Engineering Psychology

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Week-05

Lecture-11

Multitasking - 1

Welcome to this lecture on multitasking, which is part of the series on engineering psychology. Up to this point, we have examined the definition of engineering psychology and the research methods associated with it. We have also explored two sensory capabilities in detail: one related to vision and the other to auditory perception. Additionally, we have discussed methods for evaluating design modifications. The upcoming lectures will focus on the cognitive capabilities of humans.

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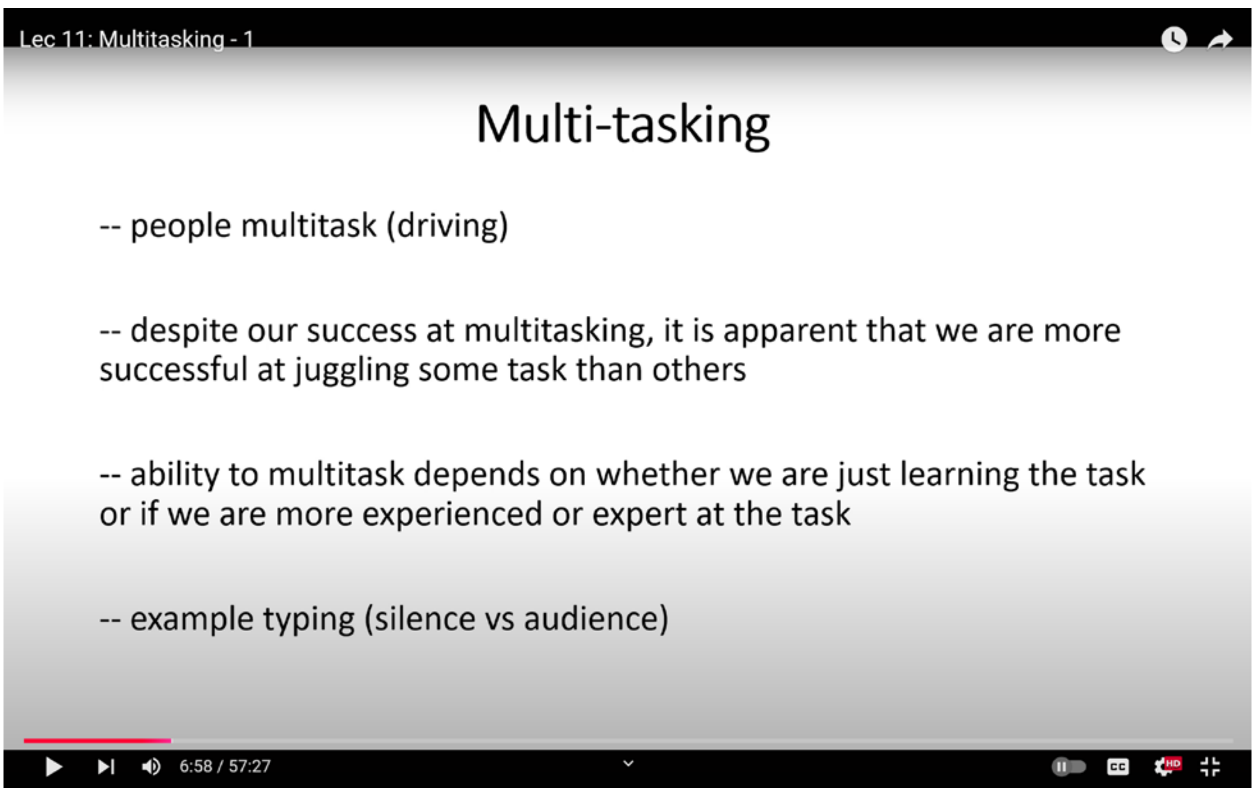

Although the auditory and visual systems provide the sensory stimuli necessary for cognitive processes, understanding cognitive capabilities is fundamental to grasping the principles of engineering psychology. In the present lecture, as well as the next one, we will delve into the cognitive capabilities of the human information processing system. Following this, we will explore a critical higher-order cognitive function known as decision-making. Let us begin today's lecture, which centers on multitasking.

If you observe your surroundings, you will notice that multitasking is a common occurrence. What does multitasking entail? I will illustrate this through several scenarios. Consider the role of a locomotive driver. The driver's job appears straightforward: he must transport the train from point A to point B safely and on time. At first glance, this task seems simple. All he needs to do is start the engine, and in the case of locomotives, there are generally no competing trains. Thus, driving appears to be an uncomplicated task. However, if it is such an easy job, why do we witness numerous accidents?

Let us examine the responsibilities of a locomotive driver in more detail. Driving is a multifaceted task that requires the driver to perform multiple functions simultaneously. In addition to starting and monitoring the engine, he must also keep track of various system parameters. For instance, if the locomotive is diesel-powered, he needs to be aware of how much diesel is remaining, how much has been consumed, and how much will be necessary to complete the journey from point A to point B. Furthermore, he must pay attention to specific controls and warnings provided by the integrated system.

Inside the locomotive cabin, the driver faces a myriad of responsibilities, but he must also remain vigilant to external signals from the stations he passes. He must monitor various signals along the route and be alert to any obstructions on the railway line. All of these responsibilities necessitate that the driver multitask effectively.

Now, imagine a train in motion. The driver is looking through the viewing window, observing signposts as they pass, interpreting their meanings, and adjusting the speed of the locomotive accordingly, all while ensuring his own health and well-being. This requires the simultaneous execution of multiple tasks. In contrast, there are situations that demand little multitasking. Consider a person applying stamps to letters in a post office. This task is relatively simple; all that is required is to affix stamps to incoming mail. However, the worker does have one or two checkpoints to consider: he must verify that each letter has a destination address and is intact before applying the stamp.

From these examples, it is clear that individuals engage in multitasking at various levels. An engineering psychologist must recognize that any job requiring system interaction involves an essential element of processing multiple pieces of information simultaneously in order to complete tasks.

Thus, multitasking is a fundamental aspect of human functioning. In this lecture, we will explore the different types of multitasking and the processes involved in multitasking. We will also examine the cognitive systems that facilitate multitasking. This raises the question: is multitasking easy or difficult? Furthermore, what can we do to make certain tasks easier to multitask than others? Specifically, are there factors that determine whether a job can be accomplished with minimal cognitive resources, while others require significantly more cognitive effort?

Let us begin by understanding what multitasking entails. As I mentioned earlier, people multitask frequently and often excel at it. For example, when driving, a person simultaneously manages the vehicle's controls while observing traffic and pedestrians crossing the road through the windscreen.

You are also monitoring various road signs that assist you in navigation while engaging in a conversation with the passenger seated next to you. Additionally, you are checking your rearview mirrors to observe the traffic behind you and listening to music or the radio. This results in a multitude of tasks being performed simultaneously. But how do you manage to accomplish all of this? Furthermore, what strategies can be implemented to enhance multitasking abilities?

Let us explore these questions. Despite our success in multitasking, it is evident that we are more adept at juggling certain tasks than others. This brings us back to the earlier question: Are there specific jobs that are easier to multitask, and are there those that are more challenging? The answer is yes. Well-practiced tasks are generally easier to multitask, while novel or complex tasks tend to be more difficult. This is a straightforward explanation, but I will elaborate to clarify what constitutes an easy task compared to a complex one.

The ability to multitask hinges on whether we are just learning a task or have gained experience and expertise. For instance, if you are a new driver, your primary concerns will include managing the vehicle's controls and steering, while also ensuring that you do not collide with other vehicles or obstacles. This involves processing a significant amount of information. New drivers often exhibit noticeable stress and heightened attention levels. If a person is instructing them from the passenger seat, there is a high likelihood that the driver may overlook or fail to register these comments. Consequently, for novice drivers, multitasking is a challenging endeavor due to their limited experience and practice.

Now, let us consider a scenario one year later, assuming the driver has persisted and continues to drive. At this point, he has gained more experience. When this new driver gets behind the wheel after a year, the act of driving becomes considerably easier for him. He has mastered the controls and acquired extensive knowledge about the road, which enhances his navigational skills. As a result, he can now safely direct his attention to other activities, such as conversing with a passenger or listening to music. Thus, the more experience you accumulate and the more practice you engage in, the easier it becomes to multitask.

For instance, consider the task of typing. When you are typing in silence, it is typically easier and much faster. However, if there is an audience speaking to you while you type, you find yourself performing multiple tasks simultaneously, making it significantly more difficult. Thus, multitasking is particularly challenging when an audience is present.

To better understand multitasking and the reasons behind our successes and struggles in this area, we should examine how information is processed within the human cognitive system. Understanding the steps and processes through which information from our sensory organs is received and interpreted can reveal factors that facilitate effective multitasking. Multitasking is crucial because, in many scenarios, when you are interacting with a system, it presents you with multiple pieces of information. The operator's responsibility is to comprehend this information, integrate it, and provide feedback to the system regarding the next steps to take.

Now, let us investigate how the human cognitive system processes information. One of the primary motivations for increased research focus on multitasking in engineering psychology arose from concerns regarding cell phone use while driving, which has been linked to a significant number of accidents. In fact, driving licenses often explicitly state that using a cell phone while driving is prohibited. So, what makes this behavior so problematic? From a cognitive perspective, talking on the phone is one modality, while driving is another.

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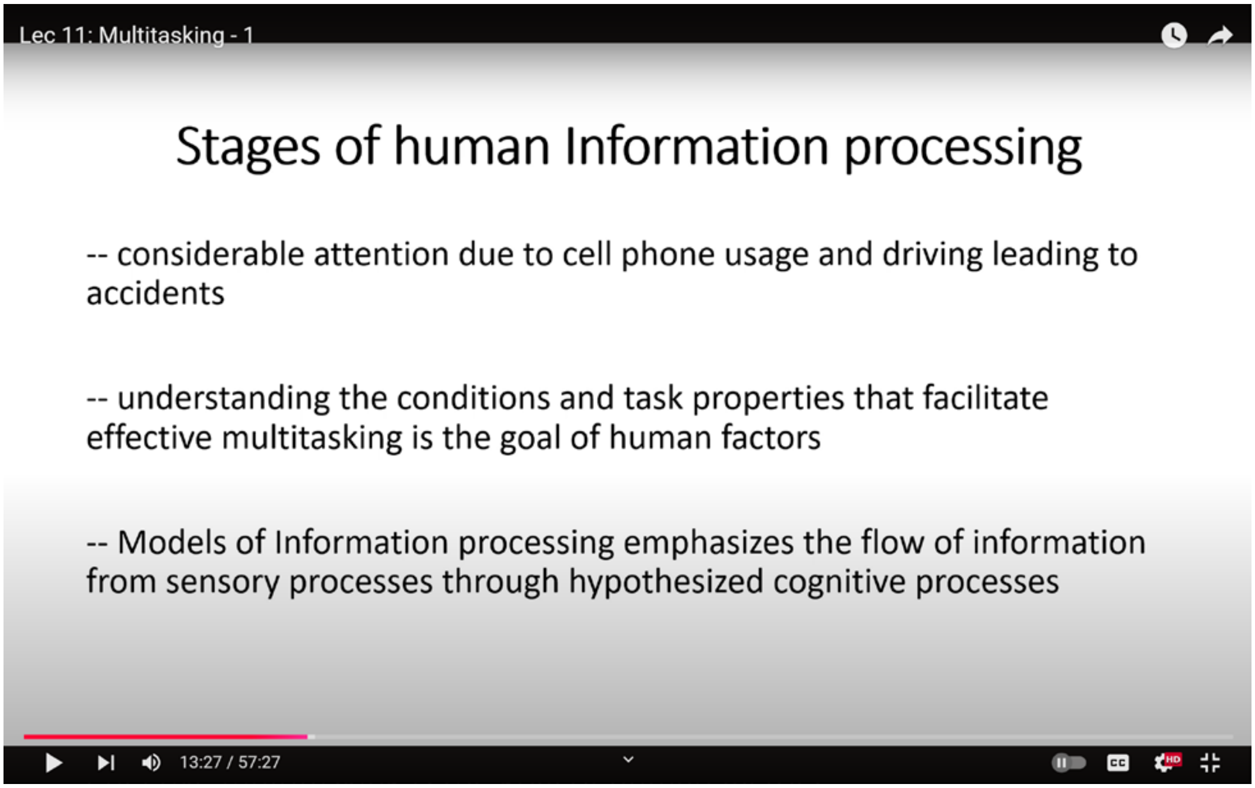

While talking engages both auditory and visual inputs, driving mainly relies on motor inputs. Since these tasks utilize different channels, one might wonder why it is still challenging to converse on a cell phone while driving. To comprehend this, we must examine the information processing mechanisms involved.

One proposed solution to mitigate risks associated with cell phone use while driving was the introduction of hands-free cell phone systems in vehicles. These systems connect via Bluetooth, allowing users to take calls hands-free while driving. However, research has shown that these hands-free arrangements are associated with as many accidents as handheld phones. What accounts for this phenomenon? The answer lies in a deeper understanding of how information is processed.

The field of human factors aims to explore the conditions and task properties that facilitate effective multitasking. It is essential to identify the conditions and characteristics of tasks that can modulate multitasking efficiency. This understanding can help improve multitasking performance at a high level of efficiency.

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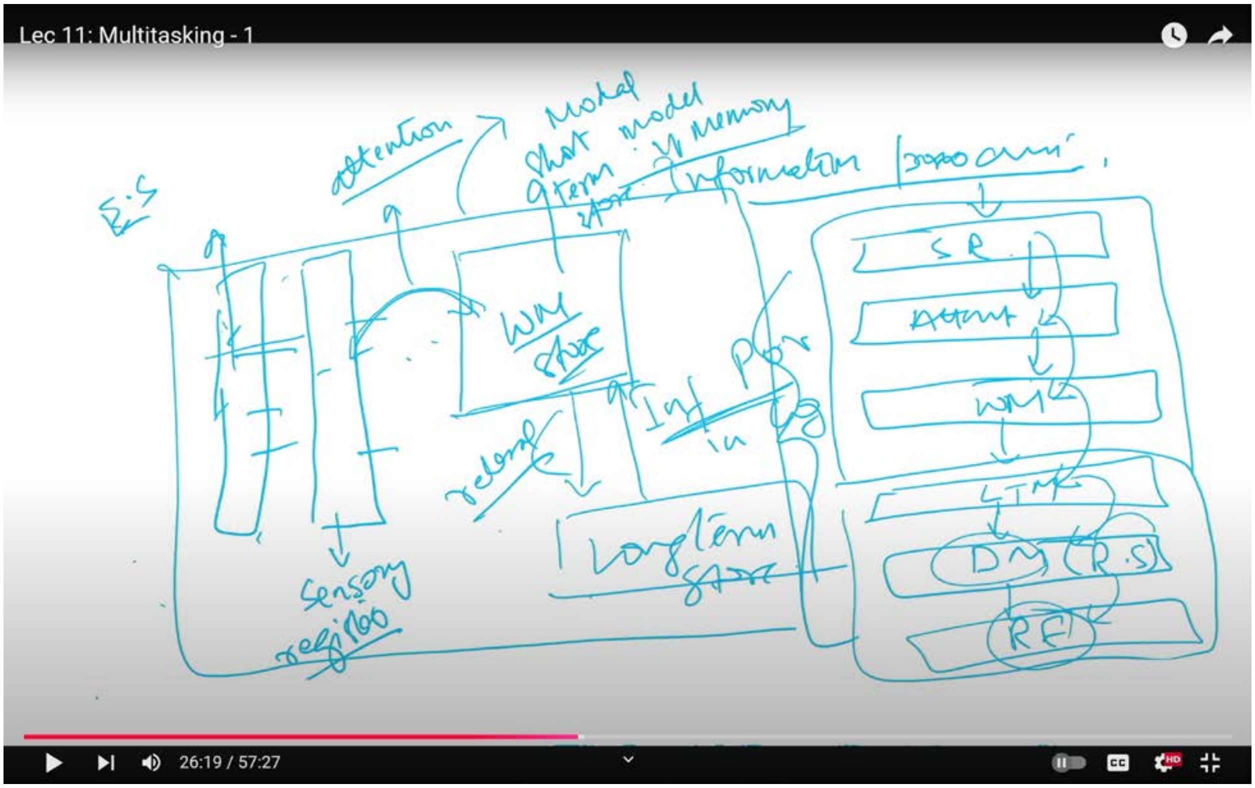

To achieve this, we must investigate how information is transmitted from sensory organs to cognitive processors that make sense of the information. These cognitive systems provide alternatives for action. For instance, while driving, if a child unexpectedly steps in front of your car, your cognitive system must quickly process this information and enable you to choose an appropriate response.

Your immediate reaction would be to press the brakes. If you are traveling at a slow speed, the car will stop, but at a high speed, the risk increases that the car could topple over. Therefore, you must execute additional driving maneuvers to navigate this situation safely. However, this straightforward task of noticing the child and executing the necessary driving maneuver to avoid an accident involves multiple stages. It begins with receiving information through your sensory receptors, which constitutes the initial point of contact between the external world and yourself.

This information is then relayed to other cognitive systems, which we will explore shortly. The model of information processing emphasizes the flow of information from sensory processes through hypothesized cognitive processes. What does this imply? Typically, information processing in humans occurs through a multi-step system.

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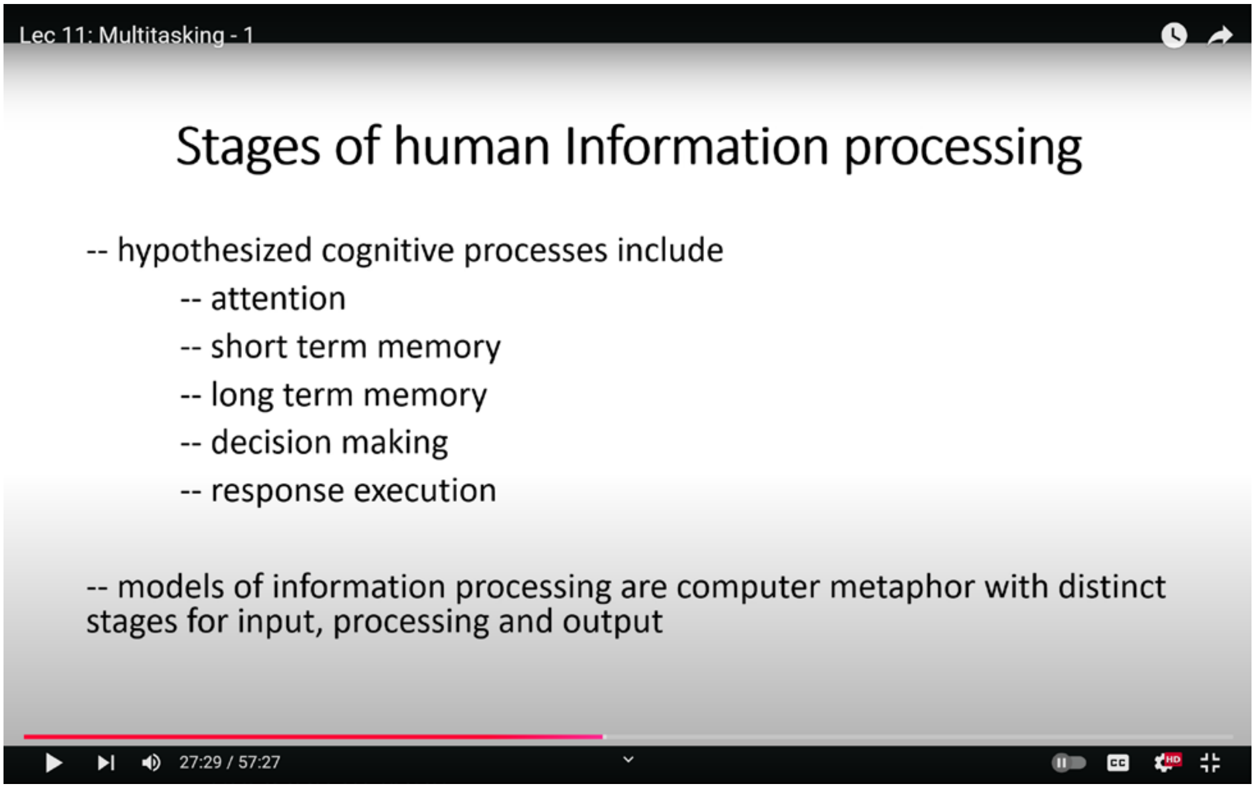

The process begins with information from the environment, which may include sounds, light reflected from surfaces, or pressure sensations felt by your skin. All of these stimuli, whether sound, light, or pressure, interact with your sensory organs. This interaction marks the first impact of the external world on you. Let us consider the example of vision. The light reflected from a tree in the external environment enters your eye, which serves as the sensory organ.

A significant amount of information will be registered by the eye, including the color of the object, its shape or physical properties, its orientation, and more. This information, which impinges on the sensory receptor in the eye, is then transferred to a buffer system known as the sensory register. The sensory register acts as a buffer for the input side, which consists of two components: the input and the output. The input side of the sensory register processes vast amounts of information, while the output side conveys only a limited amount of information.

To summarize, environmental stimuli are transmitted to the sensory register. We will examine the properties of these systems shortly. The sensory register subsequently transfers this information into the working memory store. Previously, this working memory store was referred to as the short-term store. However, due to advancements in our understanding of short-term memory and some debates surrounding its nature, it has been redefined as the working memory store.

Thus, information from the environment enters the sensory register, which employs a process called attention. Attention functions as a filter, similar to the sieve used to strain tea. This filter determines which information will proceed to the working memory store. The working memory store then relays this information to long-term memory. The sensory memory store and long-term memory work in complete synchrony with one another.

The flow of information processing is as follows: Information from the environment reaches the sensory register, which utilizes attention to facilitate the progression of this information. It is then forwarded to working memory, which subsequently sends it to long-term memory. From long-term memory, decision-making occurs regarding the appropriate response, followed by a stage known as response execution. Within the decision-making process, this is referred to as response selection.

Information travels from the sensory register, through attention, to working memory. Working memory then transmits this information to long-term memory, where further processing occurs. From long-term memory, decisions are made regarding the appropriate response to a specific situation. Once the response is selected, it must be executed, which constitutes the response execution stage.

These elements together form the foundation of information processing within cognitive systems. The structure that incorporates the sensory register, attention, working memory, and the rehearsal process for transferring information to long-term memory is known as the modal model of memory. This framework is a component of the broader information transfer paradigm or system.

Now, let us discuss these stores individually. The first store we mentioned is the attention store.

Attention serves as the filter that determines which information from the environment should be processed. For example, when a child runs in front of you, although your eyes can perceive a multitude of information, the presence of that child takes precedence. Consequently, attention is focused on the child, and this critical information is relayed to your higher cognitive processes.

Short-term memory is now referred to as working memory. This component stores information indicating that an event has occurred, and if it is deemed important, it will be mentally rehearsed. If the event is not important, it will be quickly discarded, perhaps as quickly as a fleeting glance at a child, or, upon further reflection, it may not have been a child at all, but rather a plastic bag.

Such information needs to be verified against long-term memory. The data that something has passed is stored in short-term memory for a very brief duration. If this information is processed so rapidly that, before a response is executed, nothing substantial occurs, it will be deleted from short-term memory. However, if you confirm that it is indeed a child, this information is relayed to what is called long-term memory. Long-term memory then assesses what you are witnessing, whether this situation has occurred previously, and what necessary actions can be taken.

This process involves utilizing your prior experiences, as well as the incoming information from the sensory system, which are combined to generate possible solutions. One possible solution could be to apply hard brakes to stop the car; however, this action carries the risk of causing the car to topple over. Another alternative might involve maneuvering the car to allow the child to pass safely. These two options are presented by long-term memory. The decision-making system then evaluates the advantages and disadvantages of each alternative provided.

Calculating the odds leads to the execution of a response. For instance, if it turns out to be a paper bag moving in front of you rather than a child, you would continue driving without stopping or hitting the brakes. Conversely, if it is indeed a child and they remain at the periphery of your car, you may opt to honk your horn loudly, prompting the child to step back. However, if the child has entered the path of the car, you would then either apply the brakes or maneuver the vehicle to avoid them. This action of honking, maneuvering the car, or applying the brakes is termed response execution.

From the moment you observe the child to the time you execute a response, these hypothetical systems are engaged. The model of information processing is often likened to a computer metaphor, featuring distinct stages for input processing and output. As previously illustrated, the input corresponds to the sensory register, processing occurs within the working memory and long-term memory, while output manifests as motor execution, involving the act of maneuvering the car or applying the brakes through the motor system. Each of these stages is distinct.

The properties of each stage, including their capacity and coding for representing information, are derived from research across various fields, including experimental psychology, neuroscience, computer science, and physiology. Each stage, from input to processing to output, has its own limitations and capabilities, as well as distinct features and properties. These properties have been experimentally verified and tested through various types of assessments, and understanding these characteristics will aid system designers in creating systems that assist users rather than overwhelm them with excessive information that could lead to accidents.

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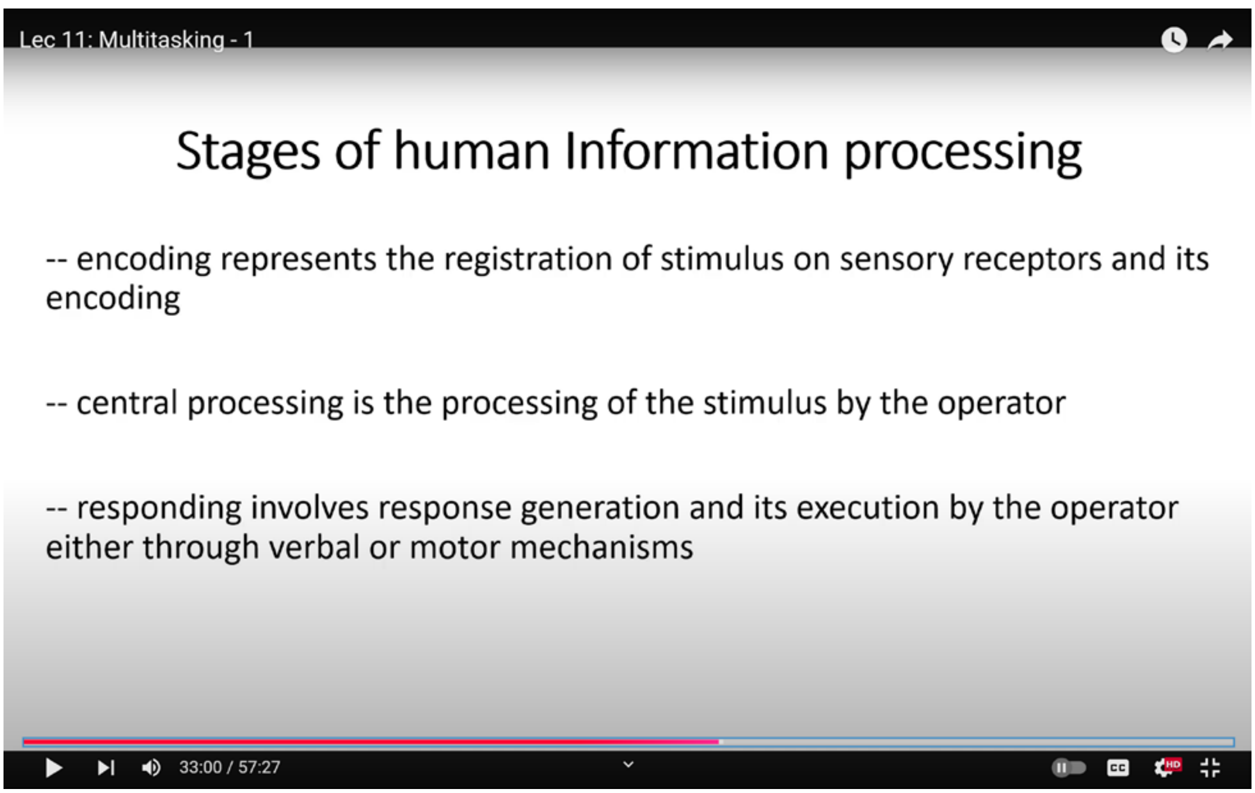

We examine the various stages to clarify the different codes, limits, and properties inherent in each stage. The three general stages of information processing are encoding, central processing, and responding. Encoding refers to the act of capturing information from the environment and processing it with the assistance of attention. Central processing is the system that utilizes working memory and long-term memory to process information, thereby generating alternatives for action in a given situation. Responding is the part of the information processing architecture that involves generating either a motor or verbal response.

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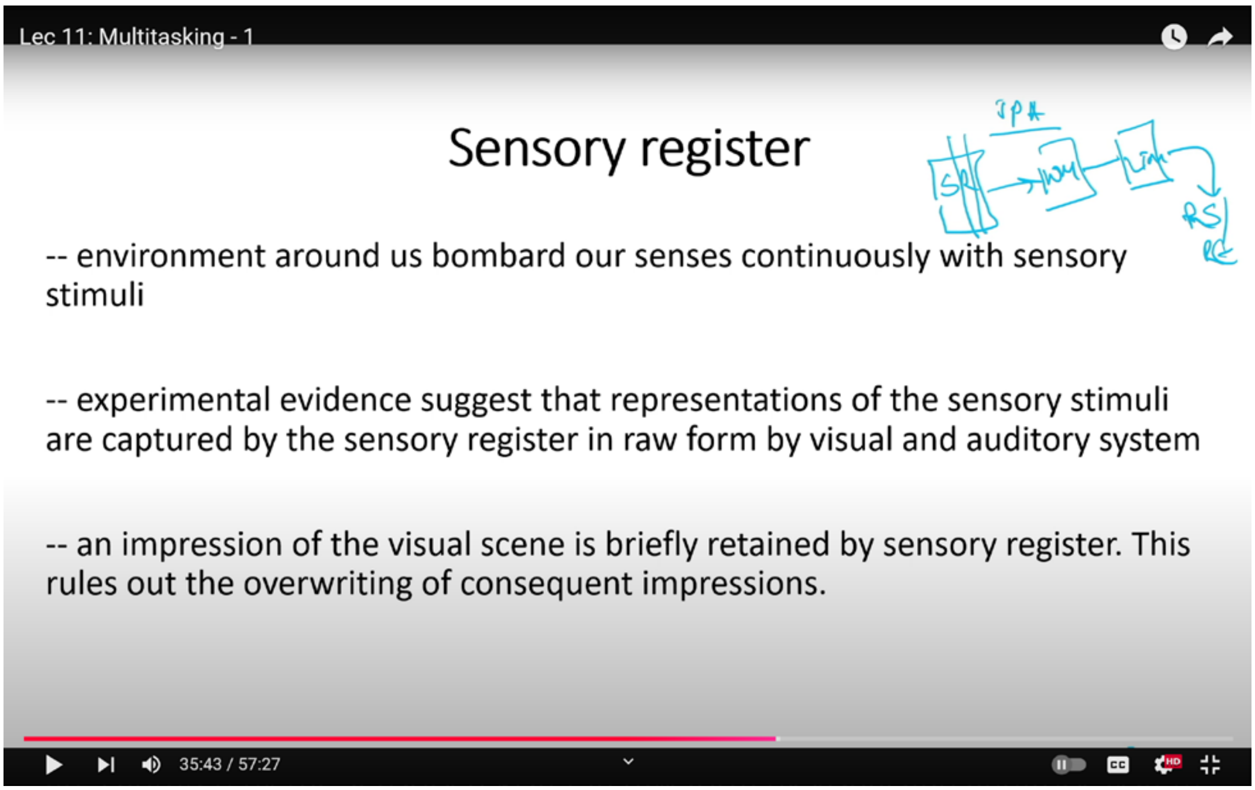

What is encoding? Encoding is the registration of stimuli on the sensory receptors and their subsequent processing using attention. Thus, encoding consists of taking information and preparing it for the next stage. This represents the initial entry point between the human receptor and the external world.

Central processing refers to the processing of stimuli by the operator. This stage encompasses the information received by the receptors up to the point just before a response is made by the individual, which may involve hand movement, verbal action, or visual response. Everything that occurs in between is part of the central processing stage.

Responding involves generating a response and executing it by the operator, either through verbal or motor mechanisms. In our scenario with the car, encoding is the step where you see the child approaching in front of your vehicle, alongside a multitude of other visual stimuli. You use your attention to prioritize the child, as this information is more critical. Thus, through the use of attention, you process this information.

This information travels from your eyes to your brain, where higher cognitive processes perform various calculations to determine the appropriate action. This stage is known as central processing, and the action you take is classified as responding. As previously mentioned, the information processing architecture in humans comprises a sensory register, a working memory component, and a long-term memory system, which further connects to response selection and execution.

Now, let us discuss the sensory register, examining its function and significance.

The environment around us continuously bombards our senses with sensory stimuli. We possess five distinct sensory registers, with the most extensively studied being the visual and auditory registers. In this context, we will focus on the visual and auditory sensory registers, which are responsible for processing all available information from the environment.

Imagine you are sitting in a lecture. You hear your professor's voice delivering the lecture, but other sounds are also entering your ears, such as the noise from the fan, a friend talking, the sound of a pen moving across paper, or the rustling of a shirt against your body. Depending on what you find important, you try to focus on a particular stimulus. As you immerse yourself in the lecture and listen attentively, all other sounds seem to fade away.

This disappearance of surrounding sounds allows you to concentrate on your professor’s voice and absorb the lecture. However, this does not mean that the other sounds have ceased to exist; they continue to reach your ears. Instead, your auditory system uses the mechanism of attention to focus exclusively on the lecturer's voice. This system, which registers all sounds but prioritizes your professor’s voice, is known as the sensory register.

Each sensory register has its unique properties. Experimental evidence indicates that the sensory register captures representations of sensory stimuli in their raw form through the visual and auditory systems. Experiments have been conducted to ascertain the nature of the stimuli that impact the sensory register, revealing that this information is indeed captured in raw form. The environmental information reaching the input of your sensory register is accessible for only a brief moment; if it is not processed, it will quickly fade away. Various experiments have demonstrated that all this information is momentarily available, which we will examine shortly.

The sensory register retains a brief impression of the visual scene, which prevents the overwriting of subsequent impressions. The temporary retention of all information in the sensory register ensures that stimuli do not overlap excessively, thus preventing the overwriting of the initial perception.

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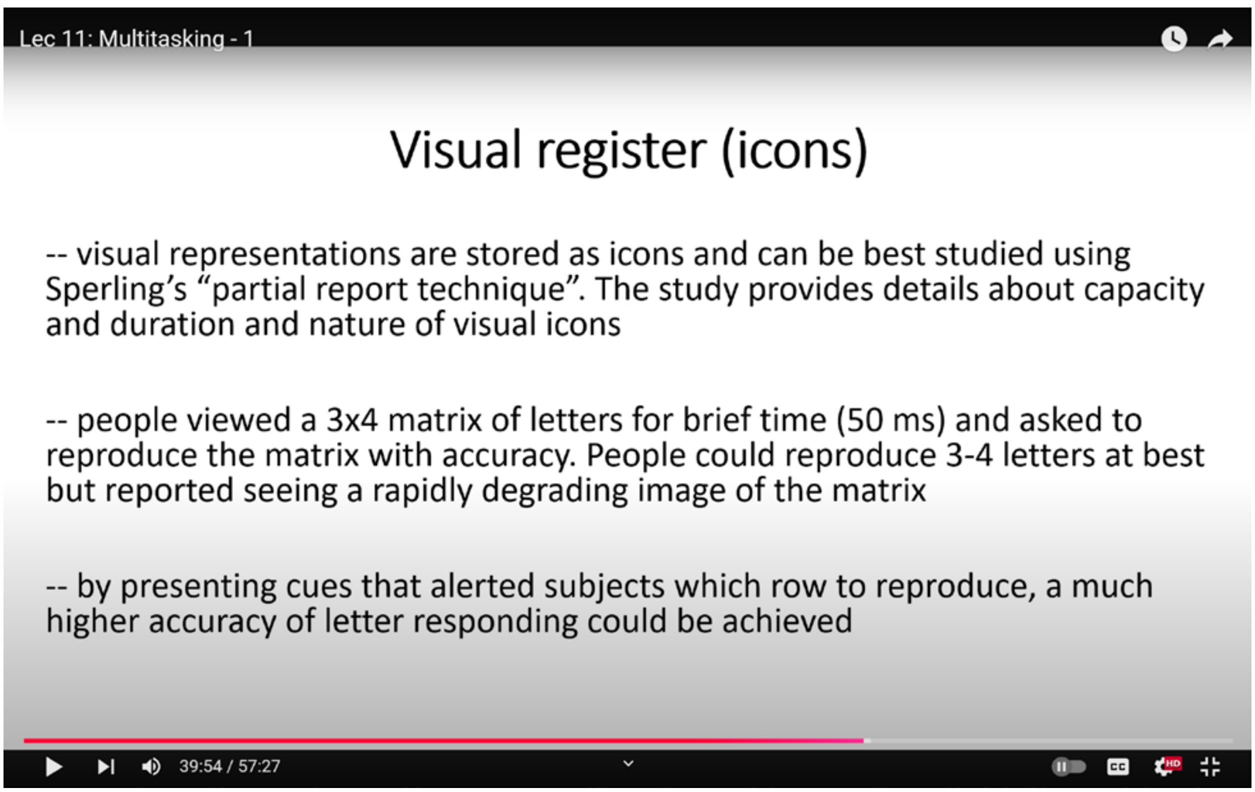

Now, let's consider the two types of sensory registers. As previously mentioned, there are five different senses, and at the sensory register level, the information contained varies. Visual information is represented in the form of light, whereas auditory information is in the form of sound.

The visual register is referred to as the "icon." Visual representations are stored as icons and can be best studied using Sperling's partial report technique. To illustrate what the visual register or icons entail, consider a scenario in a classroom where the professor quickly tests their slides by projecting them briefly to check functionality. If you are gazing at the screen, you will perceive a fleeting image of the slide, which quickly fades away. This phenomenon, where stimuli are present and then disappear almost instantaneously, is termed an "icon." Since it pertains to the visual medium, it is called a visual icon.

The presence and brief duration of these representations (icons) can be demonstrated through Sperling's partial report technique. This study provides insights into the capacity and duration of visual icons. In this experiment, participants view a 3 by 4 matrix containing letters (for example, A, B, K, T, P) presented for a mere 50 milliseconds. The viewers are then asked to reproduce the letters from the matrix accurately.

Typically, individuals can accurately recall only 3 to 4 letters at best, yet they report perceiving a rapidly degrading image of the matrix. This quickly deteriorating image is what is referred to as the icons. The fact that participants report seeing this degrading matrix serves as evidence that all information is indeed available for a very brief period.

To further investigate whether all information is accessible, Sperling modified the experiment by introducing cues, tones that alerted subjects to which row they should reproduce. This adjustment led to significantly higher accuracy in letter recall. Initially, during the whole report phase, subjects were presented with the matrix for 50 milliseconds and were asked to report all the letters they saw, yet they typically managed to recall only three or four letters.

Initially, a matrix was presented, with three tones associated with each of its rows: a high tone for the first row, a low tone for the second row, and a medium tone for the third row. Just before this matrix was displayed, the corresponding tone was presented. For instance, if a high tone was given, subjects were instructed to reproduce only the first row of the matrix. Conversely, if the medium tone was presented, participants were asked to reproduce the last row. Sperling found that it was much easier for subjects to reproduce the row associated with the tone. They only needed to recall four letters, which indicates that the information is not only available but also degrades rapidly.

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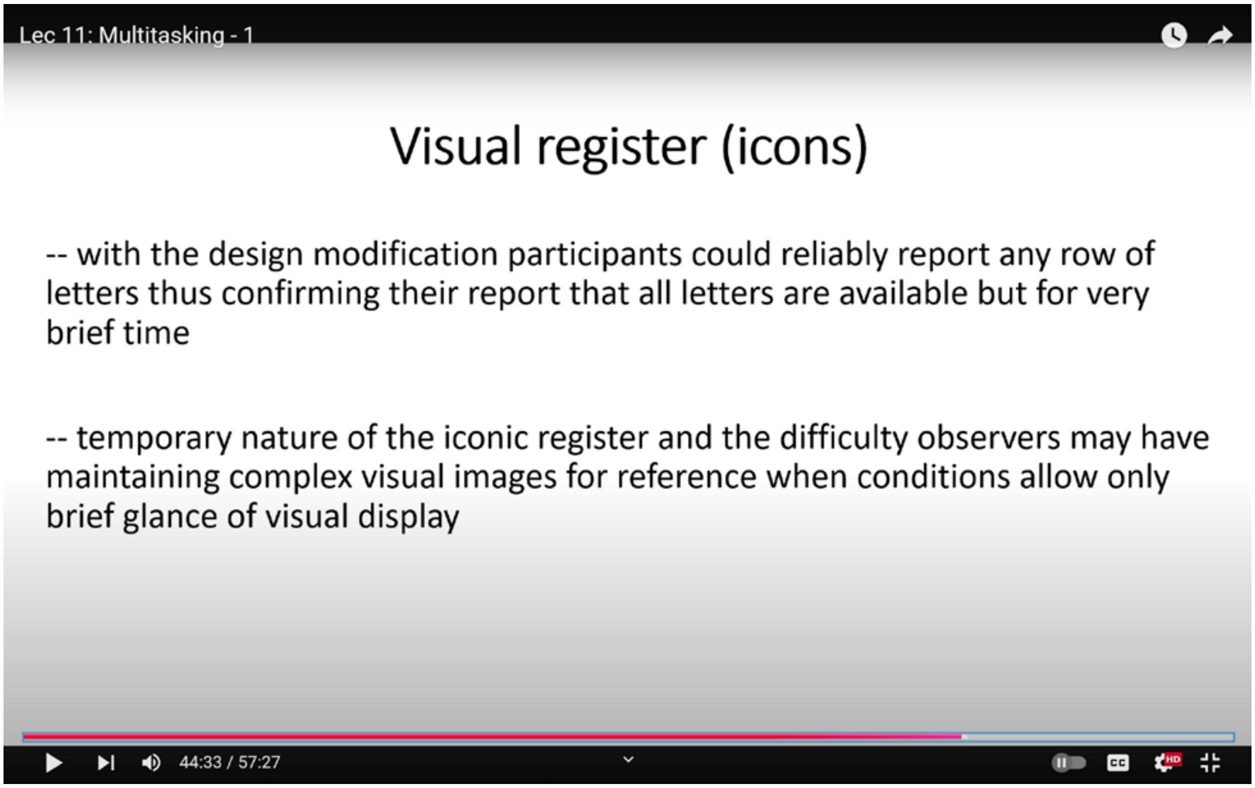

If a method can be implemented to preferentially select specific information from the vast amount of sensory information available, that information can be processed more effectively. With this design modification, participants could reliably report any row of letters, thus confirming that all letters are available, albeit for a very brief period. The temporary nature of the iconic register and the challenges observers face in maintaining complex visual images for reference, especially when they can only glance at the visual display, are noteworthy.

This situation is analogous to viewing a complex scene where numerous elements are present. A quick glance at the scene will not enable you to evaluate every aspect. By employing attention, you can focus on certain parts of the image while other parts may fade from perception. Now, the question arises: is there an auditory equivalent to the icon? The answer is the echo.

What is an echo like? When you watch a movie, a loud sound is produced. Even after the sound ceases, you may still experience a ringing in your ears, which is referred to as an echo. Thus, echoes serve as the auditory analogue of icons; they are short-lived, yet their repetitive nature allows individuals additional time to respond.

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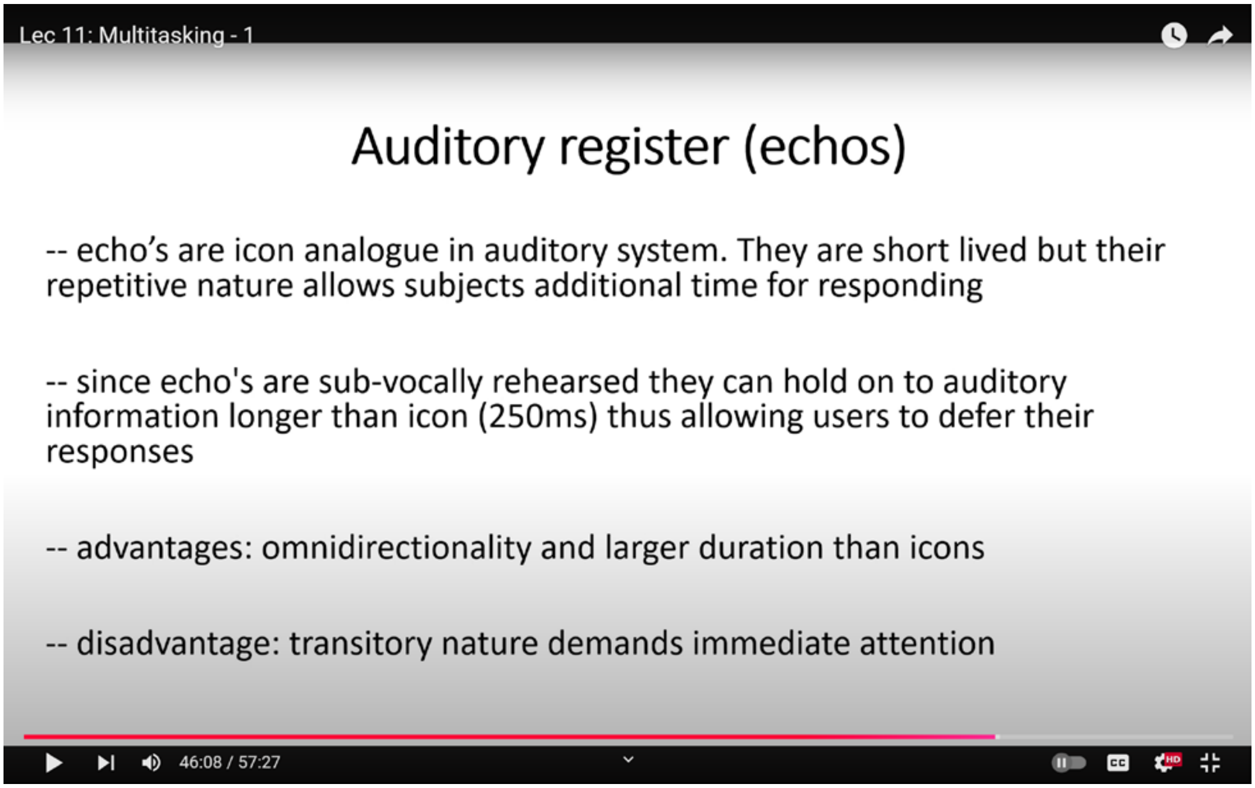

In the auditory system, auditory warnings are known to be transitory. Although they are available for longer periods, the information they convey is limited. Despite their brevity, the vibrations they produce in your ears provide you with a moment to respond. Since echoes are rehearsed sub-vocally, they can retain auditory information for longer durations than icons, which last about 250 milliseconds. This allows users to delay their responses.

Echoes persist for a longer duration, giving individuals additional time to react. One advantage of echoes is their omnidirectionality and longer duration compared to icons. Echoes can emanate from any direction, and they persist longer. However, one disadvantage is their transitory nature, which necessitates immediate attention. Echoes are fleeting and do not last long, compelling you to focus on them promptly.

These concepts regarding icons and echoes represent fundamental information blocks in our processing architecture. The next component in this architecture is known as short-term memory (STM). Short-term memory functions as a store that retains information for a very brief period. If this information is not rehearsed, it will be lost; however, if it is rehearsed, it can persist for a longer duration. Furthermore, if this information is associated with meaning, it can be transferred to long-term memory, where it may remain for a lifetime.

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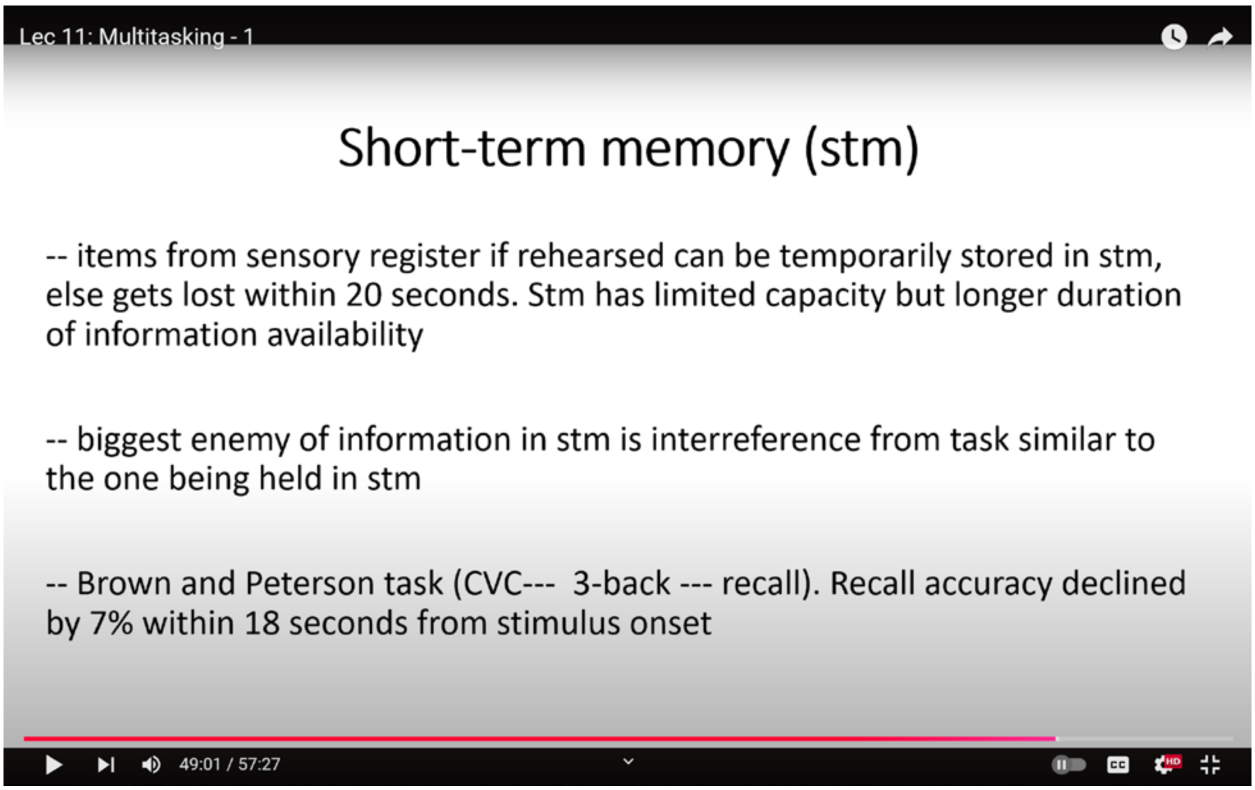

Let us examine what short-term memory entails. Items from the sensory register, when rehearsed, can be temporarily stored in short-term memory. Without rehearsal, this information is likely to be forgotten within 20 seconds. Thus, the duration of short-term memory is approximately 20 seconds. Short-term memory has limited capacity, yet it allows for a longer duration of information availability compared to the sensory register.

Although the amount of information that can be stored in short-term memory is limited, the duration of retention, 20 seconds, is significantly longer than that of the sensory register. As previously mentioned, if information is rehearsed, it can be retained for much longer periods, sometimes even over a lifetime.

The greatest challenge to maintaining information in short-term memory is interference from similar tasks. For example, if you are trying to remember a mobile number by repeating it aloud, and someone speaks another number to you simultaneously, the two numbers may interfere with one another, making it difficult to recall the first number accurately.

It is important to note that the coding or storage of information in short-term memory occurs in verbal terms, with an auditory nature. Therefore, if two items share similar auditory characteristics, they are likely to interfere with one another. Letters such as B and P, for instance, can often be confused due to their similar phonology.

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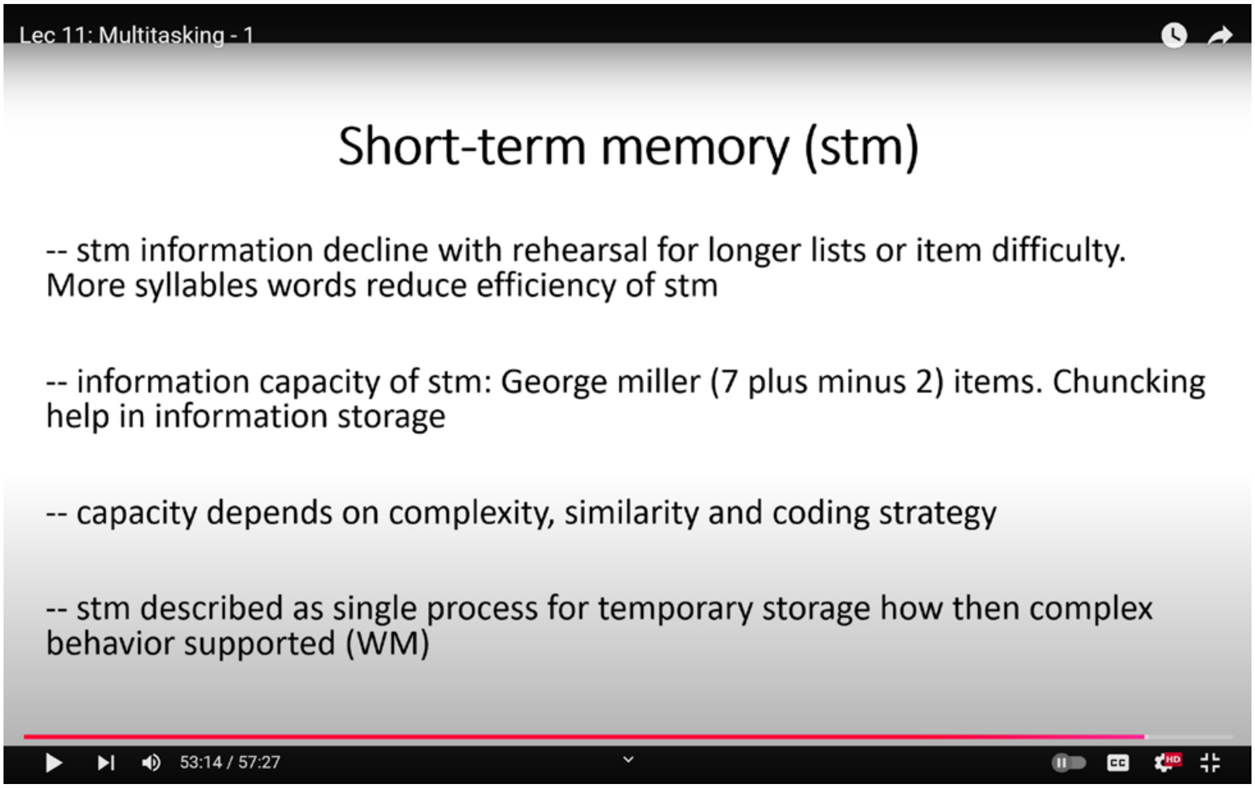

To demonstrate how long information can be retained in short-term memory, Brown and Peterson conducted a significant study. In this experiment, participants were presented with three-letter consonant-vowel-consonant (CVC) combinations, such as ABC or PQR, and were instructed to hold onto these words. Subsequently, they were asked to count backward from 1000 to 3 (e.g., 1000, 997, 994, and so on).

At various intervals, participants were prompted to recall the initial CVC combination they had been given. Warren and Peterson found that by the 18th second, recall accuracy had declined to only 7%. This finding indicates that if information is not repeated in short-term memory, it will be lost. The intention behind the task was for participants to rehearse the information in their minds. However, since this was not happening effectively, individuals lost access to the information.

Participants were instructed to remember a three-letter consonant-vowel-consonant (CVC) word, but the task of counting backward proved to be too taxing, which interfered with their ability to remember the CVC. This interference meant that they did not have sufficient time to rehearse the initial letters of the three-letter word provided to them. Consequently, at the end of each minute, individuals were asked to recall the word. Due to the lack of repetition, by 18 seconds, retention accuracy had declined to approximately 7%.

Short-term memory (STM) information deteriorates with rehearsal difficulty and the length of the item list. If a list is lengthy or if the items stored in short-term memory are complex, the likelihood of forgetting them increases. Words that are more difficult to articulate decrease the efficiency of STM. The more challenging a word is to say, the less efficient STM becomes.

George Miller tested the information capacity of short-term memory and determined that it is approximately seven items, plus or minus two. This means that, at maximum, individuals can store seven items, while at minimum, they can store five items. Therefore, the range of plus or minus two defines the limits of information storage in short-term memory, with seven plus two equaling nine and seven minus two equaling five.

Chunking refers to the practice of grouping items together. For example, if I provide you with several lists of items, such as a list of vegetables, a list of domestic animals, and a list of everyday objects, totaling 50 items, you would likely chunk them into groups. Items that are similar would be clustered together, and this grouping characteristic is known as chunking. The more effectively you can chunk information, the more you can store in your short-term memory.

The capacity of short-term memory is influenced by factors such as complexity, similarity, and the coding strategy employed. The more complex an item is, the more cognitive space and processing it requires, thereby reducing the capacity of STM. Additionally, two similar items may interfere with each other. The manner in which you code information, whether through chunking or by using raw phonological processing, also affects how much information can be stored in STM.

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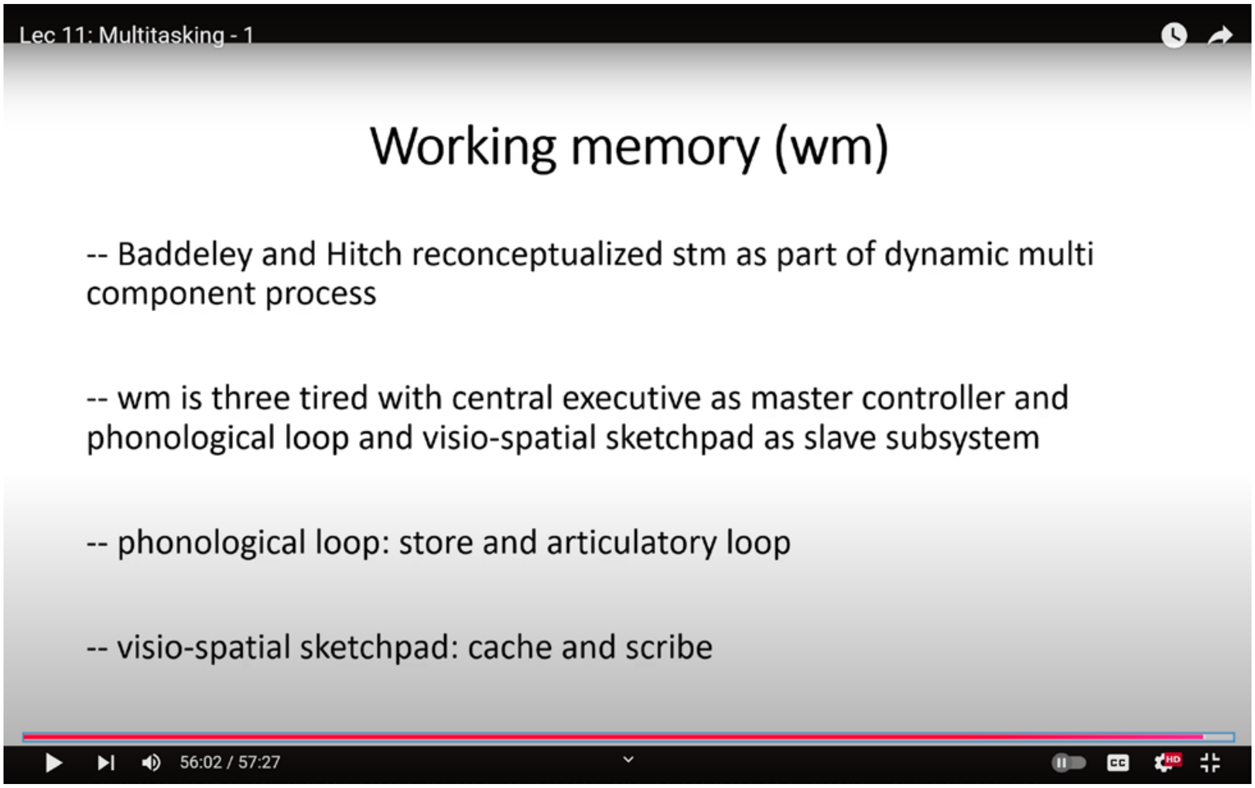

Short-term memory is typically described as a single process for temporary storage. However, the question arises: how does complex behavior get supported by working memory? Short-term memory serves as a temporary store for information that can be lost quickly. For instance, consider the scenario where a child unexpectedly crosses in front of you while you are driving. This information resides in short-term memory, and if you do not mentally rehearse the fact that the child is crossing your path, the information may be lost.

How, then, does long-term memory understand the situation and determine an appropriate response? It must recognize the context. If information is lost within 20 seconds, especially under stress, this timeframe can shorten even further. How does the cognitive system know which alternatives to choose in such scenarios? To address this, another system was proposed, known as the working memory system.

We will delve into the workings of the working memory system in the next class. In today’s class, we briefly explored information processing and the stages involved. We examined multitasking and discussed two systems within the human information processing architecture. When we reconvene in the next class, we will explore additional structures that facilitate information processing within the human cognitive system. Until then, it is Namaskar from the MOOC.