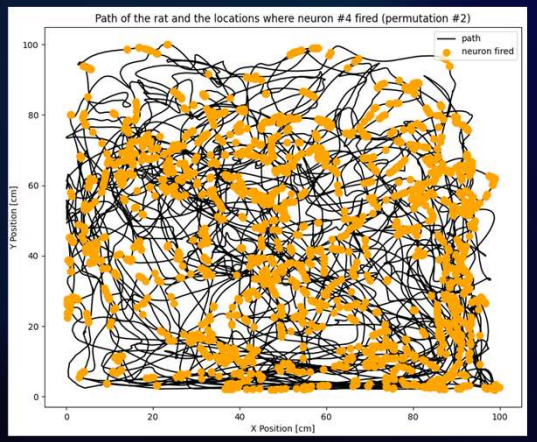


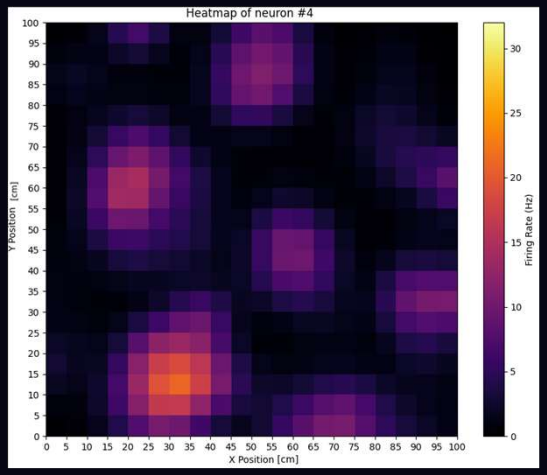
Neuron #4 Permutations

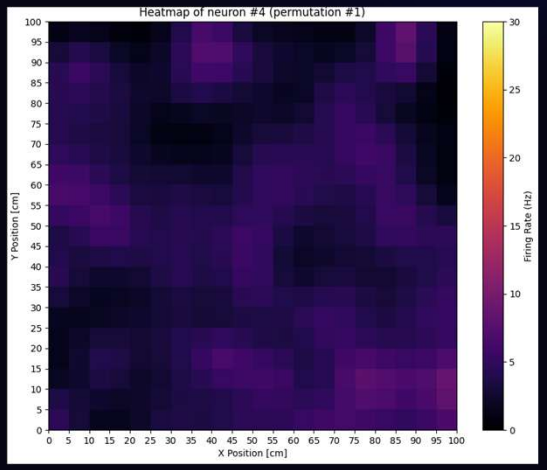
In order to eliminate the possibility of random artifact making these patterns appear as grid cells here are 2 permutations (center and right) of the new graphs compered to the originals (left):

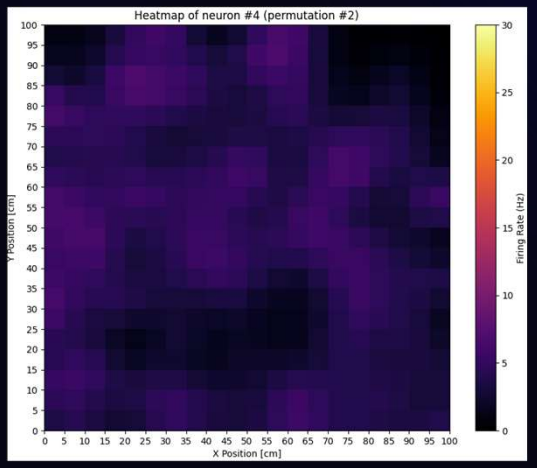








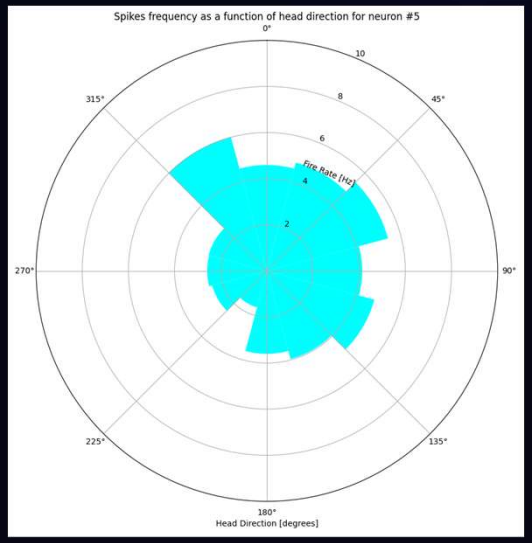


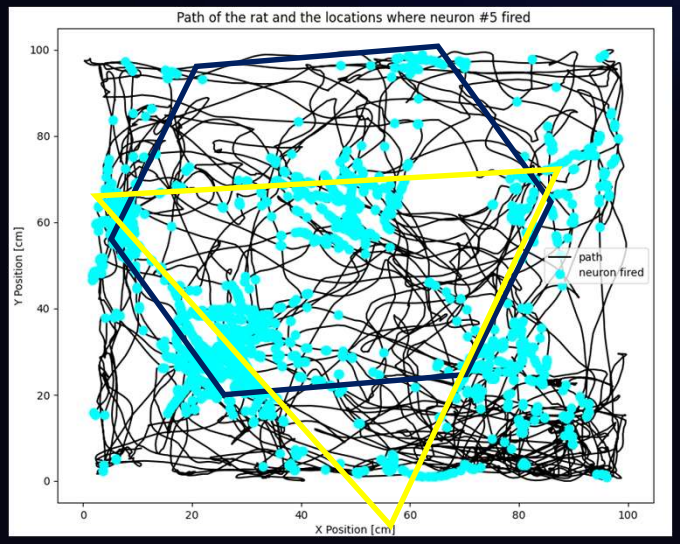


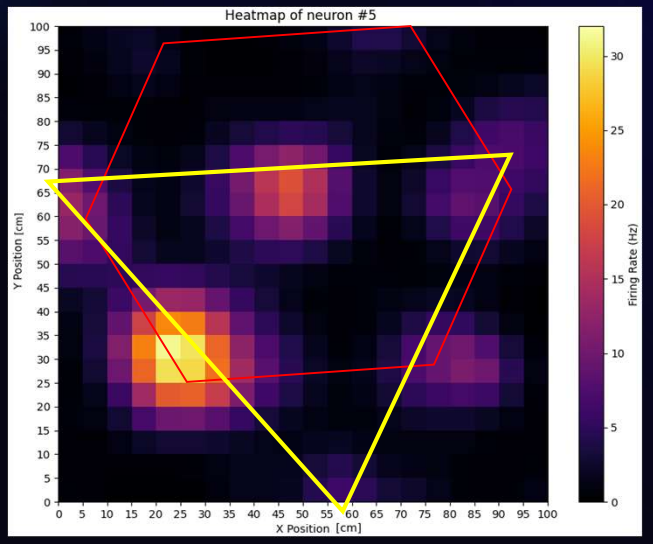
Final Classifications – Neuron #5

Originally, I classified this neuron as not head-direction cell because I didn't see the attributes head-direction cells should show.
And now I believe that this is a **grid cell** because of the shape that is seen in the heatmap, it holds a close resemblance to the grid cells that were shown in the original paper by Hafting, and both the triangle and the hexagon can be seen here.

Also, I believe that here as well as the first neuron, this neuron is functioning as a **place cell** as well because there is a "preference" of the neuron to a specific area and it fires there more then in the other places that form the grid, the place of the maximum firing rate is around (±5cm) y=30, x=25

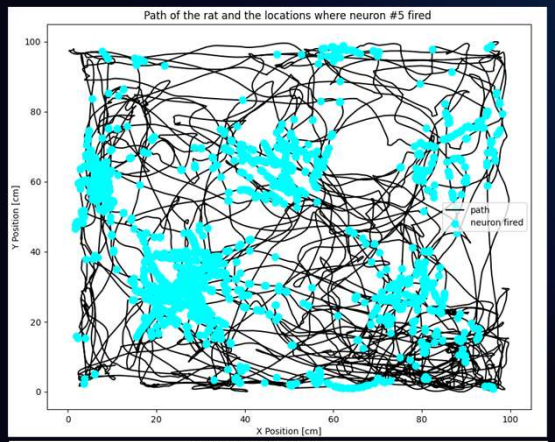


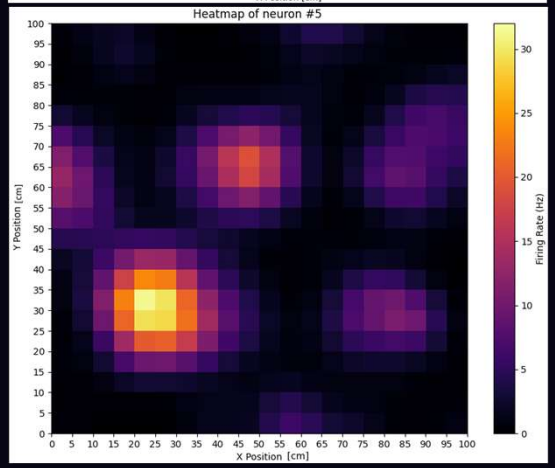


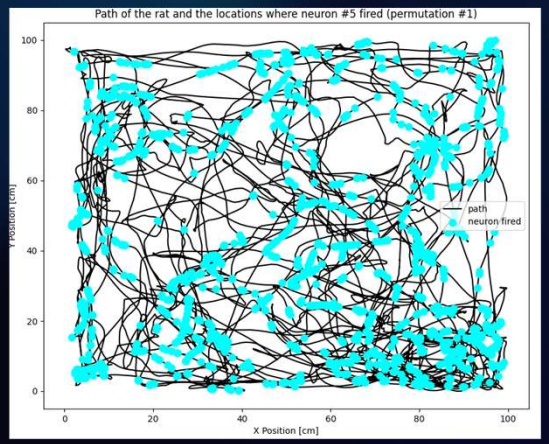


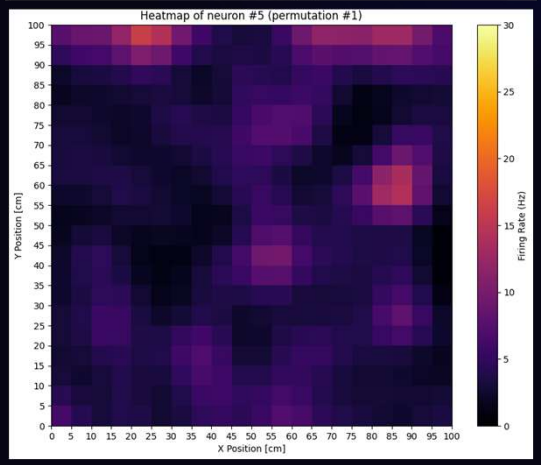
Neuron #4 Permutations

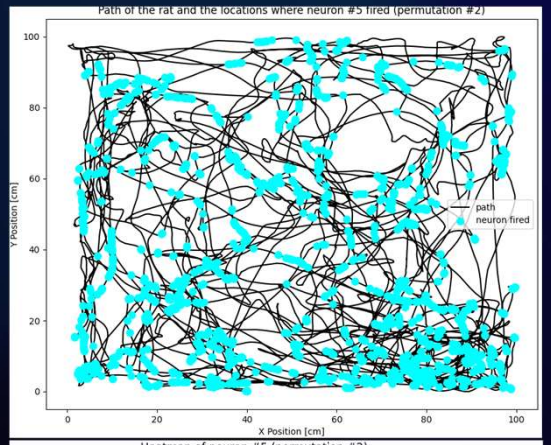
In order to eliminate the possibility of random artifact making these patterns appear as grid cells here are 2 permutations (center and right) of the new graphs compered to the originals (left):

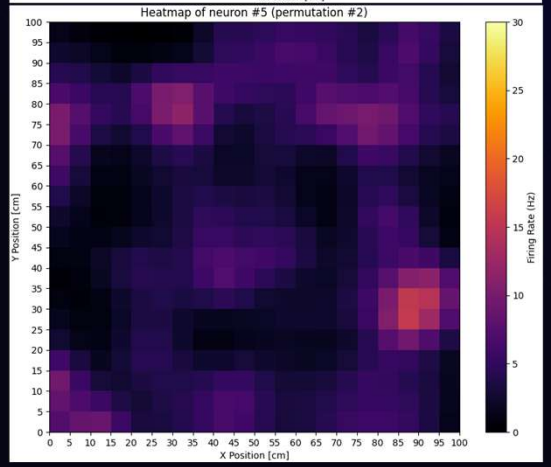






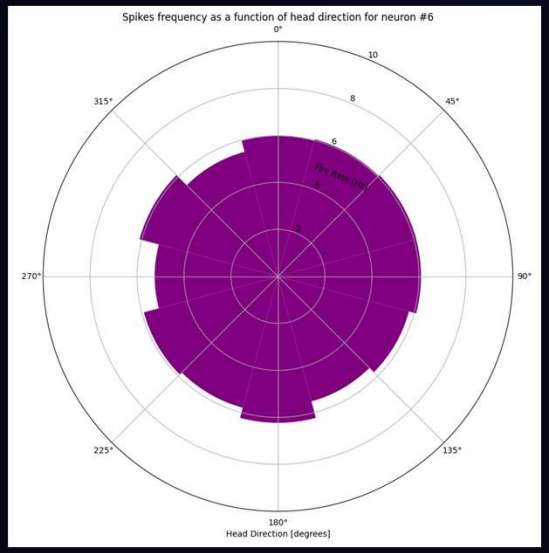


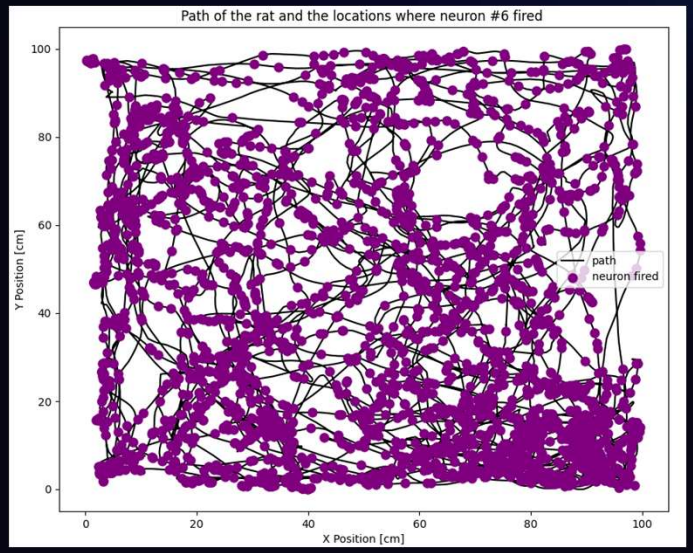


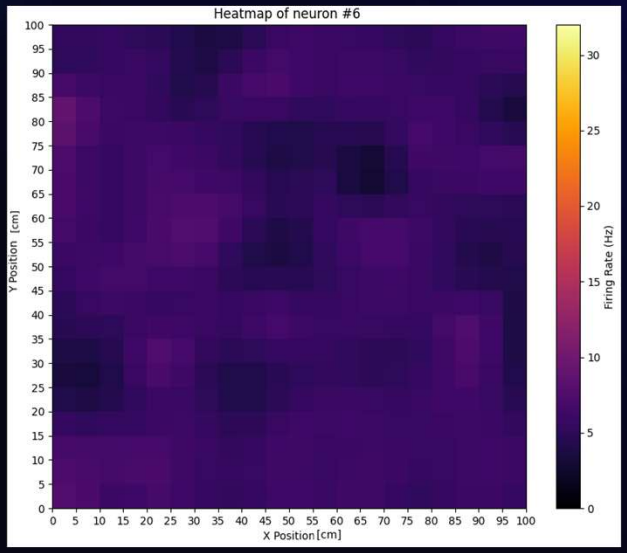


Final Classifications – Neuron #6

Originally, I classified this neuron as a none directional head cell, and the new graphs provided no reason to believe that this neuron is any of the options that we have. I'm going to stay with this classification, this neuron is **none** of the options we got.







Final Classifications – Conclusions

Finally, here is a table of my final classifications:

Neuron	Classification
#1	Grid cell and Place cell
#2	Head-direction cell
#3	Grid cell
#4	Grid cell
#5	Grid cell and Place cell
#6	None

(I've classified the grid cell neurons that showed a very high peak at their maximum places on the heatmap, as place cells as well, only because of the peak high value and because we were told that there could be some bi-functional neurons)

Thank you for reading