Cognition and its Computation
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Lecture - 57
Topics in Current Research - II

Welcome so, continuing on our open questions lectures particularly from a theoretical perspective or computational perspective the next idea that we will go on to is that of plasticity and again I will base it on one particular line of work that was done by originally the first work along that line was done by Gal Chechik.

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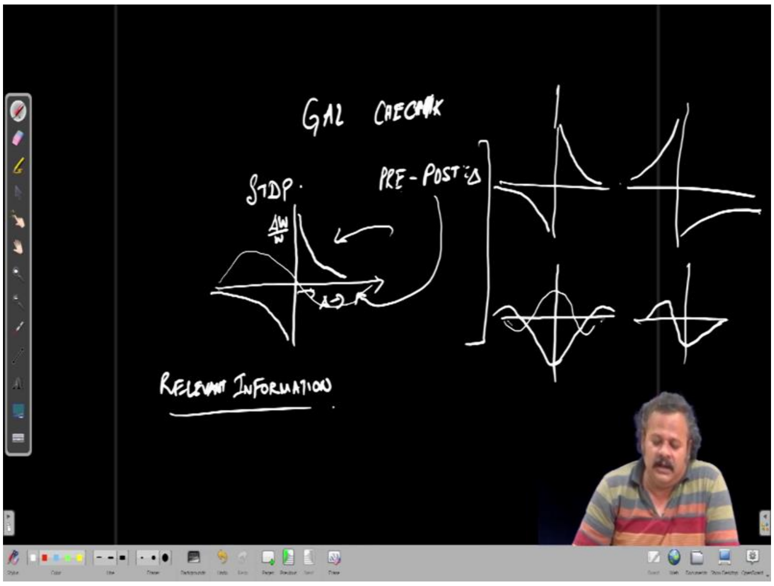

From the Hebrew University in Israel and we have talked about plasticity throughout the course especially in terms of cognition when we started our discussion on attention, modulation of representation due to attention, how during development representation changes, how circuits change based on our experience and so on.

And we have said that plasticity is what makes the brain the brain or the degree of plasticity or the degree of adaptability that is present in the brain basically determines how much like humans are different from the other species apart from there being extra structures and elements, the ability to adapt is probably more profound in humans than in others.

So, again in order to understand or in order to go forward from a theoretical angle it becomes important to be able to understand why and how under what principles govern plasticity. We have talked about the Hebb’s principle that is neurons that fire together wired together and we have talked about Hebbian plasticity, but at the same time we have also talked about anti- Hebbian or non-Hebbian plasticity. So, all those kinds of plasticity are present.

So, if we talk of the spike timing dependent plasticity or STDP, we came up with the idea or rather experimentally we know about the plasticity rule for the pre and postsynaptic spike time it is pre minus post if we have that if the presynaptic spike precedes the postsynaptic spike.

So, this axis here is the pre minus post axis. So, if the pre synaptic spike precedes the postsynaptic spike that is this is positive that is on this side the this delta is on the right hand side then we get potentiation and on the other side we get depression and it is asymmetric. So, this is the change in weight normalized by the original weight and this axis is the delta axis which represents the time difference between the pre and postsynaptic spiking.

So, in order to understand why the learning rule or the STDP window is of this form Gal Chechik theoretically approach this question again from the perspective of an optimization problem, that is if we have an input spike trend with certain properties and there is an output spike trend following non-linear processing unit which is the neuron. Then how should the weight change in order to maximize the information that is relevant information in the presynaptic spikes so, the relevant information maximization. So, there are particular ways of defining the amount of information.

And the way this question was approached is that ok if we have an arbitrary learning rule that is we have function here of some sort like this and we want to maximize the information transfer or rather maximize the relevant information transfer from the presynaptic to the postsynaptic neuron. Then how should the synapse adapt and that uses a form of transformation from the presynaptic spike to the postsynaptic spike which is what the neurons do and it is a non-linear transformation based on rates.

So, with this optimization they were able to show that we approach the kind of Hebbian STDP learning rule that is derived experimentally. So, relevant information maximization could be a way to approach this problem in the sense that we can theoretically predict what the presynaptic what the learning rule should be. That is how every spike in the presynaptic relative to the postsynaptic spike should change the synaptic weight. So, this only predicts one behavior under some under a particular circumstance, under a particular information type maximization.

We have also known that we have also discussed that it is not that all synapses follow this kind of learning rule in terms of STDP. We have learning rules that are exactly the opposite that is the anti-Hebbian that is in this manner we know that there are inhibitory synapses that have learning rule of this manner where it is depressing on nearby spikes in the pre and postsynaptic neurons and slight enhancement in far away spikes.

So, there are also learning rules that are different from these and there are other measured learning rules that are exactly the opposite of these also. So, is there way that we can predict a particular learning rule between a particular type of synapse.

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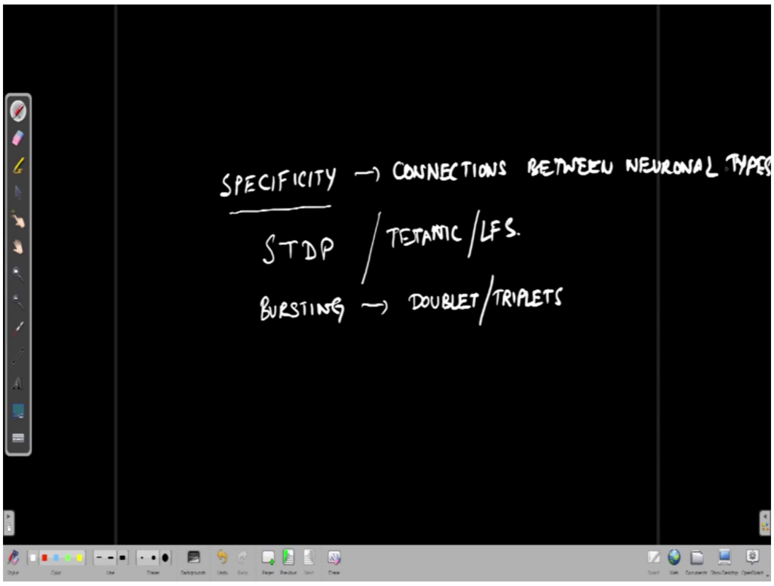

As we have constantly discussed that there is tremendous specificity in terms of connections between neurons of different types and the subclasses of different types, when I say types I mean excitatory and inhibitory and within them there are subclasses with different functional properties.

And there is tremendous specificity in terms of what is connected to what in what size in, what extent specially and so on. So, based on those experimental data or coming up with more general principles of a neuron that could be excitatory or inhibitory and the postsynaptic neuron that could be excitatory or inhibitory with certain functional properties each of them may be imparted with certain functional properties.

And similarly properties of the spike trends can we come up with methodologies applying this kind of principle to be able to predict the kind of plasticity rule that would be followed in a particular type of synapse with a particular type of function in the pre and postsynaptic neurons..

Again this is not an easy problem, we have to start with the kind of approach that was taken in the kind of work that we talked about. So, we have been talking in in terms of plasticity we have been talking about STDP and also the titanic burst and low frequency stimulation these were the basic principles behind the plasticity occurred occurring in synapses, but in recent work over the past decades we experimentally known that these are not all the elements that govern plasticity in synapses.

Bursting activity in presynaptic neurons or postsynaptic neurons can modulate the plasticity in a completely different way, similarly doublets 2 spikes together or triplets 3 spikes together presynaptically they affect the plasticity or the synaptic strengths in different ways.

So, given this variety of observations and the specificity of connections between neuronal types, it becomes in human task in order to be able to actually measure empirically experimentally the learning rules of each kind of synapse.

And unless we know the learning rules or the principles behind how these kind of synapses change under different conditions of activity. We will not be able to understand or rather be able to model an essentially be able to replace them with artificial elements or mimic them in other systems if we are not able to measure all of them.

And it is inhuman to measure all of them because there are a tremendous variety of conditions that have to be tested. So, this problem needs to be actually approached theoretically very much like the work that we talked about earlier and starting from very small cases just like the case that Gal Chechik took and then building on that one over the other in order to able to theoretically predict what the plasticity rules should be based on some optimization principle.

And then we can actually test experimentally some of the cases to conclude whether the work is correct or not and based on the experimental results again and come back and modify the principle and finally, come up with an ability or a theory in terms of what computationally plasticity should be or is and in that case we should be able to predict behavior of networks of different kinds of neurons connected in a particular way under different regimes of activity.

That is only possible theoretically and so, it remains to be seen whether we can actually go beyond what we know in terms of synaptic plasticity from a theoretical point of view. And so, with this open question I conclude this lecture and we will come up with more of the open questions in our next lectures.

Thank you.