4a | Introduction to Attention

The famous philosopher William James, in his textbook Principles of Psychology, remarked:

"Everyone knows what attention is. It is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalization, concentration of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others, and is a condition which has a real opposite in the confused, dazed, scatterbrained state which in French is called *distraction* and *Zerstreutheit* in German." William James, from *Principles of Psychology*, pp. 381-382.

As we'll see in this module, James' comments were amazingly prescient. Not only is attention one of the most studied areas in cognitive psychology, but the issues that James focused on are still hot topics of debate today.

In this unit on attention we'll focus our attention on how theorists believe we perform selective attention- in other words how we decide what to pay attention to- how and why it is that some behaviours or actions seem not to require any attention at all, or are automatic, what can happen when there are problems with attention, some of the so-called disorders of attention, and attention in the real-world. The popular press is rife today with reports of cell phone use while driving a car. What does our knowledge of attention have to say about this?

4b | Selective Attention

We've all had moments like the little boy in the cartoon. We know we were present to receive some information, but just don't seem to have access to it. This is undoubtedly a failure of selective attention to help us process what we should be processing. Sometimes, despite our best intentions we find our mind wondering and we leave a situation without vital information that we should be able to remember.

We'll start our attention unit with a short demonstration. On the screen in front of you, you'll see a paragraph written in two fonts—a bold font and an italicized one. Take a moment to read only the message written in the bold font, beginning with the word **Among**. While you're doing this I'm going to ask you to perform a technique that was first used in psychology a long time ago. That's the technique of introspection and you probably remember learning about that in your introductory course. In introspection, what you are asked to do is think about what you're asked to do is to think about your experience as you're performing some task. So as you are reading this paragraph I want you to think about what makes it hard to do, what makes it easy to do? What kinds of things are affecting you while you read this paragraph?

Now that you have finished reading, what was it that you read? Were you able to understand the bold message? Did you happen to notice any of the italicized text? If you are like most observers, you were able to get the gist of the text in bold, but you also had intrusions from things you were not supposed to pay attention to. Certainly the content or the story line of the text and its syntax or the rules for putting sentences together helped keep you on track, it helped keep you able to read the message in bold. As for what made the task more difficult, people generally mention that novelty, like the presence of numbers, emotional words, and names were likely to be distracting. Those were the types of things that they ended up noticing.

We'll begin now with our discussion of the theoretical views of selective attention. The key elements in these theoretical approaches concern when selection takes place, that is, how much processing do we do on information before we say that attention actually selects that information. The other main issue that we're interested in is not only the fate of information that we do select to process, but what actually happens to that information that we don't select for processing? Does any of that get in and can any of that information ultimately affect our behavior.

Broadbent

One of the first theoretical views of attentional selection was Donald Broadbent's Filter Theory. His model is referred to as an "Early Selection" model because it posits that attentional selection operates very early in the stream of processing, before the observer actually knows what the information is and that this selection is based only on physical characteristics like where the information is coming from, its pitch, volume, colour, brightness, and so on. Critically then, selection occurs early, before any meaning information, also known as semantics is processed from the item.

The figure in front of you depicts the dichotic listening task. This was one of the most popular methods of studying selective attention. In this task, an observer is played two distinct messages, one in each ear. The observer is then asked to shadow one of those messages. Shadowing is essentially repeating everything that is spoken to you, as quickly and as accurately as possible. Anyone who has a brother or sister has likely experienced shadowing as an attempt at sibling irritation. Shadowing in an experimental setting is actually very difficult however, because the second message is played at the same time. What Broadbent found was when observers in his experiments were doing a good job of shadowing the message they were supposed to paying attention to, let's say it was the left ear, they noticed virtually nothing at all about the message being played in the right ear. They might notice the volume of the message or the pitch of that message, but they could not accurately say what was being spoken. That was true even if the same word was repeated again, and again, and again in that other ear. They also were unable to notice if the language spoken in that second ear was different from the language in the ear they were shadowing.

Broadbent argued then, that attentional selection was selecting material from the appropriate channel, allowing it to be processed to the point where one can understand that information. Moreover, he said that information in the unselected, unattended channel was not being processed beyond its basic physical features, and certainly not enough to allow the observer to know what that information was or even what language that information was being conveyed in.

As is often the case in science however, things can turn out to be much more complicated than they initially seem, and problems with Broadbent's Filter Theory began to appear.

You've probably experienced one of these problems first hand. Have you ever been in a crowded, loud party and been struggling to carry on a conversation with a friend? You find yourself concentrating on his or her words so that you can hear them over the background noise. All of a sudden, you hear someone mention your name- not calling out to you- just in regular conversation. According to Broadbent, that should not occur, because you had not selected that information. Instead, you were intently processing your own conversation and therefore you should not have "known" that it was your name that was being spoken.

This phenomenon is known as the cocktail party effect and was described by Moray in 1959. Using a dichotic listening task, Moray showed that people often did notice their own names when their own names were played in the unattended channel, even though they were keeping up with the difficult task of shadowing information in the attended channel. Again, according to Broadbent, that should not have occurred.

Treisman

Work by Anne Treisman further underscored this problem with Broadbent's model by showing that when shadowing we sometimes do pick up information from the unattended channel, but only when that information is important to us. So for instance, it could be our name, or a warning word like fire, or some other information that's relevant to the context of the information we're currently trying to process.

This led Treisman to propose our second model of attentional selection, the Attenuation Theory, or Leaky Filter model. Hers, like Broadbent's, is an early selection model and states that there is almost no processing of information from the unattended channel. The only information from the unattended channel that will be become processed is information that ultimately leaks through the filter and that's because that information has some kind of special value to us.

Corteen and Wood

Perhaps the most clever challenge to the class of early selection models was an experiment done by Corteen and Wood at the University of British Columbia. If you remember back to your days of studying introductory psychology, you'll know that it is possible to elicit a fear response to a non-fearful stimulus by simply pairing it with an aversive event, such as an electric shock.

Corteen and Wood paired select Canadian city names, such as Vancouver, Montreal, Regina and Winnipeg, with electric shocks until the mere mention of these city names produced a fear response that could be measured in the observers' galvanic skin response or GSR. A GSR measures changes in respiration, perspiration, and so forth that can be picked up on the skin.

Corteen and Wood then had their observers participate in a dichotic listening task and asked them to shadow a message. Unbeknownst to the observers, Corteen and Wood played the names of the Canadian cities in the unattended channel. Despite the fact that the observers did not report hearing the city names, they produced a GSR when the names were played, indicating that they had indeed processed this "unattended" information.

Even more amazingly, Corteen and Wood had also embedded names of other Canadian cities in the unattended message. These city names, such as Toronto, Saskatoon and Halifax, had never been paired with shock before. Fascinatingly, the observers also produced GSRs when these new city names were presented, despite the fact that they were not aware of having heard them.

This clearly indicates that these items were processed to the level of semantics, as only then can one know that Toronto is indeed a Canadian city. This result provided a major challenge to early selection theories, as it would suggest that perhaps all information in the unattended channel is processed all the way to the level of meaning or semantics, even if the observer never becomes aware of that.

Deutsch

Results like those of Corteen and Woods led to the development of a late selection model of attention, also known as the Deutsch-Norman model.

This model posits that all information—whether we are trying to attend to it or not- is processed until the point at which we can access its meaning in long term memory. Selective attention then operates at this late stage in order to direct our awareness or to guide our response to that information.

So, even if we aren't aware of information, it is possible that we have processed it and have actually activated its representation in memory and that it can, in fact, influence our behavior.

4c | Automaticity and Practice

In the first part of our unit on attention, we talked about attention as our ability to process or respond to some things, but not others—so-called selective attention.

In this section, we will view attention according to a resource metaphor—much like having the fuel that is necessary to accomplish some task. For instance, we all have the intuitive sense that it takes many more resources, or much more attention, to read our cognition text the night before the big exam than it does to read our favourite novelist in bed on a rainy day. Likewise, those first few times we drove a car, operating that vehicle required so many attentional resources that we couldn't listen to music or carry on a conversation without sometimes feeling overwhelmed. Now, however, it seems hard to imagine driving without music and we are sometimes even tempted to carry on a cell phone conversation while we're driving— but we'll talk about that specifically later.

We say a process or a behaviour becomes more automatic as it requires fewer attentional resources to perform. This typically occurs with practice. For instance, in addition to driving and listening to music, you probably find it much easier now to listen to a lecture and to take notes at the same time than when you began university and it may have felt like a struggle to keep up with the pace that your instructor was setting.

In addition to practice leading to greater automaticity and the need for fewer resources to complete a task, it can sometimes have an unwanted side effect. That is, sometimes the more automatic behaviour becomes so automatic that we simply cannot prevent it from happening, even when we don't want to do it, and when doing it actually impairs our ability to do the thing that we're trying to do.

Stroop

The Stroop effect, named after John Ridley Stroop, is probably the best known example of the interfering effects of a relatively automatized process. In addition, the Stroop effect is one of the most popular and well studied phenomena in psychology. There have been hundreds of papers published on the Stroop effect since John Ridley Stroop published his first paper on it in 1935.

We'll introduce the idea of an automatized process actually interfering with behaviour by way of an experiment. While performing the following little experiment, I'd like you once again to practice introspection. That is, as you're performing this exercise, think about what you're experiencing.

Your task is a simple one—one you've likely been able to do since you were a toddler. The next slide you're are going to see a column of ink colours and what I'd like you to do beginning at the top of the screen and working your way down, is as quickly as you possibly can, yet as accurately as you possibly can, name aloud the colour of the ink that you see. While you're doing this please remember to introspect and think about what the process is like for you. After you've completed the first slide, please do the same thing, name aloud the ink colours that you see for each of the following two slides.

What happened? You undoubtedly found slide 3 to be much more difficult than either of the other 2. Indeed, when we perform this experiment in a large classroom, the class inevitably breaks into laughter because they find this process so frustrating. You obviously noticed that whereas the stimuli on slide 1 were colour bars, on slides 2 and 3 the ink colour was carried on a word spelling a colour name. On slide 2 the ink and word indicated the same colour name, whereas on slide 3 they indicated different colours. It is hypothesized that reading is such an automatic process in expert readers that one cannot prevent it, even when its effects are deleterious on what we intend to do. This in fact is what produces Stroop interference which you likely just experienced.

Those of you with little brothers or sisters, say in kindergarten, will find that they are not at all troubled by Stroop interference, or at least not like you are. They simply are not yet expert readers performing an automatic behaviour. For them, reading is a controlled behaviour. If you have a friend who is just learning a new language, you might also find that in the new language, these individuals do not yet produce Stroop interference, although they would produce Stroop interference in their native language. Beginning readers and readers learning a brand new language are not yet expert readers performing an automatic behaviour. For them, reading is still a controlled process.

Controlled Processes

What, then, are the theoretical characteristics of controlled vs. automatic behaviour? Controlled behaviours are said to be those that we undertake serially, or one at a time, and that require attention. Moreover, they are said to be capacity limited, meaning that if we attempt a second process that also requires attention while we're trying to perform the first, at some point we'll not have enough resources to perform both—we'll simply run out of fuel. Finally, controlled processes are under our conscious control.

Remember those early days of riding a bicycle or driving a car? Remember how aware you were of trying to stay balanced and when to brake when you're on your bike, or how to keep on the road or when to shift if you're learning to drive a car? As proficient bicyclists and drivers, we're simply not aware of those things anymore.

In contrast to controlled processing, automatic processing occurs without our intention, and we often are not aware of doing it. It does not require attention, so it in itself does not interfere with other mental activities, although the result of such automatic processing might, as we just saw as in the case of reading in the Stroop task. When you read those words, it actually interfered with your ability to name the contrasting ink colours.

Finally, automatic processing can occur in parallel with, or along with, other processes and they do not constrain capacity limitations, because they require little or no attention at all.

To summarize, then, in this section we've discussed attention as a processing resource, and we've seen that humans can be quite flexible in allocating this resource, but that there are some limitations, and sometimes these limitations in themselves interfere with behaviour.

4d | Disorders

So far we've talked about selective attention and attention as a resource and we've done so discussing what we call normal or "intact" populations. These are most commonly psychology undergraduates that we study in the lab. It is also true, however, that we learn a great deal about attention by studying individuals who have undergone unfortunate brain traumas and those traumas have led to various disorders of attention.

One class of brain trauma that often leads to a disorder in attention is stroke. As of the end of 2009, the Heart & Stroke Foundation of Canada reports that there are over 50,000 strokes in Canada each year. Of these 75% of individuals are left with at least a minor impairment or disability, and an impairment in attention is commonly seen.

The most common attentional disorder is known as visual neglect and is also sometimes called hemispatial neglect or unilateral neglect.

Visual neglect is associated with lesions in the parietal area of the right hemisphere. As a result, the patient tends to "neglect" the contralateral hemi-space. In other words, the patient suffering from a RH parietal lesion will neglect the left visual hemi-space. In some cases, the patient will even neglect the contralateral, or left side of his or her body, even sometimes denying that the left arm or the left leg belong to him or her!

It is important to note, however, that this is an attentional deficit, rather than a sensory one. It isn't that the patient cannot see the information in the left hemi-field, but rather that he or she cannot pay attention to it. Some patients even report the feeling that their attention is being held on the right side and that it cannot be moved to the left.

Some very simple tasks can be used to show the profound effect of unilateral neglect. One of the most readily used is the line bisection task. In this task, a person is presented with a horizontal line and simply asked to draw a vertical line to bisect the horizontal line, or cut it in half. As shown in the slide, whereas most people are pretty accurate at this task, a person suffering from neglect will bisect the line much too far to the right, indicating a failure to attend to the left part of the line when judging its length. Researchers often present individuals with not just a single line for bisection, but with many spread across a page. Whereas an intact individual will bisect them all, an individual with neglect generally fails to attempt any of the lines on the left side of the page.

Neglect can also be demonstrated by providing patients with simple drawings to copy. Their reproductions of the objects , although fairly accurate on the right showing that they can still see and draw, typically miss most, if not all of the information on the left, even resulting in incomplete objects that don't make sense. Again, it is not the case that the patient cannot see what is there, the processes that support vision are intact. They simply cannot pay attention to it. This doesn't occur just for tasks such as line bisection and copying. Sadly, unilateral neglect affects all aspects of the individual's life, even things as important as eating and grooming. Patients often fail to eat food on the left side of their plate and to groom half of their bodies.

One of the most profound demonstrations that visual unilateral neglect is an attentional disorder, and not a disorder of visual sensation was published by Italian researchers Bisiach and Luzzatti. They tested two individuals who suffered from unilateral neglect who had grown up in very distinct, old, Italian villages. In these villages, important buildings such as churches, town halls and libraries were organized on a square plaza, centered around a fountain. Bisiach and Luzzatti asked the individuals to imagine that they were standing at one end of the plaza, say on the steps of City Hall, and to look out and describe the plaza. Their patients accurately described the "right hand side of the scene," but neglected all the buildings on the left. Next, Bisiach and Luzzatti asked them to imagine that they were at the other end of the plaza, standing on the steps to say, the Catholic Church, and to describe what they remembered seeing. Once again, they accurately described the right hand side of the plaza, but ignored all the buildings on the left. Incredibly, this means that they had just described buildings they had previously neglected to report, while neglecting to report buildings they had described only moments earlier. Clearly, all the information was present in memory and hadn't been simply forgotten. The patients' ability to attend to the left hand side of a visual memory was clearly affected.

So, as we see, brain injury can have a profound effect on our ability to attend to visual space. In term of our earlier metaphors, people suffering from neglect have difficulty in selecting information from visual and or mental space.

4f | Summary of Attention

To summarize our exploration of attention, it is important to keep in mind that we framed this concept in a few different ways. We spoke about attention as a selection device, which allowed information to be processed, and we found that selection is likely much more flexible than we initially believed, although there are probably also some serious limitations.

Selection appears to be early—or before meaning—sometimes, and late—or after meaning—at other times. This may even be in response to the environment, our internal state, and the number and type of other things that we're trying to do.

We've seen that automatic performance, or performance requiring little or no attention, can come from practice, as in riding a bicycle. This often brings benefits, as in allowing us to think of things other than just how to balance when we're biking, but it can also result in interference from the automated process. We experienced this first hand with the Stroop effect.

We discussed the fact that we can learn about attention by investigating cases in which it is impaired, as in unilateral visual neglect.

Finally, we broadened the scope of our treatment of attention beyond the lab, to consider its impact on life in the so-called real world. We talked about the impact of cell phone use on driving. As technology continues to advance, you can rest assured that attention researchers are going to stay very busy.

05a | Introduction

In this module we're going to be talking about memory structures. Memory is probably one of the most studied areas in cognitive psychology, the reason being is that memory enters into almost every cognitive activity that we do. Memory is obviously involved when you're sitting in an exam and thinking hard and trying to recall that information that you studied for that test. However, other activities also involve memory. For example, if you're playing a game of Texas hold 'em poker, you need to remember all the rules of the game, you need to remember how much to bet if you're the small blind, or if you're the big blind, and which is the better hand to have, a full house or a straight. Even very simple tasks, like carrying on a conversation with someone, are highly dependant on memory. When someone speaks a sentence to us, we have to keep in mind the beginning of that sentence while we process its middle and end. Furthermore, we have to remember what they said maybe one or two minutes before, in order to understand the context of what is being said now. As you can see from these examples, memory is central to pretty much every cognitive activity that we have.

What researches have found over the years is that memory can actually be broken down into many small subcomponents, each with its own abilities and capacities. How these subcomponents operate is what we're going to focus on in this module. We're going to begin this module by talking about different memory stores, that is, places in our mind that store information for a specific amount of time. We're going to start off by talking about sensory memory – that is, the briefest area of storage – then move on to short-term and long-term memory. We're then going to talk about working memory, which is just simply a more expanded version of short-term memory, and then move on to episodic and semantic memory – and here, episodic and semantic memory is just another way of actually further breaking down the types of information that are stored in long-term memory. And then we're going to finish off this module by talking about neurological studies of memory, as neurological studies of memory have been very useful in helping researches not only understand the human mind in general, but memory in particular.

Even though we're not going to get into neurological studies of memory until later on in this module, I think it's worthwhile to expose you briefly to the case of Clive Wearing, an individual who, after a bout with encephalitis has experienced profound memory deficits. When you watch the video of Clive Wearing, think about those things that seem to be spared, and those things that seem to be particularly affected. For example: he can still play the piano beautifully, he can still conduct the choir, he can still sing – those abilities obviously rely on some form of memory. However, he can't remember what happened five minutes ago, and he can't go outside alone, because he would quickly become lost and unable to find his way home. You see, every time he sees his wife, it's as though it's for the very first time. In this module, we'll try to explain some of these phenomena. We'll try to explain how you can have different types of memory, and some things can be affected by certain types of deficits, where as others will not –

they can be spared. So, before we go on with the rest of the sections of this module, and before we begin talking about the different sub-components of memory, do take a look at that Clive Wearing video, as it will help you gain some insights into the different types of memories that we have. We will be referring to this case of Clive Wearing throughout this module.

05b | Sensory Memory

Before we talk about the different types of memory we need to go through a couple important terms. These terms are relavent for all the different types of memory that we're going to be talking about. First off, when we talk about memory, we're going to be talking about the encoding of information and the retrieval of information. Encoding simply refers to how information is acquired, and it occurs when information is first translated into a form that other cognitive processes can use – that is, how is it that you get information into your mind. Retrieval, on the other hand, is simply calling to mind previously stored information, that is, once you have information stored in memory, after you've encoded it, how is it that you bring this information to mind? We will also be talking about storage, that is, how information is stored in memory and how it is coded in memory. And finally, we'll be talking about forgetting, which is simply when we cannot retrieve previously stored information. And again, how information is stored and how information is forgot from memory will be different depending on the type of memory structure that we're referring to.

Let's move on now and talk about memory structures. Perhaps one of the most influential models of memory, and actually referring to memory in terms of different structures or different stores, comes from Atkinson and Shiffrin in 1968. They came up with a very influential model, called the "Modal model" of memory. This Modal model of memory is represented in the following figure. You'll notice in this model that there are a number of different modules, or places where information can be encoded, stored, and retrieved from. Just to orient you to the figure, if you look to the far left side, where it has some information, and that's Jane's phone number, 751-0579, that is some information out there in the world. Now if you just simply view this information or hear this information it will be imprinted very briefly in the sensory memory system. If this is a phone number that you wish to remember, what you might do is you might rehearse it over and over again. Well, that act of conscious rehearsal of information happens within short-term memory. And, if you give enough attention to it, and if you try to rehearse it over and over again, and perhaps try to encode it into a more meaningful fashion, that information will get stored into long-term memory. Once it gets stored into long-term memory, it will basically be stored there indefinitely. This basic model, this Modal model of memory, has stood the test of time, that is, I think it's fair to say that the majority of researchers in cognitive psychology to this day believe that memory is broken up, at least loosely, into these different storage systems. In the remainder of this module, we're just going to focus on sensory memory. Then, in later sections of the module, what we're going to do is we're going to talk about short-term and long-term memory.

Now, sensory memory refers to the initial, brief storage of sensory information. For example, if you hear a telephone number, or see a telephone number, that brief instant where that information is imprinted on your mind. Now, if this sounds like what we talked about before, in perception, well that's a good thing, because a lot of researchers argue that sensory memory is just simply another form of perception. In addition, many cognitive psychologists believe that we have different types of sensory memories. Specifically, they argue that we have a different type of sensory memory for each of the sensory modalities – that is, researches believe that we may have a separate visual sensory memory, an auditory sensory memory, an olfactory sensory memory, a tactile sensory memory. However, the vast majority of research in cognitive psychology has focussed on visual and auditory sensory memory, and here, what we're going to refer to it as is iconic memory, for visual, and echoic memory, for auditory.

We're going to spend the majority of our time talking about iconic memory. A good real-world example of iconic memory is when you view a lightning strike. When you see and experience a lightning strike bolting across the sky, it feels like that actually lasts a fair amount of time. In fact, it seems to linger in our perception for a second or so. In reality, however, that lightning strike is occurring very briefly, on the order of a couple hundred milliseconds. The same thing happens when you, perhaps, write your name in the air with a sparkler, or with a burning ember from a fire. When you actually have a burning ember and you shake it in the air and write your name, it feels like you can actually see your name hanging in the air for a second or so. Of course, your name isn't floating there in the air – it's just your perceptual system. What's happening is that your sensory memory, your iconic memory, is storing ever-briefly an imprint of that image which is occurring in front of you. It's basically freezing reality for a split second. This fascinating phenomenon has intrigued cognitive psychologists for decades. When it comes to memory, however, two main questions pop up. How much information can be stored, so the amount of information that can be stored, and how long does it persist. Those central questions will come up again and again as we talk about different types of memories. So how is it that you go about testing the length of time information can be stored and the quantity of information that can be stored in iconic memory?

Well, Sperling in 1960 came up with a brilliant experiment, and we're going to walk through this experiment in some detail. So, what Sperling did is he presented participants with a brief, very brief display of a three by four matrix of letters. So, for example, in this matrix we have the letters going across the top in rows: S, D, F, G - P, W, H, J – X, C, V, and N. So what he would do is he would present displays like this very briefly, for around 50 milliseconds. Now, 50 milliseconds is fast enough that you can barely just see a flash. And then what he did is he asked participants to report just how many letters they could actually see. And what he found was is that participants could report, on average, about four or five of the letters, so four or five out of twelve. So, what you would take from this at this point is, well, sensory memory can only hold about four or five pieces of information. Well, that's not necessarily the case. When Sperling spoke to his participants afterwards, many said that they had seen all the stimuli quite clearly, but, once they started to report them, they forgot the rest. So, once the participants started to report them, it would take a couple of seconds for participants to be able to report a couple of letters, and once they had actually reported those couple of letters, they had forgotten what the whole display was. Sperling came up with a very clever condition to test to see if there was more information stored than could actually be reported in that brief amount of time. What he did is he came up with a partial report condition. The previous condition we talked about is called the whole report, where participants just had to report all of the stimuli that they had actually seen. In the partial report condition, however, participants were given a cue to report only a single row. What would happen was, was that the three by four matrix of letters was presented to participants, very briefly, again, and then it was taken away, followed by either a low, medium, or high pitched tone. If they heard a low pitched tone, they were supposed to report only the top row, if they heard a medium pitched tone they were supposed to report back the medium row, and if they heard a high pitched tone, they were supposed to report back the bottom row. Using this method, that is, when receiving a cue to only report a single row after the whole display was removed, participants could reliably report either three or four of the four letters in that row. Therefore, what Sperling showed was, was that regardless of which tone sounded, participants' reports indicated they had roughly nine out of twelve letters available in sensory memory.

Now, you might want to stop the lecture here, just to think about that for a bit. It's a bit of a complicated point, but the main idea is, is that once the display was presented and taken of the screen, if a participant can be cued on any one of those rows, and still show around three out of four average recall of the information in that cued row, necessarily, they had to have held all that information about all three rows in their sensory memory. So, we now know how much information can be stored in sensory memory. At least, when it's concerned with letters, we know that sensory memory can hold anywhere between nine and twelve letters.

So how long does information last in sensory memory? Again, we all pretty much have that subjective experience, as when we actually look at a lightning strike, we actually get this very brief imprint in our minds, in our visual perception, for a very brief moment of time. Well, sensory memory as experimentally examined in the laboratory operates on a very similar level. What Sperling did in the follow-up experiment is actually insert a delay between the time that the stimulus was presented, and the time at which participants could report, or could report back and retrieve the information that was in their sensory memories. And what he found was, was that after a delay of about one second, they partial delay advantage, that's the advantage of being cued for a single line, completely disappeared. This information is all portrayed in the following figure. In this figure, what we have here is the average number of letters recalled by a participant as a function of the delay between the presentation of the letters and the tone signalling when to recall the letters aloud. As you can see, if they were cued immediately, they'd recall between nine and ten letters. That is what was originally found in Sperling's earlier experiments. However, if they were delayed by about one second, all of a sudden their recall advantage by using this partial recall technique was down to around between five and six letters. So, after that much of a delay, after a second delay, participants were no better at reporting in the partial report technique than the full report technique. This was taken as evidence that visual sensory memory, or iconic memory, only lasts around one second. If you aren't allowed to rehearse that information or de any more meaningful encoding of that information, it will delay and it will fade away in that very brief amount of time.

Now, as I mentioned previously, there has been a fair amount of research conducted on other sensory modalities as well, such as auditory sensory memory, or echoic memory. I'm not going to go into the details of the research conducted on echoic memory, however, I will just say that it does seem to behave in a similar fashion to iconic memory, except, of course, that it's dealing with auditory stimuli and not visual stimuli.

When I introduced this module I said that we were going to be talking about different types of memory structures, and it's important to keep in mind when we talk about these things what role they all play. So, let's think about sensory memory, here. Why is it that we have sensory memory? Well, when we get into talking about short term and long term memory later on, what you're going to find out is, is that information stored in short term memory and rehearsed in short-term memory, and information that gets stored and moved into long-term memory seems to require our attention to it, that is, it doesn't just passively happen. Information doesn't just passively get processed in working memory and passively move on into long-term memory – while there are some exceptions to this rule, of course. But typically it takes our active participation, our active rehearsal, while sensory memory, on the other hand, doesn't require that, it just needs your visual system. So, you can see from this how sensory memory is useful from a cognitive perspective, in that in the real world it guarantees a minimum amount of time during which information given to us is available for processing, that is, this information will hit our perceptual system, and we can choose to attend to it and to have it then flow through and be processed more and more into later cognitive systems like short-term memory or long-term memory, or we can ignore it, and it will just passively fade away.

05c | Short-Term Memory

Before we begin talking about the specifics of short-term and long-term memory, I want you to participate in a small experiment. Now, in this experiment, I'm just going to simply read to you twenty words, and after I've finished reading the twenty words I want you to recall, just by writing them down on a piece of paper, as many of the words as you can. Alrighty, so here we go, lets begin: table, candle, maple, subway, pencil, coffee, towel, softball, curtain, player, kitten, doorknob, folder, concrete, railroad, doctor, sunshine, letter, turkey, hammer. Okay, press pause here for a second, and write down as many of the words as you can, in about a minute or two.

Welcome back. So what I'm going to do now is I'm going to talk about typical responses to that task. Now, I don't know how you responded, but you can look at your own sheet of paper, and you can map on how you responded to typical finds in an experiment just like this. So what happened was is I presented you twenty words, and by asking you to freely recall them, you probably showed a tendency to respond better on some words than the other. Specifically, you were probably more likely to remember words that were presented at the beginning and end of the list, rather than those that were presented at the middle of the list. So, if you look at the following figure, this is called a serial position effect. On the X axis is the serial position, for example, the first word in the list would be "table," and the twentieth word in the list would be "hammer," and the tenth word in the list would be "player." And on the Y axis is the probability of correct recall. So, why am I showing you this, now? Well, the reason is that the serial position effect has been taken as evidence for separate short-term and long-term memory systems. Specifically, the finding that people are typically better able to remember the last few items in a list, also referred to as the recency effect, is thought to reflect short-term memory processes. The reason being is that people typically try to off-load those items form short-term memory first. After you've off-loaded the contents of short-term memory, then you try to drudge through and get that information that made it into long-term memory, and that is typically items that were first presented in the list, and that is the primacy effect. So, to understand how this works, think about how you might have done this task. Typically what happens is, when the experimenter is reading the words, the participant begins rehearsing them right away. So, for example, when you hear "table, candle, maple, subway," you're likely to encode those words and rehearse them over and over again in short-term memory, and since you're giving a lot of attention to them, you're liable to get them into long-term memory. However, what happens is as more and more words come in, you're not able to do that for all of them. So, the first few words get into long-term memory, and then, once you get to the end of the list, since you can recall right away, what happens is that you're able to off-load those last few items like "letter," "turkey," and "hammer" right away, and actually write those ones right away before they actually fade out or decay from short-term memory. And then after you do that you go back through and think through what were the original ones in the list – and to do that you need to search long-term memory.

So now that I hopefully have you convinced there are separate short-term and long-term memory systems, let's talk about the both of them in detail. First, let's talk about short-term memory, and to start this off I want to read a quote to you. This quote is from George Miller's article from 1956, published in *Psycological Review*: "My problem is that I have been persecuted by an integer. For seven years this number has followed me around, intruding into my most private data, and has assaulted me from the pages of our most public journals. This number assumes a variety if disguises, being somewhat a little smaller than usual, but never changing as much as to be unrecognizable. The persistence with which this number plagues me is far more than a random accident, there is, to quote a famous senator, "a design behind it," some pattern governing its appearances. Either there really is something unusual about the number, or else, I'm suffering from delusions of persecution." Now, what George Miller is referring to in this beautiful quote is called the "magic number seven." and what that simply is, is the maximum number of information that can be correctly recalled from short-term memory. And through a variety of experiments – doesn't matter is it's letters, digit spans, spatial discrimination, tone discrimination – what has typically been found is that people can remember, on average, around seven, plus or minus two, bits of information. Importantly, this amount of information, this seven, plus or minus two, bits of information, can be increased dramatically by what is referred to as "chunking." So, for example, try to recall the following items, in order: F, B, I, P, H, D, C, F, L, I, B, M. Chances are, when you try to recall those items, you could probably remember around six or seven of them. Now, try to recall the following items: F B I, P H D, C F L, I B M. Now here, chances are, you're probably able to remember all of them, even though they have the same number of letters: twelve letters. However, in this case, they were organized into meaningful chunks. These acronyms, FBI, PHD, CFL, and IBM, allow you to meaningfully group, chunk, or code this information, so that you can move past the typical limitations of short-term memory. This linguistic recoding of information requires the use of long-term memory in conjunction with short-term memory. So, what happens here, is you make use of what you know in long-term memory, to organize and structure information so that it can be more efficiently coded and stored and rehearsed within short-term memory. So, what happens then is no longer does the letter become the unit of storage and representation, but because it is grouped into a meaningful chunk, that new chunk becomes the unit of information to be stored.

So, so far we have established that there are separate short-term memory and long-term memory stores. And we've talked a little bit about, now, how much information can be stored in short-term memory, that is, around seven, plus or minus two, bits or chunks of information. Now we're going to spend a little bit of time talking about how information is thought to be forgotten in short-term memory. Now, when we talk about forgetting, whether it be in short-term memory, or in long-term memory, for that matter, there are two main theoretical approaches. One is trace decay, and that is the automatic fading of the memory trace, and the second is interference, and that is the disruption of the memory trace by other traces, where the degree of interference depends upon the similarity of the two memory traces. We're going to focus predominately on interference theory, as that, is seems, is the most predominate view of how forgetting happens in short-term memory, and again, we talk about long-term memory later on. So, when we talk about interference, there are two different types of interference. There can be proactive interference, where old information makes it difficult for you to acquire new information, and there is retroactive interference, where new information makes it difficult for you to recall old information.

So, let's just put this into some real-world terms. So, imagine the case where you just got a new phone number, and you're trying to remember your new phone number, trying to give it to other people, but every time you try to remember your new phone number, your old phone number just pops into your mind. Well this is proactive interference, that old information is making it difficult for you to recall new information, or to learn new information. After a while, however, once you've efficiently encoded your new telephone number, it would become difficult for you to remember your old telephone number. That is retroactive interference, where that new information, that new phone number, makes it difficult for you to recall that old information, or that old telephone number. When it comes to short-term memory, it seems that both trace decay and interference likely play a role. The experiments that have been used to support this have typically involved what is referred to as the "Brown-Peterson paradigm." Here, participants are presented with a three-consonant trigram, such as the letters HLM, and then they are given a number, such as 492, and asked to count backward, out loud, by three's for a fixed rate of time. The purpose of the counting task is to prevent participants from rehearsing the trigram, and thus preventing them from getting it into long-term memory. That way, it gives a better assessment of what is going on within short-term memory. What has been shown using this task is that information decays from short-term memory very quickly. That is, if you're asked to count backwards for only three seconds, roughly 80% of participants can recall the trigram. However, if you're asked to count for around eighteen seconds, this drops way down to around 7%. That is, after only eighteen seconds of counting backwards by threes, if you cannot get that information out of short-term memory, it's gone.

However, shortly after this original work, a lot of researchers challenged the idea that forgetting in short-term memory was just due to trace decay. They argued, rather, that you could account for forgetting in the Brown-Peterson paradigm with interference. They just argued, however, that the task that the original authors used wasn't deigned efficiently enough to tap into that interference. Now, recall when we introduced the idea of interference, that the degree of interference depends entirely on how overlapping, or how close, the two different pieces of information are. If the two pieces of information are very similar to each other, they're more likely to interfere with each other. So, for example, an old phone number is going to make it difficult for you to learn a new phone number, however, it's not going to make it difficult for you to learn a new postal code. What Wickens, Born, and Allen did is they designed a modified Brown-Peterson paradigm that switched categories after a few trials. The idea being is that if you switch categories what you can find is something called release from proactive interference. So, the study was conducted as follows. So, recall in the original Brown-Peterson paradigm, participants were simply given a three-letter trigram and then had to count backward from a specified number by three. What Wickens, Born, and Allen did, is they extended this paradigm by having participants repeat this over and over again. Critically, however, when they received repeated trials, sometimes the trials were of a different category type. So, for example, in the control condition, all the participants had to do was either remember letter trigrams or number trigrams. In the experimental group, however, the categories would switch. So, for example, they may receive a letter trigram for the first couple, and then it would switch after either four, seven, or ten trials, to a number trigram.

So, let's look at the data here. What was found? So, if you look at the Y axis, what we have there is percent correct recall, and if you look at the X axis, we have the number of trials. The solid lines represent the control condition, that is whether they just received letters or just received numbers. And, what you see in both of these conditions is that there is a significant drop off, from around 70% down to around 10% for letters and down to around 40% for numbers, and then it pretty much levels off. The dash lines, however, represent the experimental conditions when that information was changed. So, for example, if you received numbers first, the category would have been changed to letters, or if you received letters first, the category would be changed to numbers. And what you can see here, right off the bat, is when participants' categories were changed, in this very simple Brown-Peterson paradigm, performance went right back up to ceiling again. That is, even though they were previously exposed to a trigram, because that trigram was categorically different, it did not interfere with their ability to learn that new trigram. As you can see, this is a very complicated study, and what I'd do is I would recommend that you go through this in the text a couple of times, just to make sure you understand the details.

05d | Long-Term Memory

Okay, let's move on to long-term memory. So, we'll return to the Modal model here and what we see is that we've already talked about sensory memory, and that is the very brief, kind of perceptual experience that is when you first experience some stimulus in the environment. Then, if you attend to that information, it goes into short-term memory. And here, short-term memory, again, is a very short term store where you can hold about seven, plus or minus two bits or chunks of information, and if you do anything further, if you encode that information any further, or rehearse it over and over again, it can get into long-term memory, and long-term memory is this relatively permanent storage facility for all information. We're only going to briefly talk about long-term memory, here. We're going to talk about the capacity of it, the coding, how information is coded in long-term memory, how long it might last in long-term memory, how forgetting is thought to happen, and then encoding and retrieval processes. We're going to return to long-term memory in later modules of this course.

So, first let's talk about the capacity of long-term memory. Well, it's hard to guess how much information can be stored in long-term memory. In fact, it could store a potentially infinite amount of information. For example, every experience you've ever had is somewhere, stored in long-term memory. Every word that you know, and the associated meaning with that word, is stored in long-term memory. The important thing about all this is that not every bit of information in long-term memory can be easily retrieved at any given time. That is, there's information stored in long-term memory that we have long lost easy access to. However, just because we can't easily access or retrieve that information doesn't mean that it's not there. We're going to talk more about this a little bit later on, as well, too, when we talk about different encoding and retrieval strategies.

So, moving on, now – how is long-term memory coded? Well, researchers have discovered that long-term memory is likely coded in terms of semantics – that is, in terms of meaning – and this is one way in which long-term memory is different than short-term memory. Short-term memory is thought to be based on, or is thought to code information based on, acoustic properties or visual properties – that is, very superficial or low-level features – whereas long-term memory codes information based on deeper semantic, or meaningful, features. So, how long can information last in long-term memory? Well, researchers think that some information might be able to stay in long-term memory relatively permanently. As you can imagine, it's very difficult to conduct a study where you test the duration of long-term memory, of course, because it's going to last a very, very long time. Bahrick, in 1984, did conduct such a study. Now, what he looked at was the retention of Spanish language information from 733 adults who had taken or were taking, a high school or university course in Spanish, and he looked at the retention of this information for up to fifty years. What Bahrick found is pretty startling, and it's highlighted in the following figure. On the Y axis it shows the percent of original score, that is, it's a measure of their Spanish language knowledge. On the X axis, it's the measure of the lag time, or the duration, and it goes from right from when they finished taking the class, and all the way up to 49 years and 8 months. Now, the important thing to look at here is not what each of the different lines represents, but the fact that they all pretty much follow the similar pattern. There's a significant drop from around 100% to around 40% after the first 2 years, 2 months, and then it pretty much levels off and remains flat – that is, there really is not much forgetting after the first initial couple years. Because of this, Bahrick coined the term "permastore" for long-term memory, and that is because large portions of this originally acquired information remained accessible for over 50 years, in spite of the fact that it was not used or rehearsed. This study by Bahrick also demonstrates a well-known phenomenon about forgetting in general, that is, initially, forgetting seems to happen relatively rapidly, but then it tapers off.

So, what causes forgetting in long-term memory? Well, again, we can bring back those same two things that we talked about before when we talked about short-term memory: trace decay and interference. And likely, both of those things have something to play in long-term memory as well, however, the vast majority of research has focussed on interference theory. And specifically, with the case of long-term memory, on the use of retrieval cues, and what a retrieval cue is, is it's a point to recover a target memory. And we use these all the time. They're kind of like putting a sticky note on your computer monitor, as a reminder to do something. The more unique retrieval cues you have for a given target memory, the more memorable that item will be. However, if you have retrieval cues that are associated with multiple memories, then that item will be less memorable, and the reason it's less memorable is because of interference, that is, interference among multiple targets being associated with a single retrieval cue. That is highlighted in the following figure, taken from the textbook. In this figure, it shows an episode of you trying to find your car, parked in a parking lot. However, the problem is that you have a single retrieval cue, that is, you sitting in this familiar parking lot on a Thursday at noon, however, since you often come to this parking lot on a Thursday at noon, that retrieval cue is not very good discriminating cue, and as such, it activates multiple parking locations. This association between a retrieval cue and a target memory highlights a very important concept about long-term memory – that is, in order to correctly recall information from long-term memory, you need to have a very powerful and uniquely associated retrieval cue.

So, what makes a good retrieval cue? This brings us to the encoding and specificity principle – probably one of the most important principles in cognitive psychology – and what this states is that recollection of an event or a certain aspect occurs if, and only if, properties of the trace of the event are sufficiently similar to the retrieval information. What this basically means is that recollecting information, or retrieving information, is kind of like reliving that original encoding experience: you bring yourself back into when you originally experienced the event at retrieval. The power of the encoding specificity principle can be demonstrated in a number of ways. One such way is by looking at context-dependent memory, that is, information learned in a particular context is better recalled if recall takes place in that same context. This brings me to one of my favourite studies. Gaudin and Baddeley wanted to look at the effect of encoding specificity in general, and context-dependent memory in particular, in the context of a very powerful cue, a very salient cue, that is, environment. So what they did was they took a bunch of professional scuba divers, and asked them to learn lists of words either on land – on the shore – or underwater. Then, after they encoded this information, they gave them a memory test, and they either did this memory test on land or underwater. What they can do, then, is they can cross these conditions – they can look to see whether having a test and the study in the same location is beneficial. And the following figure clearly shows that it is. What we have here is a perfect double dissociation. On the Y axis we have the percentage of words recalled correctly, and on the X axis we have recalled on land vs recalled underwater, the solid lines represent those words that were learned on land, and the dash line represents those that were learned underwater. So, first let's look down at the X axis there, and let's focus on the "recalled on land" words. What you can see here is that those words that were studied on land were much better recalled on land. And then we'll move over on the X axis to "recalled underwater," and what you can see here is that those words that were studied underwater, or learned underwater, were recalled better than those that were learned on land. So, in summary, the best recall happened when the encoding conditions mapped onto the retrieval conditions. Put another way, the environment, or the location, served as an appropriate retrieval cue for that retrieval of information from long-term memory, and, relating this to the encoding specificity principle, likely what is going on here is that by reinstating that individual into the same experience where they encoded that information, all those retrieval cues surrounding that original encoding of information are there, available to be used, at retrieval. If, on the other hand, the encoding and retrieval conditions don't match up, so, for example, if a participant learned the words on land and were tested underwater, then the appropriate retrieval cues just simply aren't present, and thus, memory for those words is less accurate.

05e | Working Memory

In the previous sections of this module, we discussed the characteristics of short and long-term memory. We're now going to unpack short-term memory a little bit more, and what we're going to see here is that short-term memory is a little bit more complex than what we originally thought. In the original formulation of short-term memory, which we talked about previously, by Miller, is that short-term memory was simply a short-term storage device, and that it could hold around seven, plus or minus two, bits of information. Since the time of Atkinson and Shiffrin, though, in 1968, with their Modal model, what we've discovered is that short-term memory can do much more than that. For example, it's been equated with consciousness, that is, any piece of information that you hold in your mind at any given time, can be thought to reside within short-term memory. In addition, it is also thought to be the place where various cognitive control processes happen, that is, it's the place that governs the flow of information into, and out of, consciousness. One of the first key studies that showed that short-term memory was more than just a temporary storage facility, that is, an area that can only hold seven, plus or minus two, bits of information, was conducted by Baddeley and Hitch in 1974. The general idea of this study was that they had participants perform two tasks at the same time, and I'll walk you through what these two different tasks were. So, in one task, what they did is they had participants hold in their mind either zero, two, four, six, or eight digits. So, for example, in the six digit condition, they could be given the following numbers: 4, 8, 5, 3, 7, 2, and were told to hold that in their mind. Now, importantly, based on what we think that we've known about short-term memory, before this time, was that that should pretty much tie up all the short-term memory resources, and not leave anything left over for any other sort of other processing that might require short-term memory. Now, what Baddeley and Hitch did, however, was that they had participants also do what is known as a syntactic verification task, that is, participants were also presented with a very brief statement, and asked to verify whether it was true or false. So, for example, they could be given "A follows B," and then shown "AB," and what the participant's task was was to judge whether the answer "AB" was correct, given the preceding statement. In the example I gave you, that would be false, because, for example, in the statement "A follows B," "AB" is not correct, it should be "BA." Then, after they verified that statement, then what participants needed to do was to recall the numbers that were presented beforehand. So, to reiterate, in this experiment participants were first given a series of numbers, and this series of numbers would range from zero to eight, and this is called the concurrent digit load, and then, while they're holding those digits in memory, they had to judge whether a given answer necessarily followed from a given statement. Then, after they judged whether the answer was correct or not, they had to recall the numbers.

So let's look at what they found. So, if you look at the following figure, on the X axis what we see is the concurrent digit load, that is, how much information, or how many digits, the participants had to hold in mind when judging the statements. On the Y axis to the left we have reasoning time in seconds, and that is how long it took participants to answer that syntactic verification question, and on the right we have percentage errors, that is, how many errors did they make in that syntactic verification task. The line with the open circles shows us their reaction times, and the line with the closed circles shows us their error rates, as a function of concurrent digit load. And what we can see here is that although it took people longer to respond to the syntactic verification task as a function of increasing concurrent digit load, percentage of errors remained flat, that is, whether participants had a zero digit load, or a digit load as big as eight, it did not increase the number of errors people made in the syntactic verification task, although it did slow them down. Now, these findings are really important, because what they show to us is that that previous conception of short-term memory as just the storage receptacle for seven, plus or minus two, bits of information is not entirely correct. If that was correct, participants, while holding that digit load in mind, should not be able to do the syntactic verification task – that is, errors in the task should have raised dramatically. However, what we see is that participants can quite easily actually carry on these two different tasks at the very same time. So, why is that the case? Well, researchers now think that that old idea of short-term memory – that it's just a very small storage receptacle for a very limited amount of information, that is, seven, plus or minus two bits of information – is incomplete. Rather, researchers have argued that we have what is called a "working memory." This working memory system is thought to consist of a limited capacity workspace that can be divided between storage and control processing. Specifically, Allan Baddeley, in a series of papers, conceived of working memory as consisting of three components. The first is the central executive. The central executive can be thought of more as an attentional system, rather than a memory system, per se, and what it does is it directs information to and from the two different sub-systems. These are the phonological loop and the visual-spatial sketchpad. The phonological loop is thought to carry out sub-vocal rehearsal and maintain verbal information, while the visual-spatial sketchpad is thought to retain visual material, through visualization. Importantly, these two sub-systems, the phonological loop and the visual-spatial sketchpad, can function relatively independently, that is, you can carry out a task that uses resources in the phonological loop and it won't really impact processing that's going on in the visual-spatial sketchpad, and vice-versa. Let's think about, now, those results of Baddeley and Hitch that we talked about previously, in terms of this more complex working memory model. You'll recall, in that experiment, holding on to these digits in mind didn't really impact the participant's ability to carry out that syntactic verification task. Granted, it slowed them down, but they didn't produce any more errors whatsoever, so they were able to do it. Well, holding those digits in mind would take resources in the phonological loop, that is, you'd have to take those numbers, store them, and likely rehearse them sub-vocally over and over again in your mind. Now, consider the syntactic verification task. In that task, participants are given a statement, such as "A follows B," ad then an answer, "AB," and then simply asked if that answer was correct given the preceding statement. Arguably, a portion of this task does require verbal information, and likely does tax, to some degree, the phonological loop. However, the majority of resources to solve this task likely require some form of visual-spatial processing. You have to look at the letters and decide if they are in the correct spatial orientation, given the preceding sentence. Judging whether they are in the correct spatial orientation would likely tax resources in the visual-spatial sketchpad. So, as the concurrent digit load likely taxes resources in the phonological loop, and the syntactic verification task likely taxes resources in the visual-spatial sketchpad predominately, these two tasks can be carried on relatively independently and do not interfere with each other to a great degree.

Now, as we leave this discussion of working memory, it's probably a good idea to stop and spend some time thinking about some daily mental activities that you might do that take resources from the phonological loop versus those that might take resources from the visual-spatial sketchpad. For example, reading a book or talking on the phone utilizes resources from the phonological loop, whereas, trying to picture in your mind what you had for dinner last night, or simply doodling a picture in your notebook, requires resources from the visual-spatial sketchpad. Given that, you can probably, without too much interference, talk on the phone while doodling a picture in your notebook. Rather, if you try to talk on the phone while reading a book, it may prove highly difficult, because those two tasks will compete for the same resources in the phonological loop.

05f | The Semantic/Episodic Distinction

In this final section of the module we're going to talk about episodic and semantic memory, as well as neurological studies of memory. And the reason we're going to be talking about them together is that a lot of the evidence for episodic and semantic memory comes from neurological studies of memory. So, in the previous section we talked a bit about working memory, and that helped us understand a little bit about how information is stored for very brief amount of time, and how it is that we can store multiple different types of information. Well, researcher have found out that long-term memory works in very similar ways, that is, we can store multiple different types of information in long-term memory. Now, a lot of this work really was pioneered by Endel Tulving in the seventies, and what he found was one of the biggest distinctions in long-term memory, was that it contained two distinctive, yet interactive systems, called episodic and semantic memory. Episodic memory contains information about one's personal experience, and memories here are a specific time and date attached to them, or they are temporally organized. For example, if you look back and think about what you were doing on your last birthday, or, even a more traumatic and significant event, like, perhaps what you were doing on September 11th in 2001. When you attempt to remember those things it's like you are actually going back in time and reliving those original experiences again, and again, that is the defining feature of what is episodic, or autobiographical, memory. Now, to be contrasted with this, is semantic memory. Now semantic memory is just our general knowledge base, that is, information about language and the world. It seems to be organized around meanings – for example, facts, concepts – rather than temporally organized. So, for example, knowing that Paris is the capital of France doesn't require you to actually go back in time and relive the original encoding experience of when you actually learned that fact. However, you can retrieve that fact from memory without having any sort of episodic or autobiographical recall. Rather, it just simply comes to mind.

05g | Neurological Studies of Memory

Now, some of the most powerful evidence for these two different memory systems comes from neurological studies of memory, and when we talk about neurological studies of memory what we're really talking about is patients who have suffered damage to the hippocampal system, and that is the hippocampus and amygdala, and related nesial structures around those areas, due to head Injury, stroke, brain tumour, or disease. And what these studies have shown is that patients may show very selective impairments in memory. For example, Dan Schacter talks about the case of Jean, who had a motorcycle accident at the age of thirty, and because of this accident he suffered damage to his frontal and temporal lobes, including the hippocampus. And what he found was that Jean has preserved intellectual functioning, so, for example, average intelligence, average memory span, language, and normal vocabulary – these are all things that would be subsumed under semantic memory. Critically, however, he seems to have lost his episodic memory. He doesn't remember his brother's death, which would have been a very traumatic event for him, years before. He doesn't know how he broke his arm, etcetera. He can't remember critical life events that have happened to him – that is, any sort of information that has a time stamped to it, information that would require him to go back and re-live that original encoding experience to recall it, can't be done. However, his knowledge of facts, that is, information that is stored in semantic memory, seems to be relatively intact. The case of Jean can be contrasted with another case than Dan Schacter talks about, of a woman who, because of encephalitis, suffered damage to the front temporal lobes of her brain, and because of this damage to the temporal lobes, she lost semantic memory. She forgot meanings of common words, cannot recall basic attributes of objects. However, she seems to have completely intact episodic memory. For example, she remembers her wedding, her honeymoon, her father's death, and, importantly, she can produce lots of verifiable details about these events. So these are two examples of patients that both have had damage done to the brain, damage to areas known to affect memory, that show completely dissociable disorders of memory, that is, one patient can show intact semantic memory but damaged episodic memory, and another patient could show damaged episodic memory and intact semantic memory.

This brings us now to two general classes of amnesia that I'd like to talk about. These are anterograde amnesia versus retrograde amnesia. Now these two amnesias are not to be dissociated from episodic and semantic memory deficits we just previously talked about – that is, you can have an episodic memory deficit that is anterograde in nature, or, you could have an episodic memory deficit that is retrograde in nature. So let's first talk about anterograde amnesia. Now, anterograde amnesia is the inability to form new memories, that is, after you have an event – now this could be a traumatic brain injury, disease due to encephalitis, a stroke, or anything like that – so you have a traumatic event and you're unable to learn new information. Typically, this anterograde amnesia affects episodic memory, but not semantic memory, that is, your memory for general knowledge typically remains intact, so does your skill performance. So, for example, if you knew how to ride a bike before, after a traumatic event that caused brain damage to, typically, the hippocampus region in the temporal lobes, what you would find is that you can still ride a bike after that. It only affects the formation of new, explicit, episodic memories. So, recall in the beginning of this module, when I talked about the case of Clive Wearing. Well, hopefully you watched the videos of Clive Wearing, and what you would see n those movies is that every day to Clive is like a new experience. If you walk out of the room and come back a couple of minutes later he will forget that he had any interaction with you at all previously. However, his skill set remained unaffected. He could still play the piano beautifully, he could still conduct a choir – all those things, again, which of course require lots and lots of exposure to information to learn that, remained intact. This form of amnesia can be contrasted with retrograde amnesia. In retrograde amnesia you have loss of memory for past events. So, for example, after a traumatic head injury, what you could experience is loss of memory for past events prior to that injury. However, you would still be able to learn and encode new autobiographical events post-injury. And just like anterograde amnesia, it doesn't affect overlearned skills, such as general social skills, or language, and procedural knowledge. That type of information remains intact. And, when comparing anterograde with retrograde, typically what you can find is that patients might experience retrograde without anterograde amnesia, however, if they have anterograde amnesia, they likely will have retrograde as well.

05h | Summary

In summary, we began this module on memory structures talking about Atkinson and Shiffrin's modal model of memory. And what they propose is that we have separate sensory short-term and long-term memory storage systems. We then moved on and talked about the characteristics of each of these systems. We began by talking about sensory memory, and what we learned there is that sensory memory is a modality-specific, brief-duration storage facility for visual, auditory, and other basic modalities of information. If that information in sensory memory is attended to, it then may pass on to short-term memory. Short-term memory has been likened to our conscious experience, that is, any information that we are thinking about at any given time is arguably within short-term memory. Originally, based on the work of George Miller, it was thought that we could hold around seven, plus or minus two, pieces of information in short-term memory, and it would remain there for around 20 seconds unless any sort of deeper rehearsal was done on that information. However, years later, work by Allen Baddeley showed that short-term memory wasn't that simple. In fact, it could be further sub-divided into three components – that is, the central executive, the phonological loop, and the visual-spatial sketchpad – in a more complex working memory model. And here we learned that the two sub-systems of the working memory model, the visual-spatial sketchpad and the phonological loop – could carry on relatively independently. We then talked about the many characteristics of long-term memory, and I'm only going to focus on one in this review, because I think it's the most important one, and that was the encoding specificity principle, and what we learned here was that recall of information will be made easier if the recall context is the same as the learning context. And then, in the final sections of this module, we further broke down long-term memory, and talked about neurological studies that supported these distinctions. For example, we talked about episodic and semantic memory, where episodic memory is memory for information about one's personal experience, and semantic memory is memory for general-knowledge-based information, such as facts and concepts. Evidence for these two different types of memory systems comes from neurological studies, which has shown that you can have a patient that has selective brain trauma that can show a deficit in episodic, and not semantic, and vice-versa.

06a | Introduction

In the last unit, we talked about memory in terms of the structures of various memory stores. We are going to discuss memory again, but this time more in terms of the processes that are involved in processing memory. The general idea here is that one's ability to retrieve information in memory depends largely on how well we stored that information in memory, not in the particular place where it is stored.

We will also spend some time discussing the fact that memory is not a carbon copy of what one has seen or processed. Instead, memory is quite malleable and often changes over time.

We've all experienced forgetting- that's simply a normal consequence of memory. We will spend time discussing profound forgetting, or amnesia. This type of profound memory loss is usually the result of some form of brain trauma or disease.

We'll also make an important distinction between two types of memory- episodic, which is our own personal memory, and semantic, which is the store of all our world knowledge, and tends to be similar across people who have had the same experiences.

Finally, we'll spend some time discussing two types of ways to test memory- implicitly, or without the individual realizing that his or her memory is being tested, and explicitly, when people are aware that their memories for particular events or things is being tested.

06b | Levels of Processing

In the last unit, we talked about various memory stores (sensory memory, short term memory and long term memory) and what is thought to happen in each of them. The view of memory that we are going to discuss now does not treat memory as some form of storage place, but rather focuses on the types of processing that we do in order to store and retrieve items from memory. This is known as the levels of processing theory of memory.

Levels of processing was first discussed by Gus Craik and Bob Lockhart at the University of Toronto, and we'll introduce it by way of the following demonstration.

Basically, this theory identifies two types of rehearsal that can be done in order to store information in memory- maintenance rehearsal and elaborative rehearsal. Maintenance rehearsal is essentially what one does when trying to simply memorize something. For instance, a new friend has just given you his or her phone number, and while you're getting ready to input it into your cell phone, or write it down, you might repeat it. Basically, then, all this type of rehearsal does is to maintain or hold information until you need to use it, without transforming it to any other type of code. Not surprisingly, Craik and Lockhart state that this type of rehearsal does not promote good memory. In contrast, elaborative rehearsal is argued to promote good memory. When we perform elaborative rehearsal, we elaborate on the meaning of a concept. Craik and Lockhart argue that this allows us to transform the information into a deeper code, thereby promoting better retrieval. In terms of the demonstration that you just completed, both the physical appearance (PA) task and the rhyming task (R) are considered to be relatively shallow, whereas the meaning-based task (M) is considered to be deep. Therefore, Craik and Lockhart would predict that your memory would be better for the M items, than for the PA and R items.

Craik and Endel Tulving published an experiment much like this one in 1975. As you can see in the Figure before you, memory was better for their meaning based task than it was for their case and rhyme tasks. Although levels of processing makes good intuitive sense, it is not without its detractors, however. Specifically, theorists such as Alan Baddeley have argued that it is a circular or tautologous theory, and cannot be falsified. How does one decide what is shallow processing and what is deep processing prior to the experiment? Despite these challenges, however, LOP provided a useful, novel way of conceptualizing memory.

06c | The Reconstructive Nature of Memory

Our discussion of memory to date has relied on lab studies. What about memory for real-life events and objects? How can we assess that? Bartlett, in the 1930s, studied memory for more than just lists of words, and introduced the concept of a memory schema. The panel in front of you shows the story “The War of the Ghosts,” used by Bartlett to study more real-life memories. Participants in his experiments were asked to read this story, and their memory for the story was tested a short while after, and also several weeks later. What Bartlett found was that far from being like a camera or tape recorder, memory was quite malleable. The manner in which individuals’ memories changed was interesting, as well. That is, over time, their memories for the story began to become distorted, and these distortions were consistent with items in their own cultures. Bartlett states, then, that a schema is a framework for organizing memory, and our own schemas are consistent with our prior life experience.

Also along the lines of more “real-life” memories are what are known as flashbulb memories. These memories are held to be crystal clear, vivid memories of some important event. For instance, most of us have very clear and detailed memories about where they were when they first heard about the terrorist attacks of 9/11. There is some debate as to whether these really are such special, accurate memories, but it is generally thought that they are different from our memories for everyday, mundane events. This is possibly because of the highly emotional content of most of these memories, and our desire to link ourselves to history.

In the US, over 50,000 court cases each year are decided on the basis of eyewitness testimony. Jurors are very strongly affected by the testimony of an eyewitness, especially when that witness seems very confident. Is this good, or should it be a matter of concern in the judicial system?

Elizabeth Loftus is a pioneer in the study of eyewitness memory. In one of her earliest studies, she showed participants a film clip of a car crash. All participants viewed the same film. Afterwards, they were asked this question: About how fast were the cars going when they ____ each other? The blank was filled by the words “smashed, collided, bumped, hit and contacted” for separate groups of participants. As you can see in the panel, despite the fact that everyone had observed the same event, the participants’ speed estimates varied as a function of the verb put in the sentence. Amazingly a week later, all participants were asked if they had remembered seeing broken glass? There was no broken glass, yet some people remembered seeing it. Remarkably, people who had received the stronger verbs were more likely to misremember broken glass than were those who received the weaker verbs.

Clearly, then with memory being so falliable, it is important to keep this in mind when evaluating eyewitness testimony.

You are going to see a short list of words. I'd like you to read through the list, and after the last word disappears, write down all the words that you read, in the order that you read them.

This is the basis of a study first done by Deese in the 1920s, and recently made popular by Roediger and McDermott. What I am most interested in in this demonstration is whether your list of memories included the word "spider." In Roediger and McDermott's experiment, 40% of the participants recalled a word that was not presented at all, but was related to the other words on the list. Amazingly, they were nearly as confident in these false memories as they were in their actual true memories!

Cabeza and colleagues, using brain imaging techniques showed that despite an individual's belief in a false memory, the brain regions activated by the false memories actually activate a brain area different from that activated by real memories.

06d | Amnesia

We've spent some time talking about memory for things that did not occur, but what about the loss of memory for things that have occurred? Scoville and Milner, of the Montreal Neurological Institute documented the case of Henry M, who had profound memory loss after surgery on his temporal lobes and hippocampus to help control his severe epilepsy.

After the surgery, HM's epilepsy did improve, and he retained his intelligence, and his perceptual abilities. He could remember much of his life prior to the surgery, but was unable to form any new long-term memories. That is, you could meet HM, carry on a conversation, and if you were to return to him an hour later, he would not remember having met you!

The case of Clive Wearing is perhaps the most profound case of amnesia that has been recorded. Clive was a music producer and commentator for the BBC when he became ill with viral encephalitis. As you see in the movie clip, although Clive's memory for his past is somewhat impaired, the biggest disability is that he, like HM, is no longer able to form new memories. In fact, Clive's experience of life is that of constantly waking up and being conscious for the very first time.

Both HM and Clive Wearing suffer from anterograde amnesia, or the inability to form new memories. In terms of the modal model of memory that we discussed last unit, anterograde amnesia is argued to affect LTM but not STM. Individuals like HM and Clive can keep information active in STM just like you or I, but are not able to transfer it into LTM.

In contrast, retrograde amnesia is the loss of memory for past events, and how far back in time it goes varies from person to person. Alzheimer's disease and Korsakoff's syndrome are two examples of this. Korsakoff's syndrome is brain damage resulting from a lack of B vitamins generally due to the long-term abuse of alcohol. Less severe retrograde amnesia is also commonly seen when one has a concussion- perhaps from a car accident, or a fall. Although it affects memory for life events, it does not appear to affect things like social skills, language, or any previous skills that we have mastered.

06e | Semantic Memory

In discussing HM and Clive Wearing, we've talked primarily about the loss of their episodic, or personal, memory. Obviously, each of us has a unique episodic memory, given our unique existence and experiences.

Memory researchers are also interested in what is known as semantic memory, or our general collection of world knowledge, our language, etc. Semantic memories tend to be pretty similar between people who have had the same general experiences. That is, as speakers of the English language, we all have fairly equivalent memories for words. We know about the law of gravity, and what meatloaf is.

Researchers are interested in understanding how that information is stored in semantic memory. One of the first models of semantic memory was Collins and Quillians hierarchical semantic network. As you see in the Figure, in this model concepts are organized into hierarchies. For instance, a bird is a type of animal, so is therefore stored under the concept "animal." An important characteristic of this model is cognitive economy. Cognitive economy means that a concept shares all the characteristics of the concept it is stored under, unless a specific exception is made. Therefore, a bird, because it is an animal, has skin, can move around, eats and breathes. Those characteristics don't need to be stored again under "bird." Notice that one of the characteristics of a bird is that it "can fly." Therefore, all concepts stored under bird can fly, unless an exception is noted, like in the case of an ostrich.

According to this model, when a concept is activated, all of its characteristics are activated, and activation also spreads between the links to related concepts. That is known as spreading activation, and it is hypothesized that spreading activation allows us to activate associated concepts in memory. For instance, spreading activation can account for why, after having read the word doctor, we often think of the concept nurse.

Patient KC provides an example of someone who has relatively preserved semantic memory, but very badly impaired episodic memory. That is, as you see in the clip, he can remember facts, but does not know how he acquired them.

06f | Implicit versus Explicit Memory

We are all very much aware of explicit tests of memory. Any exam that you write in class is an explicit test of memory. You know you are being tested on your memory for material in that course. Explicit memories, then, are ones that we consciously recall. That is, you can at this moment, pick up a pen and write down all the things you remember doing on your summer holiday. Explicit memories are generally linked to particular periods of time.

In contrast, implicit memory is a memory test that you are not aware of taking. Although individuals like HM and Clive Wearing have greatly impaired explicit memory for new information, they do show some signs of implicit memory. That is, there is some small amount of learning that they might not be able to tie to a particular event, but if tested, it will be evident.

The Figure in front of you shows the results of a study conducted by Warrington and Weiskrantz examining memory in amnesics and healthy controls. As you can see, the amesics showed impairment relative to the controls on explicit tests of memory such as free recall and recognition, but their performance on two implicit tests, word fragment identification and word stem completion, was not affected. Therefore, even though the amnesics would likely not consciously recall having studied the items, or possibly even the study session at all, their behaviour shows evidence of having studied those items before. Thus, they show a form of implicit, or unconscious memory.

06g | Summary

In this unit we've viewed memory as a process, rather than a place. We discussed the fact that if we really want to remember some information, our chances of doing so will improve if we do more complete, or deep, processing of that item. So, for instance, if you really want to remember the material that you learn in this course, or any course, the best way to do so is to try to elaborate on it when you study it. Put concepts in your own words, think about what they mean, try to explain them to someone else. That will promote memory that is better than if you merely read through your notes and the textbook.

We've also seen that despite the fact we are able to remember quite a lot of information, our memory should be in no way viewed as perfect. That is, we are prone to misremembering things, especially if we are asked about those things in a suggestive manner, as Loftus' work shows. Some of our memories seem crystal clear and detailed, the so-called Flashbulb memories, but it is also possible to show that people actually form memories for things that never happened.

In discussing our 3 neuropsych cases of amnesia, we get evidence for different types of memories. Episodic memory is our own personal memory store, whereas semantic memory consists of the basic facts that we know, the concepts we know, etc. We've seen that it is possible to lose one, but not the other. We've also seen that amnesia can either work backward in time, when we lose information we used to know, or forward in time, when we are unable to form new memories.