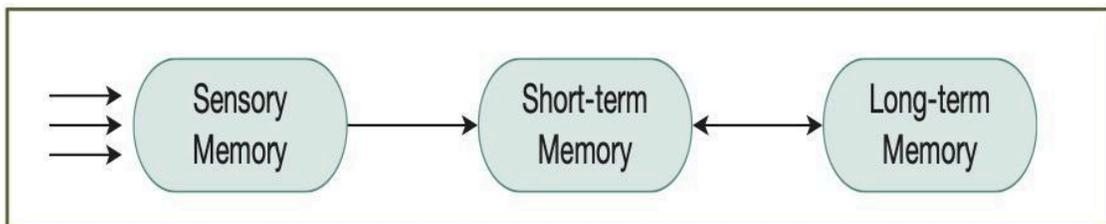


**Memory**  
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**Lecture 16**  
**Working Memory - I**

Hello, I welcome you all in the lecture series of memory. Today we are going to start a new lecture topic, working memory. Working memory to start with, before there is such discussion, we have to see the multi-store memory model proposed by Richard Atkinson and Richard Shiffrin in the year of 1968. This model one which was being proposed, it was proposed that there are different storehouses for the memory. First storehouse is the sensory memory.

This storehouse is for very brief period of time. Then another storehouse is the short-term memory. And then the final storehouse is the long-term memory. What is being proposed is that, the sensory memory registers the incoming sensory information from the



**Figure 2: Atkinson-Shiffrin (Multi-store Memory) Model**

environment and holds the information here for a brief period of time. When we talk about the sensory memory, briefly we have to discuss that there are two major types of sensory memory which researchers in the discipline of memory cognitive psychology, neuropsychology, cognitive neuroscience and related discipline talked about, are echoic memory, which is related to the sound, and another type is the iconic memory, which is related to the visual information.

Now, this information, sensory information, if you pay attention to, then this information passed down to your short-term memory. Register the information for a brief period of time, but the capacity and duration depends upon its rehearsal. More and more rehearsal

you do, more and more overlearning you do, the information duration will expand. The duration may expand from 30 seconds duration to up to six hours. Some studies depend on the nature of memory also. The nature or type of memory, what type of memory we are talking about it, and upon rehearsal definitely is an important element when we want to pass on this information from short-term memory to the long-term memory. Then, the sleep plays a crucial role. When we sleep, then this information get registered in a long-term system for indefinite period of time for future references.

Now, then you want to retrieve this information. When we retrieve this information, then it comes back to our short-term memory and then the process if you leave it, then get consolidated over period of time. Now the notion that short term memory is there, people were talking about it in psychology, but we have seen that in recent years, in recent decades, there has been development and in 1975 when Baddeley and Hitch came, then they proposed a new multi store memory model. They tried to revise this Atkinson-Shiffrin model and through the modification, they brought changes in the short term memory, such short-term memory, they referred it as working memory. So this modification, this change in the short-term memory into working memory, the reason for justification they proposed is that the working memory, the short-term memory is undergoing a lot of manipulation and short-term memory cannot be so simple in nature.

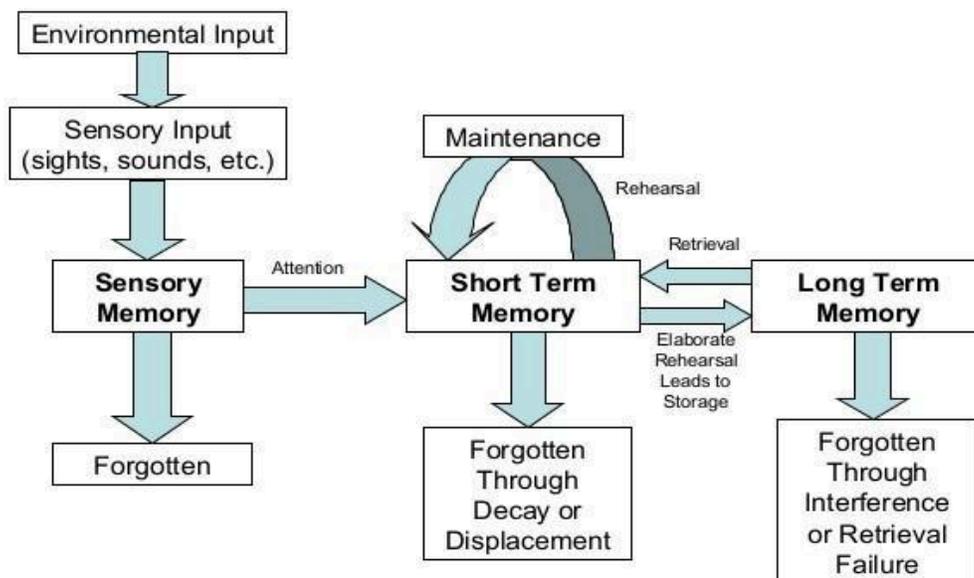
It involves a lot of other types of memories such as, visual memory, auditory memory. Also based on different types of sensory system, the different types of memories come together and then binding integration happens. So such system cannot be so simple, such system cannot be so short lived; it depends on the different types of information. So Baddeley and Hitch gave this concept as working memory, and last 3-4 decades, in the science of memory research, people are referring short-term memory as working memory. Now, let us spend some time here to understand short term memory and why short term memory is being referred as. So, it is nothing but the neural structures, cognitive processes are there, where you are just accessing the information for short period of time.

As I mentioned earlier, this short period of time depends from 30 seconds to up to 6 hours. This accessibility of information from 30 seconds to 6 hours depend upon the

rehearsal, and more number of rehearsal, more number of retrieval an individual does, more robust the information becomes with respect to storage. And that is what we have also discussed in the previous lectures about the repeated retrieval. So, repeated retrieval can be seen as the rehearsal as well. Now, because this information is there for a short period of time, we call it as short-term memory.

So, the information processing model, which people have been talking about it, here you could easily see that the environmental input, which is nothing but sensory stimuli is there, present in the environment and we are registering those sensory stimuli. But not all stimuli we pay attention to. So, we put a buffer, we put our selection and then based on our selection, the information get prioritized or get preferred. Based on the sensory system it could be visual, tactile, olfactory, auditory in nature. But sound and light, similarly iconic memory and echoic memory seems to be preferred because these two types of sensory system is being extensively studied. There are some literature available on different types of sensory system, but it has seen that mostly these studies have been done with respect to sensory memory with these systems only.

So, the information which one is not processing, the information which individual is not paying attention to, just get lost from the system. The short-term memory, the working memory system tries to maintain the information. For the maintenance, rehearsal is required. More and more rehearsals are performed. More and more memory is being performed and get more and more solidified or robust in nature.



Source: <http://www.slideshare.net/Snowfairy007/aqa-as-psychology-unit-1-memory>

The information which individual is not paying attention to gets lost from the system. It decays slowly and gets displaced also. The information gets displaced from the memory system itself. Once we go for the sleep, then the information moves to the long-term memory. And upon retrieval, this inactive form of memory becomes active again, and this active state of memory makes memory susceptible to disruption also.

This we have studied in the previous lecture. Elaborate rehearsal leads to the storage. Elaborate rehearsal, or repeated rehearsal, or addition of more information in detail can lead into it. The information where the individual is not paying attention to, or registering it get out from the system slowly. A few important aspects which one has to consider in the information processing model are the low ecological validity, that in the environment, the environment which is highly rich, the environment which is highly informative, the information which is coming to the system is more in nature.

So this low ecological validity is there in the system itself, and the understanding of our multi-store memory model or information processing model is happening in a controlled environment. So how easy and how valid it would be to apply this model which is extremely linear and lacks some components, where in the real environment there are some more parameters, there are some more crucial elements interplaying with each other and also they are intertwining with each other such as the social component, cognitive component, affective component are intertwining with each other and making the system so complex in nature. Such simpler model cannot address that. That is one such shortcoming.

However, such simpler model also gives an understanding to the researchers that how the information is being processed serially and sequentially in an individual. One aspect which we discussed earlier, that the short term memory was being replaced with the working memory which was being proposed by Baddeley and Hitch in 1974 period they proposed it and slowly changed into game. Then after 75, the model was being revised in 2001 when the buffer was being added. This we will be addressing it in detail in the coming lectures. So, when we talk about the sensory system, though we have talking about only five basic type of sensory system, there are more than five types of sensory system.

Till date 9 types of sensory system has been established and we talk about it. Some of those systems are thermoception, nociception, where the pain and temperature of the body, and body balance also being considered into such system. This sensory system is holding the sensory information, where the categorization is happening, where the meaningful interpretation is happening, and once an individual pays an attention to, then this system pass on the information from sensory memory to the short-term memory system or the working memory system. This occurs before the conscious access to it. So too much conscious an individual is sometimes unaware of the information where he or she is looking at it, but once the selection has happened.

So here when we are talking about the before conscious access, then we could talk about two types of system, early selection and late selection of the information as well. So, here the type which is happening in early, maybe the individual is not unaware of the fact, but some context some scenarios we have seen that people put an effort in the selection of the sensory information. One should be also aware of it as we were discussing earlier, that the encoding and storage does not require sensory system. However, the encoding and storage requires the sensory system. However, the retrieval process do not require the sensory system.

Separate memory systems are there for each perceptual system. So, different types of memories are there; based on the nature of the memory, different types of memory system is there. Though there is only one type of memory, previous lectures we have discussed about it, that the primary storehouse is the hippocampus. But as the information gets consolidated, it tries to become independent of a structure. So based on the nature of information, different brain structures come into play.

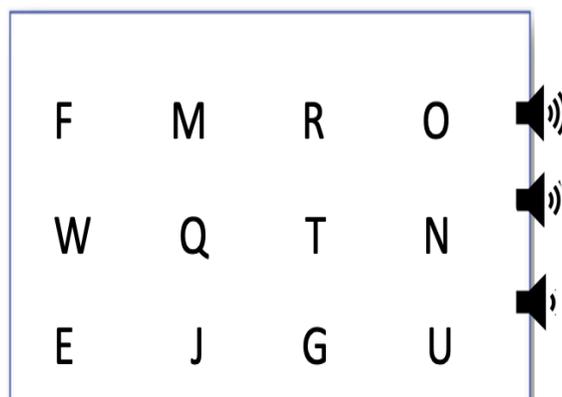
And we have discussed this in previous class. So this creates a buffer maintaining sensory information also. So there is a buffer is there which selects the information. Of course, as we are talking about it, the buffer here cannot be so explicitly accessible by the individual because for the buffer to function, the individual has to select the information. But the information present at this level, individual is processing information, selecting information less than 1 second.

In some cases, it is less than 100 milliseconds also. So, long enough for the cognitive mechanism to detect the information. So, the sensory system is just selecting the information and passing this information. Now, the famous classical experiment was done by George Sperling. He tried to understand how the information is being stored, how this visual information is being registered by an individual, and how much information an individual is registering it, and how much information an individual is recalling it.

So in a very simple experiment, he just used the three rows, four column letters. Twelve letters were being used and these letters were being presented less than 50 milliseconds. He was just trying to understand how people are encoding this information, and how they are recalling this information, and how much information they can recall. So, this whole report procedure was there where they have to report the items which are being displayed on the screen. What he observed is that, while the individuals are performing the task, the performance was bad.

They were not able to register the information at easiness. The nature was too complex for them. The three rows and the four columns were there. During the free recall, some letters were being recalled easily. However, when the recall has to be performed in a sequence, then they failed several occasions.

To solve this problem, and to provide an aid to the users, to the participants, Sperling just added the low frequency, middle frequency and high frequency tone. So, different frequency tones were given to the individuals. So, this low frequency tone, middle frequency, middle tone and then the high tone was given and paired with each row. What he observed is that, the participants who were just partially reporting the items, their performance changed drastically because along with visual information, they were now having the additional sensory information, that is the auditory sensory information. So,



they bonded the two types of sensory system together, visual and the auditory together, which started to provide an aid.

So when an individual were learning the last row, then they paired the last row with the low tone, the middle tone with the middle row and the high tone with the top row. And when the tones were being presented to the participants, they were being asked to recall the letters and their accuracy was increased and better. So, this George Sperling experiment gave an understanding that the information is being recollected and recalled easily based on the bonding and association of the sensory, two different types of sensory stimuli. The performance can get better and better. And using this principle, the visual aids in the navigation, visual aids for the blind people are being extensively used in modern world.

So working memory capacity, we talk about what is the capacity of the working memory. George Miller did a wonderful experiment in a digit span task. In this digit span task, he

5-digit: 8 1 5 6 3
6-digit: 9 7 4 3 2 6
7-digit: 4 8 9 6 3 7 1
8-digit: 2 0 9 8 3 1 5 7
10-digit: 2 3 1 8 4 0 7 9 3 0

12-digit: 5 2 4 6 7 8 6 9 3 9 5 7

just gave a series of digits to an individual to remember and after every series of digit, they have to recall the digit. Once the accuracy has reached 100%, then an individual has to recall this list of items. So what we observe is that there is a magic number to it.

Source:

<https://www.nytimes.com/2012/08/02/us/george-a-miller-cognitive-psychology-pioneer-dies-at-92.html>

People were not able to register too much information. Either they can go to 7 plus minus 2 level, which means that 5 to 9. Between this range, 5 to 9 only participants were able to recall the digits. But this was being also being a challenge because though we are talking about the digits, what about the letters and what about the words? Because in some cases

like you might have experienced and encountered the words like "biotechnology" or "nanotechnology". When we are talking about it, the principle of 7 plus minus 2 doesn't fit here.

So this magic number 7 is critical for the working memory because we are not only talking about the manipulation, but also the components, which we will be addressing in coming lectures. But this plus minus 2 is referring to the individual differences. We have seen that human memory system is more robust, human memory system is more complex, and human memory system is wide, so it can store more and more information depends on the nature of the information one has to register and depends on the rehearsal type. The method which he used was the digit span task which is well established paradigm. The result shows that average performance is about 7 digits. Okay, so the point comes that, as I was telling you earlier, that individuals do have a capacity to store more than seven items and how an individual is capable to register more than so many items together. So, let us take an example of neuropsychopharmacology and this long word is comprised of more than 7 items. And then how we are able to register this information or if one has to remember the mobile number.

So, if the mobile number is more than 7 items then also an individual is able to perform a register. The simple principle we do is we do the chunking. The chunking is a very simple process. It is a smallest unit where people just chunk the pieces together and this chunking provides us an opportunity where individual chunk this big letter of neuropsychopharmacology into four chunks one is 'neuro' second is 'psycho' and third is 'pharmaco' and then the fourth is the 'logy'. So this actually, chunking, individual is being performing to all sorts of information which is being presented to an individual in a dynamic environment. So, when in a dynamic environment individuals are being exposed to such information they do the chunking.

So, these items and then you decompose into small parts and it is nothing but it is the smallest unit of the information for working memory. Another aspect in this working memory is the pronunciation time. So, it has been seen that people hold a memory, but they have a smaller memory for long words than for the short words. So, when we are talking about the pronunciation time, pronunciation time for the longer words will be

little long and the pronunciation for the short words will be quick. Long words require more time to read aloud, while the shorter words do not require that much effort.

So, if you consider this word, as you can see on your screen, the example of "neuropsychopharmacology", this requires a longer period of time for the pronunciation. Now, this process of chunking, individuals have been using it at different scenarios and places to understand. One such easy example is also the remembrance of the number plate of the cars. So, the state, the city number and then the car number is being provided. When we talk about the memory processes in any type of memory, sensory memory, working memory, long-term memory, the two aspects we have to discuss about.

One aspect is the capacity. What is the capacity of the memory? Second aspect is the duration of the information. For how long we can register or store this information? In the case of the working memory, here we talk about the rehearsal, and more and more rehearsal an individual will perform, they are maintaining the memory and making the memory more and more robust.

As we studied in earlier lecture about the retrieval process, repeated retrieval makes the recall better and performance better. So, here an individual what they do basically they actively maintain the item in working memory. Now, this is context dependent also. So, context plays a major role in such instance, if an individual is paying more time in one context then the context actually helps in the rehearsal. As a result, an individual performs better and better. So, if you are in a bank and dealing with cash counter all the time, then you are counting with the cash becomes more and more robust in nature and such rehearsal over period of time, actually rehearsal of the coordination of the motor movement with your central executive system becomes more and more refined as you spend time here.

By relating the items also some items are there which is requires the elaborative rehearsal. Elaborative rehearsal is required for the complex nature of the information. So, when the information is complex in nature, an individual requires more clarity, then these kind of rehearsal can be made with the elaborative details. One has to understand that here we are talking about the working memory, which holds more complex information

than the model we can say Atkinson-Shiffrin proposed earlier, short term memory, where the list of items only one has to rehearse and remember and respond to. But here we are talking about a working memory which is a very dynamic memory

And here we are acquiring information from different types of sensory system and when the buffer was being added in the year 2001 then the selection of the information through this buffer reaches to your central executive system where the integration of information happens. When the integration is happening, then for some information, it is easy to do the rehearsal. However, for some information, it may become more ambiguous, complex, and tricky. In that case, elaborative rehearsal helps. For the remembrance, such as here you can see on your screen, we are talking about the Nelson Mandela suffering from tuberculosis.

Then the elaborative rehearsal could be providing more detail about what tuberculosis is, what kind of disease it is, what is the mortality rate it is and how he may have acquired this disease, what was the nature of his physical state is and now when he was president then how he dealt with this disease. So, that requires more and more detailing. We also know that there is an interference to this. Memory process cannot be so simpler and so easy to acquire. Some information, when you are acquiring the other type of information, can start behaving as an inhibitory role and can interfere with the information.

So new information, where it is going? Into the working memory system, it displaces the older information. In some instances, it can displace. In some instances, it cannot. So, interferences also are of two different types.

We may be addressing this thing in detail, retroactive interference and proactive interference is there. Where the new information is coming into the system and then displacing the old one, you know, then retroactive is happening, robust, fine, good. But some occasions we have seen that the old information is so strong and robust in nature, that the incoming new information cannot erase it, cannot displace it, cannot, you know, modify it. As a result, proactive interference happens. But all these things, all these aspects gives us an understanding the nature of working memory, and the nature of working memory depends on many other parameters.

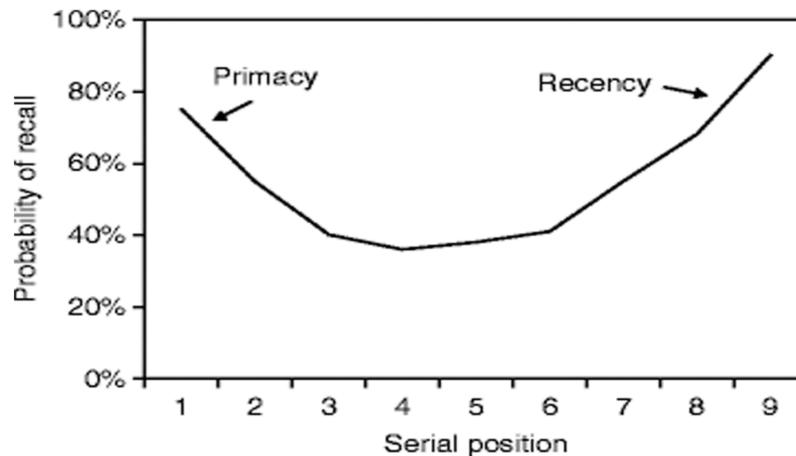
One important concept and understanding which we study in the working memory is that, when we are doing the registry, when we are doing the encoding, when we are doing the storage, then their unique pattern has been seen. This unique pattern is the inverted bell shape, and this inverted bell shape curve reflects upon how much information an individual can recall. Now what has been seen that if this is the initial state I and this is the end state E, then people have seen that the recall at the end state is always higher than the initial state. Now this process, this mechanism or this process we call it as primacy and recency effect. So to differentiate between the short-term memory and long-term memory, free call is generally being used, where the individual just have to recall the list of item whatever he or she has remembered or registered. And in this free recall what people have observed is that the recall is better at two time points; first time point is that, when they are starting the study primacy primarily primary level.

And then at the end, when it is very recently, an individual has encountered. So what we see, what we have understood, if you apply this understanding in a real world, then when you take a course, then the early lectures will be registered more and then the recent lectures will be registered more. But the lectures which are in the middle, will be stored or registered little less. So the recall of these lectures, the better recall is for the recent lectures, which has recently been covered or taken up, or the initial lectures or which has been conducted in the past, at the very beginning. But in the middle there is a some recall which is there but it is not that high and good from studies to studies from task to task. This primacy and recency also varies.

So and also it is important to mention that the culture may also affect it. Generally this kind of a study, primacy and recency individual has researchers have conducted the studies with the English words. But it could be conducted in one's own native language. One important parameter which one has to consider is the frequency of the word, familiarity of the word and dominance of the word. These three parameters one has to include in such studies.

Serial positioning curve has given us a lot of insight about how people are registering the information, not only that, but how people prioritizing and giving the importance towards the initial list of words and then the end and the last end of these words. So serial

positioning curve has been very helpful in the human research, particularly in the working memory. Understanding this concept about the working memory, that we hold information for a short period of time, which is referring as short-term memory and this short term memory later has been proposed by Baddeley and Hitch in 1975 that it is a



working memory. Why? Because memory cannot be so simple in nature.

It is complex in nature and it requires an integration, coordination with the different type of sensory system. The magic number 7 plus minus 2 items by George Miller, 7 plus minus 2 item is there. So, we do register information, but on an average 7 items we can register. Though later on people talked about it, that if we are using a process of chunking, where the 3 to 4 letters can be clubbed together and can be seen as a one unit in that case people can remember 3 to 4 chunks. And based on the rehearsal, people can have more chunks and they can remember more number of items or more number of chunks, more than 3 to 4 chunks.

Source: <https://practicalpie.com/serial-position-effect-curve/>

Factors which could affect the working memory could be the word length, so larger the word length is, people may have different strategies, different time can be taken in order to encode this information. Pronunciation time, if it is large, larger the word is, larger will be the pronunciation time. Smaller the word is, small pronunciation time will be required. But both these things directly affects the working memory and then the information fades

over a period of time. How we store the information, how we maintain this information is by simple process which is rehearsal.

More and more rehearsal one will do, more and more robust they will make the memory. Elaborative rehearsal provides an aid, some complex nature of the memory requires an elaborative rehearsal, then the primacy and recency effect. Understanding of these aspects of working memory, we have been using extensively this understanding in the human factors design, psychology of engineering or engineering psychology discipline. In many domains, we have been using this information in the design domain, navigation, even in the discipline, several other disciplines of mental health, we have been constantly using these aspects. With this, I will end the lecture here and in the next lecture, we will discuss some more concepts and ideas on working memory.

Thank you.