Introduction to Brain and Behaviour
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Lecture-22
Mechanisms of Memory

Hello and welcome to the course introduction to brain and behavior. I am Dr. Ark Verma from IIT Kanpur. This is week 5 of the course. We have begin to talk about the neural basis of memory. In this lecture we will talk about the mechanisms that establish or that basically using which memory is established.

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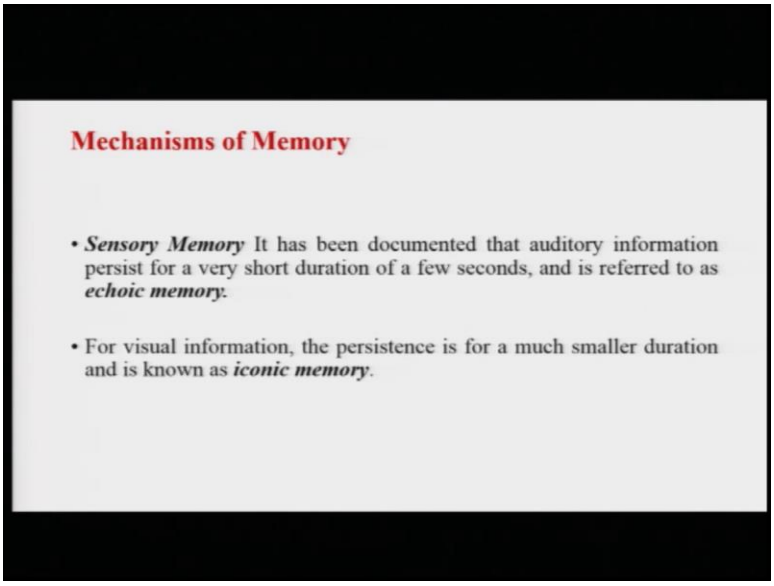

Let just talk about sensory memory. Now, it has been documented that auditory information can persist for a very short duration of up to few seconds and this persisting auditory trace is referred to as echoic memory. For visual information the persistence is for a much smaller duration and is known as iconic memory.

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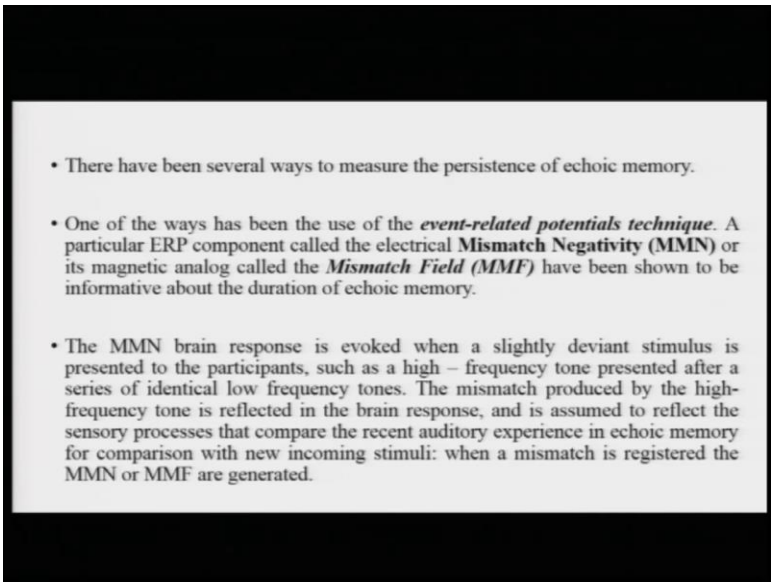

Now, there have been several ways to measure the persistence of echoic memory. One of the ways has been the use of the event-related potential techniques. We have talked about the ERP technique in the past. Now, a particular ERP component called the electrical Mismatch Negativity component or say for example if you are using image e its magnetic analog is called mismatch field component.

They have been shown to be very informative about the duration of the persistence of this echoic memory. Now, this MMN brain response is basically evoked when a slightly deviant stimulus is presented to the participants such as say for example a high frequency tone is presented to the participants after it has been presented with a series of identical low frequency tones. Things like pa pa pa pa paa something like this.

As soon as this paa is registered there is this component in the brain that evokes a particular response. This mismatch basically produced by the high frequency tone is reflected in the brain response and is assumed to reflect the sensory processes that compare recent auditory experience in echoic memory for comparison with new incoming stimuli. Now, again as I was just saying when a mismatch is registered the MMN or the MMF are generated.

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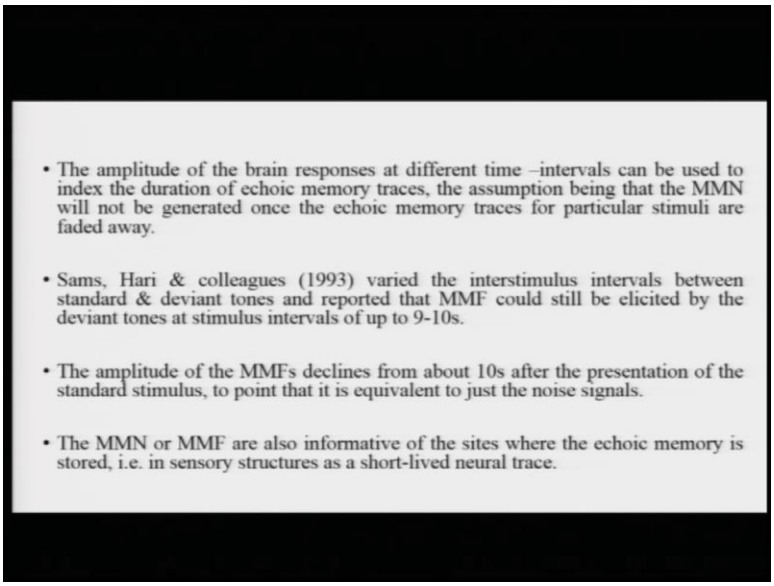

Now, the amplitude of the brain responses at different time intervals can be used to index the duration of echoic memory traces. What does this mean? Basically if the brain responds let us say, 200 milliseconds is very high we are sure that the trace is still alive and it is there available for comparison. If let us say we are testing this after 2 seconds and the amplitude is reduced so you know that maybe partly it is been decaying or let us say after 10 seconds if there is no firing at all or if there is no MMF or MMN generated at all.

Then we know that the trace has faded away and therefore it is not available for comparison with this new incoming stimulus and in that sense that is one of the reasons why the mismatch negativity is not being elicited. So, the amplitude of this brain responses at different time intervals can therefore we used to index the duration of the duration of the echoic memory traces.

The assumption being that the MMN will not be generated once the echoic memory traces for particular stimuli have faded away. Now, Sams, Hari and colleagues have varied these interstimulus intervals between the standard tones and the deviant tones and reported that MMF could still be elicited by the brain or in the brain by these deviant tones at stimulus intervals of up to 9 to 10 seconds.

So, this is probably let us say a maximum duration for the persistence of these echoic memory traces which is by the way a fairly long time, 10 seconds. Now, the amplitude of the MMFs basically declines from about 10 seconds after the presentation of the standard stimulus to the

point that it becomes just equivalent to the noise signals so that you can say that there is no MMF or MMN being generated.

The MMN or the MMF are also informative of the sites where the echoic memory traces are stored. So, basically from you know by performing activities like source estimation you can register where exactly this MMN, where exactly on the scalp this MMN or MMF are being generated and in that sense it will index the stress, the structures where this echoic memory trace is being stored. What are those structures? They are basically the sensory structures where this short lived memory trace is being laid out.

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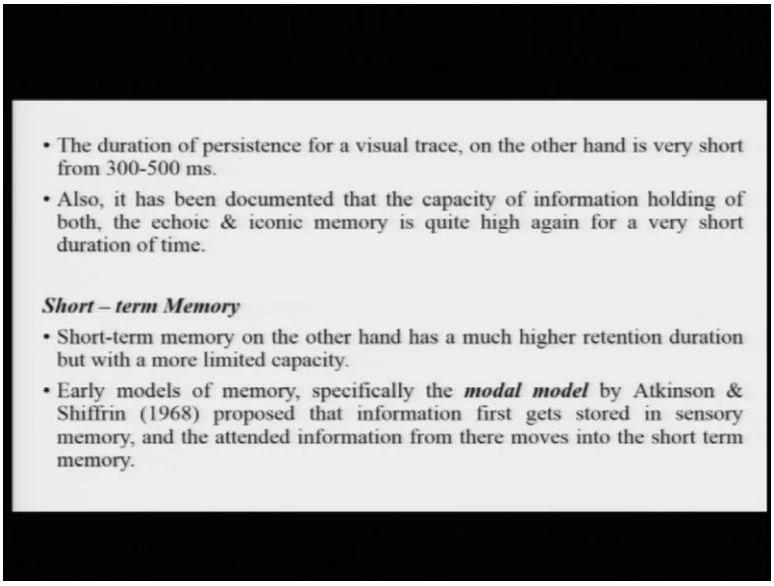

Now, the duration of persistence for a visual trace on the other hand is very very short. It is hardly about between 300 to 500 milliseconds. Now, also it has been documented that the capacity of information holding, the capacity of holding information for both iconic and you know echoic memory is quite high and although the duration is as you see very very short. Now, let us talk about short-term memory. Now, short-term memory on the other hand has a much higher retention duration up to a few minutes but it has a very limited storage capacity.

Now, as I was referring to in the last class the earlier models of memory specifically the modal model which was forwarded by Atkinson and Shiffrin long back in 1968 had proposed that information first goes and gets stored in sensory memory. Then the attended information on there

goes to the short-term memory and then the rehearse information from there goes to the long-term memory.

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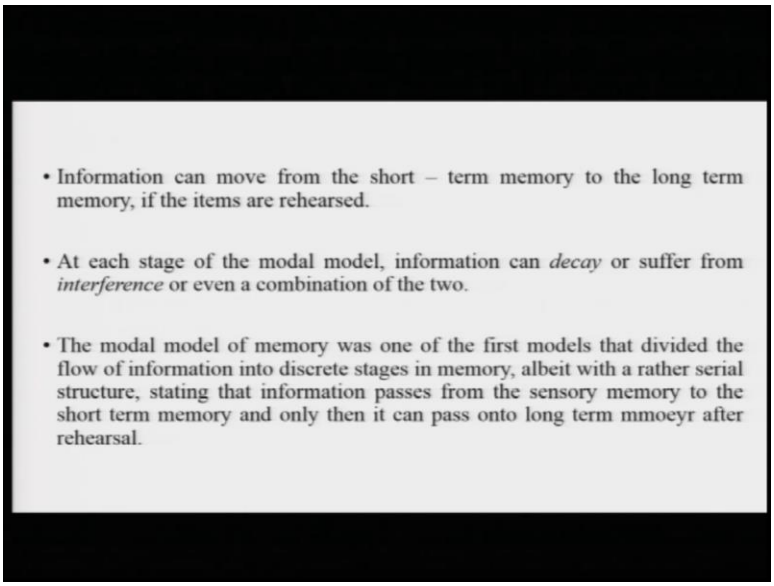

Now, this is basically the chronology of information processing that has been proposed. Now, at each stage of this model sensory, short-term, long-term the information can decay. It can fade away from lack of attention or rehearsal or say for example it can suffer from interference. Say for example being interfered with by older information or sometimes even a combination of the two.

So, this is basically what allows from decay of information from this chronology of information processing. Now, the modal model of memory was one of the first models that divided the flow of information into these discrete stages in memory, albeit with a rather you know serial sort of a structure. Since it is short-term, long-term there was no parallelism here and there is no you know provision that since anybody can directly turn into long-term memory and bypass the short-term memory stage. So, that you know facility is that processing assumption is not there.

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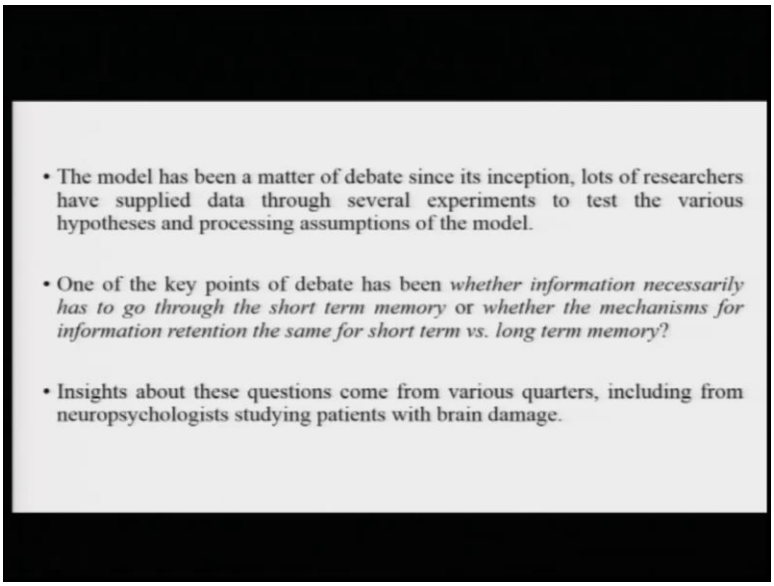

Now, this model as most model has been a matter of debate since its inception. Lots of researchers have supplied data through several experiments to test the various hypotheses and processing assumptions of this model. One of the key questions, one of the key points of debate about the Atkison-Shiffrin model is a question that whether information necessarily has to go through the short-term memory to pass into the long-term memory?

Or say for example, so the other question is whether the mechanisms for information retention are the same for short-term versus long-term memory? So, these are the 2 questions that have sort of asked you know over time. Now, insights about these questions can come from various quarters. They have come from various quarters.

In fact including studies from neuropsychologists, people who study patients with different degrees of brain damage and experimental work and animal studies etc.

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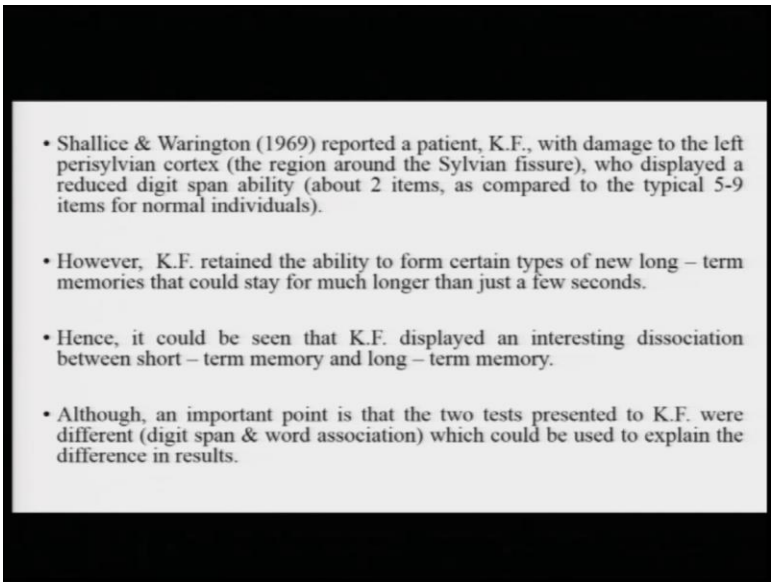

Let us talk begin talking a little bit about patients or neuropsychological studies. Now on the front of neuropsychological studies Tim Shallice and Elizabeth Warington in 1969 reported a particular patient called K.F. and now this K.F. had damage to the left perisylvian cortex around the Sylvian fissure who displayed reduced digit span ability, shortened working memory.

His working memory span was around up to 2 items whereas for normal individuals it is anywhere between 4 to 8 or 5 to 9 items. Now, K.F. had retained his ability to form certain long-term memories that could stay for much longer than for just a few seconds. Let us say hence it could be seen that K.F. displayed an interesting dissociation between short-term memory and long-term memory. Short-term memory is affected. Long-term memory is intact.

Now, some people can say that the tests that were presented to K.F. were different. So, as for short-term memory the digit span test was given. For long-term memory word association test was given. Some people have argued that because these two tests are different you cannot conclusively say anything about his deficit in long-term memory. But then there are other patients as well.

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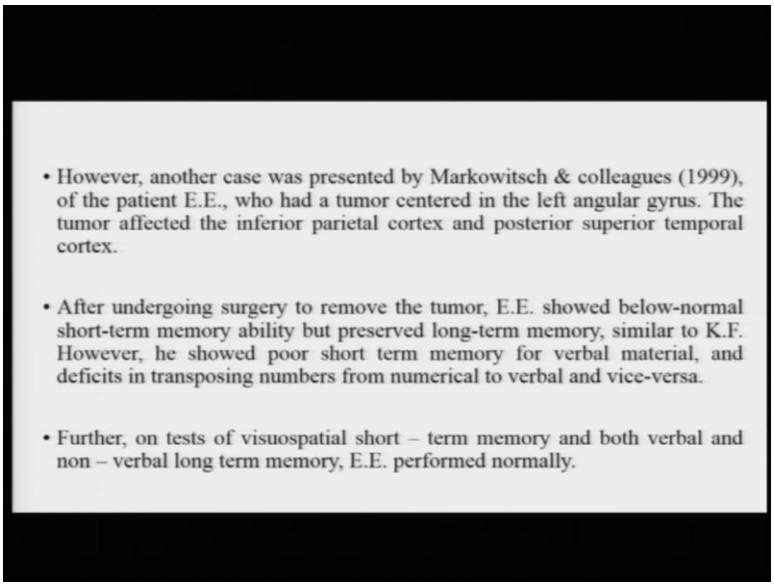

So, for example Markowitsch and colleagues documented the case of a patient called E.E. who had a tumour in the left angular gyrus. The tumour affected the inferior parietal cortex and the posterior superior temporal cortex. So, after undergoing surgery to remove the tumour he showed below-normal short-term memory ability but preserved long-term memory, similar to K.F. So, he showed poor short term memory for verbal material and deficits in transposing numbers from numerical to word form. Say for example, from 1 to they to verbally.

Now, further on tests of visuospatial short term memory and both verbal and non-verbal long term memory, E.E. performed normally. So, he is also presenting very similar thing that long term memory, verbal and non verbal is safe. Visuospatial short term memory is affected. So, but what is basically not working is the verbal short term memory. So, that is basically something that is not working. Still you can see that it presents a bit of a dissociation between aspects of short term memory and long term memory being separately or differently affected.

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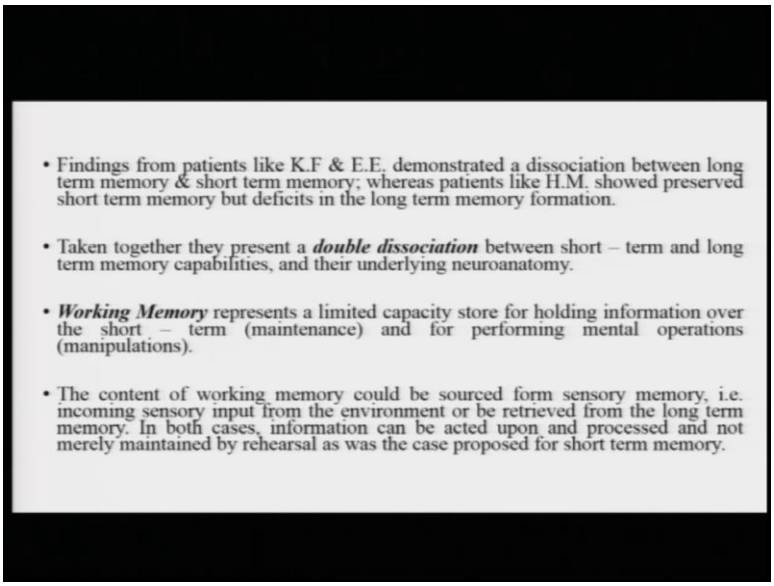

Now, finding some patients like K.F. and E.E. demonstrated dissociation between long term memory and short term memory and say for example whereas patients like H.M. showed preserved short term memory and depleted long term memory. K.F. and E.E. showed preserved long term memory and depleted short term memory.

So, taken together these if you kind of put all three cases together you will see that there is a double dissociation between short term memory and long term memory and also their underlying neuroanatomy. So, because we know that lesions in different areas have affected long term memory.

So, this is something we will keep note of and we will come back to this at a later point. Now, let us talk little bit about working memory. Working memory is basically a concept that is an elaboration of what really short term memory does. Working memory represents a limited capacity store for holding information over time that is maintenance and for performing mental operations using this information that is manipulations.

So, the content of working memory could basically be sourced from either whatever you are gaining from the environment, the sensory stimulations or it can be retrieved from your long term memory. Suppose somebody is asking you the path from let us say point X to point Y in your university campus. Now, obviously if you are not exactly standing in that path and you are

sitting in your room and somebody wants that okay can you tell me how to get to the petrol pump from the bakery shop.

Now, in order to be able to describe this path to this say individual you will have to recall the location of the bakery shop and the petrol pump from your long term memory, bring them in your working memory and then draft a path exacting it with details like, you have to go for 200 meters and then take a left turn and again go for 300 meters and again take a right up things like that.

So, that is basically what the working memory is supposed to do. So, the content of our as in both of these cases whether you are basically acting upon information that you have just gained from the internet or you say for example talking about information that you just retrieved from your long term memory.

But in both cases information that is made available can be acted upon and it can be processed and this is not just merely maintained by rehearsal as were sort of proposed in the modal model by Atkinson and Shiffrin.

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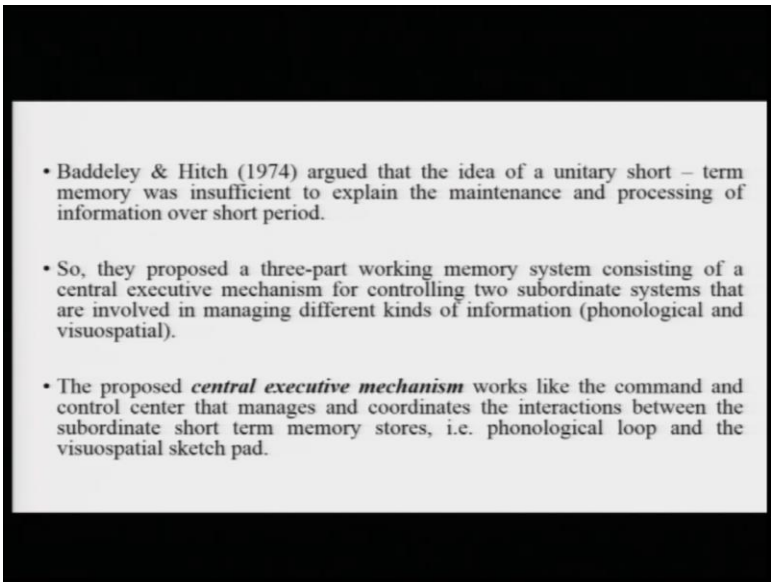

Now, Alan Baddeley and Graham Hitch argued that the idea of a unitary short term memory store was insufficient to explain the maintenance and processing of information over a short period of time. So, they proposed three part working memory system consisting of central

executive mechanism that controls 2 subordinate systems that are involved in managing different kinds of information. So, there is a central executive. There is a visuospatial sketchpad and there is a phonological loop. Now, this proposed central executive mechanism is supposed to work like the command center that controls and coordinates manages the interactions between these two parts.

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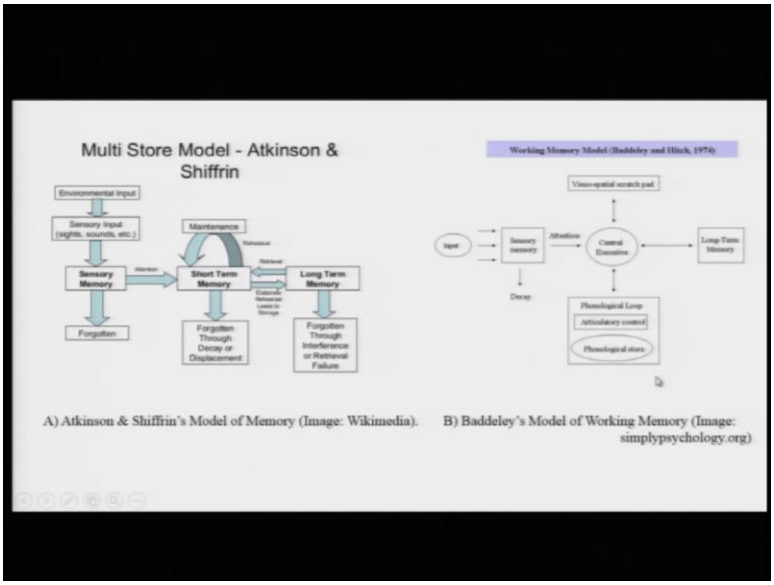

So, let us look at the comparison. Here you can see the modal model by Atkinson and Shiffrin, sensory memory, short term memory, long term memory, maintenance and rehearsal, retrieval. So, on and so forth the simplest slightly older version of the working memory model by Baddeley and Hitch. You can see the sensory memory.

From sensory memory, there is a central executive, which kind of sense information to the visuospatial scratch pad and the phonological loop which handle visual and verbal information respectively and then from here information can pass on to long term memory.

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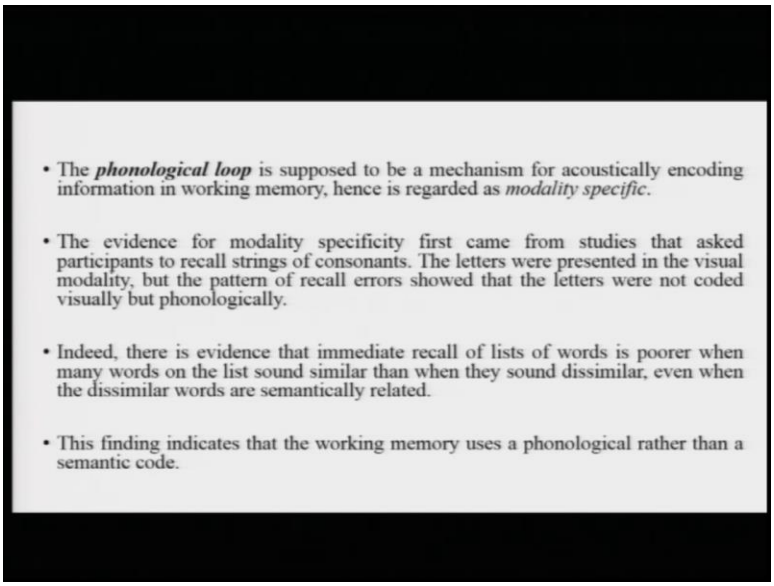

Now, this phonological loop is supposed to be a mechanism for acoustically or phonologically encoding information in working memory and hence it is regarded as modality specific. It deals with information from a specific modality only. Now, how can we conclude that this is modality specific? The evidence for phonological loop being modality specific basically started coming from studies that asked participants to recall strings of constants.

So, they were given like a, b, c, d, e, f, g, ab, xy, z, tc, ef, bj, k things like that strings of constants. The letters were presented in the visual modality but the pattern of recall errors actually showed that the letters were not really being coded using the visual format but actually they were being coded phonologically.

More specifically there were evidence that the immediate recall of the list of letters or words is poorer when many words on the list sounds similar than when they sound dissimilar. So, that the same was true for letters as well. Letters that were sounding similar were sometimes missed, not recalled, confused with other letters because the sound was too similar.

The same would was also observed for list of words. So, basically this kind of gives the evidence for the fact that even though the stimuli is being presented in visual format it is not being registered in the visual format rather you are sounding them out and remembering them in the phonological or acoustic format. So, this finding basically indicates that working memory uses a

phonological rather than a semantic code. Why phonological rather than a semantic code? Because the semantic relationships of the list of what did not really matter.

More importantly words that sounded together were sort of confused, were sort of difficult to remember because the sounds of these words were getting mixed with each other, muddle with each other.

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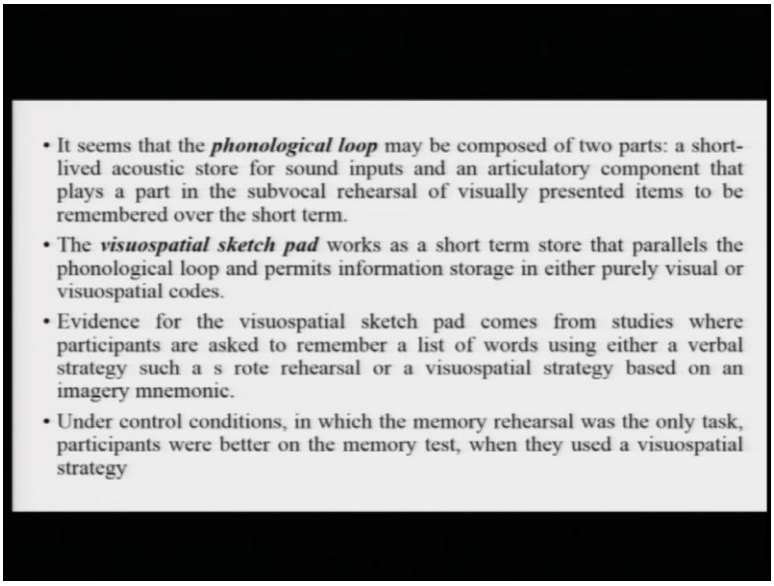

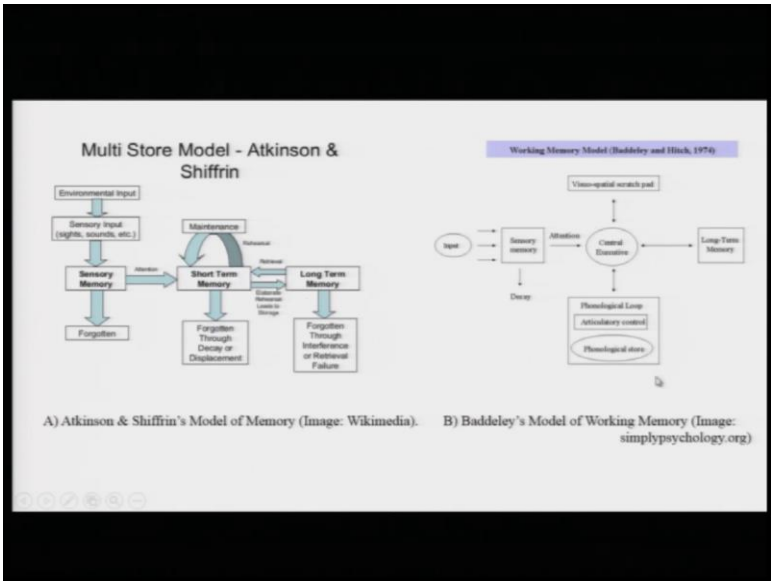

Now, it seems that the phonological loop maybe composed of two parts. There is a short lived acoustic store for sound input and an articulatory component if you remember just this diagram.

There is this articulatory control thing and this is phonological store. So, it seems as a phonological loop maybe composed of two parts.

One a short lived acoustic store, phonological store for sound inputs and an articulatory component that plays a part in this sub vocal rehearsal of visually presented items to be remembered over time. Again this is not very difficult. I am sure some of you have taken psychology earlier. So, you might be already aware of this. For those of you who do not just remember it like this, if somebody is giving you a number you know, their phone number to remember and they are just writing it on sheet of paper and showing it to you, so what you could do?

You could either try and remember visually each of the numbers that are there or you can just sound them out and it is repeated. Say for example 9839022587 something like that. So, you kind of a sub vocally rehearsing this. On the other hand if somebody is just speaking unto you then you have this articulatory here that you have this phonological store to maintain these sounds for a little bit of time.

The other thing the visuospatial scratch pad or visuospatial sketchpad works as a short term store that parallels the phonological loop and permits information stored in either purely visual or a visuospatial codes. So, this is something which will basically represent information more in a visual manner.

Something like how you would recall a map or a graph and so on. If you remember in class 5, 6, 7 when you have these geography exams then you have to say for example draw the location of rivers, sometimes the location of mountain ranges etc. I hope some of you would remember that, this is basically how you used to do it. You used to visually remember on the map which are the areas where each of these rivers or mountain ranges lie. So, evidence for the visuospatial sketch pad where does this comes from?

Now, evidence for the visuospatial sketch pad actually comes from studies where participants are asked to remember a list of words using either a verbal strategy as rote rehearsal or the visuospatial strategy based on an imagery mnemonic. So, just you remember the image of the word and that is how you are going to remember it.

In under controlled conditions in which memory rehearsal was the only task, participants were found to be better on the memory test, when they used a visuospatial strategy. So, there is evidence for the fact that the brain sometimes also uses visuospatial strategies to encode information.

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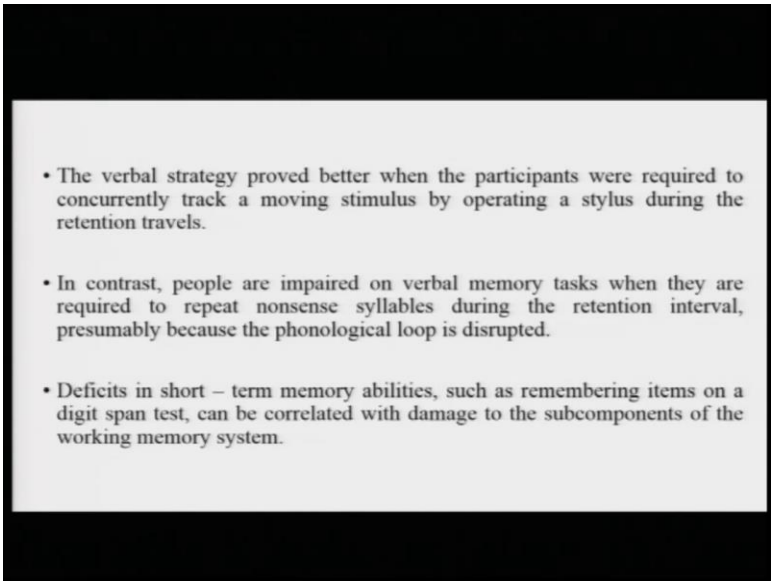

Now, the verbal strategy proved better when the participants were required to concurrently track a moving stimulus by operating a stylus during the retention. Suppose you are basically crowding up the visuospatial sketch pad by giving a concurrent visual task, then the verbal strategy would fare better because this visual spatial sketch pad is already crowded by this task where you are asked to move the stylus.

Now, in contrast people are found to be embedded on verbal memory tasks when they are required to repeat nonsense syllables. So, you can sort of crowd both of these two things. In latter case you are crowding the phonological loop by asking the participants to repeat nonsense syllables like okay to remember these lists of words but you have to remember these lists of words while at the same time speaking babababa etc. So, this kind of caused impairment in the verbal memory condition.

So, deficits in short term memory abilities such as remembering items on a digit span test can be correlated with damage to the subcomponents of the working memory system. So, basically that aspect of working memory at that aspect of short term memory that is affected can be correlated

with okay if visual information is affected then visuospatial sketch pad is damaged. If phonological information is affected then the phonological loop is damaged and this kind of differential tests have been carried out.

Several of these have been carried out by neuropsychologist and there is ample evidence that these aspects of short term memory can be differentially affected.

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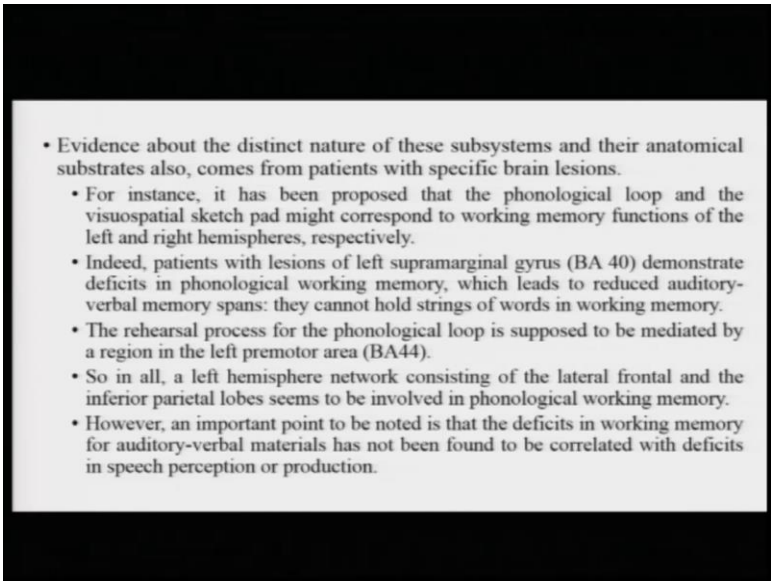

Now, is there any evidence about the distinct nature of these subsystems and the distinct possibility of their anatomical substrates? This comes more specifically from patients who have very specific brain lesions. Say for example it has been proposed that the phonological loop and the visuospatial sketchpad might correspond to working memory functions of the left and the right hemisphere respectively.

So, phonological loop, language based material left hemisphere, visuospatial sketchpad, visual material right hemisphere, that was the assumption. Now, patients with lesions of left supramarginal gyrus BA 40 demonstrates deficits in phonological working memory which leads to auditory verbal reduced auditory verbal memory spans and the patients cannot hold strings of words in working memory. Now, the rehearsal process for the phonological loop is supposed to be mediated by a region called in the left premotor area which is the Broadmann area 44.

Now, so in all a left hemisphere network consisting of the little frontal and inferior parietal lobes seems to be involved in the phonological working memory, the rehearsal and the maintenance parts. However an important point to be noted here is that these deficits do not correlate with speech perception deficits or speech comprehension deficits. So, these two things are kept very separate.

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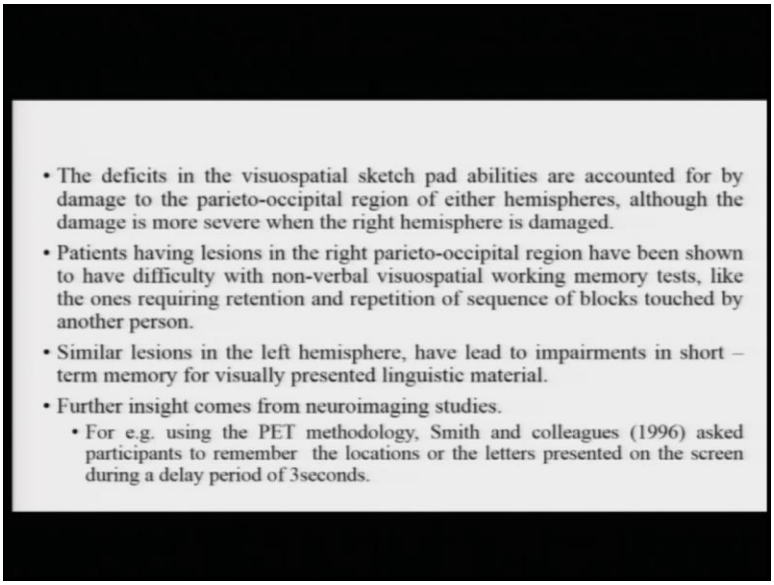

Now, the deficits in the visuospatial sketch pad or abilities of the visuospatial sketch pad are accounted for by damage to the parieto-occipital regions in either of the two hemispheres although the damage will be or the deficit will be more stronger if the damage to the right hemisphere of the brain. Patients having lesions in the right parieto-occipital region have been shown to have difficulty with non-verbal visual spatial working memory tasks like the ones that require the retention and repetition of let us say a sequence of blocks touched by another person.

Suppose somebody is touching say for example, I have kept on the screen 5, 6 different blocks and I am touching them in some order. So 1, 3, 4, 6 or 1, 2, 3, 5 something like this. If you are asked to remember what blocks I am touching and you have to ask you to maintain them then basically will be deficient if they have damage to the right parieto-occipital region. Now, similar lesions in the left hemisphere in the parieto-occipital area have been shown to lead to impairments in short term memory for visually presented linguistic material. So, the modality is sort of changing a little bit.

Now, further insight about this comes from neuroimaging studies. So, what happened was the Smith and colleagues using the PET methodology asked participants to remember the locations or the identity of the letters presented on a screen after a delay of about 3 seconds. So, they were being presented with an array of locations marked on the computer screen or sometimes an array of letters and then they were presented with either the location marker for a special memory task and later at fixation for the verbal memory task.

The partners were asked whether this location marker was presented in the initial array or not or whether this letter was presented as an initial array of letters or not. So, they have to look at these tests or a test location or test letter and match them and see whether they were presented in the original location or not.

Now, what happens for the verbal memory task activation was found in the left hemisphere sites in the left infero-lateral cortex but for the spatial memory task activation was found mainly in the right hemisphere regions. Regions like inferior frontal, posterior parietal and extrastriate cortex. So, you can see that verbal short term memory and visuospatial short term memory are actually activating very different areas of the brain.

In fact different hemispheres in the brain are responding through these two different tasks. To add several years later Smith and colleagues actually compiled a meta-analysis of more than 60 studies PET and fMRI where they found that although for verbal stimuli activations were documented mainly in the left ventrolateral prefrontal cortex.

The evidence for spatial working memory showed a little bit of a bilateral activation in the brain. So, it seems that the visual part is more distributed or the processing of visual information is more distributed in the brain.

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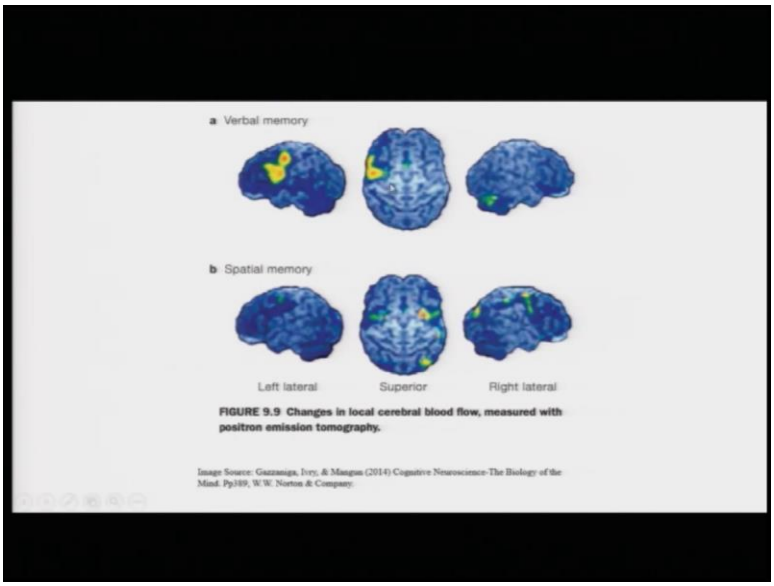

This is basically in the tasks you can see for verbal memory left part of the brain is mainly involved but for visuospatial you can see activations in the left as well as in the right parts of the order, right hemispheres of the brain.

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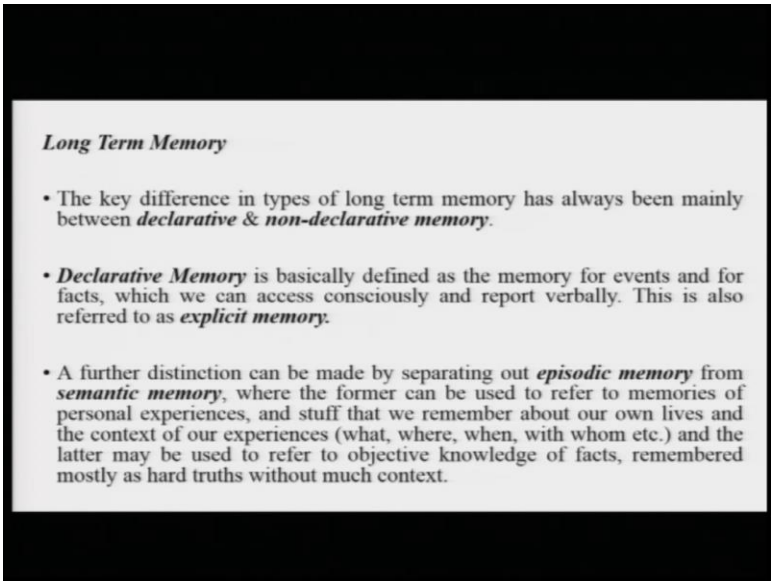

Let us talk about long term memory. The key difference in different types of long term memory has always been between declarative and non-declarative memory. So, declarative memory is basically defined as the memory for events and for facts which we can access consciously and report verbally. This is also referred to as explicit memory.

A further distinction within explicit memory can be made between episodic memory and semantic memory. Whereas the episodic memory is used to refer to memories of personal experiences stuff that we remember about our own lives and the context of this experience. Where did I go for dinner last night which place, which restaurant, with whom, what did we order, what was the ambience, what was the music like, what was the smell like things like that.

And the later which is semantic memory can be used to refer to the objective knowledge of just facts. Things like who is the chief minister of Uttar Pradesh, who is the Prime minister of the country, what is the capital of Delhi, what is the capital of the United States of America things like that. Mostly plain facts.

So, we are talking about declarative memory. Declarative memory is also referred to as explicit memory. Explicit memory has two parts episodic memory and semantic memory. So, this is what we have to remember.

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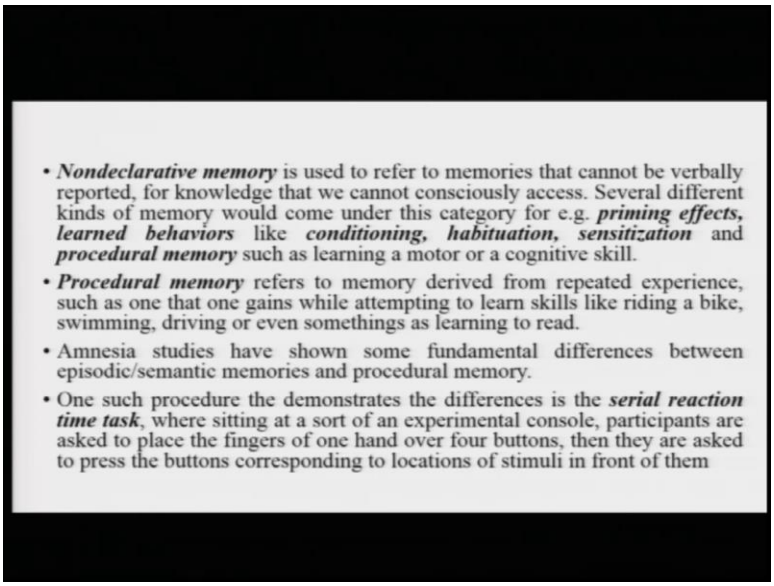

Now, we can talk about also non declarative memory. Non declarative memory is mainly used to refer to memories that can not be verbally reported. So, you can not verbally describe them as to okay I was doing this things like priming effects, learn behaviours like conditioning, habituation, sensitization and memory for skills or the procedural memory. How did you learn to pick up the bat, how did you play that shot exactly?

All of those kind of things are very difficult to sort of grab. Sort of difficult to put into words and describe and detail them and that is why they are called they are clubbed under non declarative memory. Now lets talk little bit about procedural memory. Procedural memory basically refers to memory that is derived from repeated experience such as one that gains while attempting to learn certain skills.

Say for example, riding a bike, learning to swim, driving or even something as basic as learning to read. You can not verbalize the entire process of learning to drive. You cannot say that I took this step then this step and this step and this is how I kind of gathered this entire thing. So, that is something that is not really very easy to do. Now, amnesia studies have shown that there are some fundamental differences between episodic and semantic memories on one hand and procedural memory on the other.

One of the procedures that sort of demonstrate or clarifies the difference is the serial reaction time task where participants are basically made to sit at a sort of an experimental console and they are asked to place their finger of one hand over four buttons. So, let us say this is the console there are these four buttons 1, 2, 3 and 4 and right on the opposite side there are these four lights and which will flash in a particular sort of order and there will be a sort of a special relationship between these buttons and these lights. So, button 1 may respond to light 1, button 2 may respond to light 2 and so on.

Now, what happens is participants can be presented with either a completely random or a bit of a pseudorandom sequence of these flashing lights which can then be repeated over and over again. The participant's task is to press these buttons corresponding to which lights are being flashed on their screen. So, what happens is over time normal participants learn to respond faster to the repeating sequences as compared to the completely random sequences of light.

So, however but when they are asked they would mostly report that the sequences were completely random. Even though you are presenting the sequences in a bit of a systematic manner. Participants can not decipher that the lights are coming in a systematically but their pressing response becomes faster.

So, they are learning something. There is some systematicity in the flashing of these lights and they need to press these buttons but they are not conscious of that there is a particular pattern

here that all the time 1 comes first and then 3 and then 5 and then 4. They are not basically being able to deduce that.

Now, this specific finding shows that while they learned to press the button in a response to the changing stimuli changing flashing lights they could not retain any explicit knowledge about the sequence of the lights that were basically being presented. So, they are not picking up explicitly the sequence of the lights suppose it is through some mathematical formula they are not being able to grab that.

This pattern is typical of whatever happens in procedural learning or accusation of procedural memory which does not really require any explicit knowledge but people just pick up the skills they learn how to deal with that skill. Now, while finding pattern here that all the time 1 comes first and then 3 and then 5 then 4. They are not really basically being to deduce that.

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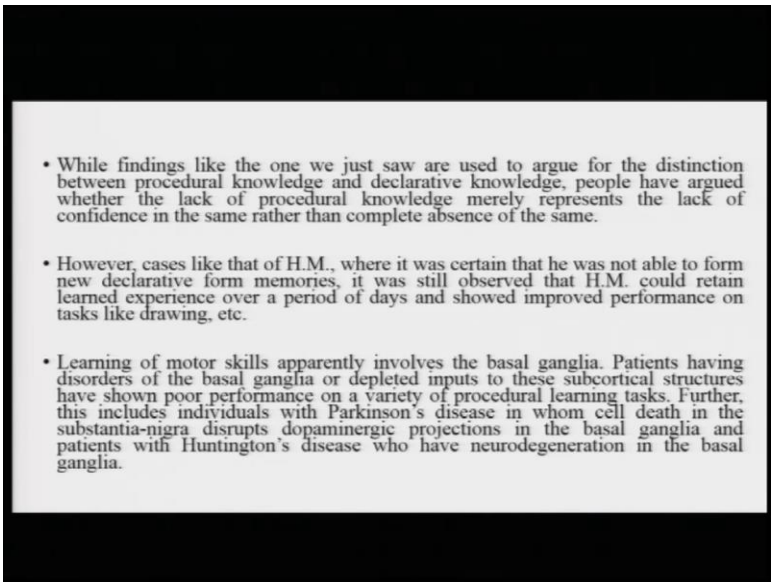

Now, this it is actually a case people lacking procedural knowledge or it is in fact a case where they cannot demonstrate knowledge. They cannot just verbalize it they have the knowledge. They know which sequence is what they are. So, there is a bit of a doubt there but if you add to that cases like H.M where it was certain that he was not able to form any new declarative memories bit it was still observed that H.M.s could retain from learned experience over a days over a period of days and he actually showed improved performances on tasks like driving.

So, H.M. was say for example sometimes you know trained upon these procedural task and his performance did improve over a period of time. Even though you ask them he would every time tell you that okay this is something that I am doing for first time. So, as no conscious memory of doing the task on the previous day or the previous day or the previous day. But his performance is increased.

So, that is something that can act as a very solid distinction between procedural memory and explicit declarative knowledge. Now, again learning of motor skills apparently involves so let's talk a little bit about the neural structures. Learning of these procedural skills or motor skills apparently involves the basal ganglia.

Patients who have disorder of the basal ganglia or who have depleted inputs to the subcortical structures have shown poor performance on a variety of these procedural learning task. Further this also includes individuals who have Parkinson's disease in whom cell death in the substantia-niagra actually disrupts the dopaminergic path ways in the basal ganglia and also patient's with Huntington's disease who suffer from neurodegeneration in the basal ganglia. So, the basal ganglia in this structure is a very very for acquisition of these memories.

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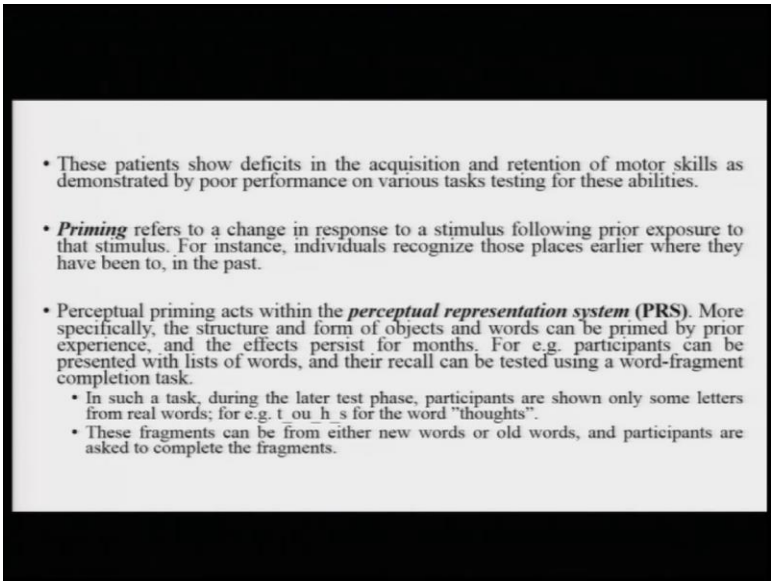

Now, these patients were Huntington's Parkinson's and basal ganglia deficiency patients actually show deficits in the acquisition and retention of motor skills as demonstrated by poor performance in various task that test for these abilities. We can talk about priming. Now,

priming basically refers to a change in the response to a stimulus following previous exposure to that stimulus.

Suppose you have been to a place earlier and you have had a good experience. Next time you come here you automatically feel pleasant. You have been to a place, you had bad experience last time you ordered some food which was tasting very horrible, next time you come to the place as soon as you enter the place that experience is relieved almost and you start feeling not very pleasant being at that place. So, this is basically what is referred as priming.

Now, priming is supposed to be happening through the system called the perceptual representation system. What this perceptual representation system does is that it kind of maintains the trace maintains the memory traces for experiences with particular kinds of stimuli. So, what happens is the structure in the form of objects and words and ambiances can be primed by prior experience and the effects may persist for even months.

For example, participants can be presented with a list of words and their recall can be tested using a word fragment completion task. So, I present a participant with a list of 20 words and then I can give him a word fragment a fill in the blank kinds of task. So, for example, for the word thoughts I can give you T dash O U dash H dash S.

Now, if you have seen the word thoughts in the list that I presented to you earlier, you will respond much faster to the word. You will complete this fragment very quickly. If on the other hand, you have not been exposed to this word and the frequency the word is very low etcetera you will not be able to complete this or you will take too much time in completing this. So, this is something that was done and people sort of were found to be significantly better and faster at correctly completing the older words as compared to the newer words.

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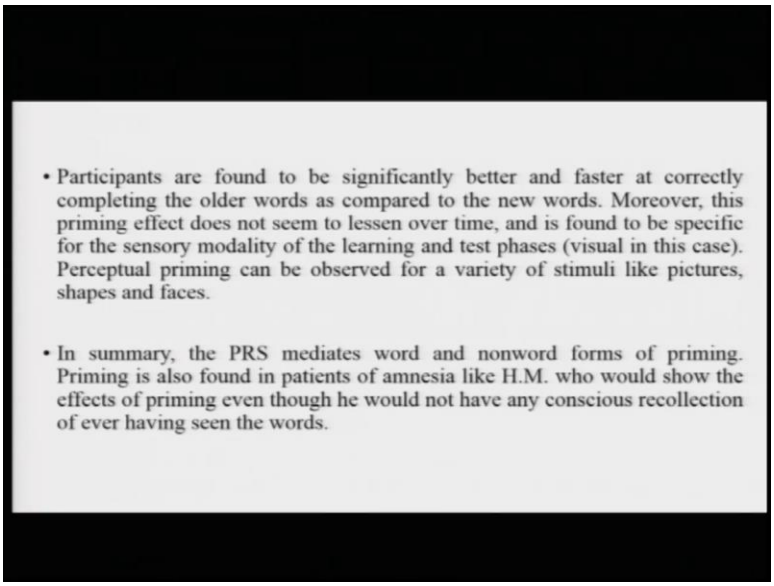

Now, moreover, this priming effect does not seem to lessen over time, it does not reduce over time. It is found to be very specific for the and it is on the top found to be very specific for the sensory modality of the learning phases and test phases. If the learning phase is in visual and the test is in the auditory then the priming effects may not persist.

Now, in summary the PRS mediates the word and non-word forms of priming and priming is also found in patients like H.M. who would show effects of priming even though he would not have any conscious recollection of ever having seen those words or ever having undergone a particular experience.

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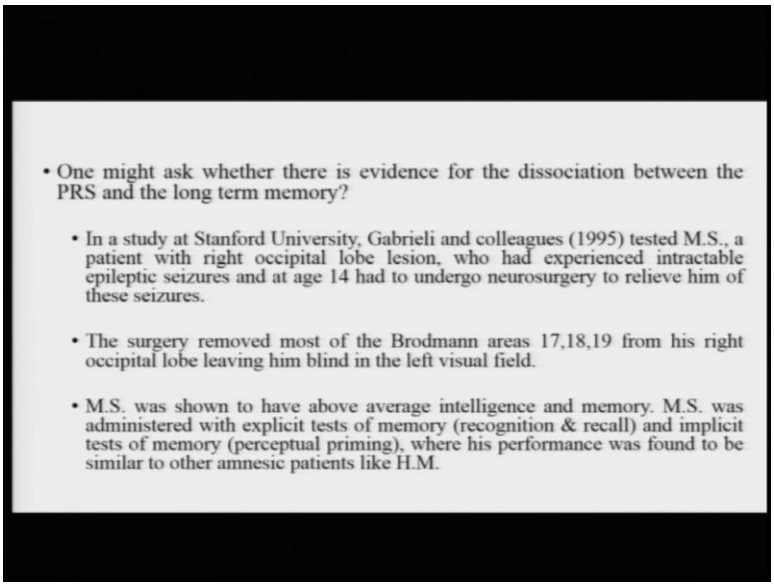

Now, one might ask whether there is evidence for the dissociation between the PRS and the long term memories? In a study at Stanford University, Gabrieli and colleagues tested M.S. who was a patient with right occipital lobe lesion and had experienced intractable seizures at the age of 14 years and at the age of 14 years he had to undergo surgery to relieve him of these seizures.

Now, the surgery removed most of the early visual areas Brodmann areas 17, 18, 19 the occipital the striate and extra striate cortices and that left him blind in the left visual field. So, M.S. was shown to have above average intelligence and memory. M.S. was administered with explicit tests of memory recognition and recall and implicit tests of memory where his performance was found to be similar to the amnesic patients like H.M.

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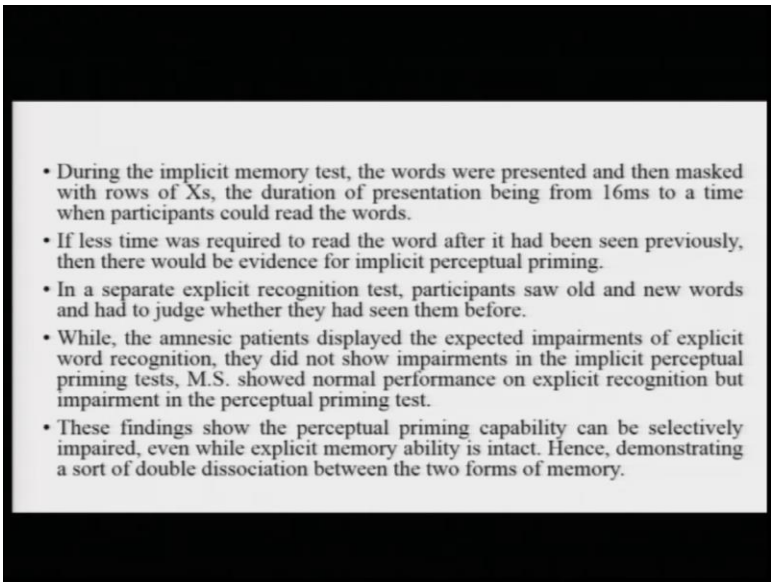

Now, during the implicit memory test, the words were presented and then masked with rows of Xs. So, the word will come and the X's will replace. The duration of presentation being from 16 millisecond to a time where the participants could actually read the word. Remember these are amnesic participants lesion brain damage participants. Now, if less time was required to read the word on a successive representation after the participant has been exposed to these perceptual words, earlier it will be counted as priming. Now, this is the implicit test.

In a separate explicit recognition test participants were shown the old and the new words and they had to judge whether they had seen these words earlier or not. So, a list has been presented whether you sort this earlier or you did not see this earlier. So, explicit recall. Now, while the amnesic patients displayed the expected impairments of explicit word recognition, they did not show impairments in implicit perceptual priming tests. M.S. showed normal performance on explicit recognition but actually showed impairment in the perceptual priming test.

Why because the visual modality is lesion, the areas 17, 18 and 19 are not there. So, if you look at these findings, these findings show that perceptual priming capability can actually be selectively impaired even while the explicit memory ability or explicit recognition is intact. So, the demonstration this sort of again demonstrates the double dissociation between perceptual priming effects and explicit recall of information.

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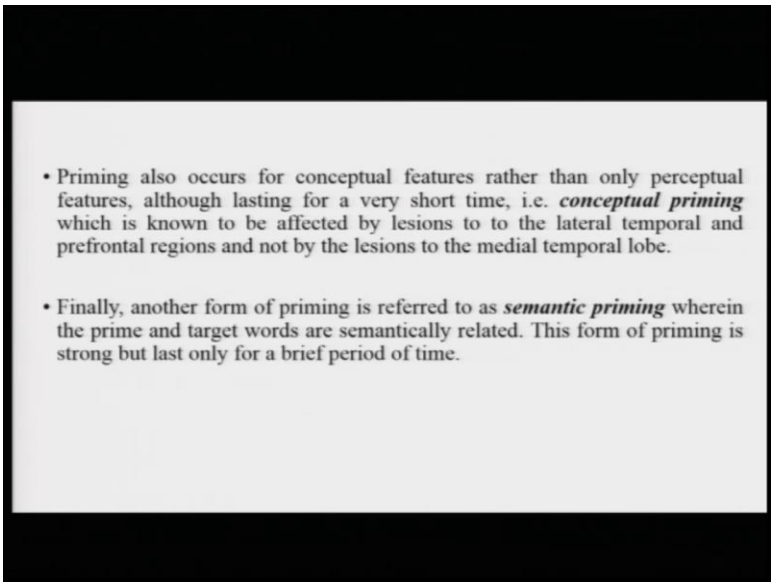

Now, priming is also supposed to occur for conceptual features rather than only perceptual features although lasting for a very short time say for example conceptual priming is also supposed to happen where things that are conceptually related to each other will prime each other.

The target and the prime can be conceptually related and basically the conceptual priming is affected by lesions to the lateral temporal and prefrontal regions and not by the lesions to the medial temporal lobes. Finally the final form of priming that can happen is semantic priming where the prime and target maybe semantically related. Now, this form of pattern here that all the time one comes first and then three and then five. They are not really and then four. They are not really basically being able to deduce that.

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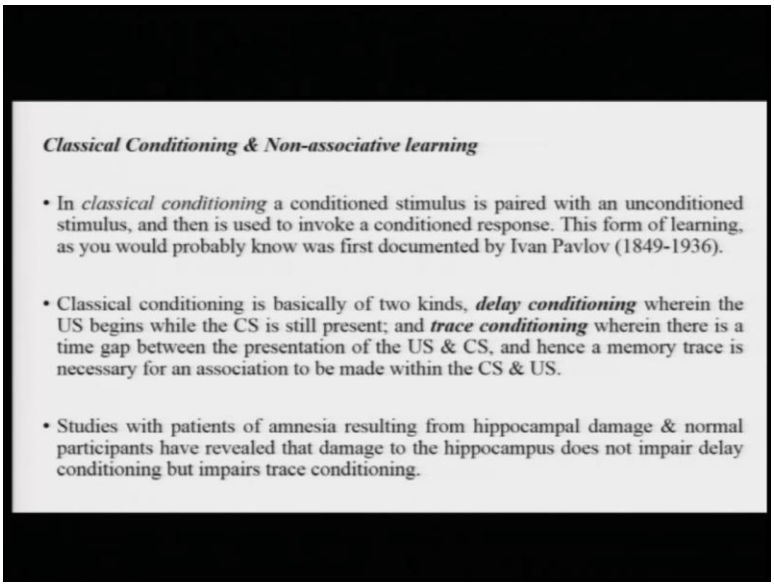

Now, this conditioning a conditioned stimulus as you know from your basic psychology lectures a conditioned stimulus is paired with an unconditioned stimulus and then this conditioned stimulus evokes what is called a conditioned response. Say for example, if you remember the classic experiment from Ivan Pavlov the helper was ringing a bell before he was presenting food and food typically let to salivation after a few pairings of the bell and the food the bell started evoking salivation. So, that is basically what classical conditioning looks like.

Now, classical conditioning comes of two kinds. Delay conditioning where the US unconditioned stimulus presented simultaneously with the conditioned stimulus or delay or trace conditioning where there is a time gap between the unconditioned stimulus and the conditioned stimulus. So, a memory trace needs to be form and it needs to associate the unconditioned and the conditioned stimulus.

Now, studies with patients of amnesia have shown that when people have hippocampal damage and normal you know compared to people who have normal brains, they have revealed that damage to the hippocampus does not impair delay conditioning but impairs trace conditioning. So, if you have damage in hippocampus then trace conditioning variety of classical conditioning can actually be affected. You will need to have form a memory trace, you will not be able to form a memory trace which will associate the two stimuli and that is why hippocampus is necessary for this classical conditioning effect to persist.

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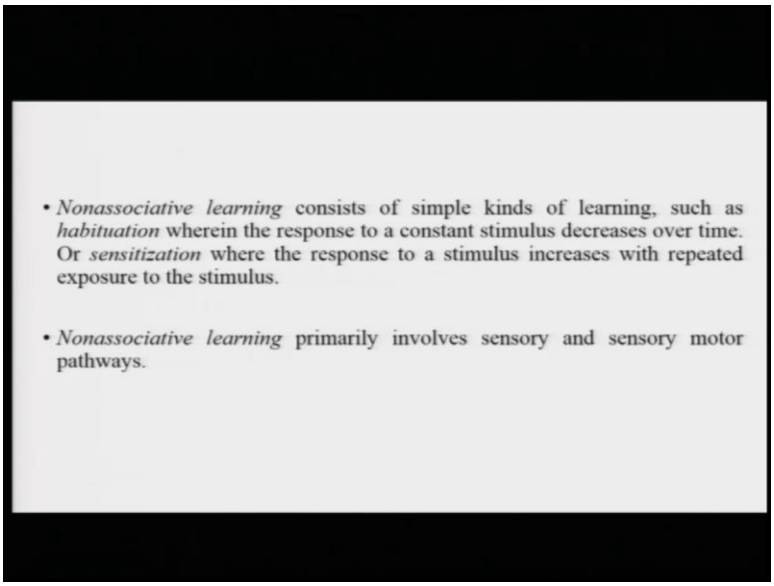

Finally non associative learning consists of simple kinds of learning such as habituation where a response to a stimulus decreases over time. If you are presented with high flashes of light then the neurons in the individual field area will stop responding or stop firing to that limit or things like sensitization where the response to a stimulus increases with repeated exposure to the stimulus. You start appreciating more finer details of that kind of stimulus representation.

Non associative learning primarily involves the sensory and sensory motor pathways. So, we will probably not talk too much in detail about these forms of learning going further ahead. What we will talk about other aspects of learning from the next lecture onwards. Thank you.