Computational Neuroscience
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Lecture – 54

Lecture 54 : Attention - II

Welcome. So, we have been discussing attention and here our main objective was is to look at network of neurons, how they change themselves from and when the animal or the organism is attending to a particular object to and and when it is not attending to a particular object and that change is is being observed at a network level. And we found in our previous lecture that noise correlations which is correlated variability in pairs of neurons plays a big role in terms of how attention achieves enhancement in performance. So, in order to look at the mechanisms underlying the the changes that we have talked about, we will be discussing a few a few experiments which show other than noise correlation what other aspects can play a role in attention. So, to begin with it is known from many studies that nucleus basalis, this is forebrain structure or basal forebrain that actually plays a role in modulating and providing cholinergic inputs to the entire brain. So, if we simply think of this as the brain in from the basal forebrain region, the nucleus basalis there are projections that go on to this is just a cartoon go on to variety I mean in fact, the entire cortical areas.

So, this is nucleus basalis. So, acetylcholine is the neurotransmitter and almost every region gets inputs in in the cortex from the nucleus basalis. And we the first so, so the hypothesis is obviously, that that nucleus basalis can it somehow cause the changes in noise correlations that was observed in the previous experiment. So, this is we are talking of a different group of people studying attention in a different way and this is in the mouse where and looking at the primary visual cortex.

So, what the experiment did was first it is testing that if I if nucleus basalis is stimulated. So, it is known that there is activation of nucleus basalis in attention. So, the question is that if I if we stimulate nucleus basalis then the effect on responses of neurons does it match with attentional modulation or not. So, the experiment that was performed is that there is a stimulating electrode in the nucleus basalis. So, and and in in a mouse in the anesthetized state video a natural video is shown in front of the auditor in front of the mouse.

And responses from multiple neurons in V 1 is recorded based and during that

presentation of the video. And the the data was collected on two cases the same exact video one is with NB stimulation, electrically stimulation and the other is without nucleus basalis stimulation. So, what the authors observed is that in the case of without stimulation and in and in the case of with stimulation the biggest difference was not really in the rate responses at rate response changes were not as large the degree is small. The main observational changes were if you looked at the responses simultaneously. So, let us say each row is the is one particular neurons response and we are recording simultaneously from n neurons this is without stim and in this case with stim.

So, these are neuron 1 to neuron n. What was observed is that without stimulation there was strong correlation that is between the neurons that is all the neurons seem to fire in the in a synchronous manner. Or rather many of them fired in a synchronous manner at the same time during features of the movie based on whatever receptive fields there are. That is neuron 1 responds here very little and then when it responds then neuron 2, neuron 3 and most of the other neurons also respond and so on. So, that means that across ah neuron correlations are high without stimulation and with stimulation it was found that they became de correlated that is these bands of activity at the same time by all the neurons together that got washed out.

So, it it it it if you think of high levels of activity in ah different neurons ah they were not synchronized in time anymore. So, this is reduced dramatically and the basically it goes down to a very low and go creates a de correlation between neurons. So, if now you think about it ah I mean in terms of what this can achieve in terms of ah behavior or in terms of information transfer or processing. So, you can see the all the neurons behaving ah in the same manner simultaneously ah actually gives redundancy in the representation. That is if all of them are saying the same thing you might as well have only one or two of them say the same thing.

The other it was simply a waste of resources in terms of the amount of information to be transferred by those neurons. And ah if you have uncorrelated or de correlated activity between neurons in response to the exact same stimuli that would mean that there the capacity of carrying information is higher now. So, the neurons are ah carrying separate aspects information of the stimulus most ah that is sort of the idea. So, that means, essentially you are getting more resolution of whatever you are observing ah I mean that is how you can think of it. So, this is one of the things that is observed with nucleus basale stimulation.

And the other is the other large change that is observed is the so this is also known as the that is reliability in responses. That is if you look at the same neuron for the same movie on multiple trials that is trial 1, trial 2 and up to trial k let us

say ah without stimulation and the same thing with stimulation. Then there is low reliability without stimulation when the movie is observed that is the neurons are not repeatable in their responses to the same stimulus that is each time there is a change in the pattern of responses to the same stimulus. So, this is what we are looking at is only one neuron, but multiple trials and they are not correlated across trials. So, earlier we were looking at across neurons and here we are looking at across trials and this is actually low correlations in the without stimulation case.

And in the with stimulation case they become more reliable in the sense they fire the same action potentials I mean they fire action potentials in the same time point based on the feature of the video that they might be encoding. And so in every trial generally the number the spikes occur at the same point of the video for the same neuron for one neuron. So, this reliability means that essentially an upstream neuron that is trying to decode based on this information has lesser noise in every trial in order to perform something based on the same inputs. So, that given these two effects of nucleus basale stimulation. So, reliability increase and de-correlation between neurons the question then comes up is it the same as what is happening during attention that is is nucleus basale is the one that is actually performing this during attention or not.

So, in order to test that they changed the whole stimulation of nucleus basales from electrical to optical and they changed the whole stimulation they coupled it with behavior in a behaving animal. So, in an attentional task. So, first they replicated the so what we mean by optical if you recollect that now they are expressing channel rhodopsin an opsin that is going to depolarize the neurons that are trying to carry it they are and miss essentially make them more excitable or make them fire action potentials when light is when a particular wavelength light falls on them. So, they express this channel rhodopsin on the nucleus basales cholinergic neurons that is the neurons that have acetylcholine as their neurotransmitter. And so as we know that the nucleus basales projects all over it also projects on to the V 1 region and so the opsin that is injected or that is expressed in the nucleus basales that is expressed in the terminals of those axons in the V 1 region also.

So, basically if you stimulate with that light in this case of 473 nanometer light then the light these terminals get excited and they release the neurotransmitter based on what you know of synaptic transmission basically they depolarize the synaptic terminals calcium comes in neurotransmitter is released in this case acetylcholine. And so they replicated that like electrical stimulation with optical stimulation also they got the de correlation between neurons while observing while the animal observed the movie. And similarly also there is increased reliability in responses that is higher correlation from trial to trial. But the to establish

causation one has to now couple this with behavior. So, there are two things that can be done I mean there is one more thing over this 473 nanometer case that is this is exciting or stimulating the nucleus basales inputs in the V 1 region.

You can also turn off based on arc, arc rhodopsin. So, you can actually turn off the arc rhodopsin and express instead of channel rhodopsin that was expressed here. You can express arch instead and with that is a different opsin that hyperpolarizes the neurons and this is stimulated by 590 or so nanometer of light. And so this is suppressing or inhibiting inhibiting the cholinergic neurons. So, the thing is that now if the channel if the nucleus basales is actually doing this and the changes that we see have a role to play in behavior that is cross de correlation of activity between neurons and increase reliability across trials.

Then if we turn off the nucleus basales during an attentional task we should get a reduced performance or if we provide more or excite the channel rhodopsin excite the nucleus basales inputs we should be able to enhance performance. And side by side we should also be seeing that the cross correlation across trials increases with the increase in the cross correlation cross correlation across trials increases with excitation and the cross correlation between trials reduces with inhibition and cross neuron correlation is reduced with excitation and cross correlation between neurons is not reduced when inhibiting the channel rhodopsin. And the nucleus basales inputs. So, indeed so the in this case the animal was trained to perform this kind of a task where in front of the animal. So, this is in the mouse as I mentioned and they are not very very what should I say very good viewers.

They have poor visual I mean visual equity. So, they cannot resolve let us say oriented bars with very good resolution. So, an easy task was set up and that is discriminating between vertical orientation bars or vertical gratings and horizontal gratings. So, either it was shown vertical gratings or it was shown horizontal gratings and the animal had to discriminate between these two cases. It is an easy task the it is made difficult a slightly made difficult by changing the contrast between this dark and light regions.

That is you can have 100 percent contrast that is based on the gray scale basically the two limits. The white is at the one extreme and black is on the other extreme and you can have gradually lower and lower contrast. And so they did experiments where the animal had to detect the orientation changes. So, the performance of the animal was very good of the animal is on this axis. So, with lower contrast the animal had made errors and with higher contrast it their performance increased.

So, this is the behavior of the mouse. So, this axis is contrast. So, essen-

tially to make the long story short with the nucleus basally stimulation or with the excitation with channelrhodopsin with the 473 nanometer light they found improvement in performance I mean up to the saturation level when at 100 percent they were doing 100 percent correct. And so this is with the N B stem optical stem in this case and with arch that is with N B inhibition the performance was reduced. So, this is that case and as we had also discussed the reliability of the neuron remained high in this reduced performance and the across neuron sorry reliability remain low sorry extremely sorry reliability remained low and across neuron correlations remained high that is higher redundancy.

And obviously, the opposite was observed along with the improved performance as we had seen with nucleus basally stimulation earlier. So, with this with these studies we can show how a network of neurons and the computation performed by those network of neurons to explain behavior requires incorporation of how they are behaving simultaneously that is how their responses are related to each other during a particular task. So, the methods the numerical or the quantitative methods that are associated with this we had actually discussed earlier that is noise correlations and reliability is something that is very easy to compute in the sense that you simply look at correlation of the entire stimulus entire spike train between trials and quantify it in terms of the correlation coefficient and know what the result is. And know what the reliability is. So, with this these studies we can actually conclude our discussions on attention and how modulatory inputs like inputs from the nucleus basalis in this case cholinergic inputs play a role in providing a change to the entire network that goes beyond the enhancement in responses that we have been talking about in plasticity that is the potentiation depression and so on.

Of course, the long term potentiation long term depression is at play here, but the bigger factor in this picture is how the whole set of neurons are changing together. And while that some of the changes that we have talked about for example, in the ferret case if you remember that there is a change in the receptive field. So, let us say there is an enhanced meant in the side. So, let us say this is time, this is frequency, this is the STRF. And the change in the receptive field is that this is the detected tone frequency, then there is an enhancement from the passive case which was let us say only an excitation band in this region this particular frequency which is its best frequency that changes during behavior from the passive to the active case.

With this enhancement and overall when we look at the average and align them to the target frequency or the detected frequency this is the target frequency. Now, we are combining these results the difference between the two and aver-

aging across many trials many neurons we see a large enhancement and maybe some depression on the sides. And so although during behavior the change that is occurring and the average change that is occurring is an enhancement that we are looking at. Many of these neurons switch back to their original receptive field that is or rather from this change state they go back to their original receptive fields. However, many neurons actually continue to be in this change state which is actually a long term change now.

So, however in the case of attention the kind of changes that we are talking about or at least the examples that we are talking about it has not been really studied that whether there are some permanent changes that are induced that carry on forward beyond that task. So, that I mean most likely we can hypothesize that some of them do just like in this particular case some of them continue to have a change receptive field while some switch back that that part remains to be seen what what actually happens. So, with this we come to the end of our discussions on attention and next we will be discussing more on incorporation and the implications of implementing long term plasticity in some phenomena in particularly those during development. Thank you.