Computational Neuroscience
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Week – 11
Lecture – 53

Lecture 53 : Attention - I

Welcome. So, we have been discussing our implementation of plasticity in various kinds of examples or various kinds of situations and models. So, so far we have seen how to incorporate short term plasticity in neuron models and also what the importance of short term plasticity is in terms of deviant detection and so on. So, those were some very specific examples that we discussed how to implement or incorporate that STD or STF into a variety of situations. So, after adaptation what we will now discuss is how attention can be modelled or rather how attention comes into the picture through activity of network of neurons. So, here the plasticity that we are talking about or in fact, it is more of a modulation or a temporary kind of change which can lead to a longer term change that we are talking about.

So, if you recollect the example of the ferret task in the two situations where the animal it was a go no go task where the animal would get a water reward if it detected a tone in the midst of a number of tokens of noise. And the receptive fields of those neurons that we were recording or they were recording from they changed to show an enhancement of the tonal frequency. And basically the receptive field difference which is the spectro temporal receptive field difference showed and showed that and averaging it across many many neurons showed a big enhancement of the target frequency. And it was opposite for a the other kind of behaviour where we or the ferret had to avoid licking when the tone came on or rather it would get the water when the tone came on.

So, there we only saw one aspect of the whole picture of sort of attention and plasticity and that is in the single neuron level. And if we think of it if the if this is axis is the frequency axis or some other parameter axis let us say theta on which on a particular region is being detected or being paid attention then we get an enhancement in single neurons contrast enhancement either in the positive direction or we saw could also be in the opposite direction the two different tasks. So, it is a sort of so this is the point of attention. So, this is at a single neuron level and although we showed those changes that that receptive fields went through we did not quite look at the relevance or the the magnitude of the changes and how that change related to behaviour. So, it becomes important to see whether these changes are sufficient to explain behaviour from an attended state to an unattended state or vice versa.

So, if we look at the for a moment look at the framework of attention we will see that our short term plasticity also comes into the overall picture and this is an idea that has been around for quite a few decades maybe two three decades, but there are changes that are being incorporated in the framework that we will talk about. However, some of the fundamental data that explains some of the observations they are similar it is only that different hypothesis are being tested out now compared to what we will discuss. So, if we think of it in this way there is an external world. So, there are stimuli that is coming in this goes through our peripheral system and then basically we have saliency filters that selectively allows or rather that provides enhanced version of some of the stimuli or one of the stimuli. So, for example, this could be simply from the bottom up side from the stimulus and the properties of the stimulus itself provides that novelty part of it or the saliency part of it.

For example, we had those tones standard tone standard tone standard tone and then all of a sudden a deviant tone and automatically when we are listening to the standard standard standard we adapt to that standard and we are not paying so much attention to that standard anymore, but all of a sudden when the deviant comes it captures our attention at least momentarily. So, that is based on the stimulus properties itself. So, it does not depend so much on our volitional control of paying attention to one particular thing. So, from this there is some representation that is formed in the brain then from there there is some comparative selection so this is neural representation, this is external world, this is saliency filters, this is competitive selection that is there are multiple competitive selection, there are multiple stimuli that are vying for our attention right now there are many things in front of us me or even you and I am trying to focus on what I am writing and on that camera and so similarly you are also focusing on one particular thing, but there are many that are coming in and so based on the current requirement and properties of the stimulus everything together one or few of them make it to working memory only a little bit very few of them. So, that is what we mean by the items that we will be working with in the current state this is a temporary sort of memory which is being used for the task at hand.

So, it is almost like a ram. So, this is what our working memory is and this then goes and modulates some motor output which can interact with the external world can change the representation for example, cause this enhancement and also modify the comparative selection process based on the requirement and this representation is also modified by variety of internal factors memory for example, skills that we already have and so on. So, there are a number of inputs here. So, now the basic point is that we are interested in this modulation part. So, here one is that the output control.

So, for example, this output control is based on let us say we have a siren we immediately look towards the door if something has happened and so that is changing providing a motor output that we want to do use to interact with the external world and that is what we mean by this, but similarly on the same lines you also have some sensitivity control of the stimulus itself or the representation itself. So, that is essentially here that is sensitivity control that is the representation control. So, this part of it where we have a change in representation in this case we saw is an enhancement, but is the single neuron changes in that response is sufficient to provide us the required resources to do the task at hand that is in that case of the ferret is that single neuron changes in their receptive fields by that small amount can it explain its behavior or is there more to it than just the particular changes in the receptive fields. So, the most important or I would say the elegant experiment that was done regarding this and we will see how computational neuroscience also comes into play there. This was done by Cohen and Maunsell.

So, in this particular case what they were doing is they were recording from V4 structure in the visual pathway which is in the where pathway I what pathway of the visual cortex that is object identity. If you remember from our initial basic discussions on the systems organization of the sensory systems, this is somewhere higher up than the primary and secondary visual cortexes and here we have a more complex representation of the visual scene objects than what we see in simple cells in the V1 region. So, what the task was this so these were experiments done on monkeys and these primates had been trained to fix it at a particular point in on a screen in right in front of them. So, this point is on which the monkey has to keep on its focus on there. So, that is tracked all the time based on their eyeball movements and saccades.

So, make sure that the monkey is always viewing that particular point and along with that 2 gratings or like parallel bar light and dark bars would come up on 2 sides of the that dot in the in the screen. So, it does not matter whether I mean they can be of same orientation of the gratings may not be of the same orientation, but the animal is cued to pay attention to one particular one of the 2 one particular grating of the 2 and so this would appear the monkey is cued by some blinking that pay attention to the left side and then the image disappears there is a grey screen then again on a at a random delay the sound the same image comes on and with so this is time this way with again at a random delay. So, it is being shown this whole these 2 gratings all this time and all of a sudden one of the gratings would change its orientation. So, here say this grating it was asked to pay attention to the left side it changed orientation by slightly to make it vertical and the monkey has to detect that change on the attended side and report the change has occurred. So, the monkey is trained in this way that it will be paying attention to the cued side and so it is made sure that the monkey is paying attention to the cued side by its performance of this change detection on the cued side which is in this example the left hand side and along with that the monkey is now also provided a change in 80 percent of the trials on the cued side.

So, the monkey is expecting a change on the left hand side out of 100 trials 80 trials randomly would have a change on the left hand side, but 20 percent of the time the change would be on the right hand side which the monkey did not know and the monkey would be rewarded for detection change detection on either side. If it if it detected a change on the opposite side it would be rewarded it would if it detected a change on the cued side it would be rewarded. So, in both these cases the performance I mean basically what is happening is the monkey's performance in both these cases are equivalent to in one case is attended side and unattended side. So, basically on the cued side if you look at the monkey's performance this is the change in orientation change in
$theta$ orientation of the gratings how much amount of change was happening. So, obviously the smaller the change the more difficult the task is.

So, percentage correct would be less on the left hand side and would be at chance level for very small orientation changes and so it will start from percentage correct of a very low value and with increase in orientation change angle it would go and saturate and it actually saturates by around just above 10 11 degrees of orientation or 20 degrees of orientation. Let us say some
$theta\_0$ 20 degrees. Now, in the they they actually did the experiment for only one orientation change on the unattended side and that orientation change is was around in the middle of the near the middle of the dynamic range of this function. And what they found is the percentage correct in that case turned out to be somewhere here. So, basically what attention is providing is a gain in performance by this much amount or a gain in sensitivity of how well you can discriminate angles by this amount.

So, this is gain in sensitivity or resolution or this is gain in performance. These gains are because of attention. So, this performance that is here is the unattended performance that is even without paying any clear attention to that particular object you are still from your peripheral vision somehow detecting the change. And whereas, on the other side you are actually focusing your attention on the left hand side and your performance is based on your whole working memory saying continuously looking for a change on the left hand side. So, they were in along with this they were recording from V4 as mentioned from multiple neurons simultaneously while the monkey was performing this task and they were being shown these images.

So, this this particular period where just before the change detection is happening they were looking at the firing rates of multiple neurons from V4 simultaneously. So, based on those responses one can as we have discussed in our discrimination lectures you based on those responses you can find out how the neurons would perform based on the ideal observer receiving that information from those neurons. So, in this particular case what the authors did what does in the study what they did they looked at 3 factors. 3 factors as in the overall rate and the rate change for the or rather the rate change with the discrimination with the change in orientation then there is independent variability and correlated variability. So, this we had discussed initially this is what we mean by the noise correlations.

So, essentially based on the data that they collected they could they had data for attended state and unattended state for the same stimuli that is how the experiment was designed. And now based on only the observations of rate one can find out how much contribution or how much percentage correct the performance would be based on those rates like we discussed earlier in our discriminations lectures. So, what they found is that if the overall gain in performance is let us say a 100 percent then rate based gain could only explain like 10 percent of the overall gain. The independent variability that is you keep the independent variability intact the rates are now randomized and the correlated variability are randomized and that only explains 4 percent of the overall gain in performance. But just correlated variability itself simply that you keep the noise correlations intact between the neurons the simultaneously recorded neurons, but rates are the same as what you see in the unattended state for the same pair of neurons.

And that explains 80 percent of the gain in performance. So, this is the contribution of noise correlations or the correlated variability in pairs of neurons. So, at a network level how the all the neurons together are behaving becomes extremely important in the case of attention. So, when you take all three together all three of these together that approaches the 100 percent kind of limit it is 90 percent or so when this is all together all factors are incorporated together that is the true data. And based on that the performance in gain that is calculated that is nearly what is actually observed.

80 percent of it is based on noise correlations and very small amounts are based on simply rate changes and independent variability. So, this tells us that during attention it is not just about or during this kind of modulation or plasticity if you will rate responses of single neurons is not sufficient. It is the entire group of neurons how they are performing or responding together to those stimuli becomes way more important at least in the case of attention. So, in the case of the ferret the study that we had discussed earlier we were looking at only receptive field changes which is akin to what the rate changes are going to be. It did not take into account how two neurons together were changing their responses during that task or how an entire population of neurons together were changing their responses during those tasks and what is the relationship between them.

So, this particular study thus was landmark in showing that how network of neurons together undergoes modulation or plasticity in one way for achieving some cognitive type of goals. So, with this particular study we will stop our discussion in this section this lecture and we will go on in the next lecture with further ideas on attention and how again many other factors in a network of neurons come into play and how we can establish causational relationships during attention and during the factors that are involved in attention how we can establish the causational relationship that is one particular aspect of responses is modulating to change the attention. So, that is what we will be discussing next. Thank you.