Neuroscience of Human Movement
Department of Multidisciplinary
Indian Institute of Technology, Madras

Lecture – 62
Cerebellum Part - 11

So, welcome to this class on Neuroscience of Human Movement. This is part 11 of our discussion on Cerebellum.

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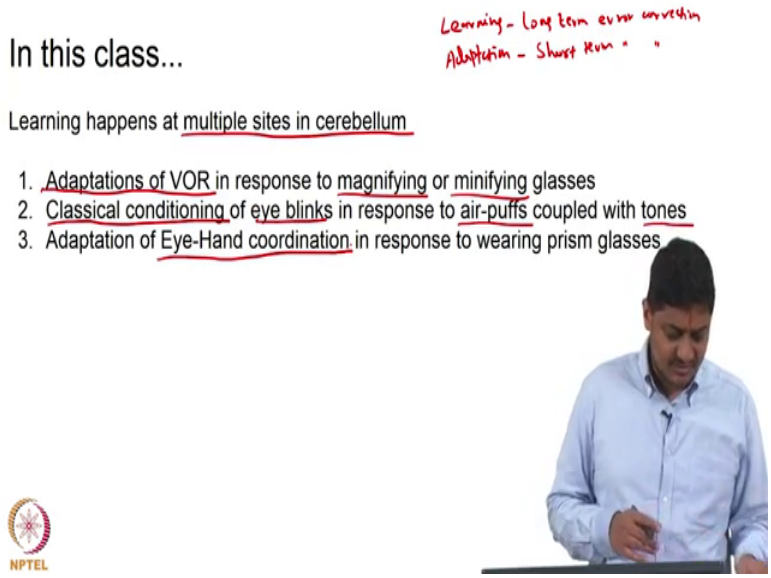

So, in this class, we will discuss role of cerebellum in learning we discussed the role of cerebellum in learning in the previous class. We will continue the discussion and note that learning happens at multiple sites in the cerebellum. In the previous class, we discussed one site in which learning could happen that is the climbing fiber Purkinje cell synapse or synapses of the climbing fiber Purkinje cell that act as teaching signals right.

Some of the examples of learning are presented. We will start with adaptations of Vestibulo ocular reflex. What is this? We discussed this briefly in one of the previous classes. Suppose I have a target that I have to look at suppose there is the tip of the pen that I have to look at as I am looking at the tip of the pin I am required to turn my head to the right, but I need to keep looking at the tip of the pen.

So, that is the task for me. Suppose then what happens I am doing that as I am doing that you note that my head is turning to the right, but my eyes are you know moving to the

left. So, head is moving to the right and eyes are moving to the left. So, as to ensure that the image that I would like to say that the object that I would like to see, I am able to see.

So, this also is true in relatively fast movements of the head this is called as a Vestibulo ocular reflex right. So, the response of eye movements are the ability of eyes to move in a direction opposite to that of the head. So, as the head is moving to the right, the eyes are moving to the left to keep the object fixated on the eye.

So, this is called as the Vestibulo ocular reflex. It turns out that if a person is wearing a magnifying or minifying glasses right. If a person is wearing magnifying or minifying glasses, initially what happens is that there is improper Vestibulo ocular reflex in the initial stages.

So, as soon as the person wears, what happens? If the so, these are glasses that either magnify the vision visual scene or make it small or minify the visual scene right. So, in those cases the Vestibulo ocular reflex or the response will be different from what is intended. So, when people were this magnifying or minifying glasses for a few hours in some cases to a few days, there is adaptation of this response are a proper response is learnt by the system. After some days or after a few hours as wearing, what happens is that peoples Vestibulo ocular reflex is tuned to the glass that they are wearing and the scene that they would like to see this is and. So, this is reversible right. So, I can then remove the glass when I remove the glass then the perturbation that is caused due to the glass wearing continues for some time. So, the original adjustment that was made is that immediately rescinded. It is not immediately corrected it takes some time for the system to correct right.

So, if for the magnifying glass the Vestibulo ocular reflex increases and for the minifying glass the Vestibulo ocular reflex reduces and after some after a few hours of wearing this there is adaptation. And this adaptation can be reversed when I remove the glass there is going to be a reverse reversal of this learning and that learning or that adaptation also takes step that is also not instantaneous.

So, this is known to be mediated by the cerebellum in particular by the Vestibulo cerebellum right. So, animal models in animals that have had lesions of the lateral Vestibulo cerebellum right in such cases or we discussed the role of the Vestibulo cerebellum in one of the previous classes. So, please do check that video.

So, animals that have had lesions of the lateral Vestibulo cerebellum do not have this ability to adapt to perturbations due to these glasses and adjust the Vestibulo ocular reflex showing that the Vestibulo cerebellum forms a crucial part are of the network that performs this action the Vestibulo ocular reflex.

So, this is adaptation. So, what is the difference from learning we discussed at least relatively crude definition is a relatively long term error correction all right. Whereas, adaptation refers to this relatively short term a correction. Also note apart from this there is the ability of the cerebellum to participate non-linear error corrections moment to moment trial to trial error corrections that is also there, but there is also motor skill learning you are learning the skill that is a relatively long term. For example, learning tennis right that is a skill that you learn; adaptation refers to perturbation such as response to perturbation such as wearing magnifying or minifying glass wearing a prism glass etcetera and or response to force field perturbations etcetera right.

Then also another study, another approach for studying this is classical conditioning of eye blinks in response to air puffs that are coupled with tones. So, the experimental approach is the following. So, there is an air puff that is placed on the cornea.

Every time when this air puff is on the cornea there has to be a an eye blink. So, you do not want this is a relatively non preferred stimulus. People do not like this. So, immediately they will close the eyes. So, they will blink right. So, when this happens it turns out when a tone is accompanied by the air puff.

So, when the air puff arise along with the tone then people learn to predict when the air puff is going to arrive or the amplitude of the air puff perturbation in response to the tone. Also what has been shown is that the characteristic of the air puff perturbation can be encoded by the tone.

So, the long tones; so, when we say tone I am meaning an auditory tone. So, tones with different frequencies or tones of different durations may encode different nature of or different parameters of the air puff. So, depending on that eye blink response is customized. So, it is crucial to note is not that all the responses that are coming or all the eye blinks are the same. So, the eye blink response is customized to the particular perturbation.

So, if the tone is longer if the tone is of high frequency that means, the air puff is going to be this strong or it is going to arrive at this latency appropriately timed response is found in the eye blink responsible right.

So, this again is feature that is probably this again is a behavior that is probably mediated by cerebellum right. Then eye hand coordination in our voluntary arm movements in response to wearing prism glasses. Suppose person is a wearing a prism glass.

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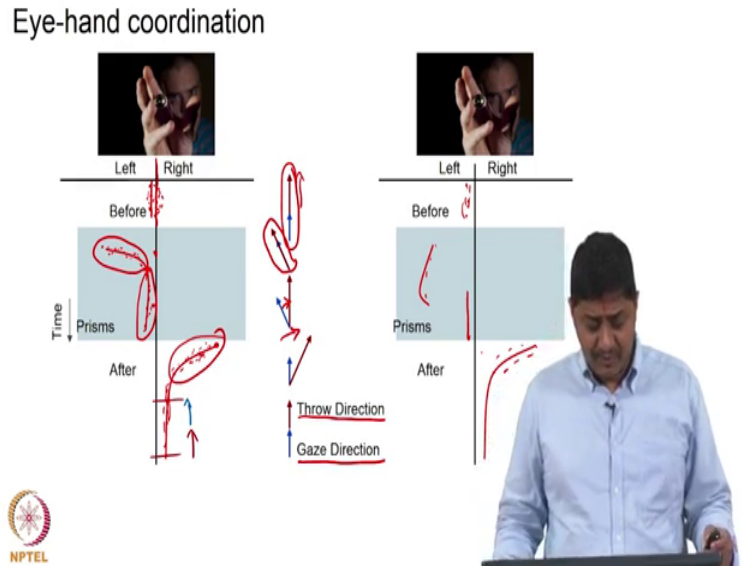

And the task is a following there is a dot and I have to throw the dot at the at the dot board as usual. So, let us suppose that people who are good at this task right. So, suppose as a person who is good at this and they are doing this and we test them before they wear any glass before any perturbation. We test their performance what happens is that they keep throwing the dot say 10 times or 20 times or 30 times and you see that suppose that is the target right and they almost always hit the target right there. These are the responses for example.

Now, then they are asked to wear prism glasses. Now what this does is this shifts the vision are the gaze direction to a different direction all right. So, in this case this shifts the gaze direction to the left.

So, initially before the person was wearing the prism glasses the hand follows the eye. So, here this is the throw direction in brown you have the throw direction or the hand

direction and in blue you have the gaze direction or the eye direction right. Initially before the person was asked to wear the prism glass the hand direction is like this as in these two right the hand direction and the gaze direction are the same in other words the hand follows the eye right. As soon as they are asked to wear the glass are in the first trial immediately after wearing the glass also the same thing happens, but note now because of this perturbation vision is toward the left and here also gaze follows here also gaze and throw are in the same direction are the hand follows the eye.

So, that is the direction that is the point that is the point at which the responses to a person is throwing initially they see something and they throw along and then they realize. So, this is a mistake I want to throw at the target which is here which is here for example, but I am throwing where my eyes are seeing and my eyes are seeing to the left.

So, what I should see, what I should do in future is I if I am looking like; this I should throw toward my right in future right that is what this glass is doing to may this glass is shifting my gaze. So, I should not throw along where I am seeing, but rather to my right and this people learn with the number of trail. So, after some trails it is like this and after a few trials you realize they are going to do something like this.

So, initially in the normal case people are going to do that for people to come to that level it takes that many trials after.

So, many trials people are able to do this, but then what you do after some time you ask them to remove the glass, but before that what happens in this case during adaptation during adaptation or just after adaptation you note that the gaze direction continues to be in this direction.

Whereas, throw has shifted to the right of the gaze is it not throw has shifted to the right of the gaze throw is not along the eye the hand does not follow the eye, but rather the hand goes to the right of the eye right that is what happens during perturbation then what happens the people are asked to remove the glass.

So, once you remove the glass what happens is that initially that this learning that was there where the hand is throwing to the right of the gaze continues, but now the gaze is straight as it is here right.

Now, that is the gaze. Now the gaze is straight like this. So,, but people have already learned to throw to the right of the gaze which is why the first response immediately after removal of the glass is here and then the next few responses are here.

And after sometime people learn oh I am throwing to the right of the target I am seeing straight and I am throwing to the right now I must throw along where I am seeing. So, after a few trials after that many trials people learn to throw along where they are seeing.

So, these are going to be the good trails after some time then what happens after sometime the gaze direction and the throw direction are expected to be the same around here for example, that is the gaze direction and that is the throw direction for example, right that is here for that part of the learning and in interestingly note that this interestingly this ability to adapt.

So, it only takes a few trials right few tens of trails to adapt to this perturbation this ability to adapt is compromised in individuals with lesions right. So, in individuals with lesions of the cerebellum what you have is that before the perturbation, they are doing something after the perturbation. They are doing this they never come back to that right and after the removal they are doing this.

So, very different distinct response in people with cerebral lesions they are not able to adapt which once again highlights the crucial role of cerebellum in this form of learning or in this form of adaptation right; so, the hypothesis.

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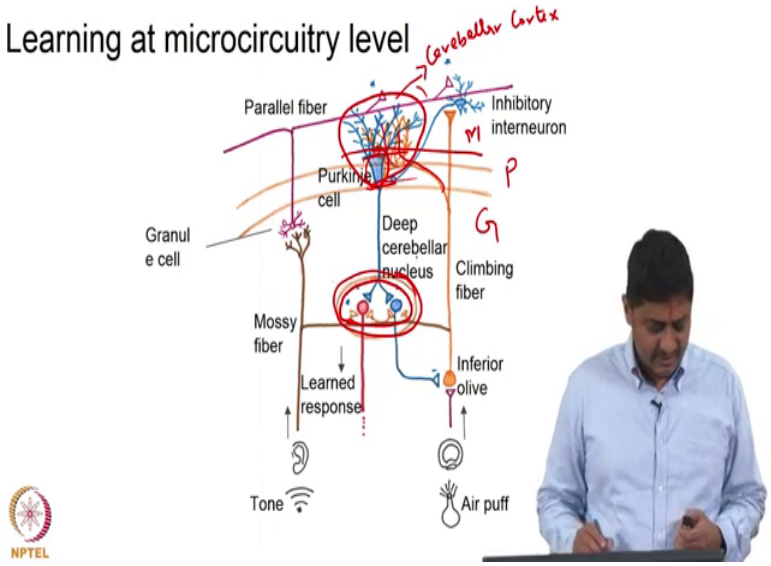

Behind this is that there are probably internal models of dynamics that whose parameters are varied in response to the sensory inputs whose parameters are varied in response to the situation context and so on. and so, forth and all these internal models are probably implemented are probably they probably reside in the cerebellum is a controversial hypothesis that continues to be challenged that continues to be supported that continues to be discussed in the literature.

At least the following is known that there are multiple sites in which learning can happen one particular site that we discussed earlier is this site. This is the climbing fiber Purkinje cell synapses or the synapses of the climbing fiber Purkinje cell where learning happens through the climbing fiber acting as a teaching signal or the instructing signal, but it is now known that it is not just at this site, but other sites for example, at the deep cerebellar nuclei also where learning is believed to happen.

So, learning happens at multiple sites at the not only in the cerebellar cortex. So, this is the cerebellar cortex of course, right. Because that is the molecular layer of the cerebellum long ago when we discuss the anatomy and the micro circuitry or the cerebellum we distinguished that this is the molecular layer and where this Purkinje cell bodies are located is the Purkinje cell layer and this is the granular layer, but deep within the cerebellar cortices are sets of neuronal cell bodies or dense groups of neuronal cell bodies called as the deep cerebellar nuclei which are the major output systems of the

cerebellum right. So, learning is now believed to happen also in the deep nuclei in addition to the Purkinje cell and climbing fiber synapses.

So, we discussed in the previous class how this happens climbing fiber through long term depression mechanism informs the Purkinje cell which parallel fiber con commands are causing motor errors right for example. So, this is what happens at the level of the Purkinje cell and climbing fibers, but similar process is also implemented probably in the deep cerebellar nuclei.

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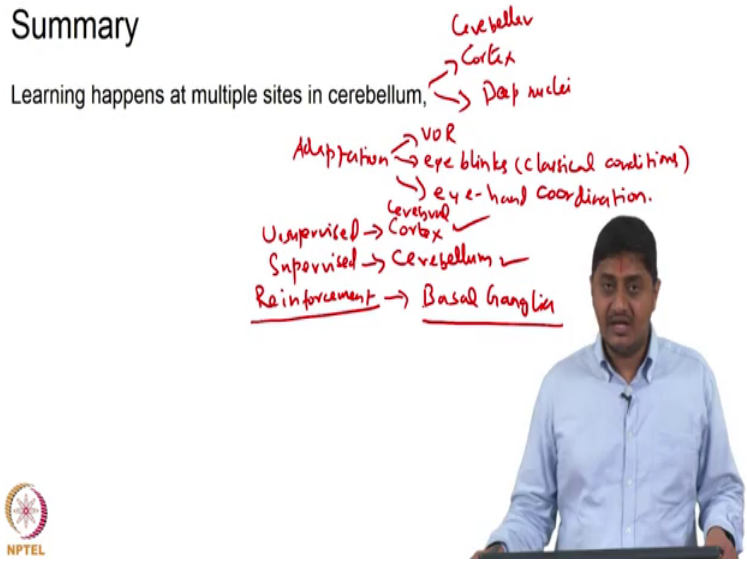

So, what we have learnt in today's class is that learning happens at multiple sites in the cerebellum that is basically the cortex as in the cerebellar cortex and deep nuclei. Also that cerebellum is crucial for different fonts of learning especially adaptation. These are a few examples of this adaptation to the Vestibulo ocular reflex adaptation to eye blinks condition or classical condition of conditioning of classical conditioning of eye blinks in response to air puffs and this and eye hand coordination. For example, and there are other examples such as force field adaptations such as such a split treadmill split built treadmill adaptations etcetera.

There are multiple experimental approaches that give us information on how cerebellum can play a role in learning at least the following is accepted that cerebellum plays a crucial role in short term actually a cerebellum plays a crucial role in online or trial to

trial moment to moment error correction in short term error correction in terms of adaptation and in long term error correction in terms of motor learning.

And it is believed a particular form of learning is probably implemented in the cerebellum it is a controversial hypothesis that. So, in computer since for example, there are different forms of learning that are discussed. These are unsupervised learning supervised learning and reinforcement learning for example.

It is believed that for the brain unsupervised learning is implemented in the cortex or the cerebral cortex supervised learning means there is we know what the expected output is what is the performance and these two are compared and then the error is reduced right approximately I am taking a very non technical view of what the situation is that is probably implemented in the cerebellum.

So, we have discussed cerebral cortex especially the motor cortex and how learning happens in the cerebral cortex. We have discussed some cases of that we have discussed cerebellum and how learning happens in the cerebellum in today's class and in the previous class.

Then how is reinforcement learning which is reward related response and reward related learning is happening in the brain that forms the discussion of our future classes that is implemented in the or it is believed to be implemented hypothesis to be implemented in basal ganglia and other related circuitries. So, with this we come to the end of this lecture.

Thank you very much for your attention.