Memory
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Lecture - 18
Working Memory - III

Hello, I welcome you all in the lecture series of memory. Today, the lecture number 18, we are going to continue our lecture on working memory. Previously, we discussed about the working memory system and in this working memory system, we talked about the systems the comprised of proposed by Alan Baddeley and Hitch that it is composed of four different components. This working memory system is a replacement of the shorter memory system. The reason for such replacement was that the working memory system is a very dynamic system.

People are using more than two types of memories such as the auditory working memory, visual working memory together and integration of this information is very dynamic in nature which cannot happen in a simpler form, which was being proposed with the help of short-term memory. Secondly, here, with the working memory system, we can manipulate the information here and there. So, the working memory system, which you are seeing on your screen, was proposed by Baddeley and Hitch in 1974. However, the section, this episodic buffer, was being added in 2001. Before that, the system was comprised of one central executive system, phonological loop and VSSP.

Now, these systems are considered as a slave system, because these systems like phonological loop and VSSP tries to provide an input to the central executive system to execute the task or to ensure the completion of the goal. When we talk about subsections, let us address these slave systems in detail. And in talking about these slave systems, firstly, let us discuss about the phonological loop. Working memory system is important for an individual to hold information for a period of time so that the task can be executed. The task such as singing a song, the task such as playing a tennis, the task such as writing a song or a task such as preparing a food in a kitchen and serving it on the table.

So, such system requires lot of input from the phonological loop and requires lot of input from the visual spatial sketch pad. So, phonological loop deals with all sorts of sound auditory stimuli, any type of auditory stimuli which is present in the environment, the integration, selection, segregation and division, all these things are happening in this system. Phonological loop is ensuring that the nature of the sound is going to be relevant or irrelevant in nature. So this system not only stores the sound, but also stores the language for a period of time, which is allowing the individual to manipulate the information in the short-term memory. So this section what you are seeing on your screen is the Broca's and Wernick's area which is a speech production area.

So phonological loop is ensuring the production of the sound system as well. You are seeing the two blue dots. These blue dots are indicating the Broca's and Wernick's area on both sides of the hemisphere left and right side of the brain. The irrelevant speech effect what we have seen is that the phonological loop is mildly impaired when an additional sound or additional auditory stimuli is present at the background. Such presence of such stimuli interferes and lowers the performance of an individual.

The reason for such interference, the reason for such lowering in the performance is because of its interference with the target stimuli present in the environment. Now, the phonological loop is seen as a very independent body. Then the visual spatial sketchpad and in order to address this thing, research has done several experiments. In one such experiment, where you are seeing is the irrelevant speech effect, the background sound was being presented, which interferes with the other target auditory stimuli present in the environment. The same time, if a motor task is given to them like tapping, tapping task, one tap means yes, two taps means no.

Presence of this task will not interfere with the phonological loop system because it requires the visual coordination, visual motor coordination rather than an auditory stimuli. With such type of interference, researchers have documented that the phonological loop system is independent than the visual spatial sketchpad. Our understanding should be very clear here that if any damage or if any impairment is happening in these brain regions, it may affect the phonological loop system. Initially, we were only talking about the behavioral side of the phonological loop system, how people

are separating the two auditory stimuli, how people are processing these two different stimuli. Later on, researchers were more curious to understand what is happening at the neural level and that is how the Broca's and Wernick's area came into picture.

The individuals who have a large working memory capacity, it assumes that they hold large amount of phonological information in their system, which helps them, which aids them in executing the task. The task could be singing a song with a melody and rhythm which requires a long term, which requires a working memory integration with the long term integration and holding information in the working memory system to execute the task. The researchers have also addressed that if phonological loop brain areas get impaired then people find a difficulty in the cognitive functioning impaired digit span task and no word length effect. What does this mean? We have understood in previous
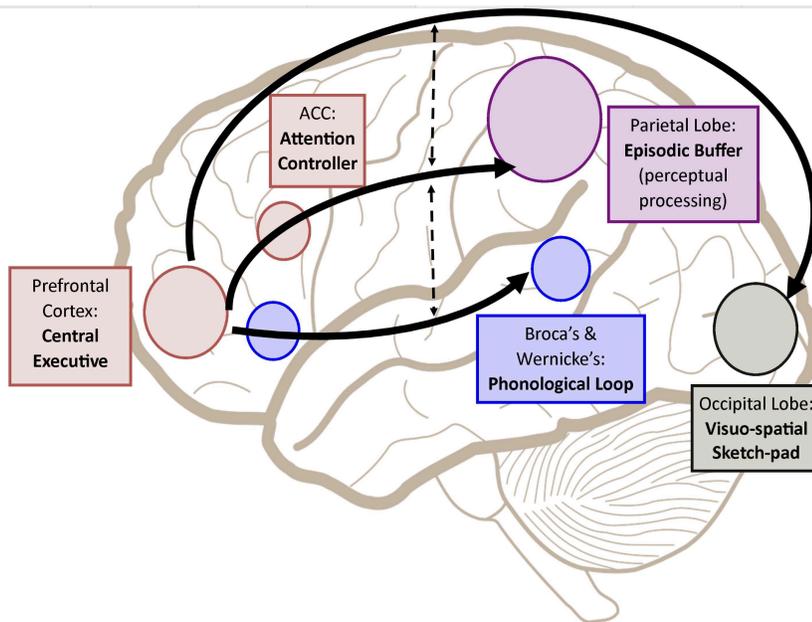
lecture that the digit span task people have to read the digit and as the number of digit increases from 3 digit to 4 digit to 5 digit to 6 digit to 12 digits, they not only have to recall the digits present in every digit trial, but they have to hold these digits in their memory span, in their working memory for a period of time.

So reading aloud these digits along with paying attention requires more effort. So if any damage happened to the phonological loop, the rehearsal or loud rehearsal cannot happen. As a result, it impairs or affects the performance. The same thing has been seen

in the no-word length effect also. So, it does not matter what is the length of the word and when the person is articulating the words, the sound system is affected, the speech area is affected.

As a result, word length effect seems to be non-significant. The other slave system is the visual spatial sketchpad. This region is responsible for the visual working memory. This visual working memory stores the visual information and the spatial information. Initially, it was proposed that it is only for the 30 seconds, but upon the rehearsal and upon the repeated retrieval, this period can get extended up to 6 hours.

It allows an individual to be more consciously aware and also more rehearsal increases the capacity of the working memory system. Unlike the short term memory system where we were just talking about the human capacity is limited in nature. It cannot hold more information into it. Visual spatial sketchpad not only stores information related to the visual information, but on certain instances, it also holds information related to the visual spatial information with multiple modality. Now, the reason for such characteristic is that the complexity of the memory itself.

Some memories are more complex than the other. Hence, in order to hold that memory information for some period of time, the rehearsal and the integration of two information seems to be beneficial. Literature has also talked about that multimodality in the case of complex and ambiguous memory information seems to be helpful rather than single modality is present in the information. Brooks also reported that the visual response task interfered with the visual imagery task. The reason for Brooks to conduct such a study was to identify the role of the visual spatial sketch pad is very independent from the phonological look.

So, how an individual can study? Similarly, like the irrelevant speech effect, here Brooks conducted a study where the two visual informations were being presented together. One was the target task and the other visual imagery task was the interference task. Now, in addition to this, there was a control experiment where the visual response task was interfered with the auditory stimuli. What researchers observed is that the auditory

stimuli did not interfere and affected the response of the individuals who were performing the visual response task.

However, when the visual response task was being interfered by the visual imagery task, the performance came down. This discrimination between the two tasks gave us an insight and understanding that the phonological loop is independent processes than the visual spatial sketchpad. The extended work of Otsuka and Osaka in 2015, showed that high performers who are very good with the arithmetic task use both visual and auditory strategies to help them with the mental arithmetic problem, while the low performers use only auditory strategies. So such understanding give us in contrasting effect and finding to us that the integration of the two modalities seems to be helpful as I was mentioning earlier in the phonological loop. So integration of two different modalities

It is an individual to perform better while compared to the individual who is only using the auditory strategy. Reason for such high performance is that the arithmetic skill is a mathematical and complex problem which is not only dependent on the visual information but also the sound, the phoneme which is available. So for the high performers, they use the aid of not only the graphemes but also the integration of the morphemes and phonemes add meaning to it. As a result, they perform better. But this could be exclusive to arithmetic problem.

If the complexity and the nature of the problem goes beyond the arithmetic task, then the involvement of two different modalities may start inhibiting the performance of the high performers. So, in this case also just like phonological loop, the visual spatial sketch pad here what we have seen is having an integration from the occipital lobe to the prefrontal cortex. Prefrontal cortex region which is lying at the center is having a projection from the frontal cortex to the Broca's and Wernick's area in the case of the phonological loop and having constant feedback in this direction. Similarly, in the visual spatial sketch pad, the frontal cortex is having projection to the visual area. This visual area, we may have simplified it here in the diagram.

However, it is composed of five different layers, V1, V2, V3, V4, V5. As the information is being processed, different types of information is being processed by different visual

areas. We cannot rule out the fact that the dense projection from the frontal cortex to the occipital cortex is providing and giving an aid to the visual spatial sketch path. Similar aid is being provided from the frontal cortex to the phonological loop, which makes the selection easier. But after 25 years, when Badley and Hitch proposed the episodic buffer, then they suggested that it seems that the two information can occur, can compete, can be present at the same time, which means the two different modalities of the information, visual working memory, auditory working memory can be present at the same time and not only being present, but can be processed also by the central executive system.

Now, the question arises how this thing is possible when both these systems are independent of each other. So, there should be an additional system which can hold this information, hold these two different information together for some period of time till the central executive system processes this information. So, episodic buffer integrates these information from the phonological loop, from the visual spatial sketchpad. And also this episodic buffer interlinks between the working memory area, working memory information to the long term memory information. Now, such aspects when we as a researcher is trying to address, it gives us a lot of clarity that there should be a system which holds information for a period of time till the further execution is completed.

So, imagine if you have to give a talk or if you are waiting for your flight, there is always a lobby where you go and if you arrive there before time, then you wait in your lobby for your turn to come so that you can go and stand in a queue to catch a plane. Or when you are going for an interview, then you do not directly barge into the committee room, but you wait in the waiting lobby or waiting room where you are going to call as per your turn when it will come. So episodic buffer is also doing the same. It holds information there for some period of time till it is being called by the central executive system for further processing. And that is why the slave system, why we are calling them a slave system because central executive system seems to be a superior system where the integration, decision making, problem solving, reasoning processes are happening and the input is being given from the slave system which is the PL and the VSSSP.

So, here you can also see watching ballet performance, episodic buffer integrates the music and the dance together. So, sound and the visual information together, binding this

information together and then retrieving some information from the long-term memory. And once you have done the such thing, then you see this skit or a diagram or an event or a movie or an event in a dynamic form. This integration is happening so fast and so quick that can be seen as a reel of strip which is moving in continuous direction. However, if you slow down the system to millisecond, then you will see that the process is being brought, the information is being brought up, binding is happening, integration is happening and then there is an output.

The theory here, void memories can be experienced as the coordinated sequence of events. So, we are trying to coordinate these different events together rather than seeing them as discrete segments. More than this, we have to also see here is that the central executive system The final system in our working memory system is the superior system. Here, this central system can be referred as the attentional system and the reason for us to calling it as an attentional system because it supervise and coordinates the information which is being received from the episodic buffer.

So, once the information from the opposite buffer is reached into the central executive system, it ensures to what level the integration should happen, to what level the coordination should happen, and which information need to be directed, which information need to be selected, and which information need to be allowed in that respect. So, this system ensures that when the task is being given to drink a glass of water, then where the glass is located, where will I get the water, how much water level is required in a glass. This decision, this integration of information is going to be executed by the central executive system. Now, it serves three major functions. First is direction. So, central executive system, because it is an attentional system, so it directs where one has to direct the attention from where one is going to collect the information.

Now, we know that this attentional system are of four different types. Sustainable, so attention is sustainable in nature, attention is selective in nature, attention is shiftable in nature and attention is divisible in nature. So knowing that attention are of four different types, we know that the attention requires to be direction, direction where the information is going to be collected from, division Division can be seen as shiftable. So we have to divide our attention. We have to shift our attention between the sources of the input. So, if

in an environment there is a high and rich information about the visual information, then we are prone to acquire that visual information.

That very moment if a foul smell enters into a room, then our olfactory system gets activated and then from visual attention, from visual information, now we have to direct our attention towards the olfactory information. And that very moment when the loud noise is being played or your favorite song is being played on the music system, then you will shift your attention from the foul smell towards your favorite song or the music played in that environment. So division is there, then allows you to switch attention among the competing source of input. So this switching constantly being happening all the time and this switching helps an individual. So how it helps actually that once as I said in previous division of attention how it is happening.

So it is also allowing to switch which environmental stimuli, which information present in the environment is more important for us. One should be very clear here and also we have discussed in previous lecture about different cues present in the environment, how the cues are aiding an individual to make a decision. So these cues are actually directing our attention and grabbing our attention in this regard. So central executive system is ensuring that how the direction, division and also allowing to switch our attention. between the different sensory stimuli present in the environment.

Goal of the central executive system is to allocate the limited attentional resources to working memory. So, the main purpose for central executive system just like the main purpose of the buffer was to integrate and hold the information into its system till central executive system requires that information. Here, the central executive system ensures how to optimize the processing. The optimization is going to help the system to reduce the cognitive load. Once this optimization is there, the individual may process effectively, efficiently in the environment.

So, efficiency and effectiveness depends on the optimization of the attentional resources done by the working memory system. Let us summarize here what we have studied here. Working memory consists of the four systems. Four major systems which is present there

in the working memory. Phonological loop, visual special sketchpad, episodic buffer and central executive system.

Phonological loop is responsible for the auditory working memory. Any type of sound or any type of information related to the auditory stimuli is being processed by the phonological loop. Similarly, visual spatial sketchpad deals with all type of visual spatial information, all types of visual processing information and it ensures that the information selected based on the preferences and biases of an individual. From individual to individual, phonological loop, visual spatial sketchpad may function differently in these individuals. Episodic buffer tries to not only link the or integrate or hold the information in its system for a period of time till the central executive system requires that information but also it tries to link between the working memory and the long term memory integration.

So, it ensures how the link should happen and how the information should be passed on, passed down to the long term memory for future references. Central executive system can be referred as the attentional system and it maintains the attentional control across the system. This understanding gave us why working memory has been replaced with the short-term memory and why Baddeley and Hitch recommended that there is a need for us to understand not only the working memory but the components of working memory in detail to understand the complexity of the memory processes. It should be noteworthy here, different types of memory depends on different type of memory integration of different types of information, integration of different types of modality information and integration of information. And an output also depends on the individual per se.

So, based on the individual preferences, based on the individual choices, the working memory system will also function differently among the individuals. Thank you all for this lecture. In next lecture series, we will continue talking about the working memory system in little bit more detail. Thank you.