Computational Neuroscience
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Lecture – 40

Lecture 40: Single Cell Encoding - II: Learning in avoidance and approach methods in Ferrets

Welcome. So we have been discussing an example of how the encoding problem can be applied to a particular scenario and that was to do with how the receptive fields of neurons change over time due to the task that the organ that the animal has to perform on the subject has to perform. So what we saw is that in a case of the active avoidance that is a ferret was trained to perform a particular avoidance task that is the ferret is trained to not lick the water spout if you recall from that is to get its water reward and for when a particular sound comes on which is a tone and in that case we saw that there is an enhancement in the responses of the neuron or enhancement in the enhance basically it is because of an enhancement in the sensitivity of the neuron to the target frequency or which we measured using the STRF differences within a passive scenario when the animal is not performing a task and an active scenario when the animal is performing that set task. So with those STRFs we saw how because of a task there are changes in receptive fields. Now we will look into the same group's work that was published much later in fact almost a decade later in 2012 where there was a comparison made in the two cases one that was avoidance based which was the past example that we had talked about and another which is the approach based training. So in this case remember we had reference sounds, reference sounds and reference sounds and then a target would come on.

So in the avoidance case the animal can lick during these periods and cannot lick during the target sound and in the approach case the animal cannot lick during the reference sounds and is allowed to get its water reward during the particular tone target sound. So essentially this is also a tone detection task but the reinforcement by which the animal has learned the task is totally different. In fact in one case it is getting a reward and in the other case to detect the target sound wrongly it is being punished. So if we now go to the actual experimental details what we will see.

So here is examples of now here they are plotting the reference sounds as the waveforms here. So the reference sounds here are shown as waveforms. So we can

always have a spectrographic representation of the same sound and what we have learned about responses of a neuron with spikes during the reference sound. One can calculate the spectro-temporal receptive field of the neuron. So again in the same setup the animal in this case is being is being head fixed and is performing the approach task where it is rewarded if it licks during the target sound when the tone comes on and in these cases when the references are on which is the shown by the red bar before the green bar on the right is if the animal licks during those reference sounds then there is a time out and hence it is not getting water.

I mean the target sound will not come on and there is a wait period which the animal does not like because it is thirsty and wants to get the water. So the animals learn this task and they are performing when they are performing this task this task correctly then the recordings are being done and again in this case the same sounds are also played by in a cued case where we have a passive representation that is the animal is passively listening to the same sounds being played and we are recording from the same or they are recording from the same neuron which they recorded from during the task as or during the passive phase. So this is what we mean by the approach case and in the avoidance task as we have discussed before the red or the punished region with a shock on the tongue that is what it would get if it detects the target wrongly or rather it does not detect the target and it is rewarded during the presentation of the references. So the receptive fields can be calculated in both cases. Actually we have now four receptive fields that we are calculating and those are all during the presentation of these reference sounds.

So in one case we are doing the passive and approach behavior two is during the behavior with behavior and approach. So these two are from the same animal and then again we have number three and number four on another animal that is passive in the animal which has learned the avoidance task and in the same animal behavior with behavior with the avoidance that we have discussed earlier. So we have four SDRFs that are being computed. So difference between four and three will be telling us about what happens when the learning is punishment based or a negative reinforcer and the SDRF of 2 minus 1 that is going to tell us about how the changes in receptive fields occur when there is a positive kind of reinforcement in the sense that the target sound would represent a reward. So in the bottom plots in B and C what they are showing is how the animal licks for the water reward or how it stops during the avoidance task and in blue is the lick rate during the reference sounds and in red is the lick rate during the target sounds.

On the left hand side as you can see since the lick rate increases during the target sound this is the approach behavior and in the other case in the avoidance case as you can clearly see when the target sound comes on there is a drastic

reduction in the lick rate. So this basically shows that the animals have learned to perform the task and there is a somewhat increased behavior I mean lick rate during the reference task or it is actually at the baseline level when it is going to be rewarded throughout the reference sounds. So now what do we expect in terms of changes in receptive fields in one example earlier we already know the answer for the avoidance case and the sort of probably the expectation could be that we would see the same kind of scenario because after all it is a tone detection task a very similar task but the contingencies are totally different. So here are the final results that they had so below is the case of the avoidance task we already know what happens in that case that is the receptive fields change with a development of an excitation or increased sensitivity for the target tone. However for the target tone in the approach behavior it is actually the exact opposite that is there is a lowering of the response strength due when for the target sound.

So this does not mean that the sensitivity is lowered it only means that the response strength to that frequency is lowered but if it is a large enough negative value it can be equally sensitive. So remember when we discussed about synaptic transmission we had both kinds of phenomena excitatory and inhibitory. So the reduction in response rates could also imply as a could also signal some change and that is essentially how I mean how the mechanism behind the case of approach. So similar changes or the fraction of STRF changes for individual neurons are shown as histograms on the right hand side where the overall mean is shifted below zero in the case of the approach behavior. So this is the approach case and as we have seen before we have an overall change to the right hand side with the mean change on the positive side.

So together these results should show you that based on the even the simple linear STI I mean linear receptive fields we can actually learn quite a bit about how the brain is adapting itself under different scenarios. So this result as we presented here the exact opposite kind of changes in the receptive fields once the task contingencies are reversed that opens up a huge number of questions as to underlying mechanisms. So these results will help has helped frame hypothesis about how to approach the problem of studying the changes in receptive fields of auditory cortex neurons. So with our results that we have discussed in the two what we have essentially seen is the alteration of receptive fields. So what we have is the same neuron in one scenario has STRF that can be represented by STRF1 let us say in the other scenario it has STRF2.

So this change is essentially plasticity that is adaptation given the scenario or the requirement of the organism or the subject or the animal and this takes place through changes in synaptic strengths essentially which we have briefly discussed

earlier. So ultimately while we have as we as you saw in the passive case and in the behavior case the stimuli were the same that is there were references on average the same references were being played in fact exactly the same and the tones are also exactly the same and remember the randomization is also same in the passive case and the behavior case. So what we mean by randomization is something that I miss to say is the number of references varied randomly in this task so that the animal is not cued to know when the tone target can come on. So this the since the stimuli are same but the system behaves in an altered manner that is basically what we mean by learning that is the animal learns to do the task and that is being achieved by this alteration in the receptive field. We cannot completely say achieved until we establish the causation part of it but yeah at least correlationally that is the that is what we can at least conclude in this particular scenario.

So with this slight introduction to the idea of plasticity we will end our lectures on the encoding and decoding part of the course here and from the next lecture onwards we will be starting our discussions on plasticity synaptic plasticity time scales of I mean different time scales of plasticity and so on. Thank you.