Neural Science for Engineers
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Lecture - 48
Memory and Learning - I

We will be closing this discussion, these classes, with Memory and Learning. I kept memory and learning towards the end of the entire discussion because there are several concepts which have to be understood before we come into memory and learning. If you go through material which is available on the net or even in the textbook which I have prescribed, you would find that it is pretty difficult to understand.

Now, that difficulty actually arises from our own, that is the medical side of the story where, we have not been able to decipher how things actually happen within the head. Now, many discoveries in Biology, in particular is experimental or something which happens in patients. So, earlier in my discussion I have told you about, you know in control systems.

So, we would wonder as to how do you say that these systems within the brain and spinal cord are responsible for control. So, you would know that, from diseases in which the systems are involved and they have a particular manifestation. The absence of manifestation in normal human beings indicates that these structures are responsible for preventing those things and allowing for smooth movement.

Now, the system is enormously complex. So, which is why you know you basically name stuff. So, if we describe diseases such as Parkinson's or movement disorders, we say that some particular pathway is involved. We are not able to devolve how these mechanisms, or the absence of these mechanisms are responsible for the exact manifestation, as to what kind of problem in gain is responsible for trauma.

What kind of what kind of mechanism is responsible for that loss of expressions in the face. So, there is a big gap in understanding and the gap becomes more difficult when we look at things like memory and learning, in which you know you have very low organism experiments which you can design. But when we come up higher in the sense

that, in terms of human learning and you know they are basically psychological experiments.

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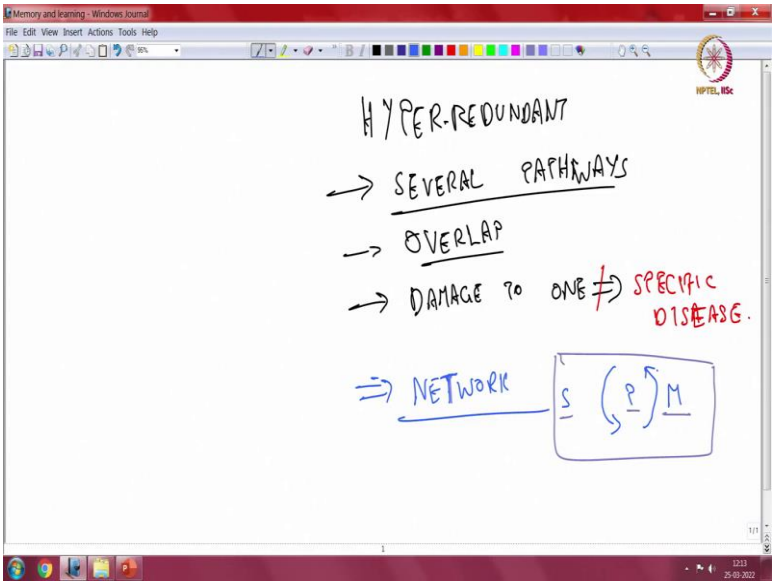

Now, fundamental property of the nervous system is, one it is Hyper Redundant. So, several pathways exist. There is overlap. And you cannot separate one from the other, that is basically overlap. So, there are several pathways and damage to one does not result in a specific disease. What I mean to say is, it's a network. So, the property which I am describing is which implies that its it functions as a network.

This has been highlighted at several points within discussion. So, there is nothing like a starting of the nervous system and then ending of a nervous system. You are looking at a system of you know, which is evolved between the sensory and the motor and the processing, all built into one single complex structure.

And at no point of time can you differentiate between individual functioning as being responsible for something or not being responsible for something not happening. So, that is the beauty of the network. But from an understanding perspective, what happens is it is very difficult to infer anything from a network, which is functioning. You break down the network and you can then analyze individual components or systems, that is how you have an understanding of it.

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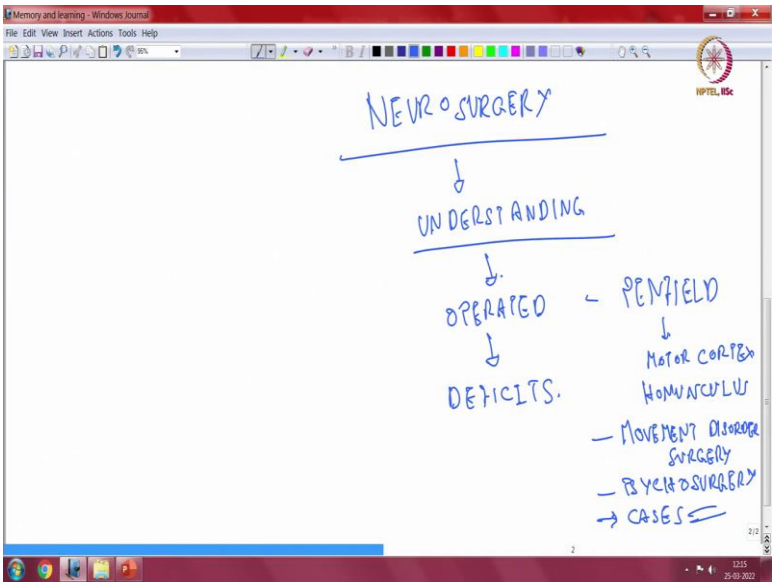

Now, neurosurgery actually forms very important contributor to basic understanding. Say some of the things which happen in operated patients. So, that causes a particular set of deficits as in neurological problems.

And that sort of helps you to understand, that this particular part of the brain has been responsible for something. So, the various examples of this. You start from the from Penfield, who mapped the motor cortex and discovered the Homunculus. Then there is work in movement disorder surgery.

Then there was work on psychosurgery and there are individual cases, you know we have had different kinds of patients, who have undergone surgical resections of various parts and we would say that this particular patient when analyzed has a particular set of problems and those problems can be attributed to the surgical intervention which has happened over there.

So, that is how studies have happened within the medical field and you attribute certain properties of the nervous system to those parts of the brain. The problem with this is many of them are individual cases.

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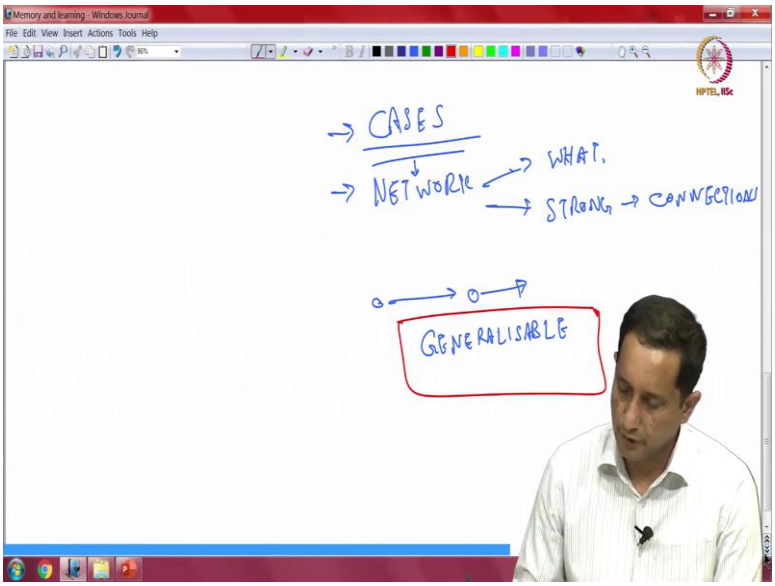

And when I was saying network, we do not have a clear understanding of, what the network is? So, what part is connected to what part, how strong are the individual connections between parts of the brain in different people. Now so, these are questions which are not answered when you look at cases and that is the problem in understanding.

So, a given patient may have a particular manifestation and we have an understanding of what may be the chain of events which cause those issues, but whether that can be generalizable is always a problem. So, we find things from neurosurgical patients. There are patients, who have these problems and then people do experiments on lower animals to replicate those phenomena.

And then see if we can generalize it to all across the nervous system of human beings and to maybe other organisms, whether these properties can be attributed.

So, having said that I think we need to revise a little bit on basic neuronal function because I would be attributing some things of, I am not delving too much into anatomy, if you have issues in anatomy there have been separate classes on structural anatomy, imaging anatomy and I would be loosely using terms over here in this class, which I presume you would understand.

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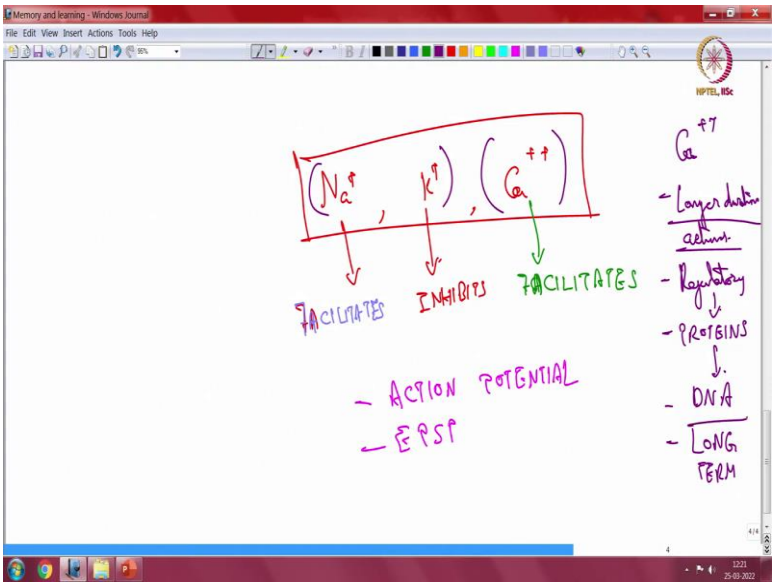

But I felt that, some more introduction has to be there on these ions and sort of revision is required to comprehend some of this stuff which I am about to discuss. So, sodium facilitates. Potassium inhibits. Calcium in general facilitates, there are places where it would inhibit. So facilitates what? Or an EPSP.

So, these ions are responsible for that, sodium and potassium can be bracketed together because they are in the immediate part of the action potential story. Calcium can be bracketed separately because I have explained calcium metabolism a little bit in muscle physiology or the neuromuscular junction and how calcium is responsible for second messenger pathways.

So, Calcium has I would put has longer durations of action, that is it works for a longer duration of time. Sodium and potassium if you remember the action potential it immediately gets restored because of the ionic gradients and the natural mechanisms which maintain the resting membrane potential.

Calcium on the other hand is mopped up within the cell, there is a calcium regulatory mechanism which ensures that the amount of calcium which is present within the cell is regulated. But there are also mechanisms connected to both the sodium, potassium protein dynamics by which calcium secretion is influenced.

Now, calcium also acts upon a regulatory implies that, it acts on proteins. And these proteins in turn can go to DNA and that in turn can you know you are looking at real long term effects. So, when I mean longer duration of action is within the cell itself, where the calcium ion does physical association with other proteins and changes things within the shorter term.

But the same calcium also is responsible for triggering second messenger pathways, which influence DNA and that in turn causes real long term; meaning even generational changes. So, between say one organism to its children you can have, long term effects which are happening.

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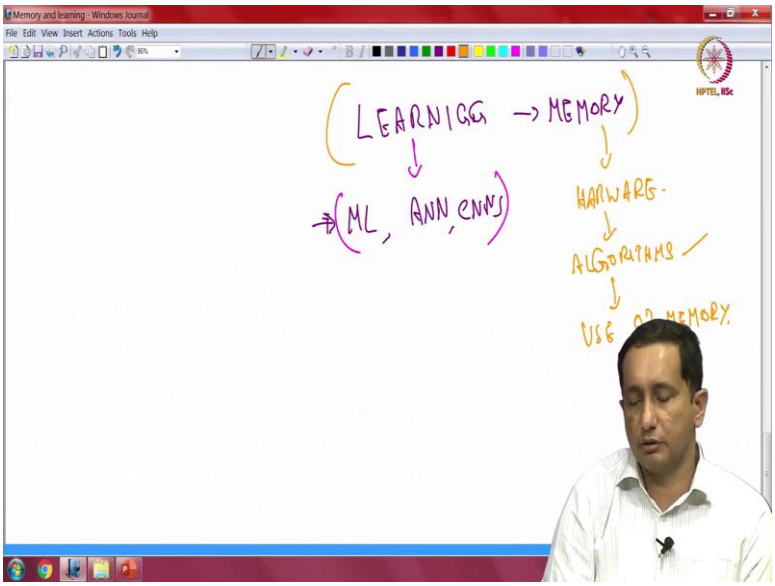

Now, I have clubbed learning and memory. Now, if you look at computer architectures learning is basically something which happens through ML or ANNs and CNNs etcetera. So, you are looking at that kind of stuff and memory basically is hardware.

So, computer memory is hardware, and you have algorithms which manipulate how memory is used. So, use of memory. So, in computer architecture terms, when you speak about learning you think of very different things and when you speak about memory you think about very different things. In biological perspective they are very closely interlinked.

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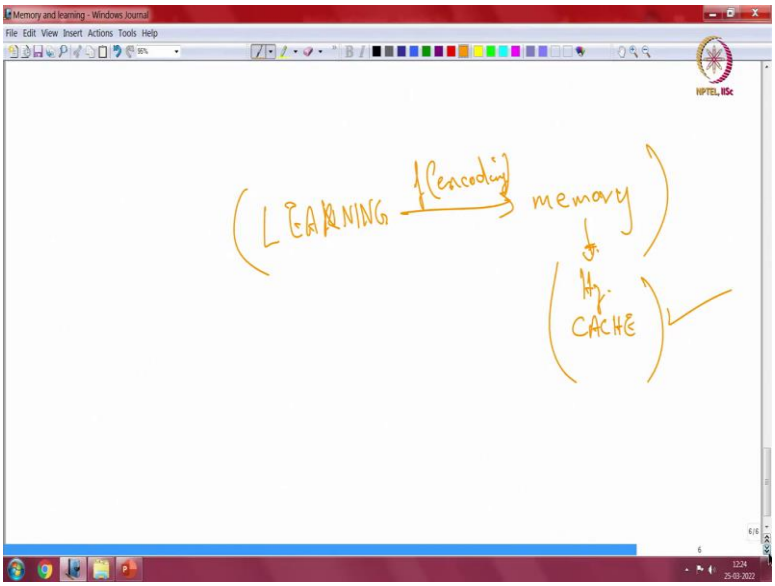

So, basically learning is a method of encoding memory. So, they are closely linked, you do not have a memory biology which is very different from learning biology. So, they are very closely linked, and these are terms which are used in close relation to each other, whenever we discuss biological learning and biological memory.

So, that is a difference. So, when we speak about chips and processing frequency and cache and hertz, you would think of only as that. But in biology, there are relationships between this methods between learning methods in biology and some of these things. So, earlier in the class on cerebellum, I had hinted on these various different kinds of memory.

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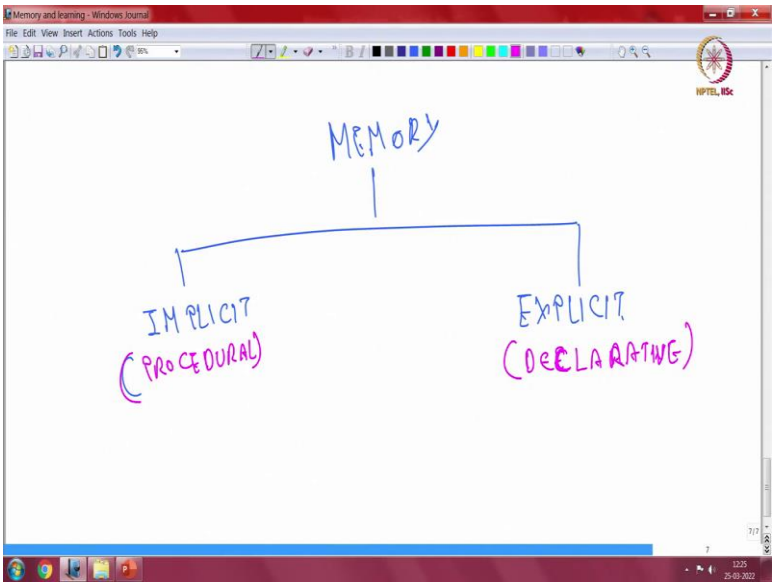

So, we will start with that. You have 2 broad classes of memory. So, one is called as Implicit and Explicit. So, implicit is procedural; explicit is declarative. So, declarative is you declare something and then store it into memory. Procedural is some kind of procedure which you have in memory.

Now, this classification is necessary because there are apparently 2 different mechanisms by which you uptake knowledge from the environment. And it is necessary to have some idea of how these things are there.

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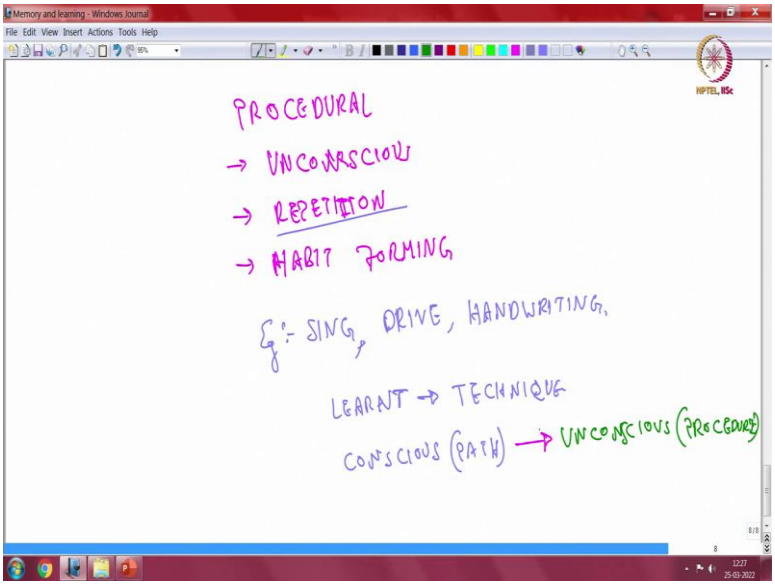

Now, when we speak about procedural, I would use this term better because, it's easier to link between the stuff which I am about to tell, this is basically unconscious. And by repetition sort of habit forming and examples are varied kinds. So, you know you learn to sing, or you would learn to drive, handwriting, these are things which are learnt. And they are learnt in a very different fashion from the other stuff which I am going to say earlier.

So, these are learnt in a different way. So, one of the important techniques is repetition you know you repeat doing these things and over a period of time, you get it corrected. So, in a way what happens is, you would initially be conscious, you have a conscious path to an unconscious procedure.

So, you can call that the technique is you know you repeat things consciously. If there is a song, you need a particular tune and then there are some other parameters in singing. So, each part of it is rehearsed learnt and then you ensure that it goes becomes unconscious. So, you continue to follow the rules, without consciously monitoring every step of it. Now, that is there for a very wide range of things.

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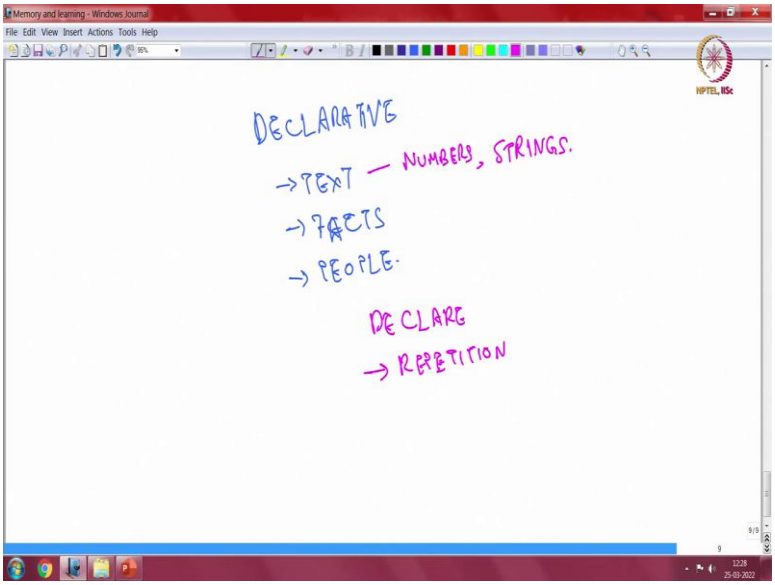

Now, declarative on the other hand. So, you declare. So, it may be text, facts. So, you need to declare things. There is also repetition, you know you would need to repeat which is actually a method of learning, repetition is there and you need to declare these things over and over.

And say it can be numbers, strings, anything, any of these things can be declared and you would remember it like that. Now, having said that there are 2 methods, that is procedural versus declarative. You would know notice that, the classification is for our understanding.

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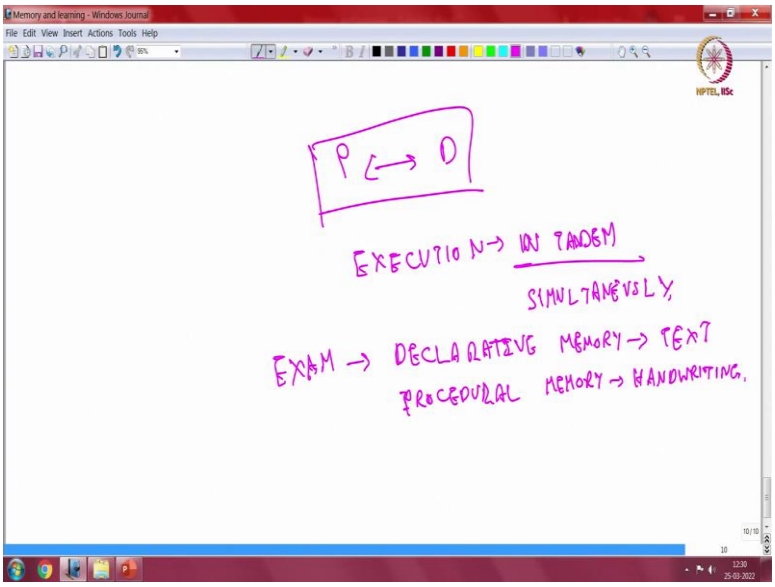

And the execution is in tandem. So, they happen simultaneously. So, let us take an example. So, you are writing an exam. So, when you are writing an exam, you would be using your declarative memory for the text and your procedural for the handwriting.

So, that is what I meant. So, any kind of task which you do, you may have a declarative component to it, and you may have a procedural component to it. The advantage with procedural memory is, you know the amount of attention which you need for recollection is very less. You say you can talk and drive, you can listen to a song while driving.

When you are writing stuff; obviously, I am talking. The amount of effort, mental efforts spent on a procedural memory during execution is lesser. Declarative you have to call that from memory and then put it to action.

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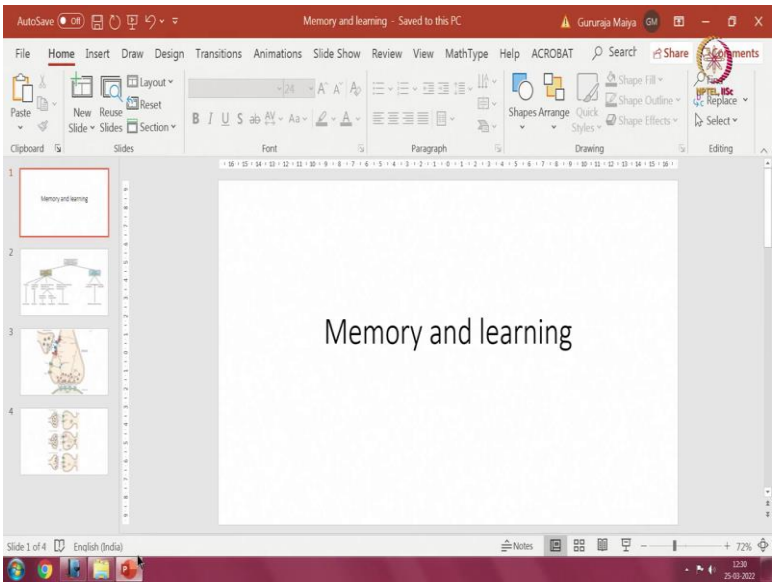

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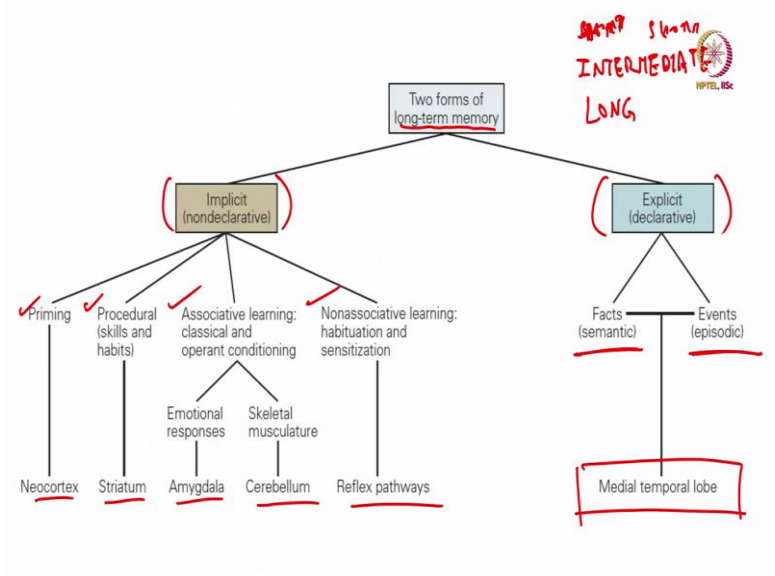

Now, so, this is what I was say saying. So, there are 2 broad classifications of implicit and long-term memory; incidentally it is called long term-memory. There are three types, it is called as short-term, intermediate and long. So, long term memory which is the point of interest is divided into implicit and explicit. Now, within implicit itself there are several other kinds of classifications which have been brought forward which I thought you should understand.

So, you can have different things called as priming, procedural, you can have associative learning and non-associative learning and the relevant paths within the head are listed over here. I would not you like to delve too much into these topics for primarily because, it's very difficult you know you start thinking about one of them it looks very similar to something else.

Now, this is more interesting, you have facts which are kept in your declarative memory and events which are kept within your declarative memory. So, they are semantic parts of the memory and then there is episodic memory and most of it is located within medial temporal lobe.

Now, the medial temporal lobe if you remember from your earlier classes, contains very important structures responsible for memory, that is the hippocampus, the amygdala and also the mesial temporal cortex, which is the part of the temporal lobe in association with these areas. So, I will start with a little more deeper discussion, with something called as Pavlovian reflex.

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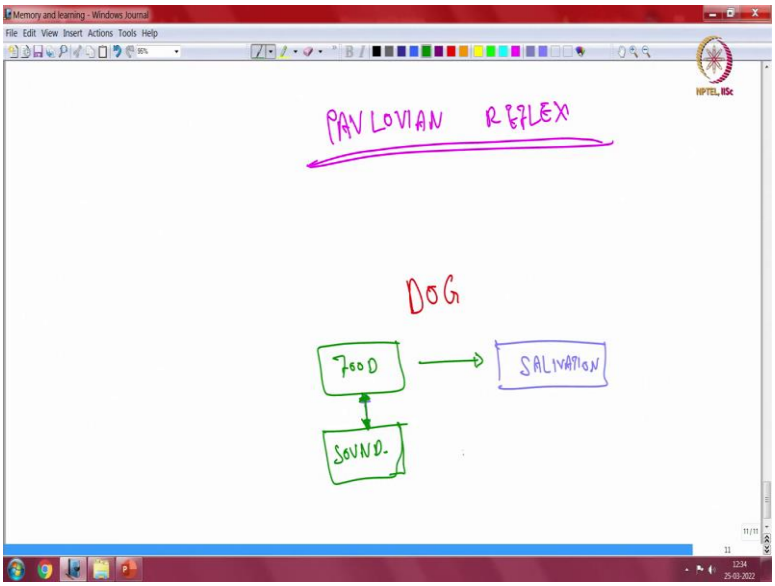

So, I think Russian scientist, not sure I will have to check back on the origins of the experiment. So, started with an experiment, in which you had a dog as the subject. He would show food and that would produce salivation, natural. So, you show food to a dog, the dog wants food and salivation is an indication that this particular the dog wants to have food and is ready for digestion.

Now, what Pavlov did is, to associate a sound along with the food which is basically like ringing a bell and you do it slightly before.

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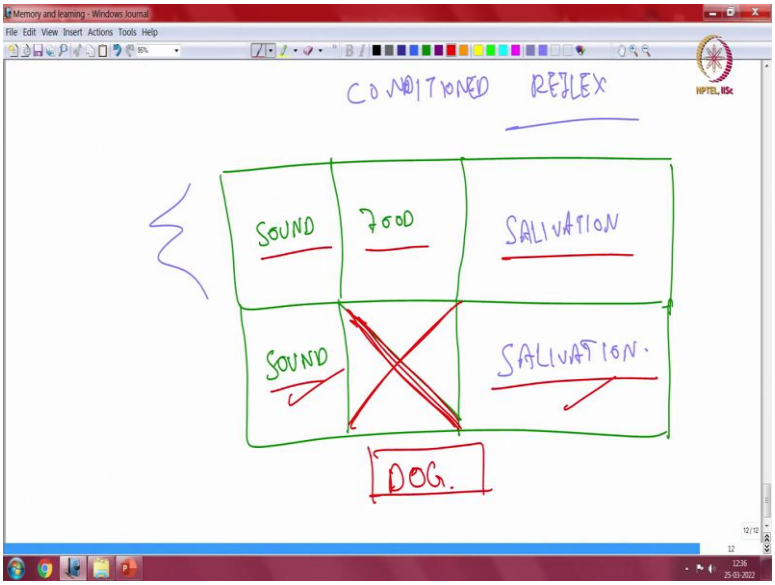

So, you have sound, food and that would result in salivation. Now, this is repeated. You know you repeat this activity over a period of time and then after some time you would notice that, sound, but no food, that would still cause salivation. So, this entire experiment is called as a condition reflex. Remember, this reflex is very different from the reflexes which you have been looking at monosynaptic, polysynaptic spinal cord reflexes, walking reflexes and things like that. So, terminologies in biology are very overlapping.

And we enjoy confusing ourselves and try to confuse others also. So, that is the condition reflex. So, you would give a lot of these sets of this set and then when you give sound you still continue to have salivation although sound and salivation are in general you know not associated. You would not salivate when you just hear the sound.

So, for that dog you have this phenomenon. And, so, this is actually a very important concept, because if you look at most of these learning mechanisms and you would find that this is a fundamental connection with many of this descriptions which are there. So, condition reflex is a method by which you are associating. Now, there are clauses to that.

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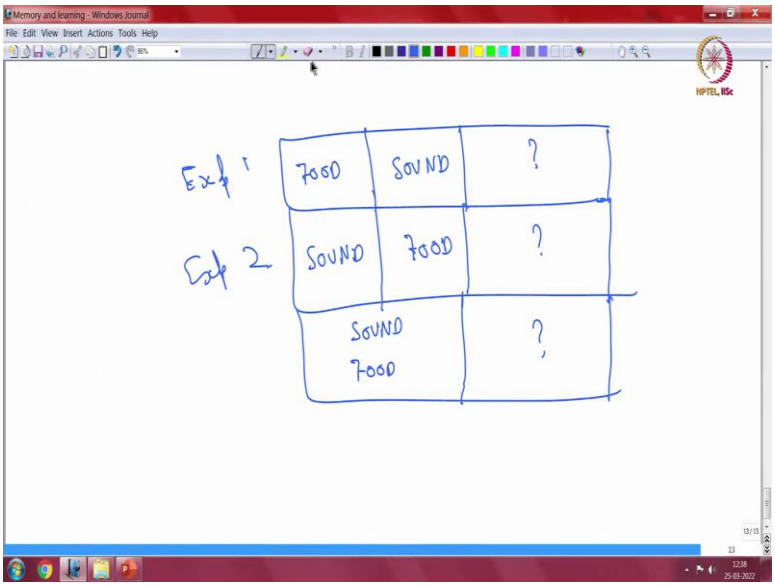

So, first case is you know you do, food, sound and what happens? You know this is the entire experiment. So, experiment 1, experiment 2. So, you would do sound, food and what happens? And sound, food together what happens? So, incidentally that is something which is interesting to note.

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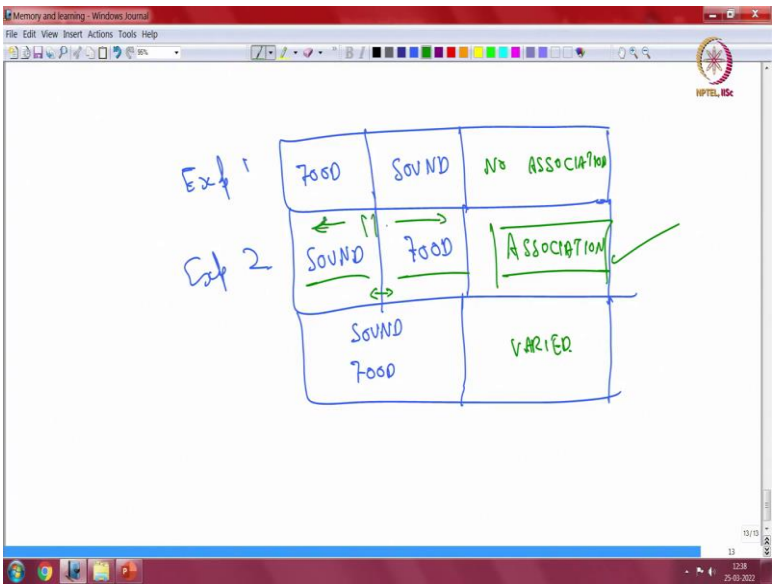

So, in the case of food plus sound at the end of your experiment, you have no association. This is association and this is, I would call it varied because I do not have experimental data on what happens with that. So, it is important that you phase your

signals. So, that is important because you need to have a short duration of interval between sound, food and to get the association linked.

So, also it should not be that say you have a long duration of time between the sound and the food, you would end up with no association. So, not only is the phasing of the stimuli, but also the timing of the stimuli is important in acquiring this association. So, this is relevant for larger kinds of networks also in which you need to associate with things.

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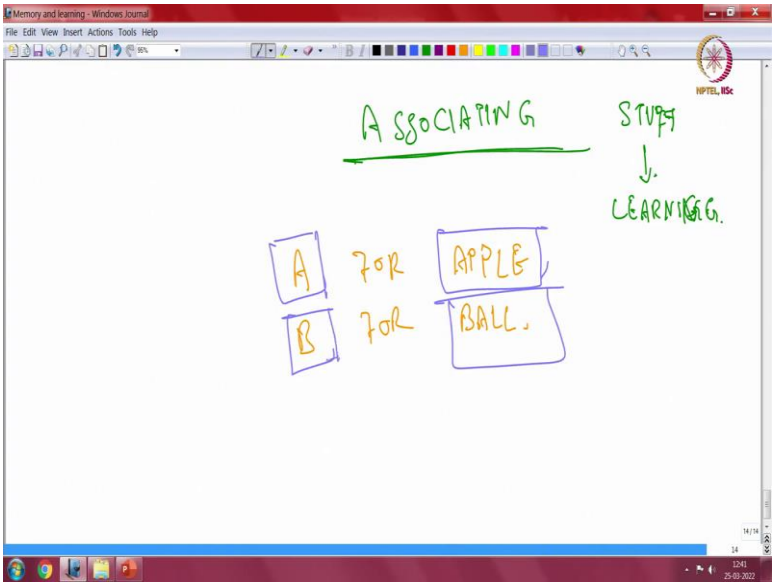

Now, this is dog experiment. You know we are discussing humans. And so, what would you think is the relevance of associating stuff as relevant for learning? You can start thinking over the differentiation between the neural network philosophy versus you know. Neural network philosophy basically depends upon what is that called back propagation, you know you have a target and then you back propagate your network until you get it.

But here we have a cardinal difference, you know cardinal difference in the sense that you need to associate 2 individual things and then you get an output connecting one of them which is not directly connected to the output. So, in the case of the dog, it is sound and salivation; sound and salivation otherwise are not associated.

But ensuring that it is connected with food, ensures that sound produces salivation. Now, associating things is important even for human beings. So, everybody get back to A for apple, B for, you know you are from childhood associating stuff for learning. So, it's a rhetorical question, whether you learn A, because its associated to the apple or whether you understand that the term apple, which is attributed to a fruit helps you in recollecting A.

But I am not discussing philosophy over here. So, what I am discussing is that human beings that learning are doing the Pavlovian dog stuff, from a very young age and that is how you know you these are fundamental things. So, you look back into anything which you have been learning, you have been doing some kind of association.

So, association between 2 separate things and that goes into one of your memories, it goes into procedural, or it goes into declarative memory. So, that is the key thing of associating stuff. Now, how deep is this principle?

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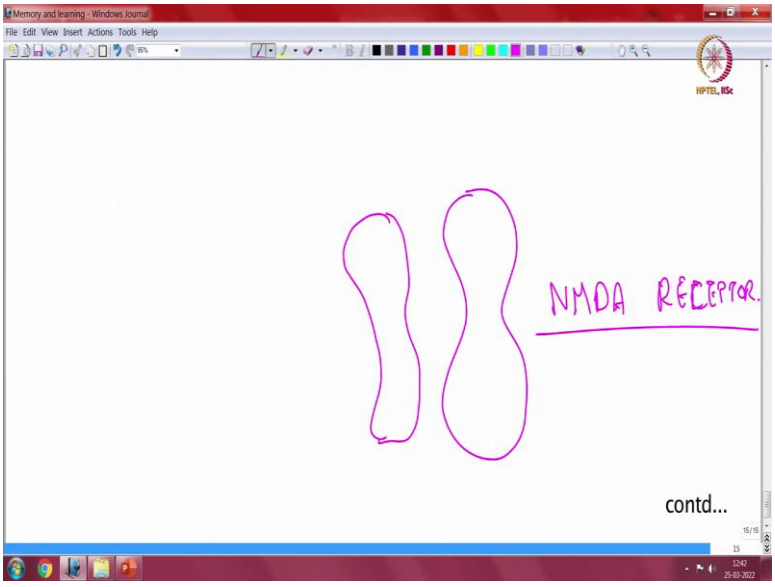

So, that is where I thought, I should introduce this very interesting molecule called as the NMDA receptor.