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

Lecture - 82
Parietal and Premotor Cortex - 6

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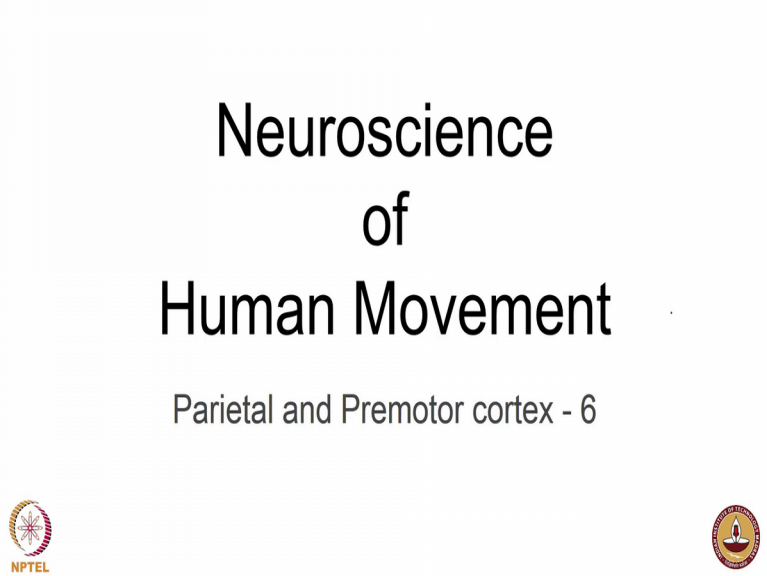

Welcome to this class on Neuroscience of Human Movement. This is part- 6 of our discussion on Parietal and Premotor Cortex.

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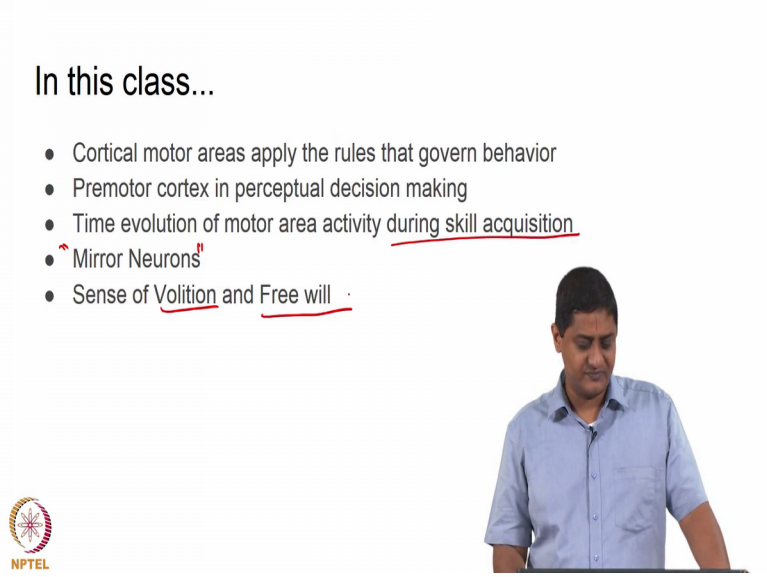

So, in this class we will discuss the specific cortical motor areas that govern behavior, right, they apply the rules that govern behavior. And premotor cortex and its role in perceptual decision making, and time evolution of motor area activity during skilled acquisition, and a discussion on what are called as mirror neurons and a very brief interlude or a discussion on the sense of volition and free will. What does this even mean? Right; given our understanding of the neuroscience of how actions are executed. What is meant by volition? What is it meant by free will? Alright, we will not go into a detailed discussion of this, we will just briefly touch upon those. Those who are interested can read more about this.

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So, you are driving on the road and you see a red light what are you supposed to do? Well, you are supposed to stop normally in civilized countries you always stop and you are seeing a green light you are supposed to proceed, this is what happens in normal civilized countries most of those places. But what does this involve? Right, essentially this decision making process right can be divided into two distinct decision making processes, right. First is to decide what is the color, right that is lit up, right what is the color of the light that is lit up that is the first question. If it is red then you need to stop, if it is green then you can proceed, that is a perceptual decision. This is performed by the prefrontal cortex, right.

What to do with it is the behavioral decision. This is red or it is going to turn red, right if you are driving in a city like Chennai where I am from right, the light turns from green to yellow that is when people push their accelerator is it not that is the behavioral decision. You are seeing green becoming yellow soon it is going to become red what people do in India in Chennai for example, people push the accelerator, right no you are not supposed to do that.

The law says when you see yellow you stop normal people do that or whatever it is the definition of normal does not matter, the point is that that is what you are supposed to do you are expected to do legally, right. When you see yellow you are supposed to stop. What do people actually do, what is your actual behavioral outcome? A majority of the people will actually push harder will actually accelerate so they can go, right that is what happens in a city like Chennai for example, that is the actual behavioral outcome, right.

Or as they say in the, or as they say in the real world that the proof of the pudding is in the eating, right what you perceived and what you decided is something that I can understand by what you decided to actually do. At the end of the day it is that action that matters is it not, whether you push when you saw the yellow or whether you stopped when you saw the yellow, right. That is the actual outcome.

What is the process that happens inside, right that could be a perceptual decision making process, is it not. So, essentially a decision making process has happened. And a behavioral decision on what to do what is the particular act should you push the brake or should you push the accelerator which particular one do you do, right which particular action do you take. Now, that is a decision that is purely behavioral and that is executed or that is probably mediated by the function of the dorsal premotor cortex, is it not. This is a example from the work of Wallis and Miller for example, right.

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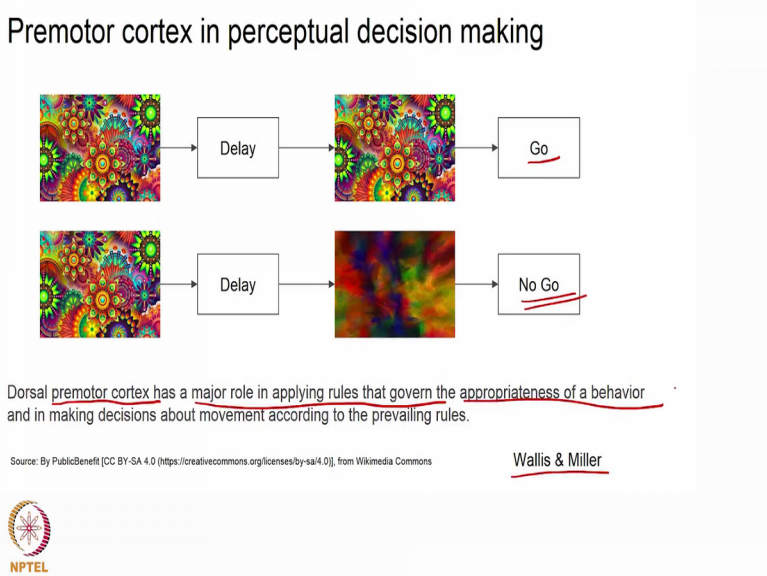

This kind of work has been studied in various ways for example, in Wallis and Miller studied it using very complicated matching tasks for example, right. If a particular image is presented and after a delay another image is presented, if the second image is the same as the first image the instruction is to go forward is to say push button green push green button. If the second image is not the same if it is not matching the first image then push the red button.

By the way I can instruct the opposite way. Suppose the two images are matching push the red button, suppose the two images are not matching then push the green button now that is a different task all together, right. Importantly the dorsal premotor cortex has an important role in applying rule that govern appropriateness of a behavior, right. So, depending on the context, depending on whether these two are the same or not the decision will be made.

So, once again let us go back and think about this. At the first stage you have to make a decision on whether the two images are indeed the same or not, right. If these two images are the same the decision that you have made is a perceptual decision. The act of pushing the button the act of performing a movement is the behavioral decision it is a behavioral outcome of that perceptual decision, right.

By the way you could as I said you could manipulate this, right you could change the instruction and then see what happens, right. So, you could have congruency, you could

have non-congruency, see which of this is getting more delayed, which is causing higher delay in the actual performance, why and things like that. This is the kind of questions that people ask.

By the way some of these experiments have involved animals that means, that you could actually record from live behaving animals individual neurons. So that means, that it gives you an opportunity to understand what happens at a very high resolution.

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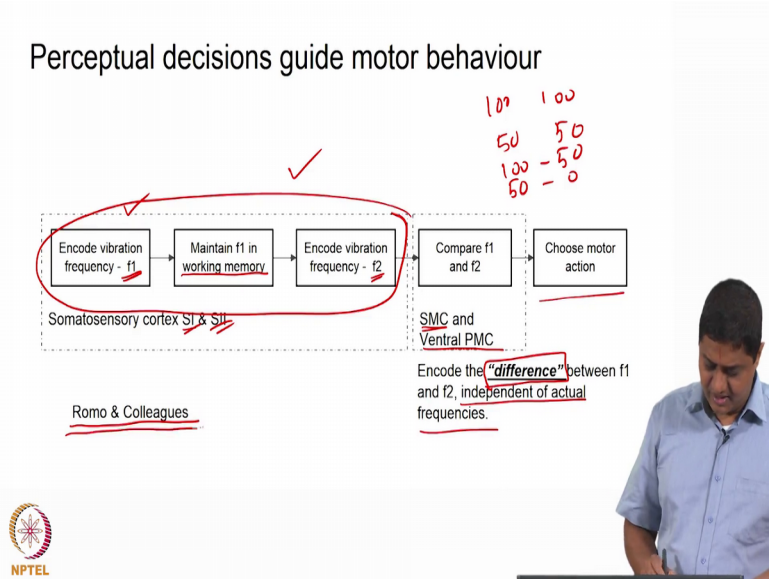

So, essentially another approach that has been used by Romo and his Colleagues is this idea of differentiating vibrations, right. So, now what happens is that you produce a vibration at a particular frequency say for example, f 1, right. After some time after a delay produce at different frequency vibrations say f 2, right.

Now, you compare f 1 and f 2 depending on whether f 1 and f 2 are the same you perform one action, if they are different you perform another action. Now, this involves a series of steps, is it not. First is to encode the vibration frequency f 1 and then store it somewhere well I mean using words such as store as if it is stored in a computer but essentially maintain it in some form of working memory, right. Then perceive the other vibration f 2, compare f 1 and f 2 if these are indeed the same then choose a motor action

And it turns out that neurons in the primary and secondary somatosensory cortex are responsible for this part of the task, as in they are active when this part of the task is

executed. Or somatosensory cortex is active when the vibrations are perceived and the comparison itself when the comparison happens this is happening at the supplementary motor cortex and the ventral premotor cortex, it turns out these regions or the neurons in these regions actually encode the difference between f 1 and f 2. Very important to know that is the reason I have underlined it and italicized it and bolted it, right very very important, that the neurons in the supplementary motor cortex and the ventral premotor cortex actually encode the difference between f 1 and f 2.

Essentially making a decision on whether f 1 vibrations and f 2 vibrations or the frequencies of f 1 and f 2 or the frequencies f 1 and f 2 are same or different, right. So, if they are the same then the difference would be 0, then the activity of these neurons will also be 0 accordingly, right. By the way this is independent of actual frequencies, very important. This is independent of actual frequencies. But I am not expecting that this is going to happen at multiple scales but this is independent of actual frequencies. So that means, this can be 100 and 100 then there will be no activity, this will this can be 50 and 50 then there will be no activity. But if it is 100 and 50 then there will be an activity and that activity will be the same as the activity between 50 and 0 for example, because what is computed is essentially a difference between f 1 and f 2, right.

So, if it is 100 and 50 the difference is 50, if it is 50 and 0 then the difference is 50 the activity is going to be approximately the same in these two cases. If it is 100 and 100 the difference is 0, if it is 50 and 50 the difference is 0, regardless of whether the frequency used is 50 or 100 the if both the frequencies are the same then activity will be 0. So, importantly the neurons in the primary and secondary somatosensory cortex encode the vibrations keep it in working memory and encode the other vibration frequency. But, the comparison itself is done by the supplementary motor area and the ventral premotor cortex, right which encode the difference between these two frequencies. Very nice protocol but developed by are performed by Romo and his Colleagues.

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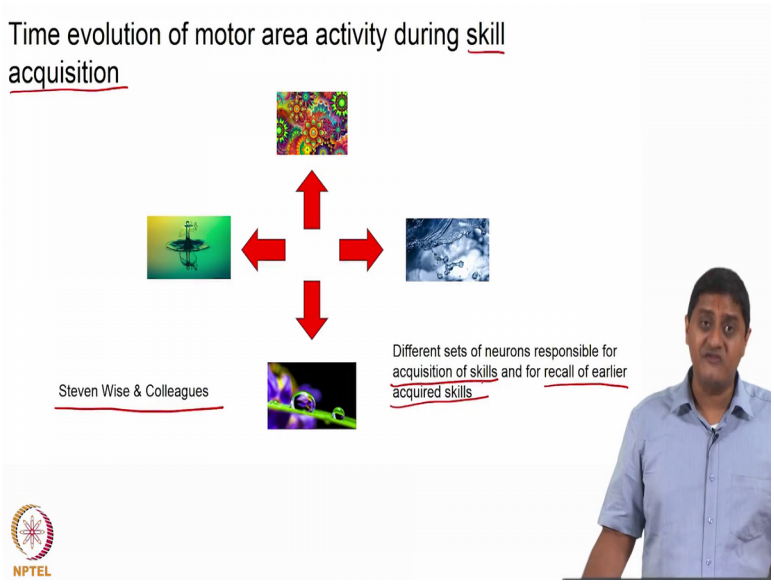

So, another important question is concerning skill acquisition. How are skills acquired is the kind of questions asked by Steven Wise and Colleagues for example, right. Now, depending on the particular tasks or a particular picture that is presented you are required to make a particular movement, right. So, what has been found is that different neurons are specialized for different aspects of this skill acquisition, it turns out that one set of neurons are responsible for acquisition of skills and another set of neurons are responsible for recall of earlier acquired skills, right.

So, we saw early on in basal ganglia for example, different regions in the striatum are responsible for different functions. We gave the example of a songbird where we said that the region that is responsible for acquisition of songbird song is one whereas, the region that is responsible for singing of the songbird song is different. So, acquisition and recall and re-performance are performed by distinct sets of neurons in the parietal premotor; very important result from the group of Steven Wise and his Colleagues.

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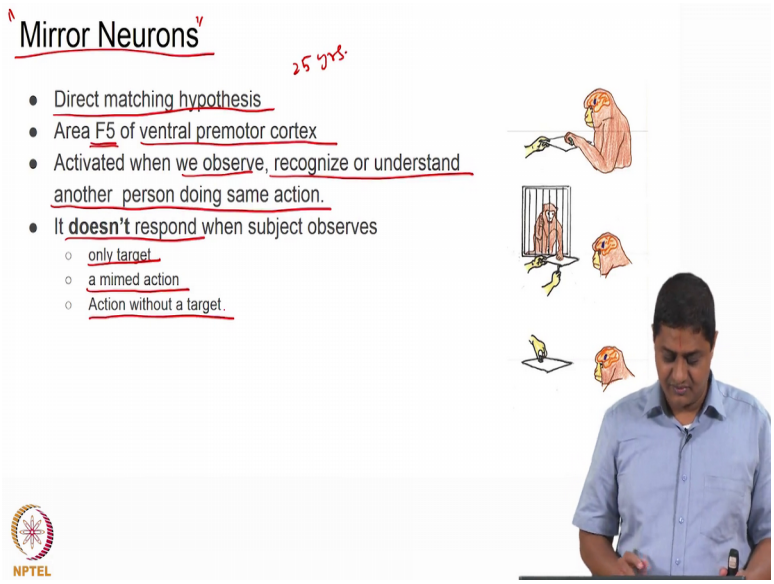

Another important idea is concerning the presence of what are called as mirror neurons within double quotes. Suppose you watch someone perform an action, right then and you want to know what could be the outcome of that action. One way to do that would be to wait and watch what the outcome would be well obviously. The other would be you are interested if you are interested in predicting for example, then your (Refer Time: 13:24) several people do the same action then if this person is doing this action then this is possibly the outcome that is a probability, it is a probabilistic approach to predicting the outcome. I have seen many people do this and the usual result is this. So, Bayesian approach, right. And x is also doing it then the outcome is most likely expected to be this for example, right.

Of course, this depends on the specific probabilities involved, but without getting into the details of the math I could say from my previous experience of other people doing this I could say this. But more than all this what you can do is I have done this or this is how I am doing it and this would be the outcome. This idea is called as the direct matching hypothesis. This is the idea where that says the direct matching hypothesis is this idea that says that when observing another person make a movement motor areas in the observer get activated so that the observer can understand the performance of the actor as the performer, right.

So, I am seeing someone take a food pellet, right from his cup and eat. I know what the outcome is going to be based on my previous experience to understand somebody else's action I actually activate my motor circuits that is the key I am not activating the perceptual circuits I am not activating the decision making or prefrontal circuits but rather I am activating my own motor circuits but I am not performing those moments. So, there must be other inhibitory mechanisms that prevent me from performing those moments but motor circuits responsible for me performing those actions are activated when someone else is performing that action and I am observing. This is called as a direct matching hypothesis.

A tremendous amount of evidence supporting this idea has been gathered in the last 25 years especially from the lab of Dr. Giacomo Rizzolatti and his Colleagues. So, this is the area F5 of the ventral premotor cortex that has that houses these neurons, right. This is activated when we observe, recognize or understand another person doing an action, right. I observe someone doing it I recognize or I understand what he is going to do I do not have to exactly see it. So, essentially I see that there is an object that can be manipulated and then a person is moving their arm close to the object as if they are going to manipulate it. But when they are actually manipulating it there is a screen or there is obstacle that prevents me from viewing the manipulation but even then I can observe I can guess what is probably going on, even then my mirror neurons circuitry will actually fire up, right but if there is no target then it will not fire up.

So, essentially the mirror neurons do not respond when there is no target or if it is simply a mimed action not an actual action and if it is an action without target. So, if there is only a target that is presented but no movement then there will be nothing if it is only an action without the target then there will be no activity, right. So, essentially there must be a target and there must be a movement, and then someone else must be observing then the observer's mirror neurons will get activated; very very interesting controversial hypothesis an idea, right.

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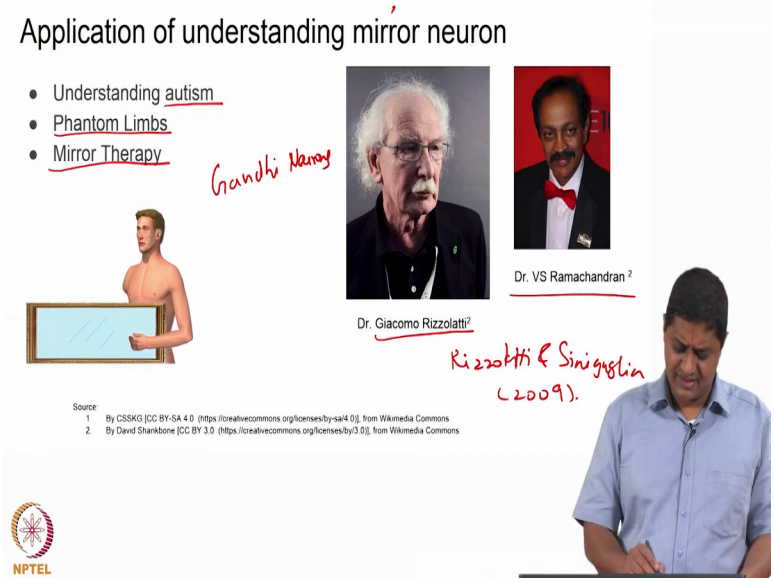

What are the applications? What could be the use of this? Right, several applications have been presented an interesting application for example is in the treatment of phantom limbs people use mirror therapy. So, this is an approach that was developed by Vilayanur Ramachandran, right from San Diego. A tremendous amount of work has gone on in this work a lot of development has gone in this work. And of course, as I mentioned the front runner in this line of research when it comes to mirror neurons of course Dr. Giacomo Rizzolatti and if you want to read what are the controversies concerning these, right. You have to read the paper Rizzolatti and Sinigaglia I think 2009 maybe I guess. Please check this. This is Rizzolatti and Sinigaglia where they discuss the philosophical questions concerning the role of mirror neurons in this.

Importantly it has been found that in children who are autistic the activity in the mirror neuron system is distinctly lower when compared with activity in age matched healthy children. So, what does this mean? This makes sense from one point of view, right. So, essentially these children find it difficult to understand the consequences of someone else's action, is it not. So, it is found that the mirror neuron system is compromised in these children, right. So that means, as to why that is happening as to why the mirror neuron system is compromised in this is a different question, is it the autism that is causing compromise of mirror neuron system or is it the compromised mirror neuron system that causes autism is the million dollar question, that is a question that I am not

handling here. But at least there is a correlation between compromise of the mirror neuron system in children who have autism, right.

Of course hypotheses have been made about the role of mirror neuron system. For example, Dr. Ramachandran likes to make comments such as that these neurons are the basis for empathy, arts, civilization, aesthetics and he also goes on to call these neurons as Gandhi neurons (Refer Time: 20:21) Gandhi; Gandhi as in our father of the nation MK Gandhi represented the epitome of empathy, is it not. So, he calls this as Gandhi neurons.

Many of these are controversial claims I will really not comment on that I request you to please go ahead and read and come to your own conclusion about that. But a lot of these are not supported by data, right. So, essentially the idea that art, civilization, esthetics, and empathy all developed from the mirror neuron system is the idea that some individuals including Dr. Ramachandran like to push forward but as to whether this is supported by data is a question that we need to answer. So, the jury is out there on that. So, this remains controversial. So, I will not really venture into this further. Please do read about this those who are interested can always read, right.

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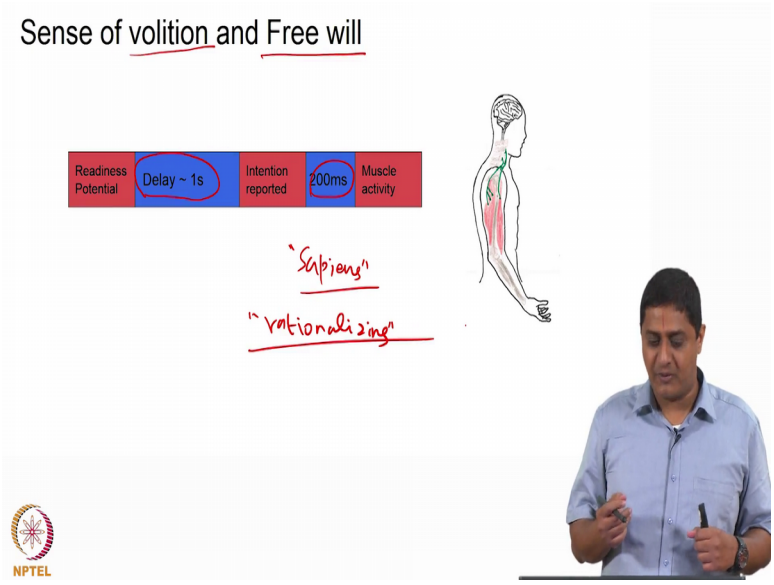

So, then the other question is the notion of free will and volition. As I mentioned earlier the reported intention happens at around 200 milliseconds, that is when I know my own decision I become aware of my own decision. But the appropriate readiness potential has started 800 milliseconds earlier, right around there. Now, if the action has already been

initiated and only later I become aware of my action, what does it mean for the notion of free will and volition.

Let us say that you are in your house and in the dark you see someone opening your door for example, well this actually happens in real life this has actually happened, right. Someone is opening the door and you think that is a burglar and you just shoot, and then you read as that is your spouse, right. Then questions concerning free will or volition by the way this is controversial because there may be other reasons why someone would want to murder the spouse, that is not the point. The point is that you do not know that you have made the decision you have made the decision, the execution plan is already on the way by the time you become aware of your decision the plan is already underway how much can you actually suppress or inhibit, right. I am not saying that there is no free will. I do not know the answer but the whole idea of free will and volition are themselves very questionable, right.

Of course, the idea of decision making as it is also questionable or the idea that we are rational decision makers, right. We have the name homo sapiens. Sapiens means what? Those who are able to make a rational decision we like to think that we think, we like to think that we are rational, it is a nice idea, it is a pleasant idea, right. So, so of course, no one would want to admit that their ideas are all irrational. However, data and scientific evidence has been consistently pointing in the other direction. Nowadays, we are getting more and more evidence to support the idea decisions that we make are not exactly rational, we are very good, we are extraordinarily good at rationalizing our decision, right. So, there is a difference between being rational and rationalizing our decisions, is it not.

So, suppose you buy a phone that is very expensive and someone is criticizing you for it, then you go ahead and say why that phone is worth the investment that is rationalizing, right. Maybe you do not actually need that phone, maybe you do not need to spend so much money on that, maybe the same features are available elsewhere but you do not want to accept your mistake.

By the way I am not saying some individuals have this problem, we all have this problem, all of us humans have this problem. We are very good at rationalizing compared with being actually rational this is a problem, right. And by the way that is

good from one point of view, right it does make you live life without much complaints without much regrets, right. So, otherwise every decision you make if it is irrational and you always think about it and then think that it is an irrational decision it will be hell it will be really horrible to live that life. In a way it at least allows you to proceed with life without much regrets in from one point of view it is good, but it is not always good, right.

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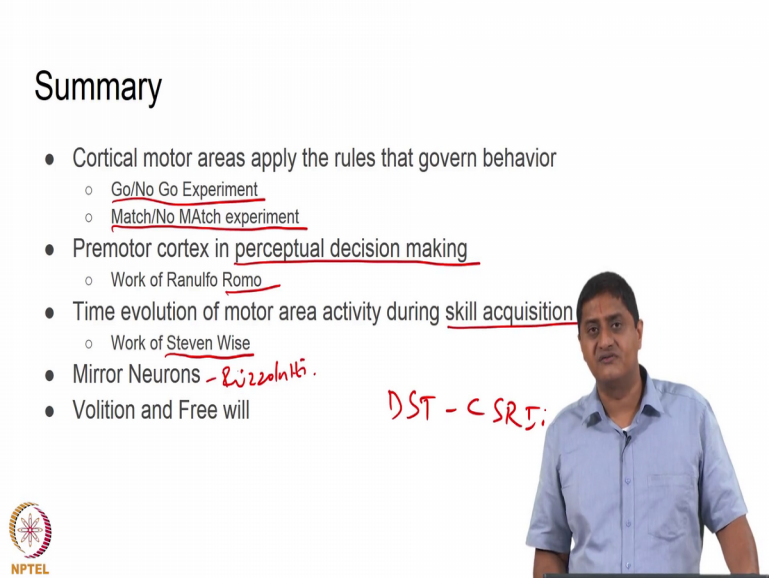

So, in summary cortical motor areas apply the rules that govern behavior for example, they matching and the go, no go experiment, the match no match experiment, right. And role of premotor cortex in perceptual decision making the results from Romo and his Colleagues, and the time evolution of motor area activity during skill acquisition, so there are different delays involved in that work of Steven Wise. And mirror neurons and their possible roles in action understanding for example; the work of Rizzolatti and some controversial hypothesis including, those that are proposed by Vilayanur Ramachandran for example, right. And the notion of volition and free will; what the free will even mean? What does the notion of volition even mean; are the other questions that we are asking.

By the way in relation to this work we are also working in this area. An important research that we are performing currently that is funded by the Department of Science and Technology, the Cognitive Science Research Initiative is our work on the role of

action observation in improving motor learning, right. So, we are also interested and we are also working in this area in my lab. I am working in this area with the help of my students. So, with this we come to the end of this lecture.

Thank you very much for your attention.