NBA Accreditation and Teaching - Learning in Engineering (NATE)
Professor N. J. Rao
Department of Electronics Systems Engineering
Indian Institute of Science, Bangalore
Lecture 38 - How Brains Learn

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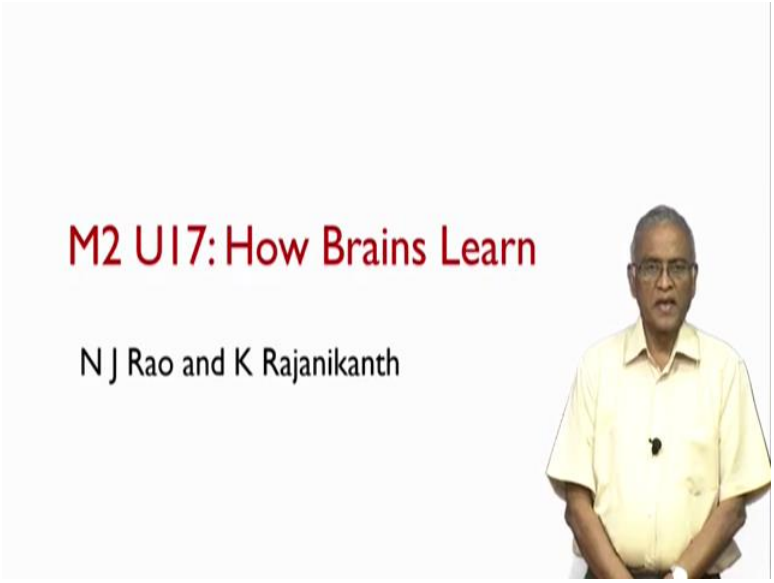

Greetings and welcome to NATE, Module 2, Unit 17 on How Brains Learn.

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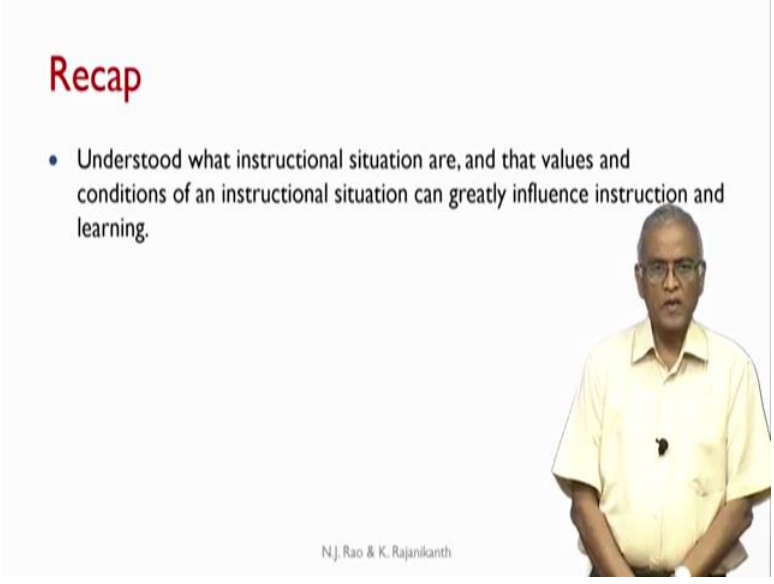

In the earlier unit, we understood what an instructional situation is and the values and conditions of an instructional situation can greatly influence instruction and learning. The entire situation are in which a teacher conducts instruction is what we are calling instructional

situation. And that is, that plays actually very, very major role in the way the students learn or in the way the teacher can conduct instruction.

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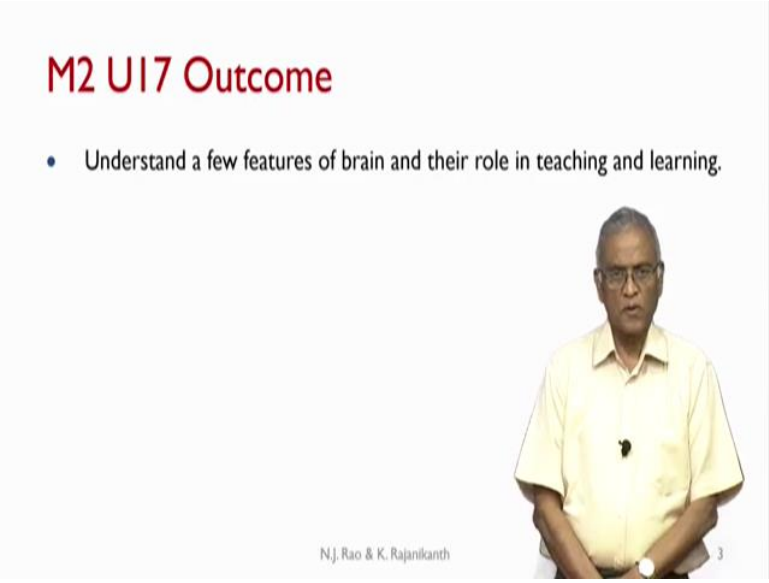

Now, we move on to a completely different topic. In this unit, we try to understand a few features of the brain and their role in teaching and learning. Brain is an entity about which we hardly know. Something we know, but we do not know how far we are from understanding it completely. But from the few things that we know, we understand that it has influence on teaching and learning.

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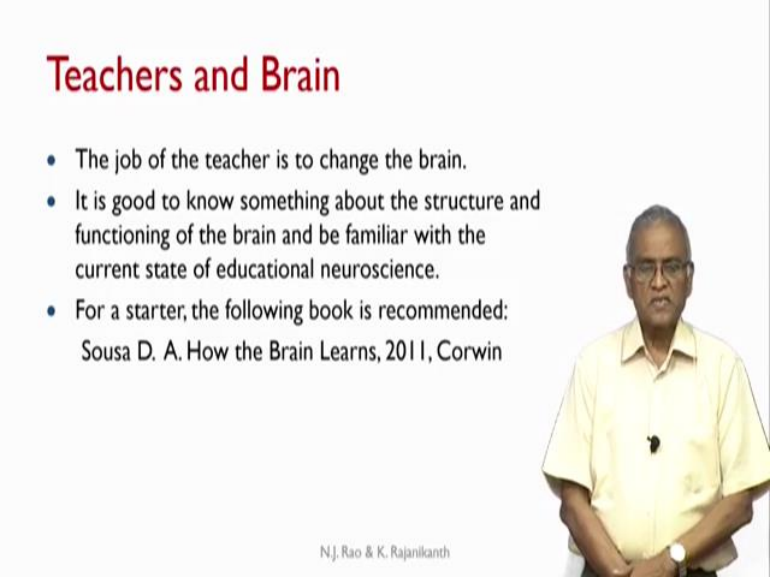

Now, teachers and the brain. What the job a teacher does is to change the brain, learning consists of changing something in the brain. So the job of the teacher is to change the brain, you can say teaching is the art of changing the brain, simple. And because we are in the business of changing the brain, every teacher should know a little bit something about the structure and functioning of the brain.

And also be get familiar with the current state of educational neuroscience, which deals with the link between neuroscience and education. So to start with, one can take a look at this particular book by David Sousa, How the Brain Learns, it is 2011 book, but it is still okay to get started with to understand. I, in my view, every teacher should read this book or something very similar to this.

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Now, let us look at some findings from the brain research. The human brain kind of continuously reorganizes itself based on the inputs, that is even physically. It is, as we are continuously receiving inputs from the external world and our brain keeps on reorganizing itself. And this reorganization will consist of what you may say sometimes new neurons are produced or the interconnections between existing neurons also keep changing. And this is called neuroplasticity and it continues throughout one's life.

So one should never agree if somebody says you cannot teach an old dog new tricks, one can always teach new tricks to an old dog. So, the brain continuously reorganizes itself, there is nothing like I am presently old, there is no way I can learn new things, let me stop learning now, that is, it need not be true. So that is the first thing. Then brains cannot multitask. Here,

the task is related to cognitive tasks. That means the brain cannot do two cognitive tasks at the same time.

So many people, students feel proud that they can multitask. They cannot. The brain does not allow such multitasking. One is, if you are not involved in a cognitive activity, like listening to music in the background, you can still do a cognitive task. Because listening to music is so deep, is in the background and it does not call for cognitive processing of that information. Or similarly, when you are driving a car, or driving any vehicle, most of the operations are a bit automatic, and so you can, your brain can do some other cognitive task.

But if there is a small crisis, somebody is just coming across, suddenly your brain switches back to cognitive activity and you have to focus attention on what has happened in front of you. So when you are trying to do two tasks at the same time, what you are actually doing is you are switching between one task and the other task continuously back and forth. And that is a very inefficient way of doing two cognitive tasks.

So, one thing you have to accept, brain cannot do multitasking. And another finding, emotions affect learning, memory and recall. There is emotions play a major role in terms of all the activities either learning, memory and recall. And another one is movement and exercise improve mood, increase brain mass and enhance cognitive processing. If we keep your body in condition by exercising, and we also say by hydrating that is drinking enough water.

Then what happens is your, it improves the mood of the person and to that extent it will enhance cognitive processing because the statement above, when your mood is good that is when you only have positive emotions, your cognitive processing also improves. And it was also observed, teaching and learning can be more difficult at certain times of the day. What we call circadian cycles, something like between 2 and 3 in a day is not the best period to learn something new.

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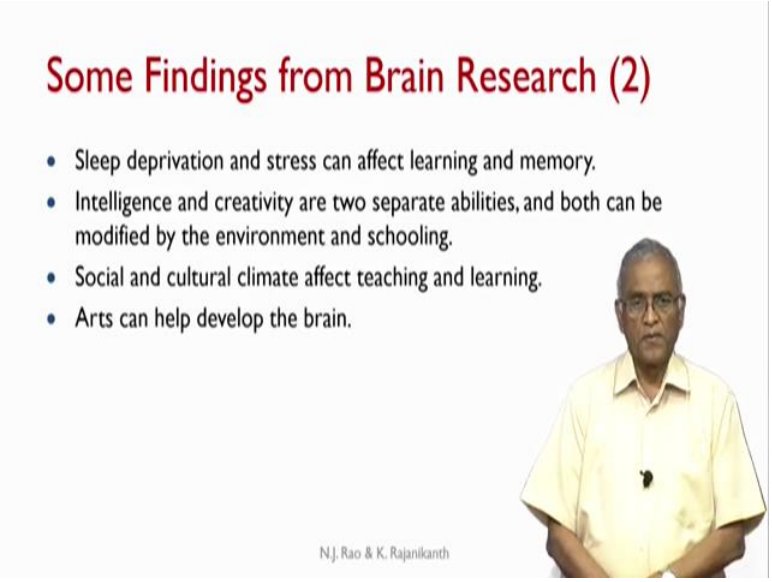

Now, sleep deprivation and stress can affect learning and memory, that I think everybody is aware of it. But when sleep deprivation and there is stress, there is some change happens in the chemistry of the brain, some hormones get released, which will affect the learning and memory activities. And intelligence and creativity are two separate abilities, they are not the same. Intelligent person need not be that very creative and a creative person need not be that intelligent.

And both can be modified by the environment and schooling, one can be trained in both. And social and cultural climate affect teaching and learning. This is also quite well known. In a classroom if there is bullying, for example, the environment social climate is not conducive to learning. Because when the student always, when a particular student feels threatened all the time, obviously, his learning seriously gets affected. And it is also known arts can help develop the brain.

If you are participating in any kind of activity that is related to art or sports, it develops the brain. So that is why it is necessary that one has an integrated experiences like this.

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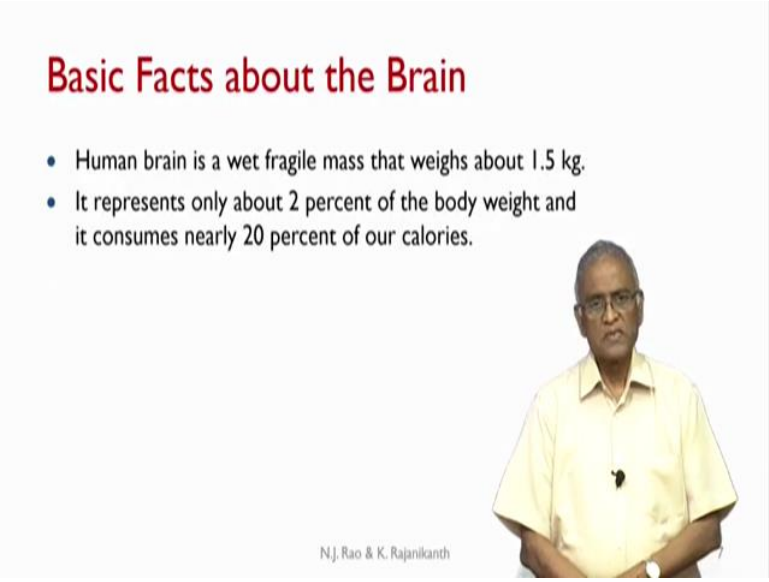

Now, let us look at some basic facts about brain. Human brain is a wet fragile mass that weighs about 1.5 kg. And it represents about 2 percent of the body weight and it consumes nearly 20 percent of our calories. And mind you that unless you have sufficient energy and hydrate yourself, especially during times of examinations and so on, when the brain works a little harder, that means you consume more calories and you require more water. That is why students generally keep drinking water during the examination, because of the brain activity, not because of the stress.

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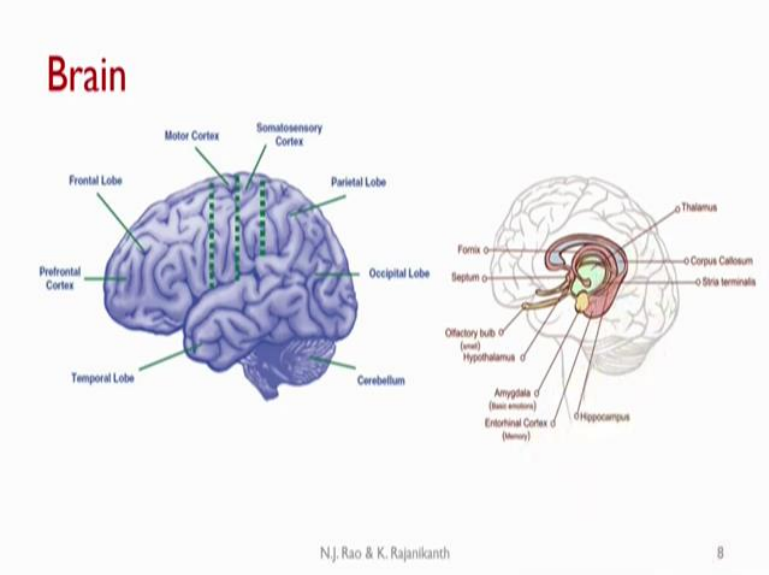

Now, let us take a look at some pictures of the brain, we will not spend too much time on its different parts, its structure and so on, but it is good for you to explore this by yourself. So,

this is how the brain from the side looks like and it has what is called frontal lobes and prefrontal cortex. And these are different portions dedicated to different activities. And these are temporal lobe, motor cortex, somatosensory cortex, then parietal lobes, occipital lobe is this whole bottom part of the brain, is dedicated to processing visual inputs.

And then you have what is called cerebellum is nothing but literal translation is small brain, okay. We will not worry about the detailed structures of this. And here this is a slice of this from one side and this part of the brain is called limbic system. And there are many important structures in this, which will have great influences, especially about emotions. We will particularly look at this little fellow here called amygdala, has a major impact on learning. We will only focus on a few parts of the brain.

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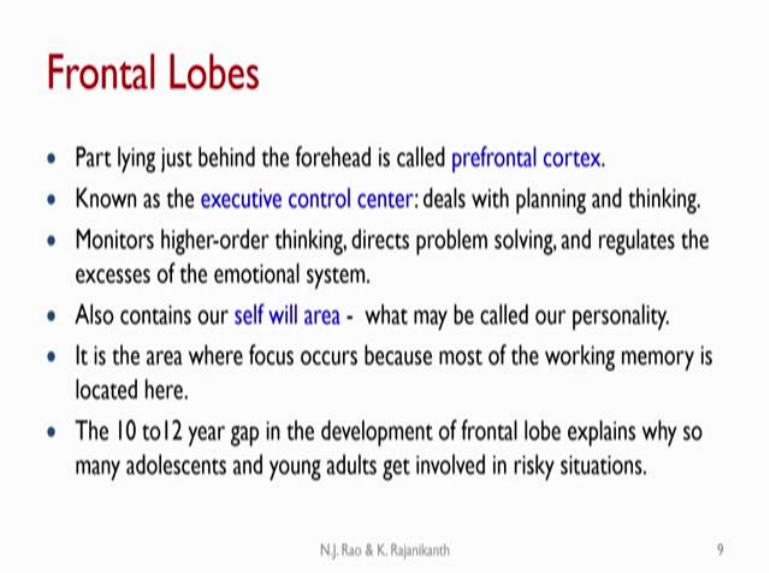

Now, let us look at frontal lobes. As we have shown, that is the part of the brain that is right behind the forehead is called prefrontal cortex. And it is also known as the executive control center, deals with planning and thinking. This part of the brain is obviously very important, crucial to human beings, that actually makes human beings different from other animals. And the prefrontal cortex monitors higher order thinking, directs problem solving, and regulates excess of the emotional system.

If, I am sure depending on the kind of experiences that we keep going through, sometimes we have excess of emotions. And the prefrontal cortex also plays a role in regulating this emotional system. It is also known that if one practices yoga extensively, the prefrontal

cortex can get altered and can have a more ability or more ability in higher order thinking and in problem solving.

And it also contains what we call our self will area, what may be called our personality. So the features of our personality are the ones that exist in the prefrontal cortex. And another very important aspect, it is the area where focus occurs, because most of the working memory is located there. We will be presently seeing what working memory is and all our learning, the working memory plays a key role. And this working memory is located in the prefrontal lobe, namely the prefrontal cortex.

And another issue is, there is a 10 to 12 year gap in the development of the frontal lobe. The frontal lobe does not fully form when a child is born, it slowly evolves to that extent, that means lots of neurons kind of get produced and get readjusted and it takes time for it to evolve. The rest of the brain, like the emotional part, kind of grows much faster than the prefrontal lobe to the extent the young adults or many adolescents, their prefrontal cortex is not fully developed to the extent like their behavior is likely to be affected more by, influenced more by the limbic part of their brain.

And to the extent they are likely to get into risky situations. There is almost 10 to 12 year gap. That is why by the time one is about 22-23, this kind of getting involved in risky situations will start reducing at least, that is about frontal lobe, which is of relevance to us immediately as far as the teaching and learning are concerned.

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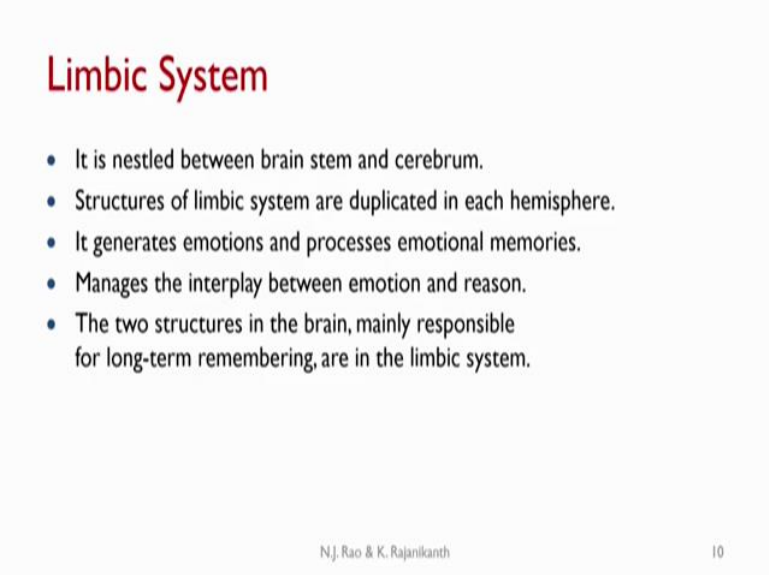

Another part that is very important to us, it is the limbic system, which I have shown you in the earlier slide, which is nestled between brainstem and the cerebrum, it is a middle area. And the structures of this limbic system are duplicated in the each hemisphere. As brain from the top if you look at as if there are two hemispheres and there is almost like there is a cleavage between the two parts and you can identify the two hemispheres. So, these structures of the limbic brain get kind of duplicated in both the hemispheres.

This is the part we will not get into the details, there are so many structures in that, each one plays a role, but together the limbic system generates emotions and processes, emotional memories. We will presently come to that and it happens to start with mainly through amygdala. It also manages the interplay between emotion and reason. That is the way the neurons are, they pass through the limbic system. So, what happens, any kind of experience, any sensory data that comes, it starts adding the emotional component also to that.

And you should remember the two structures in the brain responsible for long-term remembering are in the limbic system. So a teacher should be aware that long-term remembering is greatly influenced by the structures in the limbic system.

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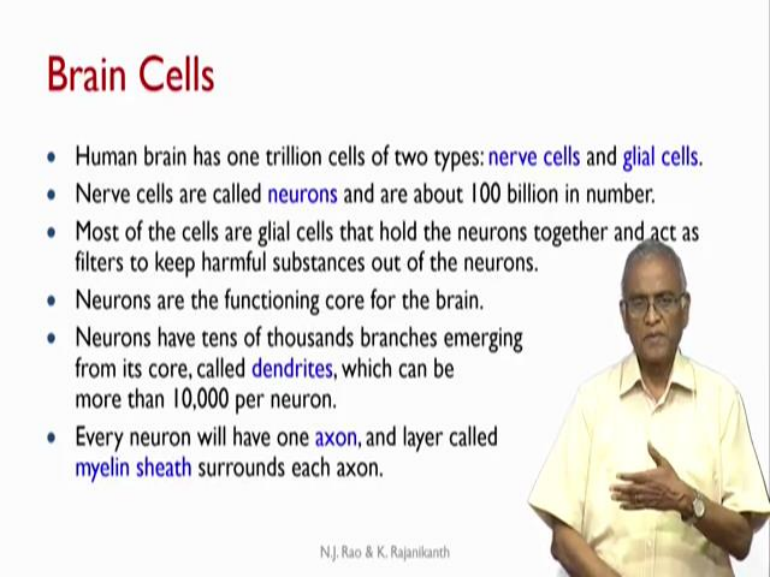

Now let us come to the main part, namely the brain cells. Human brain has about 1 trillion cells, the numbers are huge. There are two types, nerve cells and glial cells. Nerve cells are called neurons and they are about 100 billion in number in everybody's brain, and this number will keep changing with time. Some cells unused are likely to die and depending on your experience, new cells will also grow that is…whereas the glial cells, there the elements

that keep these neurons, provides this a kind of background in which neurons interact with each other.

They also filter all the harmful substances out of the neurons, and they provide the required energy to the neurons. So our focus will be nerve cells rather than the glial cells. So you can say neurons are the functioning core of the brain. And on top of this, neurons have tens of thousands of branches emerging from its core, they are called dendrites, which can be more than 10,000 per neuron, which is a huge number. And imagine each dendrite can have some kind of a linkage with some other neuron.

So, if you are looking at the brain as number of interconnections, you have 100 billion multiplied by a possibly 10,000, you are talking of 1,000 trillion possible connections between neurons. Each connection has some meaning. So, if you look at, every neuron will have one axon and a layer called myelin sheath surrounding each axon. Let us take a look at that.

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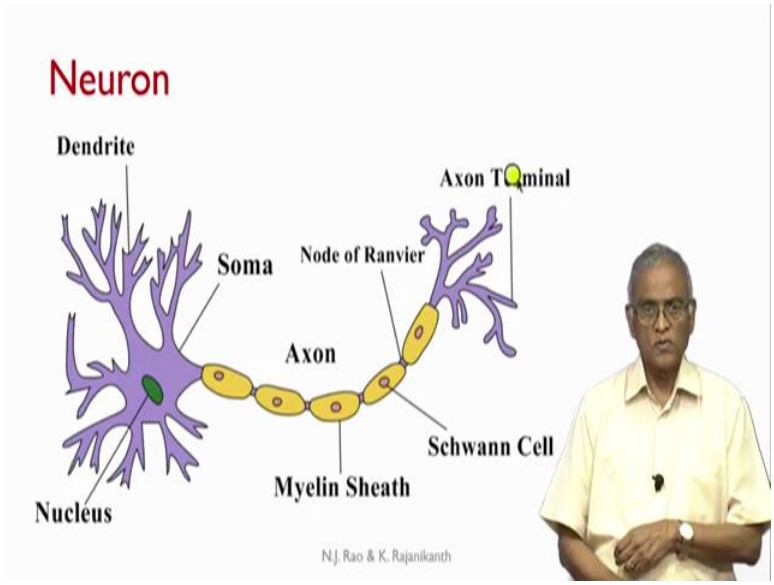

So, you have dendrites, these are the ones, that means this part is getting connected to other, each one gets connected to some neuron, other neuron. And when it gets connected, it gives you some kind of signal, electrical signal comes into this. And what happens, finally, when it comes here, it is a result of the number of inputs that come from different places. So the signal strength here will depend on what are all the inputs that have come from various dendrites.

And this axon is the one that is about it goes from here to the other end, it depends, sometimes the length of this axon can be very small, sometimes it can be very long, that is right from the brain to the different parts of the body as well. This is where you talk about the axon terminal, each axon will have several terminals and then that terminal will get connected to a dendrite of some other neuron. So, when you have such a thing and the nucleus is the one that obviously determines the structure of the whole thing and so on.

And here if you look at this axon is connected and it has certain kind of insulation you can call it, it is called myelin sheath. Now, what happens is the way the signal transmits if a signal, voltage signal comes here, it kind of keeps jumping from one node to the other like this. And if the myelin sheath is strong, it is sufficiently, then the signal travels faster from here to here. That means, your response times can be better. But if myelin sheath is weak, it is like it is leaking kind of wire, if the myelin sheath is thin, or it has not grown sufficiently, then the signal strength will be poor or it will travel slow from here to the other.

And the signal can be of the order of a few millivolts, actually, not in Pico volts and all that, and what happens if you do not have sufficient exercise, and if you are not sufficiently hydrated that you do not take enough water, this myelin sheath is likely to be weak or thin. That means the speed of transmission of signal from here to here can become weak. So, first thing is all of us should drink sufficient water and also keep ourselves physically fit for the brain to function properly.

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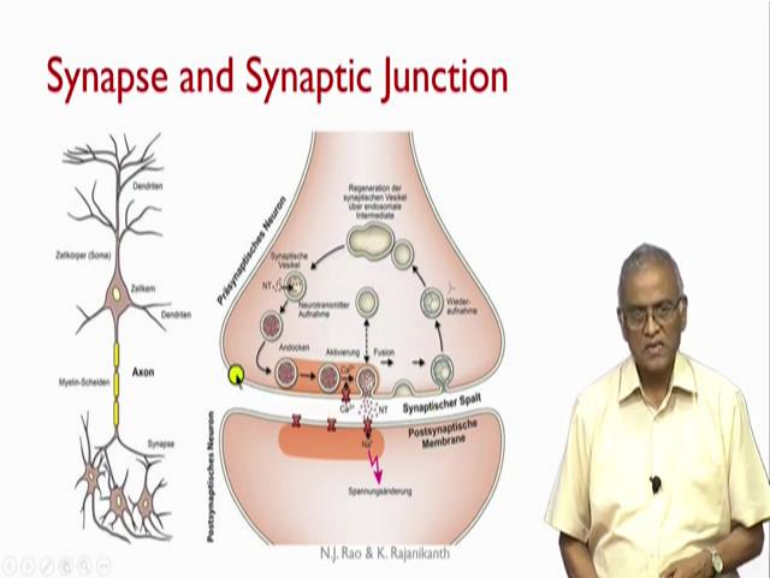

And again, with respect to the what you call, with respect to the neuron and its connection to others, this is another way of actually showing. These are all the dendrites and going into the, this is nucleus and this is the axon and the terminal here gets connected to other dendrites, dendrites of other cells here. And this connection here is shown here in expanded version. That means, this is called synaptic junction. Synaptic junction is not physical at all.

So, end of one of the axon terminal will end here and this is the other end of the dendrite. The connection here is there is space here of a few nanometers. And whenever a signal is to be transmitted to the other one, it releases some neurotransmitters and these neurotransmitters are picked up by a cell here and then this is in turn will produce the signal. So what happens is the connections between two parts, between two neurons is always chemical rather than electrical, but within the neuron the processing happens electrically. That is the nature of synapse and synaptic junction.

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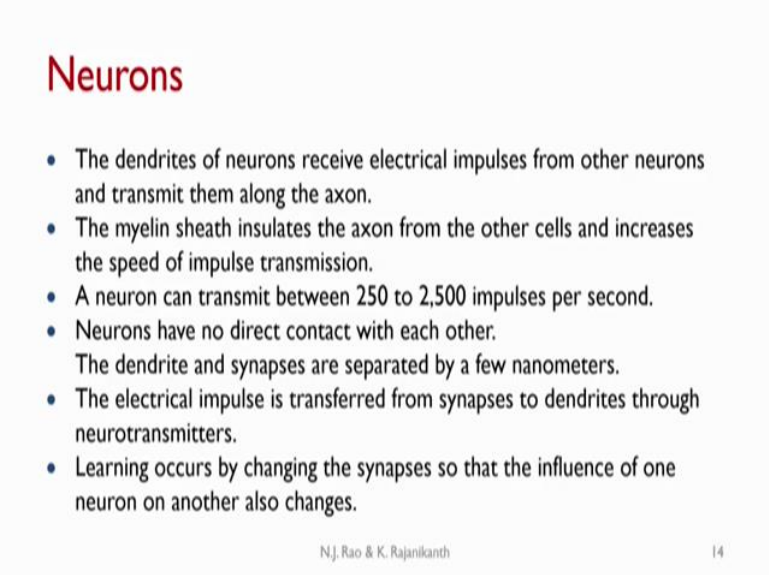

So here we just once again repeat. The dendrites of neurons receive electrical impulses from other neurons and transmit them along the axon. Myelin sheath insulates the axon from other cells and increases speed of impulse transmission. A neuron can transmit between 250 to 2,500 impulses per second. So, the times involved are in terms of a millisecond or a fraction of a millisecond kind of thing.

So, neurons have no direct contact with each other and electrical impulse is transferred from synapses to dendrites through neurotransmitters. Learning occurs by changing the synapses, so that influence of one neuron on the other also changes. So, when new synapse is formed or

the strength of connection between two dendrites or the dendrite and the synapse is also what we call, if a deep learning has taken place that connection will be stronger. And where the connection is stronger, you will also be able to recall that whatever information that is implied by that.

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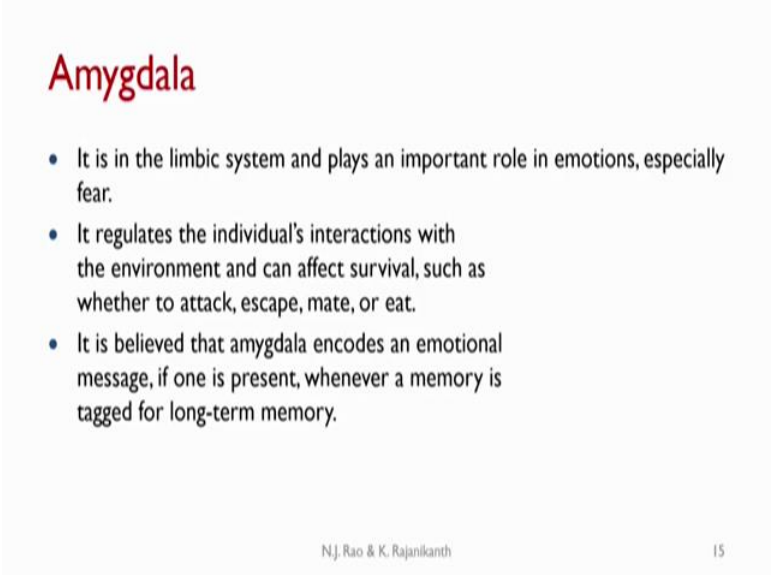

Okay, let us come to another part, namely amygdala. It is in the limbic system and plays an important role in emotions, especially fear. It regulates the individual's interaction with the environment and can affect survival such as whether to attack, escape, mate or eat. Because mind you, these things have evolved over millions of years, so they do have a very dominant effect on how the brain functions.

It is believed that amygdala encodes an emotional message, if one is present, whenever a memory is tagged for a long-term memory. So what happens, whenever I experience something, there is always an emotion that takes place. First, initially, it will be positive or negative. So, amygdala regards it as positive or negative, immediately that action takes place. And if something is strong, then what happens is the rest of the brain cannot overrule that. And rest, the brain recognizes it as a threat. When it is a threat, it will affect my reasoning ability, which means that my learning is also affected.

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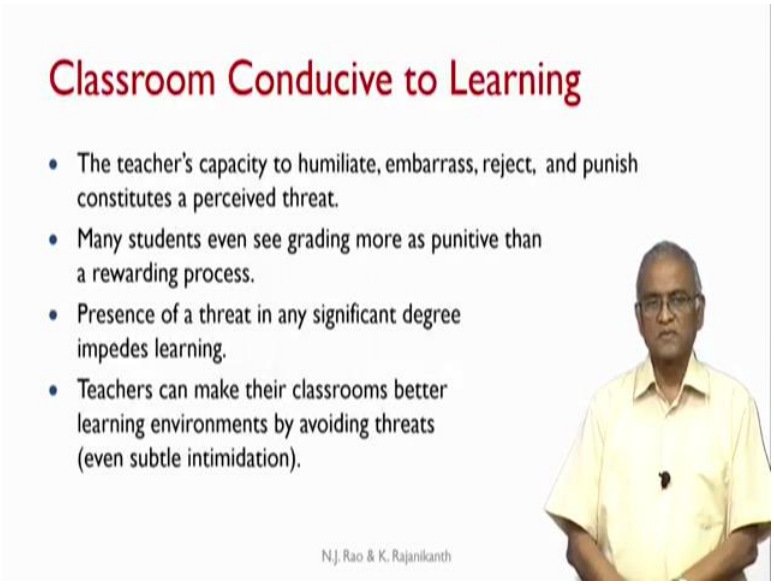

So, what is the implication of that for us? This is where teacher has to be aware of. The teacher's capacity to humiliate, embarrass, reject and punish students constitute a major perceived threat. It is only perceived threat, you may not be punishing anytime, or if the student feels that in the kind the way the teacher speaks to you, either is humiliating you or embarrassing you, or rejecting you, then the student is not likely to learn properly.

So, for a classroom to be conducive for learning, the teacher has to make sure he is never felt as a threat to the any of the students, especially the weak students. And also what happens, even grading is viewed by students as punitive rather than a rewarding process. Fundamental belief is, the students see it like that. So teacher should be aware, this is how students react. And presence of a threat in any significant degree impedes learning.

And also, teachers can make their classroom better learning environments by avoiding threats or even subtle intimidation. So, first thing, because of the amygdala, the way it works, the teacher has to ensure that he has to create an environment that is conducive to learning. To make it conducive to learning, the first thing is to eliminate threats. That you have to present yourself through various activities, that you are treated more like a friend and a mentor rather than somebody who is trying to do rewarding and punishment.

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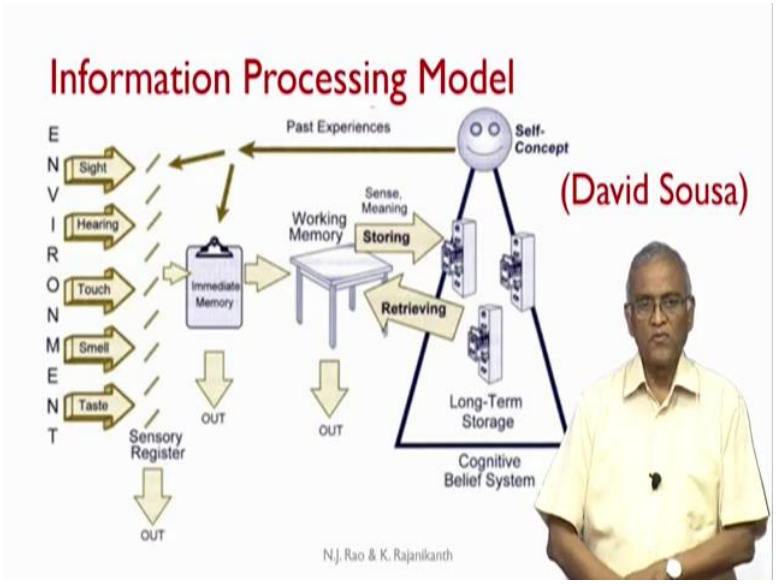

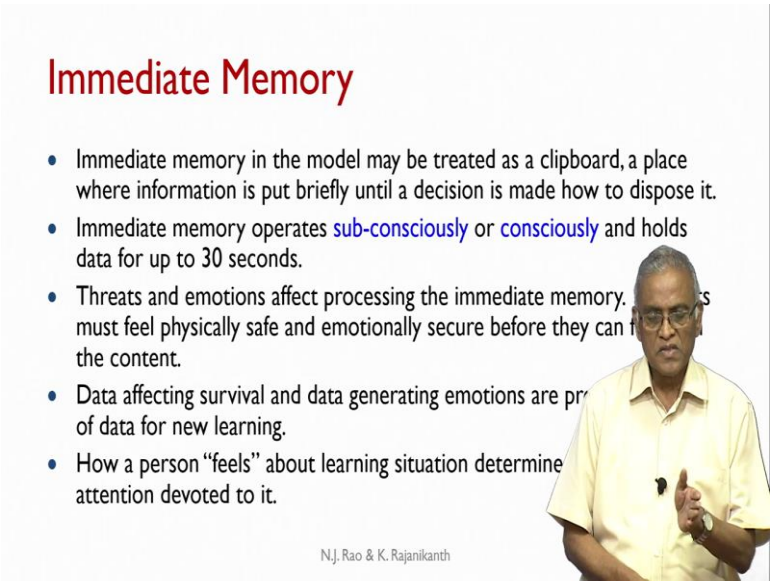

Now, we look at another major aspect of what we call, what the brain does. And this is the model given by David Sousa himself. And this is how it looks, let us take a look at, these are the environment from which you have all the five senses, from which information comes and this is called sensory register. That means when you are standing and just you are receiving information from all sides, which is not, there is no point in keeping a record of all that.

So, what happens is, the sensory register itself will keep rejecting background noise, unnecessary images and all that but it depends on how does it filter, depends on the past experience of the individual. And quite a bit of the information, possibly 90-95 percent of the information that comes to the sensory register is thrown out after due processing based on your past experience, when it comes to what is called intermediate memory.

Intermediate memory is it lasts for a few, maybe 30 seconds, in which you have to make a decision whether you are going to process that or not. And this is where the attention becomes more important. What information do I want to focus, that is also decided by your past experience. And if you do not, if you are not having attention because of this, it will get thrown out or most of it thrown out and the remaining one moves to what is called working memory.

And the working memory, also if you are not processing, it also gets thrown out. But it also receives information from this what we call, this is you, all the past experiences, people give what is called self concept or cognitive belief system, all the long-term storage is all here in this particular area. And when you are processing, you are not only using the information that is coming from external source, that is what teacher is presenting, you also retrieve some information from long term memory and process it.

And processing consists of sensing and meaning, these two activities. Depending on the result of the sense making and meaning, the final information will go into the long-term memory, that is the basic information processing mode. So, a teacher should be aware of what are all the issues that are involved so that we encourage the current processing of information in the working memory and make sure that the conditions and the way a teacher behaves will encourage the correct information to go from immediate memory to the working memory and proper processing is done here. That is broadly the model of information processing as by David Sousa.

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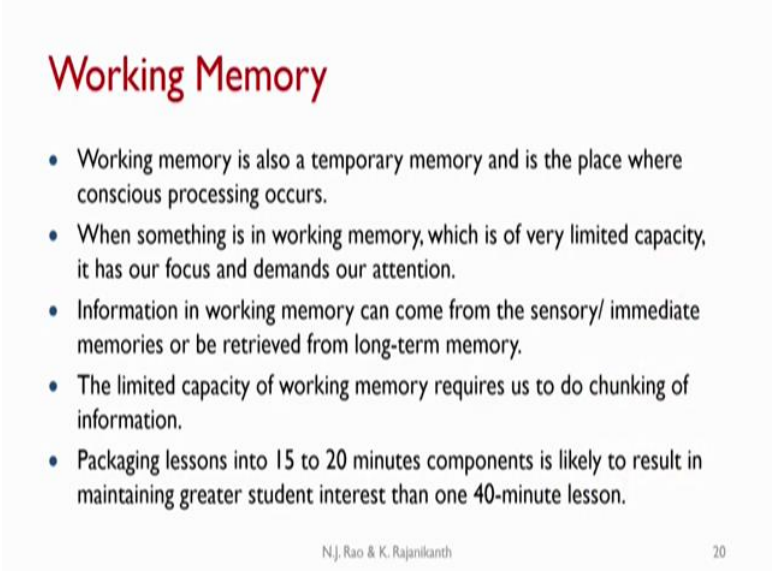

This is what I have just now communicated. What is the result now of all this? Because of the limited capacity of the working memory you cannot bring in, you cannot put in too much of information in one shot. And also you must give enough time to the student to process something before we move onto something. And by and large it is understood because of the structure of the working memory or short-term memory, packaging lessons into 15-20 minute components is much better in maintaining greater student interest than 140-minute lesson.

So do not continuously lecture for more than 15-20 minutes. Though unfortunately, in a course offered in MOOC, sometimes we have to go beyond 30 minutes as well, because of the very nature of the structure.

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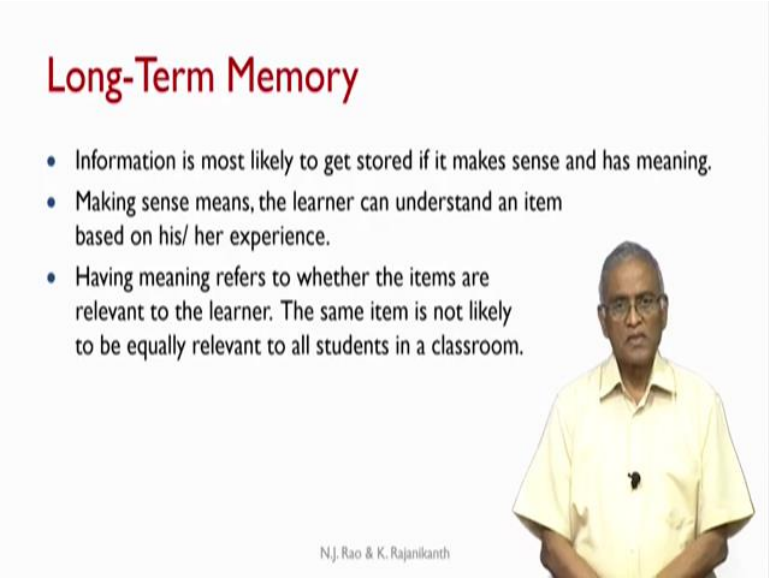

And, in the long-term memory, information is most likely to get stored if it makes sense and has meaning, which we have already mentioned. Making sense means the learner can understand an item based on his or her experience. You can understand something, but understanding does not guarantee that it will go into the long-term memory. It is only valuable up to some point. And meaning refers to whether the items are relevant to the learner.

And sometimes what happens, even though I have learned some item, I may feel it is not relevant to me at all. So, different students may find different relevances to the information that is transferred. Unless it is learned and make and has meaning, it cannot go into the long-term memory, that is the issue.

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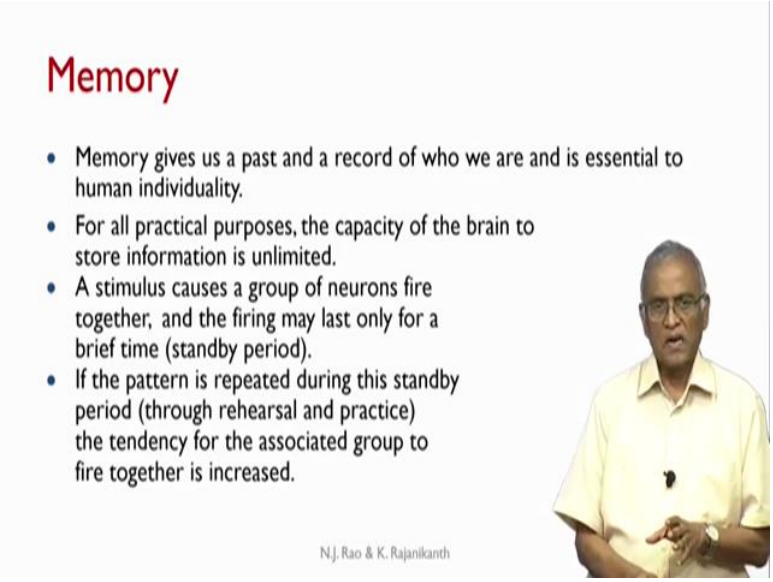

Memory gives us a past and a record of who we are and is essential to human individuality. For all practical purposes, the capacity of the brain to store information is unlimited. Nobody has yet found what is the final limit to the kind of things that are stored. That is why you keep hearing about people with phenomenal kind of photographic memories and ability to remember all kinds of past events and so on. See, whenever there is a stimulus, it causes a group of neurons to fire together and the firing may last only for a brief time.

And once again, if the pattern is repeated during the standby period, and how does it happen? When the repetition, repetition happens through rehearsal and practice. So during that standby period, if you are rehearsing or practicing something, the associated group of what you call neurons, their tendency to fire together is increased, that means you have strengthened that signal. And every time a stimulus comes, all the associated neurons will fire together and that is what is required for long-term memory.

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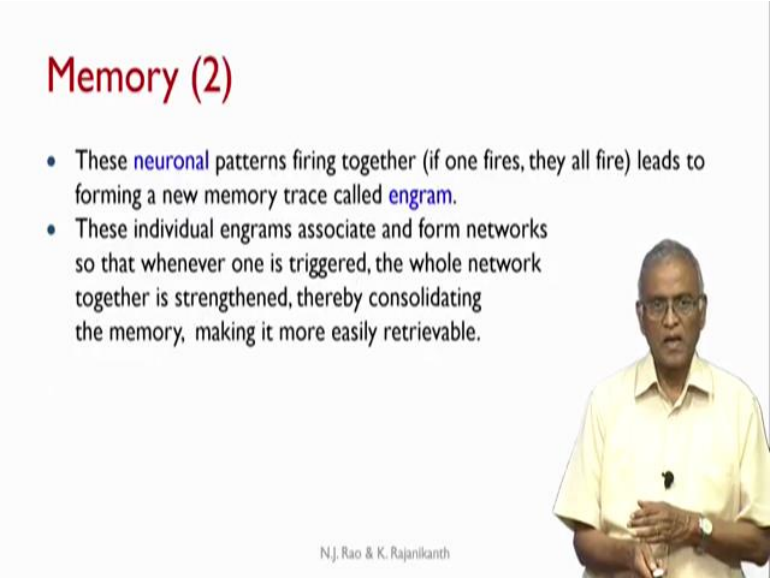

And these neuronal patterns firing together, they are called engrams. And then what happens, these individual engrams associate and form networks with other engrams, that is what for example, our idea of relating one to our previous knowledge. So when they are connected to more of earlier such engrams then what happens, the whole network together is strengthened. And when you consolidated this in the memory and it makes it easier to retrieve information. That means any kind of trigger related to any engram, that brings the entire network together into our conscious, that is into the working memory, that means it is retrievable.

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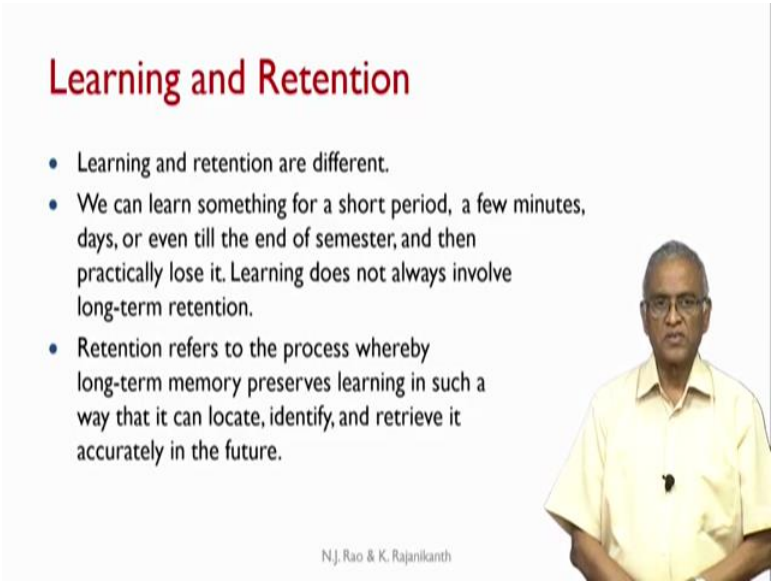

Now, let us talk about learning and retention. One can learn all right, but need not retain that information for a long period. So, these two are different. We can learn something for a short

period like a few minutes or days or even till the end of the semester and then practically lose it. I think all of us have experienced, you cannot retain all the details that you have learned or mastered in earlier semesters or earlier part of your education, you cannot completely recall.

So, learning does not always involve long term retention, that should be remembered. Teachers cannot easily say that you have learned everything in the two semesters earlier, why are you forgetting that kind of thing? Because that is the nature of learning and retention. So, retention refers to the process whereby long-term memory preserves learning in such a way that it can locate, identify and retrieve it accurately in the future. That is what is called retention.

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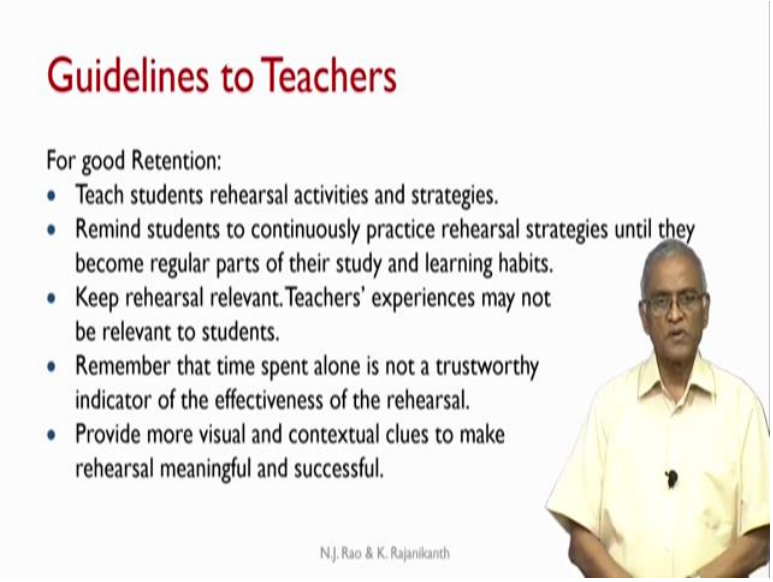

So, what are the guidelines to teachers because of this, of learning and retention? Teach students rehearsal activities and strategies. So, you must provide opportunity for rehearsal and practicing and they must be taught as well. Remind students to continuously practice rehearsal strategies until they become regular parts of their study and learning habits. So you cannot cram everything a few days before the test or examination. You have, and some students naturally do it.

And sometimes those students who naturally do this rehearsal and what you call, rehearsal and practice, they are also ridiculed by their friends. Keep rehearsals relevant, and teacher's experience may not be relevant to the students. Mind you, my practice or the way I have done, those experiences may not be relevant to your students. So you should not enforce this is what worked for me, and you have to do the same kind of thing.

And also, remember that time spent alone is not trustworthy. If I am doing something by practicing something wrong all the time, then obviously, I am learning the wrong things. So, practicing these things alone is not trustworthy indicator. And so, rehearsal, if it is possible, you should do it with a group. And actually in many places, study groups form and they talk to each other and keep exchanging and if there are any small errors in that, others are likely to correct that.

And provide more visual and contextual clues to make the rehearsal meaningful and successful. So, what happens is the, we have looked at the three aspects, the emotional aspect and how the memory works and then the retention and learning. Only we looked at these three, there are many, many more aspects of the brain that have influence on the quality of learning by the student.

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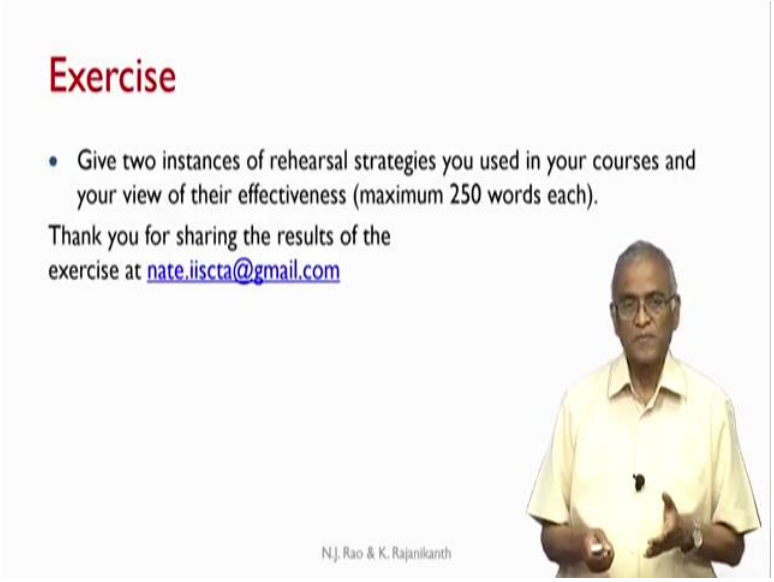

We do suggest teachers spend some time in understanding the structure of the brain or some parts from educational neuroscience, because that is our profession. The more you learn and try to relate to what you are doing, you are likely to do your things better. So as an exercise, we request you to give two instances of rehearsal strategies that you used in your courses and your view of their effectiveness, what is your experience? Write maximum 200 words and share with us at this particular email ID.

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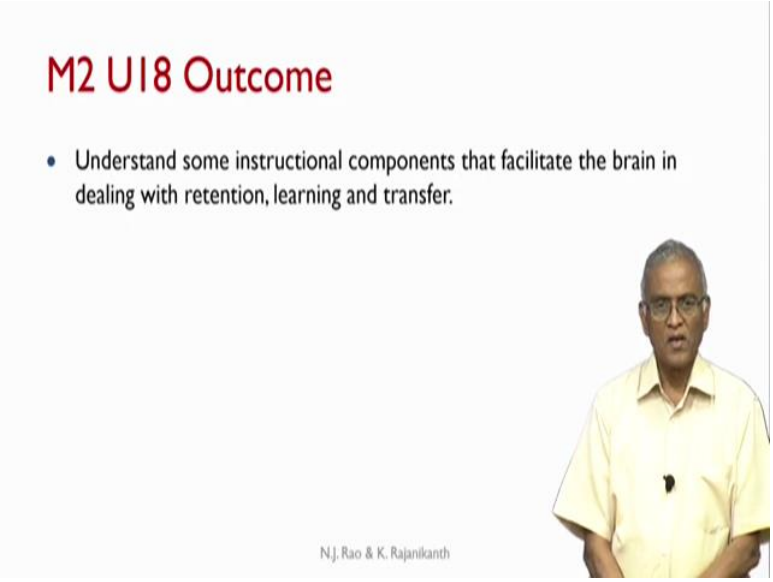

So in the next unit, we will try to understand some instructional components that facilitate the brain in dealing with retention, learning and transfer. Instructional components are, they are independent of the discipline or subject matter, they are independent of content. And these components can be used anywhere judiciously in some combination, and we will identify or we will present some components of that which have been proven in the field to contribute greatly to the learning. Thank you very much.