1a | Introduction to History, Methods, and Paradigms

Welcome to the first module of this course in Cognitive psychology. Cognitive psychology is a fascinating topic that attempts to uncover the secrets of the inner workings of the human mind. A cursory look through the textbook will reveal to you that there are many facets to the study of cognition. In this first module, I am going to introduce you to the topic of Cognitive psychology.

So, what is cognition?

Well, to get a better feel for the domain of Cognitive psychology, let's consider a real life example of a cognitive activity:

So, you're in a crowded place, such as a shopping mall during the holiday season. Throngs of people push past you, and you're hot and tired. You head for a nearby bench, aiming to combine some rest with some people watching. As you make your way, a young woman about your age jostles up against you and you both apologize for bumping into each other, glancing at each other as you do. She immediately exclaims, "Oh, it's you! How are you? I never thought I'd run into anyone I knew here—can you believe it?" You immediately paste a friendly but vague smile on your face to cover your frantic mental search: Who is this woman? She looks familiar, but why? Is she a former classmate? Did you and she attend camp together? Is she saying anything that you can use as a clue to place her?

This everyday example illustrates several key cognitive processes.

First, and perhaps most obvious, to notice that the woman is familiar you rely on your memory. That is, you might get an automatic sense of familiarity, indicating that you have seen this person before.

There are also more subtle cognitive processes going on as well, ones that might not be overly obvious to you. For example, you are using your perceptual and pattern recognition system to note that the thing you are talking to is indeed a female person. These processes are going on without you consciously being aware of them.

To communicate with her, you are using your language. This language is based on your complex lexicon, that part of your memory system that stores information about word meanings.

Eventually, you'll have to use decision making to determine how to deal with this situation. Will you admit your forgetfulness or will you try to cover it up by avoiding it?

As this example illustrates, pretty much every activity of our daily lives makes use of our cognitive abilities. In addition, even a very simple task, such as carrying on a conversation with someone, often involves several interacting cognitive processes. And again, like I noted above, much of this goes on without us being consciously aware of it.

As cognitive psychologists, our task is to find ways to examine the key mechanisms underlying the complex cognitive processes. For example, a cognitive psychologist might ask, what are the key mechanisms underlying how forgetting occurs? That is, what are the mechanisms underlying how we could not place who that woman was in the last example. In order to draw firm conclusions about such mechanisms, cognitive psychologists need to design experiments with sufficient experimental control. At the same time however, cognitive psychologists need to make sure that the laboratory tests that they develop really do preserve the essential workings of the processes under study. That is, scientists often run the risk of creating an experimental paradigm that is two-strip down and thus the results can't easily be generalized to the real world. This balance is crucial.

Throughout this course we will cover studies that use both tightly controlled experiments and more real world investigations that have the goal of uncovering the mechanisms underlying cognitive processes. In this first module, I will provide the background necessary to understand the remainder of this course. I will begin by providing a bit of a historical perspective of the main influences that served as a foundation for the field of Cognitive psychology. I will then discuss the major precursors to what has been referred to as 'The Cognitive Revolution'. We will then end by discussing some of the major paradigms of Cognitive psychology.

I will also note here, that there is a section in the text on research methods as well that I'm not going to cover in this module, as I'm sure that you have all been exposed to all of that in introductory psychology. However, do make sure you give those pages a read through to make sure that you are up to speed on the different research methods used by experimental psychologists.

1b | Antecedents of Cognitive psychology

In this section of the module we're going to discuss the major influences on the study of cognition.

So, how did the field of cognitive psychology develop?

Well, you might be surprised to hear that when your grandparents were going to school and reading books there was no such thing as cognitive psychology. In fact, cognitive psychology is a relatively recent discipline only really taking off as a separate discipline in the 1960s. However, when one looks through the history of science in general one sees hints of cognition throughout. I'm only going to touch on some of these just in order to give you a sense of the key influences of cognitive psychology.

So to begin with and to give you some historical perspective discussions of the nature of the human mind date back to at least the time of Aristotle and Plato. But we're going to jump right up to the 17^{th} and 18^{th} century to start our discussion.

During this time, philosophers began to seriously debate the nature of the human mind and knowledge. Two central philosophical traditions concerning the nature of the human mind that emerged during this time, and that in many respects are still with us today, are that of Empiricism and Nativism.

Empiricism, which was supported by David Locke, John Hume, and Stuart Mill to name a few, rests on the tenet that knowledge comes from an individual's own experience. That is, all knowledge that we have is acquired from the observation and analysis of events that we experience. Put another way, when humans are born their cognitive apparatus, that is their mind, is thought to be a blank slate and all of their cognitive abilities and their knowledge is thought to be acquired through their interactions with their environment

Nativism on the other hand emphasizes the role of biological or genetic factors in determining one's cognitive abilities. This view comes from the philosophical traditions of Rene Descartes and Immanuel Kent. Nativists attribute individual differences in cognitive abilities to innate abilities that people are born with. That is, they argue that many cognitive abilities and the cognitive processes that underly them are hardwired in the brain and are thus difficult to modify with experience.

Despite over a century of research into the mechanisms underlying the nature of the human mind the nativist/empiricist debate is still a controversial one today.

We will look next at different schools of experimental psychology that layed the foundations for Cognitive psychology today. It is important to keep in mind that when we talk about these different schools of thought or major influences, they are not necessarily all independent and they differ in terms of their stance on the nativist/empiricist debate.

Historians often date the founding of the actual field of cognitive psychology back to 1879. It was then when Wilhelm Wundt founded the first institute for research in experimental psychology. As an experimental psychologist, Wundt's primary goal was to discover the elemental components of the human mind. In other words, he wanted to discover the building blocks to conscious experience. In essence, he wanted to create a table of mental elements, much like a chemist's periodic table. Once a set of elements was identified Wundt believed that psychologists could determine how these units combine to produce complex mental phenomena. This search for the key components or building blocks of the human mind is referred to as ***structuralism***.

This structuralism tradition was also followed by one of his students, James Baldwin, who set up the first experimental psychology lab in North America at the University of Toronto in 1889. The primary experimental method used by Wundt and Baldwin was ***introspection***. This technique involved presenting highly trained observers, these were usually graduate students, with various stimuli and asking them to describe their conscious experiences. By personally reporting on one's conscious experiences Wundt and Baldwin believed that they could uncover the basic elements of human conscious experience.

Although much was learned from their work, the method of introspection has a number of serious limitations that makes it difficult to draw any conclusions about introspective reports. Most centrally, there are many aspects of human cognition that occur without conscious awareness and are thus not available to conscious introspection techniques. That being said, their research and the development of their laboratories were instrumental to the development of cognitive psychology as a discipline.

While Wundt and Baldwin were caring out their research and establishing their laboratories from a structuralist perspective, William James was caring out research in the United States from a polar opposite viewpoint. He argued that experimental psychologists' primary goal should be to explain the functions of the mind, for example, how and why it works the way it does, rather than uncover its elemental units. Hence the term ***functionalism*** was applied to his approach. Structuralists and functionalists differed not only in their key questions, but also in their methods. In order to uncover the elemental units of the mind structuralists were convinced that the proper setting for experimental psychology was the laboratory, where experimental stimuli could be tightly controlled. Functionalists, on the other hand, argued that in order to understand the key functions of the mind one must get out of the laboratory and study the whole organism in real life situations. Like the previous nativist/empiricist debate, structuralism and functionalism, to this day both have its group of followers.

You might want to keep these two dichotomies, that between nativism and empiricism and structuralism and functionalism, when we talk about the contemporary paradigms of cognitive psychology in the later section of this module.

We're now going to move on to **Behaviorism**.

In contrast to the prior attempts to uncover the elemental units of the mind and also as part of an opposition to the subjective techniques such as introspection Behaviorism developed at the turn of the century and ended up dominating research in psychology until well into the 60s. The basic tenets of Behaviorism as it was classically envisioned can perhaps best be captured by this quote from John Watson in 1913:

"Psychology as the behaviorist views it is a purely objective natural science. Its theoretical goal is the prediction and control of behavior. Introspection forms no essential part of its methods, nor is the scientific value of its data dependent upon the readiness with which they lend themselves to interpretation in terms of consciousness. The behaviorist, in his efforts to get a unitary scheme of animal response, recognizes no dividing line between man and brute. The behavior of man, with all of its refinement and complexity, forms only a part of the behaviorist's total scheme of investigation." (p. 158) (Watson, 1913, pp.158, 176)

As is clearly evident in this colourful quote, proponents of Behaviorism were quite vocal in their critique of the introspection technique. Rather, they argued that scientists should only focus on that which was observable which is overt behaviour. The study of learning was also emphasized, as was the relationship between inputs, that is the stimuli that are out there in the environment, and outputs, those are the behavioural responses from the organism. During this period, it became unfashionable to talk about mental representations, consciousness, or mental states at all. These things were thought to be beyond the scope of scientific study. Now the behaviourist tradition is often viewed in a negative light. That is that it had a negative impact on the development of psychology as a scientific discipline. However, it should be noted that the behaviourist tradition was responsible for the development of rigorous research methods that allowed researchers to examine the workings of the mind without relying on subjective measures such as introspection. We're just going to discuss two more theoretical influences before we're done with this section.

Also in opposition to the structuralist tradition, the school of Gestalt psychology began in the early 1900s. The central assumption of this approach was that psychological phenomena could not be reduced to simple elements, but rather had to be analyzed and studied in their entirety. Specifically, proponents of this view argued that an observer did not construct a perceptual experience or conscious cognitive experience of any kind based purely on simple, elementary sensory aspects of this experience. Rather, they argued that individuals were able to experience or perceive the total structure of an experience or an object as a whole.

Put another way, from a structuralist perspective, perceptual experiences arise in a bottom-up fashion, from basic elements to a perceptual experience, rather than in a top-down fashion. From a Gestalt perspective, top-down processes can determine the perceptual experience. In short, they focused on the holistic aspects of conscious experience. For example, what order is imposed on our perceptual processes? And, what are the rules by which people parse the world into wholes to give us the unified perceptual experience? Like the structuralist perspective however, and probably mainly a product of the time in which this field emerged, the primary methodology used was introspection.

Some examples of the types of stimuli Gestalt psychologists used to study these top-down influences on perception can be seen in the following figure. Note that A, B, and C in this figure all contain 8 equal lines. But people will experience them differently, saying A has four pairs of lines, B has 8 unrelated lines, and C has a circle or octagon made up of 8 line segments. Here, the arrangement of lines, that is the relationship among the elements as a whole, plays an important role in determining our perceptual experience.

The final major influence to the study of cognitive psychology that we are going to talk about is the study of individual differences and human cognitive abilities, pioneered by Sir Francis Galton. Galton's interest in individual differences in cognitive abilities was inspired by his reading of Charles Darwin's writings on evolution. Galton wondered whether intellectual abilities, like other biological properties could be subject to the same pressures of natural selection, and thus be inherited. To examine this, Galton began analyzing historical data. This involved looking at family trees of eminent men, those he judged to be superior in terms of intellectual abilities to determine the root of cognitive ability. Later in his career he invented a number of cognitive ability tests as well. One area of study he is perhaps most well known for is the study of mental imagery as a cognitive ability. That is, he found that individuals differed marketably in their ability to conjure up mental images of objects in their mind. He was a pioneer in this area and his work on mental imagery sparked an entire research area devoted to the study of the human mind's capacity to generate internal visual representations of objects. In fact, we have a whole module in this course, Module 8, dedicated to this faculty. More generally however, Galton's work on the genetic basis of cognitive abilities and capacities inspired future generations of cognitive psychologists to develop new questionnaires and new testing techniques to further understand the multifaceted nature of cognitive processes.

1c | The "Cognitive Revolution"

Okay, we've already covered a lot of ground in uncovering the major precursors to the field of cognitive psychology. But we're still not quite there yet. To this point, researchers were discussing the mind, but there was no real field of psychology strongly devoted to its study. This all changed in the middle of the 20th Century to spawn what has been referred to as ***"The Cognitive Revolution"*** There were several key points in history that acted as a precursor to this revolution. We are going to discuss four of these precursors.

The first was the fact that **human factors engineering presented new problems that needed solutions**. During the time of WWII the development of complicated equipment required highly trained personal to operate them. In order to optimize their operation of this machinery the engineers and trainers needed some knowledge of how the mind worked. The focus became what was the most optimal way to design a machine for humans to use? The textbook provides an example of how they had to redesign the controls for breaking and landing gear operation to reduce errors in landing. Other examples include the development of airplane cockpit displays and radar monitoring systems, which were designed to allow the most optimum and efficient processing of a wide range of information.

Based on these interactions between humans and machines, psychologists and engineers developed the concept of the ***person-machine system***. This is the idea that machinery operated by a person must be designed to interact with the operator's physical and cognitive capacities and limitations. Along side the development of the concept of a person-machine system, psychologists began to see humans as sharing properties with the inanimate objects that engineers designed. This resulted in individuals being described as limited-capacity processors of information.

What this basically means is that psychologists were recognizing the limits of the human mind and that peoples' cognitive apparatuses are not built to do too many things simultaneously. We're going to cover the capacity limitations of the human mind in some detail in later modules of this course.

Human factors research is still booming today and is likely going to continue to grow. For example, cognitive psychologists are employed in major industries around the world conducting experiments to determine the most efficient means for people to interact with developing technology. Two examples that come to mind are Reseach in Motion here in Waterloo, the makers of the Blackberry, and NASA. This latter example demonstrates that you can fulfill your dream of becoming a rocket scientist with extensive training in cognitive psychology.

At about the same time as the human factors movement **developments in the field of linguistics** led by Noam Chomsky began to see the central importance of studying how people acquire, understand, and produce language. Chomsky's early work showed that Behaviorism could not adequately explain language. For example, Skinner argued that children learn language by imitation and reinforcement. Chomsky, on the other hand, questioned this conditioning explanation of language on several grounds. For example, children say sentences they've never heard before, for example, "I hate you mommy", and they use incorrect grammar, "The boy hitted the ball", even though it is not reinforced. Chomsky instead argued that humans have an innate capacity to acquire language and that its development is not grounded by the laws of conditioning.

A third strand of the cognitive revolution came from developments in neuroscience and specifically the localization of function in the brain. We'll discuss this a fair bit more in the second module, but we'll talk about it here in terms of how it influenced the development of cognitive psychology as a science. Work by Donald Hebb, a world renowned professor at McGill University suggested that some kinds of functions, such as visual perceptions were constructed over time by building cell assemblies. Cell assemblies are simply connections among sets of cells in the brain.

Also in the 50s and 60s Nobel Prize winning neuropsychologist David Hubel and Torsten Weisel demonstrated that specific cells in the visual cortex of cats were in fact specialized to respond to specific kinds of stimuli, for example, the orientation of lines or particular shapes. They also demonstrated that early experience shaped brain development. Specifically, in perhaps their most famous experiment, they showed that kittens who were in a restricted environment with only horizontal lines would fail to develop the ability to see vertical lines.

Taken together, the work of Donald Hebb and Hubel and Weisel clearly showed that cognitive functions can be localized to specific parts of the brain. These discoveries forced the discussion of mind and that the discovery that cognition had a clear and localizable neural basis generated many new questions about how cognition arises from a biological organ.

The final piece to the cognitive revolution puzzle also dates from around WWII and it stems from the development of computers and artificial intelligence systems. This development led to what is known as "**The Computer Metaphor of the Mind**". Here, the development of computers and artificial intelligent systems led to the comparison of people's cognitive activities to an operating computer. Specifically, just as computers have to be fed data via keyboard press or the present day USB key, people have to acquire information through their senses. Both computers and people store information and must therefore have structures that process and allow such storage. Here computers have hard drives and people have their cerebral cortices. The parallels between the computer and the human mind are indeed many.

So, at the end of the day scientists refuse to accept the idea that mental representations did not exist and they came to accept the idea that mental events and states could be studied scientifically. In the next section of this module we're going to talk more about how people study cognition today.

1d | Paradigms of Cognitive Psychology

After having just looked at cognitive psychology's historical roots in the previous section of this module, we are now going to focus on cognitive psychology today. Specifically, we will talk about four major paradigms that cognitive psychologists use to frame their research. Here, a paradigm simply refers to a body of knowledge that is structured according to what its proponents consider to be important. Paradigms include the assumptions investigators make in studying a phenomena. Paradigms also specify what kinds of experimental methods and measures are appropriate for an investigation.

So the first and still quite dominant paradigm of cognitive psychology is referred to as the ***Information Processing Approach***. This approach was spawned by the human mind/computer analogy that we just talked about previously and is based on the idea that cognition can be thought of as information, that is what we see, hear, read about, think about, flowing through a system. This system is our mind.

A typical information processing system is shown in the following figure. Note first that information flows through the system from low level detectors and registers—for example, visual and auditory registers—through more temporary memory stores—for example, short-term memory—and then on to more long-term and semi-permanent memory stores—for example, long-term memory. Note also that different operations can be performed on information at each level. For example, information in long-term memory can be categorized, recoded and reorganized based on new incoming information.

There are **several key assumptions** underlying the information processing approach.

First, people's cognitive abilities can be thought of as **"systems" of interrelated capacities**. That is, cognition is built upon many interacting subskills and abilities that jointly contribute to cognition. In addition and in accordance to the computer metaphor, information processing theorist assume that people, like computers are **general purpose symbol manipulators**. In other words people, like computers, can perform impressive cognitive feats by applying only a few mental operations to symbols. These symbols may be letters, numbers, sentences, or visual images. Specifically, the same general cognitive operations, take for example the storage of information, can be applied to a wide range of stimuli. Scientists who ascribe to the information processing approach are mainly concerned with understanding the nature of the representations under study, and the nature of the processes that operate on the representations.

Early in the 1980s however, some researchers were dissatisfied with some of the assumptions of the information processing framework and they began to explore alternatives to this approach. One highly influential framework is known as ***Connectionism***. This cognitive paradigm proposed that the cognitive machinery that underlies all cognition is composed of a highly interactive network of connections among simple processing units. Because these units are sometimes compared to neurons in the brain, connectionist models are also referred to as

neural networks . The connectionist approach is quite different from the previous information processing approach that we just discussed.

First, the connectionist approach is inherently none localist. That is there is no central place where for example, word meanings are thought to be stored. Rather, information is thought to be widely distributed among what are referred to as simple neuron-like processing units. These units code patterns of information across a large population of similar units. In addition, units are connected to each other by weights that are modifiable by learning. For example, a positively weighted connection between units leads to activation and a negatively weighted connection between units leads to inhibition. Information, example a letter, a word, or a meaning, is represented by a pattern of activation distributed among a number of units.

The following figure depicts what a connectionist network that stores information about people might look like. In this example, the units of interest are the black circles at the centre of the figure with all the arrows pointing to them. Each of these units are specific people that you have stored in your memory. Each unit is connected to other units that depict certain information about the people. For example: their race, their sex, their profession, their car, their favorite cheese, and their name. The arrows between the units depict excitatory or positively weighted connections. When any unit reaches a certain level of activation, it activates all the other units to which it has positively weighted connections. In addition, other conflicting information that does not have excitatory links is inhibited. And once the activation is strong enough among the interrelated connections, a response for a specific person will come to mind. It's important to note here, that the positive and negative weighting of these connections are based on prior experience and prior learning.

The nice thing about these connectionist models is that they're extremely flexible. That is a single connectionist model can likely learn and acquire information about a variety of domains without changing the inherent structure of the model itself.

There are a **number of key differences and similarities** between the information processing and the connectionist approaches.

First, whereas information processing models assume cognition unfolds in a serial, that is step by step orderly fashion, connectionist models assume that cognitive processes occur in parallel, that is many processes occurring simultaneously. Both approaches are similar however in that they both assume that cognition will be best understood by uncovering the basic mechanisms or processes underlying cognition. In addition, they assume that the mechanisms underlying cognitive processes are stable across situations and can only be revealed under rigorously controlled experimental conditions. Therefore, in both paradigms research must be done in the lab. The final two approaches that we are going to talk about on the other hand consider the context in which cognition occurs.

For example, proponents of the ***Evolutionary approach*** argue that in order to understand cognition we need to understand the evolutionary pressures that our ancestors have faced in the past. Here, the idea is that much like other biological systems cognition is based on a system that has evolved over many, many generations. Therefore, the human mind has had to respond and change in response to evolutionary pressures. This has resulted in us evolving special purpose cognitive mechanisms to deal with such environmental pressures.

Cosmides and Tooby, both at the University of California in Santa Barbara, are two of the foremost researchers of evolutionary psychology. They believe that some of the most significant issues our ancestors have faced involve social issues such as, the enforcement of social contracts and the detection of cheaters. To do this effectively, people must be especially good at reasoning about social situations. Therefore, evolutionary psychologists predict, that people's reasoning and decision making will be especially enhanced when they are reasoning about social situations. As you will see later on in Module 10 of this course, this is indeed the case.

A fourth and final major approach that we will discuss is referred to as the ***Ecological Approach***. The central tenet of this approach is that cognition does not occur in a context free vacuum. Rather, all cognitive activities are shaped by the culture, the context, and the situation under which they occur. This is a very important point and one which you will see in a number of remaining modules of this course. That is, the context in which cognition happens shapes the cognitive processes under investigation. Therefore, proponents of this view argue that to fully understand cognition, you must examine it in its natural context.

Following in this tradition, Daniel Smilek, here at the University of Waterloo and Allan Kingston, at the University of British Columbia, have been focussing on how attention operates in every day life. Their primary tool to investigate attention is by measuring eye movements to both real life static and dynamic displays. For example, and as is illustrated in the following photograph, in one of their studies they presented participants with pictures of art and sports scenes and monitored their eye movements while they described the pictures aloud. They found that regardless of what type of image participants were viewing, most eye fixations were committed to the eyes and faces of the people in the scene, rather than the objects people were interacting with.

I've now given you a brief overview of the major paradigms that cognitive psychologists use to guide their research. It is important to note here however, that not all cognitive research that we will cover in this course fits neatly into one of these four paradgms. Some might not fit in any, whereas others might fit more than one. However, this overview will hopefully give you a good background to understand and interpret the experiments that we will cover in the remainder of this course.

1e | Summary of History, Methods, and Paradigms

In summary, we began this module by noting how cognition plays a significant role in all aspects of our daily lives and noting how it underlies most of our behaviour and social interactions.

We then discussed the major influences of the study of cognition. Here, we began this section by talking about one popular dichotomy that continues to be hotly debated today. That is **empiricism**, the emphasis on experience and learning and **nativism**, the emphasis on what is innate.

We then covered five major schools of thought that served as precursors to cognitive psychology as a science and helped frame cognitive questions. We started of this section talking about **structuralism**, which seeks to discover the principles that explain our conscious experience and identify the simplest essential units of the mind. We then talked about **functionalism**, which aim is to understand the function of the mind—the ways in which mental functions let individuals adapt to their environment. We then talked about b**ehaviorism**, whose aim is the scientific study of behaviour, an observable consequence of psychological experience. We then talked about **Gestalt** psychology, which holds that psychological phenomena cannot be reduced to simple elements, but must be analyzed and studied in their entirety. And then we finished off this section talking about **individual differences**, the idea that individuals differ, even as adults, in their cognitive capacities and abilities.

We then talked about how the "Cognitive Revolution" grew out of (i) human factors engineering, (ii) a dissatisfaction of behaviorist accounts of language, (iii) neuropsychological work looking at localization of function, and finally (iv) the computer metaphor of the mind.

We then finished this module by covering four major approaches or paradigms to the modern study of cognitive phenomena. Here we talked about the **information processing framework** which emphasizes stage-like serial processing. We then moved on to talking about the **connectionist framework** which claims that the cognitive machinery or apparatus underlying cognition is based on a network of connections among simple, and usually numerous, processing units. We then talked about the **evolutionary approach** that talks about how a cognitive process has been shaped by pressures over generations. And then we ended by talking about the **ecological approach** which stresses the ways in which the environment and the context shape the way cognitive processing occurs.

2a | Introduction

In this module, we'll be talking about the brain, both its structure and its function. I'll begin by providing you with a brief overview of the main structures of the brain. Then we'll discuss localization of function. That is, how is it that we can find evidence of that certain parts of the brain are responsible for certain functions of cognition. We'll then finish this module by talking about some brain imaging techniques. Here, recent technological advances that directly measure either electrical activity or metabolic processes in the brain, have provided us with a window to view the inner workings of the mind.

Before we jump in and start talking about the structure of the brain and the localization of function using brain imaging techniques and others, I should note that the study of how the brain enables cognition is a relatively recent enterprise. Throughout most of the last 50 years or so when cognition was really booming as a discipline, the brain really did not have a central role in its study. For example, cognitive psychologists might have thought the brain is interesting, but it wasn't necessary or relevant to understanding how the mind worked. The assumption being, is that things going on in the brain are likely just too inordinately complicated and thus, wouldn't provide a comprehensible picture of how the brain enables complex cognition.

However, this is now changing. Increasing numbers of cognitive psychologists have become very interested in the function of the brain as an underpining of cognitive activity. This is partly due to the recent advances in neuroimaging techniques which have provided us with a more comprehensible view of the inner workings of the brain when people are performing cognitive tasks. Given these new tools that cognitive psychologists now have at their disposal, one of the ongoing challenges now is to develop new experimental paradigms that can conclusively link cognitive processes to underlying neural activity.

I want to end this introduction to Module 2 with an analogy. As we just talked about, cognitive processes are implemented in human brains. One can make the analogy that the mind is to the brain as software is to a computer. Here, the brain is the hardware and the cognitive processes the software, although the two aspects of functioning can be distinguished. To really understand either, we must have some familiarity with both and how they interact.

2b | Structure of the Brain

We’re now going to move on to the main structures of the brain. We’ll begin with the phylogenetic division. This division of the brain organizes brain structures in terms of the order in which they are thought to have evolved.

In the following figure, you will see the main structures of the phylogenetic division. These are the hindbrain, the midbrain, and the forebrain. We are going to primarily focus our discussion on the forebrain, and specifically the cerebral cortex in the forebrain. The reason we’re going to focus on this part of the brain is because the vast majority of tasks that we’re interested in, that is the vast majority of cognitive abilities and capacities, take place within the forebrain. That is, the forebrain is where cognition happens. Whereas regions in the hindbrain and the midbrain are mainly responsible for lower level, non-cognitive functions, such as basic life support and relay of information from the spinal cord to the rest of the brain. We’ll now focus on the forebrain.

The forebrain can be generally broken down into two sub-sections. Those are subcortical structures and cortical structures. The following figure highlights these sub-cortical regions of the brain. And the sub-cortical regions are those regions of the brain that sit beneath or under the cerebral cortex. I will highlight here some of the most critical sub-cortical regions that support cognitive processes.

First, you will find located right in the centre of the brain, the thalamus. Now the thalamus has many functions, but one of its main functions is a switching or relay station for sensory information around the brain. That is, information that gets perceived and processed by multiple regions of the brain can become integrated and can cross-modaly communicate with each other via the thalamus.

Located right next to the thalamus is the hypothalamus. Now the hypothalamus also has many functions. One of its main functions though is to regulate basic biological functions including hunger, thirst, temperature, sexual arousal, and basic emotional reactions.

The final two subcortical structures that I’m going to talk about are the hippocampus and the amygdala.

The hippocampus, which is located again sub-cortically right under the temporal lobes of the brain is a very important and critical structure for learning and memory. In fact, what we’ll learn later in this course, if a person has damage to the hippocampus they often no longer have the ability to consciously recollect personal events.

Located right next to the hippocampus and related to the hippocampus in terms of supporting cognitive processes is the amygdala. The amygdala, like many structures in the brain, is involved in a number of cognitive processes. Primarily however, it seems to be involved in emotion and aggression. In addition, and this is why it's important to think about the amygdala in terms of its relationship with the hippocampus, it also is involved in memory, specifically the emotional content of memories. Here, it is thought to modulate the strength of memories in terms of its emotional content.

We're now going to switch our discussion from the sub-cortical regions of the forebrain to the cortical regions.

The cerebral cortex is the outer most layer of the brain. It contains several layers of densely packed neurons with white matter underneath. The white matter connects the cerebral cortex to the sub-cortical regions of the brain. The following figure provides a more detailed view of all the different sub-components of the cerebral cortex. At the most macro level, the cerebral cortex can be divided into four main lobes: the frontal lobe, which sits underneath the forehead; the parietal lobe, which sits underneath the top rear part of the skull; the occipital lobe, which is at the back of the head; and the temporal lobe, which is on the side of the head. In addition, there are two hemispheres of the brain, each containing frontal, parietal, occipital, and temporal lobes. There are no direct connections between these two lobes in the cortex. However, information between the two cerebral hemispheres of the brain can be communicated back and forth sub-cortically via the corpus callosum and the anterior commisure. We'll discuss the major functions of the lobe of the cerebral cortex in more detail later. However, I will just touch on a couple of the main functions of each lobe right now.
Parietal lobes support many cognitive functions such as spatial processing and attention. In addition, the parietal lobes contain a structure known as the somatic sensory cortex, which is involved in sensing information from the body, such as pain, pressure, touch, or temperature.

The occiptal lobes are primarily responsible for processing visual information. This includes processing the very low level features of visual stimuli, such as orientation, shape, and colour, to more complex aspects of the stimuli involved in recognizing what objects are.

The temporal lobes, on the other hand process auditory information. In addition, because the temporal lobes are right above the structures, such as the amygdala and hippocampus that are known to be involved in memory, they also support functions associated with the encoding and the retrieval of information from long-term memory.

Finally, to best understand the functions of the frontal lobe, it is best to sub-divide the frontal lobes into three separate regions. First, the motor cortex located at precentral gyrus, right next to the parietal lobes, the furthest back regions of the frontal lobes, directs fine motor movement. The premotor cortex, located just anterior to the motor cortex, seems to be involved in planning such movements. Finally, we have the largest part of the frontal lobe which is called the prefrontal cortex. This involves everything anterior to the premotor cortex. The premotor cortex supports a wide range of cognitive functions. Most generally, it is involved with what neuroscientists refer to as executive functioning. This involves planning, making decisions, implementing strategies, inhibiting inappropriate behaviours, and using working memory to process information. For example, anything that you're working on or thinking about in your mind right now, at this very minute, likely involves your prefrontal cortex.

In the later sections of this module, we're going to look at some of the research methodologies that have been used that allow us to determine what sorts of cognitive processes are supported by which brain regions.

2c | Localization of Function

In this section of the module, we're going to focus on localization of function. In the proceeding section, I gave a brief overview of some of the basic structures in the brain. We also talked about some of the key cognitive functions or processes that were thought to be supported by these brain structures. So how is it that neuroscientists know what brain regions support what cognitive functions? The anwer to this question lies in studies of localization of function as a means of mapping basic cognitve processes to the brain.

The original idea of localization of function traces back to an Austrian anatomist named Franz Gall. He believed in something called faculty psychology. He believed that certain human abilities and traits, such as human nature, conscientousness, constructiveness, were associated with specific regions of the brain. He also believed that each of these abilities and traits were autonomous and independent. That is, that your ability in one domain would not impact or could not be impacted by an ability or trait in another domain. Gall's student, Johan Spurzheim took this one step further. He argued that the strengths and weaknesses of specific traits and abilities were precisely correlated to the relative sizes of the different brain regions that were thought to support them. And thus was born the study of phrenology.

So for example, if you look at the following figure with a phrenology head, just above the nose you can see a location labelled punctuality. Someone who is highly punctual would have a slightly larger region of the brain just above the nose, whereas somebody is not very punctual would have a slightly smaller region there. This could be measured with a trained phrenologist using their own hands or it could be measured using a phrenology machine like the one found in the following picture from 1905. It didn't take long however for this idea to become discredited.

The major problem with phrenology was not the assumption of a localization of function. We know for example that many functions or many cognitive processes are indeed localized to some degree in the brain. The problem with phrenology more had to do with the assumption that these processes completely autonomous and independent. We now know that cognitive processes do not operate in a vacuum. On the contrary they operate highly interactively. In addition, researchers have shown that the size of a portion of the brain does not directly correspond to its relative power.

These criticisms aside, Gall's work was extremely influential as he forged the way for future scientists to more precisely map out the relationship between structure and function in the brain.

I'm now going to talk about two different lines of research, one involving patients with specific brain damage and another involving brain stimulation, that were highly influential in determining what specific regions of the brain were responsible for specific cognitive functions.

So first, we're going to talk about patients with specific damage to specific regions of the brain and how it affects cognitive behaviour. To do this, I want to introduce a concept that cognitive psychologists often use to try to isolate specific components of the mind and brain. This is the double dissociations. I'm going to talk about this first in abstract terms and then we'll go through a real example from the literature.

So, imagine you have a patient with damage to area X. Now X can be any region in the brain. And you find out that this patient is impaired for cognition A, but not B. Then you have another patient that comes in that has damage to area Y. Now this area Y is different than area X and they have impairment for cognition B, but not A. So to reiterate, you have two patients, each with different types of brain damage, one has brain damage to area X, one has brain damage to area Y, and the impairments that they show are mere images of each other. The patient with damage to area X is impaired for cognition A, but not B, and the patient with damage to area Y is impaired for cognition B, but not A, so they are complete mirror images of each other. This is what is referred to as a double dissociation, where brain damage and behaviour are completely dissociated from each other and show opposite mirror image patterns. This double dissociation logic is often used in cognitive psychology and cognitive neuroscience.

One very famous example of this, and this is one that you've probably covered in your introductory psychology class, is that of Broca's Aphasia and Wernicke's Aphasia. Here, if a patient has damage to the area known as Broca's Area, in the left frontal lobe which is highlighted here in the following figure, this patient will have a major deficit in expressive language, or speech production. If a patient, on the other hand, experiences damage to an area in the auditory association cortex, specifically Wernicke's Area, they will show deficits in the comprehension of language, but intact speech production. So to reiterate, a lesion to Broca's area impairs speech production, but not comprehension and a lesion to Wernicke's area impairs comprehension, but not production. This is a nice, simple example of a double dissociation. Now you may want to take a little bit of time here just to make sure you go through this logic and have a really good grasp of it, because we are going to see other examples of double dissociations throughout the remaining modules of this course.

Since the time of Paul Broca and Carl Wernicke cognitive psychologists began to establish connections between lesions in other parts of the brain and specific cognitive functions. For example, researchers found that select regions to specific portions of the primary motor cortex would result in the loss of a specific motor control of a select body part. A summary of the mapping between specific locations within the primary motor cortex and the control of specific body areas can be found in the following figure.

For example, damage to the very top or dorsal portion of the primary motor cortex would affect one's control of their feet, whereas damage to the ventro or lower portion of the primary motor cortex would affect the patient's control of their mouth. In addition to the primary motor cortex, neuropsychologists have also clearly mapped out the basic subdivisions of the somatic sensory cortex.

A summary of this topographic representation is highlighted in the following figure. As you can see from this figure, like the motor cortex, the somatic sensory cortex is organized in such a fashion that each part of it receives information from a specific part of the body. As I noted previously, a lot of the research that helped define the relationship between certain structures of the brain and their function was done with patients that had brain damage. So for example, you'd find a patient with a selected lesion in one part of the brain and then through a series of tests find out what capacity or what ability has been compromised.

Wilder Penfield, who is a famous Canadian researcher and neurosurgeon and the founder of the Montreal Neurological Institute, is perhaps most responsible for what we know about the localization of function in the human cortex. What he did was, is he developed a ground breaking procedure called the "Montreal Procedure" for localizing the source of epileptic seizures in patients. Before operating on his patients who were only under local anaesthetic and were thus conscious and could communicate with them, he probed the exposed brain tissue guided by the responses of the patient. And what he would do is he would search for the scar tissue that caused the epilepsy. For example, if a patient often experienced a certain sensation, such as a taste or a smell, Penfield would gently stimulate the exposed cortex until the patient reported experiencing that same sensation, thus localizing the source of the seizures. A byproduct of this procedure was that Penfield clearly mapped out the specific functions performed by various regions of the brain based on participant's responses to the cortical stimulation. Using this technique he created maps of both the sensory and motor cortices of the brain in more detail than anyone before him, and these maps are still used today.

There's a short web clip on the *History by the Minute* website that features Wilder Penfield's work. This clip is worth looking at because it'll give you an idea about how his procedure worked.

2d | Brain Imaging Techniques

We're now going to talk about brain imaging techniques. In the previous section of this module we talked about how researchers were able to uncover some of the functions of the brain by looking at patients that had lesions or damage to specific regions of the cortex. By examining a group of individuals with similar lesions one can one can determine what cognitive ability is deficient and what is spared. For example, in the case of Paul Broca's research, he found that individuals that had a select lesion in the left inferior frontal cortex showed deficiencies in speech production. By showing that that relationship exists, one can then infer that that area of the cortex supports that cognitive function.

However, as important as this research is, it doesn't always tell us enough information about a normal functioning brain. For example, it's very difficult to make inferences about a normal functioning brain from a single case study of an individual with brain damage. Even in the case of multiple individuals that have similar brain damage, no two lesions are ever going to be identical. Luckily for us however, recent advances in technology have allowed us to look inside the functioning brain using non-invasive procedures.

These can broadly be broken down into two different categories: one being static imaging where you're looking at the structure of the brain, and the second being dynamic brain imaging where you're looking at the function of the working brain. First I'm going to talk about a couple of different static brain imaging techniques and then I'm going to spend the remainder of this section of the module talking about functional or dynamic brain imaging techniques.

Two popular structural neural imaging techniques are the CAT scan and the MRI scan. The CAT scan or computerized axial tomography is a technique in which highly focused converging beams of X-rays are passed through the head from many different angles. The differing types of brain tissues have differing densities and thus deflect the X-rays differently allowing visualization of the organ.

Recently MRI or Magnetic resonance imaging has become the tool of choice to measure the structure of the brain. This technique takes advantage of the different magnetic properties of tissues in the brain, that under a powerful magnetic field, produce an electromagnetic signal that the scanner detects, and then these electromagnetic signals allow the visualization of the underlying structure of the brain.

For neural imaging purposes, MRI scans are typically preferred over CAT scans and there are several reasons for this. Firstly, MRI requires no exposure to radiation. Secondly, MRI scans can often provide a more detailed image of the underlying structures of the brain. And thirdly, MRI has several other very powerful functions. Specifically, as we'll be talking about very shortly, you can also measure the dynamic or functional aspects of the brain with MRI. This you can not do with CAT scans.

The two previous techniques we talked about, CAT and MRI, provide static pictures of brain structures. Cognitive neuropsychologists and neuroscientists could use these static pictures to pinpoint brain damage and other abnormalities. However, these static images do not allow us to see how the functioning brain is working. For this we need functional neuroimaging.

Throughout this course you're going to be exposed to several different neuroimaging techniques. They all rely on two different types of activity that happens in the brain. First, when neurons fire in the brain they produce electrical activity. By placing metal electrodes on the scalp neuroscientists can measure this electrical activity and by measuring the time course of this activity and the source or location of this activity neuroscientists can make inferences about how the brain is responding to certain cognitive stimuli. The technique that is most commonly used to measure this electrical activity as a function of cognitive tasks is called Event-related potentials or ERP.

A second group of functional neuroimaging techniques measure the byproduct of this electrical activity. This byproduct of neuroactivity is metabolism or blood flow in the brain. Two functional neuroimaging techniques that measure this metabolism are Positron Emission Tomography or PET, and functional Magnetic resonance imaging or fMRI. I'm going to focus on this later technique, fMRI as it is by far the most popular technique in cognitive neuroscience.

Before we talk about fMRI I want to read you this quote by Donders in 1868: "As in all organs, the blood undergoes a change as a consequence of the nourishment of the brain. One discovers in comparing the incoming and outflowing blood that oxygen has been consumed."

It took over 100 years after Donders wrote these words for us to be able to have the technology to accurately measure this inflow and outflow of oxygenated blood in the brain. This technology is functional Magnetic resonance imaging, fMRI for short. Now recall previously when we talked about MRI or structural magnetic resonance imaging, what we were measuring there was the structural properties of the brain. In that case, MRI was able to provide us with pictures of the brain by taking advantage of the different magnetic properties of the tissues in the brain.

Well, it turns out that oxygenated and de-oxygenated blood, also have different magnetic properties. So one can measure the inflow, and outflow of oxygenated blood in the brain by measuring the magnetic properties of that blood. The inflow and outflow of oxygenated and de-oxygenated blood in the brain is referred to as the blood oxygenation level dependent function or the BOLD function. This BOLD function is depicted in the following figure.

So what happens here is that as neurons fire in the brain blood flow increases as a function of that neural activity in the brain. This is a surprisingly slow process and that is actually depicted in the following picture. On the X axis here we have time and it shows a time scale of roughly

20 seconds. And on the Y axis we have signal strength and that's just the MRI signal strength as a function of the oxygenation level in the blood. At the point at the intersection of the X and Y axis of this graph would be when somebody started performing a cognitive task. And what initially happens is that those regions of the brain that are responsible for that task consume oxygen in that blood. What that does is that gives an initial dip in the BOLD function. After that there is a relatively slow influx of blood to that region and this peaks at around 10 or 15 seconds after the onset of that cognitive task. fMRI again picks up this BOLD function. As a researcher what you do is is you look around the brain and find those regions of the brain that show a BOLD function that is time-locked to the cognitive task that you're interested in. Once you find those regions that have that BOLD function you can then be confident that those regions are related to or correlated with performance on that task.

Now this sounds all well and good, however there is at least one caveat to this. When a person is performing a cognitive task and you're measuring the blood flow in the brain along with that cognitive task it's very difficult to know for sure what regions of the brain are specifically responsible for what aspects of that task. Specifically, every cognitive task that we do likely has many many underlying mechanisms that support that task and what we're often interested in in cognitive psychology is finding all those sub-components, all those combined mechanisms that support complex thinking.

So how is it that we can actually isolate and find those regions of the brain that are responsible for different components of different cognitive tasks? Once again, we have to give credit to Donders. He came up with what is referred to as Subtractive Logic. This idea originated with studies of reaction time differences. What the logic is is that in order to measure the time for a process to occur you need to compare two reaction times or two tasks: one which has the same components as the other, plus the process of interest.

So let's consider a very simple example. Let's just say you're interested in measuring the time it takes to make a decision about colour and in your experiment you just have a very simple choice decision task. Participants are presented with either a green light or a red light and what their task is is to hit the button when the light is green but not red. And for the sake of argument, let's just say you've performed this experiment and it takes around 250 milliseconds to perform this task. What your initial conclusion might be is, well it takes around 250 milliseconds to make a decision about colour. Sounds simple enough right? Well, not so fast, it's not that easy.

There are a number of different components to that decision task that also are contributing to the reaction time. There is indeed that decision time, that key process that you're interested in. However, there are also more basic components of that task. For example, there is a manual or motor component to the task. Just simply pushing a button takes time independent of having to make a decision about any stimuli. Ideally what you'd want to do is to gain access to that decision time or to be able to say something about decision time independent of the motor component of the task.

Well, using subtractive logic there's a way around this. What you can do is is have participants perform another simpler task that contains part of what that decision task is. For example, you could have participants just simply hit a button when they see any colour of light and take their responses to that more simple task and subtract them from your more complex task. So imagine that it took the participants around 200 milliseconds when the task was to simply hit the button when they saw any colour of light and it took participants around 250 milliseconds when their task was to hit a button when the light was green, but not red. Then what you can do is you can subtract the reaction times for these simpler tasks from reaction times for the more complex tasks leaving you with a difference of 50 milliseconds. That would be your best estimate of what the pure measure of decision time is independent of any sort of motor response.

Importantly, this logic is also applied to the analysis of functional neural imaging data. This allows us to isolate the brain regions contributing to a given underlying cognitive process. Specifically, the relative amount of activation in a particular brain region needed for a given cognitive task can be measured by subtracting a control state, for example responding to any colour of light in the last example, from a task state, like making a decision about two colours in the last example.

Throughout this course we're going to be covering a number of fMRI and PET studies and most of the time when you see a brain image picture what you're going to be seeing is the subtractive logic at work.

2e | Summary of the Brain: Structure and Function

In summary, we began this module by talking about some of the basic structures of the brain.

We first talked about the Phylogenetic Division which contains the hindbrain, which contains some of the most evolutionarily primitive structures; responsible for transmitting information from the spinal cord to the brain, regulating life support functions, and helping to maintain balance. And the midbrain which contains many "relay" centres to transfer information between brain regions. And then the forebrain which contains the thalamus, the hypothalamus, hippocampus, amygdala, and the cerebal cortex, structures that are mostly directly implicated in cognitive processes such as memory, language, planning, and reasoning.

Within the forebrain we spent a little bit more time talking about the cerebral cortex and the four different lobes of the cerebral cortex. These are the frontal lobes which are involved with movement, planning, and executive functioning, the parietal lobes which are involved with reception and integration of sensory information and spatial processing, the occiptal lobes which are involved with processing visual information, and the temporal lobes which are involved in processing auditory information as well as information about taste and smell.

We then talked about some traditional methods for determining the localization of brain function and how it has been inferred from studies of patients with focal brain lesions. Here, we also talked about double associations and how they are a very informative means of isolating specific functions to specific brain regions.

We ended this module by talking about brain imaging techniques. There have been a variety of modern techniques that have been developed to measure the function of the brain during cognitive processes. We briefly talked about CAT scans, MRI, PET scans, fMRI, and ERP.

When designing functional neuroimaging experiments and analyzing them researchers typically use the subtractive technique. This technique provides a means of isolating cognitive processes and brain regions whose activity varies in an experimental task compared to a control task.

3a | Introduction to Perception

As you sit at your computer about to begin this unit, you can accomplish an amazing thing. That is, if you scan the room you're bound to see a multitude of objects, maybe even a pet, or another person.

You can hear my voice as the lecture begins, and maybe also some background noise- a conversation or some music perhaps. If you're snacking or having a drink, you'll become aware of all kinds of textures, flavours, and maybe even aromas. The phenomenal thing is that you can do all of this with virtually no effort. Our environment is loaded with all kinds of stimuli, and this amazing feat in which we are able to attach names and meanings to all of those stimuli, to identify them, is called perception.

In this unit we'll explore the manner in which perception is achieved and the types of factors that influence it. An overarching theme to keep in mind, as we'll see, is that perception is not always accurate. That is, we do not always see, hear, taste, smell or feel what is actually there.

We'll see that perception is obviously affected by what we call bottom-up or data-driven processes, which refer to how the information in the stimulus affects perception. Perception is also affected by top-down or conceptually-driven processes. These refer to the effects that context, our prior experience, and our expectations have on perception.

Finally, we'll investigate some of the intracacies of perception when we discuss disruptions in perception that are associated with various brain injuries.

While we explore this unit, it is important to keep in mind one essential issue, and that is this: Perception operates at the so-called front-end of human behaviour. The way you decide to use an object, for instance, will depend on what you believe that object is. Therefore, to study some of these higher order cognitive processes as we'll do later in the term, such as memory, decision-making, and language, it is important to have an understanding of the earlier, more basic cognitive processes like perception.

3b | Bottom-up Processes

As we noted earlier, our environment is very complex, filled with sights, sounds, tastes, textures, and the like. In order to successfully navigate in the world we need to be able to identify, or perceive, all of these stimuli. Our ability to do so rests largely on the information in the stimulus itself, the so-called bottom-up or data driven processes. Bottom-up refers to the fact that the observer takes small amounts of information from the environment and combines it to form a percept.

This kind of perception is argued to operate in one direction only, from the stimulus to the output, and is considered to operate reflexively and passively, occurring even when we are not necessarily trying to identify something. There are 3 major classes of bottom-up processes: template matching, feature analysis, and prototype matching, and we'll discuss each of these in turn.

Every time you make a purchase at a grocery store, you encounter a machine that was built to perform pattern recognition or perception in a bottom-up fashion using template matching. Cashiers no longer have to key-in prices or item codes, they simply swipe a barcode over a code reader. The machine encodes this barcode, or brings it in to the system, and then searches its memory for an exact match to that barcode. When that code is found the item name and price will be stored along with it, allowing it to be identified, and you to be charged.

Human template matching is argued to operate in much the same way. In the case of vision, for instance, the object would be registered as a proximal stimulus on the retina and then this stimulus, in its entirety, would be compared to templates in memory until a match is found and the object can be named.

Keep in mind that this general principle operates with all of our senses, to allow perception of smells, tastes, sounds, and so forth. According to a template view then, perception depends on a physical match between a stimulus and a stored representation in memory.

This application works quite well in many machines built to do visual pattern recognition like product code readers, and it works fairly well in machines built to do auditory pattern recognition, like voice readers, as in the pre-recorded messages you hear and respond to when calling 411 for a phone number. But you may have already surmised that it doesn't do a good job at capturing the flexibility that is inherent in human perception.

One problem is that if proper identification requires an exact match, the number of templates that must be stored and searched would be incredibly large. A second problem is that this model cannot explain how we recognize a new object, one that we have never seen before. Unless we have stored a template for something, recognizing it is impossible, yet we are often able to figure out the identity of things we've never encountered before.

Third, this model does not do a good job at explaining how we are able to deal with surface variation in stimuli. The figure in front of you shows multiple writings of the same sentence, and they all lead to the same percept, to the same meaning, despite the fact that they look distinct from one another. You can also recognize your coffee mug even if you were to turn it upside down, sideways, or partially cover it with paper. Template matching cannot explain that.

The next view we will discuss is a major deviation from template matching, which posits that we compare the entire object to templates of entire objects in memory. According to the feature analysis view, we recognize objects by recognizing their component parts, or features, and the manner in which they are combined.

For example, in order to recognize the gray "o" in the panel in front of you, you have to both recognize the circular shape of the letter "o", and the colour gray, and assemble them together. One of the earliest feature-based models of, in this case letter perception, was described by Selfridge in his Pandemonium model.

Selfridges' model is built of what he termed "dumb demons," or "dumb" feature analyzers. These demons were described as dumb, because they could do one thing only, scream when they encountered the stimulus they were trained to recognize.

An image demon first encodes, or brings the stimulus, into the model. It is then examined by many, many feature demons. There's one feature demon for every conceivable feature. These feature demons represent only one feature each, say a horizontal line, or a left pointing arrow head. If a feature demon sees itself in the stimulus, it begins to scream. The more confident it is, the louder it screams.

Above these feature demons are cognitive demons, and they are trained to listen for screaming from specific feature demons. If their feature demons are screaming, they are trained to begin screaming as well. And they will also scream louder if more of their feature demons are screaming, to reflect their level of confidence.

Finally, a decision demon is listening to all the cognitive demons, and chooses the cognitive demon that is screaming the loudest. In that way the decision demon determines the letter.

Obviously Selfridge didn't believe that we have these little demons in our head, he merely used them to illustrate how features could be recognized and assembled in order to promote perception.

It should be apparent, then, that there are inherent advantages to a feature-based system. It is much more flexible than template matching because it allows for the storage of features which could be common to many different objects. These features would be stored along with assembly instructions, which would therefore reduce the total number of templates that would need to be stored in memory.

Additionally, there is neurophysiological evidence to support this theoretical position. Hubel and Wiesel, for instance, have found evidence in the visual cortices of cats and monkeys of particular cells that fire selectively to certain features, much like Selfridges' screaming demons.

In terms of human behavioural data, there is evidence consistent with the importance of feature to humans, too. For instance, the table in front of you shows the basic features identified by Eleanor Gibson in the Roman alphabet, along with a marker to tell you which ones are common to which letters.

It has been convincingly shown that humans make mistakes identifying letters when those letters have more features in common with other letters. For instance, if you've saved some of your early kindergarten class writings, you might find that you sometimes confused your lower case bs and ds.

Feature analysis-based models are not without problems, however. To some extent features are just like incomplete or mini templates. How can we identify specific features if we have never seen them before? How do we know what is a feature and what is not? In some cases, like with letters and digits, and tables and chairs, this might be explainable, but what about a dust storm or a wave crashing on the shore? We can perceive both of those as well, but what are the critical features?

A third type of bottom-up model, called prototype matching, attempts to correct some of the problems associated with the rigidity of both template-matching and feature analysis models. It, like template-matching, requires that a holistic input be matched to a stored representation, but unlike template matching that match does not have to be exact, but rather be a "best fit."

This accounts for the flexibility in human perception we find when you can recognize all of these objects as the letter "M", despite the fact that they look very different from one another.

In summary, in each of these cases we've focused on bottom-up or data-driven processes—the idea that information in the stimulus is used alone to guide perception. The approaches differed from one another only in how the comparison was made, what it was based on, and how flexible it was.

3c | Top-Down Processes

In contrast to the hypothesis that perception operates in a data-driven, or bottom-up manner, it is argued that top-down or conceptually-driven processes can also affect perception. Top-down processes, rather than coming solely from the environment, come from us, the observers. They consist of things such as our world knowledge, our theories, prior experiences and expectations.

For example, let's perform a thought experiment. Imagine you are in a place where it is difficult to see clearly because the sun is glaring in your eyes and someone holds up and offers you a round object, about 2" in diameter. Although the stimulus input, or data, is exactly the same in the two cases, if you are at a breakfast table you would probably perceive a Tim-Bit. If you were at a golf course however, you would likely identify a golf ball. That distinction relied solely on top-down processes, specifically your interpretation of the context or the environment you are in.

The fact that you correctly read this phrase as "They Bake" also relies on top-down processing. In order for this to occur, one must interpret an identical physical stimulus in two distinct ways, based on our known laws of English. Yet, you probably didn't even realize that you were doing this.

The short-story to perception, then, is that we clearly need both bottom-up and top-down processes in order to be successful. This allows us to negotiate our environment despite the fact that the same stimulus might have multiple names, depending on the context. Moreover, different looking stimuli may also have the same names depending on our point of view.

Interestingly enough, the fact that both bottom-up and top-down influences affect us is one reason why we aren't always as successful at proof-reading our own work as we'd like to be. Have you ever turned in an essay that you worked diligently and carefully on, only to have it marked-up in red with errors you overlooked? The problem here is that you familiarity with your own work contributes to you perceiving what you expect to be there, rather than what is there. Your instructor, however, does not share your familiarity with your particular thought processes and is therefore not as affected by top-down influences when reading your paper. That is why it's always a good idea to have a friend help you with proof-reading, or at least to try get your essay written well in advance so some time can pass before you have to proofread it.

If processing were solely top-down however, we'd never be able to perceive a new stimulus. Can you perceive the object shown here?

In figuring out what you see here, you initially rely solely on data-driven processes. But after you recognize it for the first time, your future encounters with this picture will be influenced by your prior experience with it. You will now know that this is the "dalmation picture," and if you look at this picture again in a week or two what you'll probably find is that you search through the black and white patterns to find the dog.

The take home message, then, is that perception is an incredibly complex and amazing ability. Human perceivers can perceive all kinds of things that machines simply cannot. Anyone who has been transferred to the wrong extension by a voice recognition system can attest to that!

Despite our incredible abilities and flexibility, however, we sometimes make mistakes in perception and these are often due to an incorrect balance between bottom-up and top-down processes, like when we think we hear something that really wasn't said at all.

In our next section, we'll talk about severe disruptions of perception that are due to acquired or even developmental brain damage.

3d | Disruptions of Perception

So far, we've spoken about so-called "normal perception," and we've tried to understand perception by studying people (and animals) for whom perception operates normally. We can learn a great deal about perception, however, by studying it in individuals for whom it has gone wrong, either because of some form of brain injury, or because of an issue that was present at birth.

In this type of investigation rather than testing groups of participants in research studies and talking about general abilities, a single-case study is typically used. An individual suffering from stroke or other brain injury might be tested with note made of both the preserved and damaged abilities. A connection can then be drawn between the perceptual ability and the brain area that contributes to it.

The first disruption of perception that we'll discuss is visual agnosia, or the inability to identify an object by sight. Individuals suffering from this can "see" the object, their visual skills are not impaired, they just cannot identify the object by sight.

There are two general classes of visual agnosia. Persons afflicted with apperceptive agnosia can see and interpret contours and outlines, but have a difficult time maintaining even these basic representations in memory to even match objects or to distinguish amongst them.

For instance, someone suffering from apperceptive agnosia would have difficulty recognizing these two pictures of a chair. In the case of "A" too many contours are missing and cannot be filled in, whereas picture "B" shows the chair from an odd perspective.

In contrast, patients with associative agnosia can match objects and copy drawings, but they do so slowly. They cannot name objects they have just seen or even just copied. It isn't that they cannot see the object or that they do not know what it is, because if they are tested in a different way the person will show that he or she can indeed identify the object.

For instance, if one were to place a coffee cup in front of an individual with associative agnosia, that person would not be able to name it, but if thirsty, would pick it up and drink from it. Thus, an individual with associative agnosia cannot access meaning, or semantics, from a visual description alone.

Illustrating the complexity of the human brain and mind, prosopagnosia is a form of visual agnosia that is specific to only faces. Persons suffering from prosopagnosia can recognize visual objects and can see details of faces, but cannot recognize a face as a coherent unit—even those faces of loved ones and friends, or famous people.

Incredibly, there has been at least one apocraphyl report of an individual suffering from prosposagnosia who became upset because someone was staring at him, only to find out that he had been viewing himself in the mirrored wall of a restaurant!

This doesn't mean, however, that a person suffering from prosopagnosia cannot recognize people. They can use other information, such as voice, hair, posture, gait, and the like to recognize people that they know.

Even more fascinating, although individuals afflicted with prospoganosia lack what we call explicit, or aware face recognition, and cannot overtly name someone from looking at a photograph of the face, that same photograph can be used to demonstrate implicit, or unaware, face recognition abilities that are preserved.

An individual who is connected to a galvanic skin response recorder will show different responses to pictures of loved ones verses pictures of strangers. Perspiration, respiration, and other measurable variables change when we view someone familiar to us. People with intact face recognition abilities can also named the people shown in the pictures. An individual with prosopagnosia cannot name those faces in the pictures, but shows the same pattern in galvanic skin response to known people versus unknown people that people without prosopagnosia show. Clearly then, prosopagnosics can recognize faces, but cannot do so consciously. They are therefore said to have impaired explicit or overt face recognition, but preserved implicit or covert face recognition.

A fascinating counterpoint to prosopagnosia is the rare Capgrass syndrome, also known as Capgras Syndrome. These individuals have preserved explicit or overt face recognition, but impaired implicit or covert face recognition. Therefore, these individuals can look at a picture and tell you whom the picture looks like, but they do not produce GSR patterns, or galvanic skin response patterns, that distinguish known from unknown faces.

Moreover, they claim that the person is actually an impostor! It looks like my mother, talks like my mother, but is certainly not my mother. This denial is hypothesized to occur because of a deficit in reasoning and an attempt to reconcile the overtly known face with the lack of warmth that one normally feels when seeing a loved one.

3d | Summary of Perception

To summarize, perception is an amazing and complex skill. As we've seen, it's more than simply the sum of sensory inputs. Although perception is guided by the stimulus itself (in other words we don't typically hallucinate and see or hear things that absolutely are not there), it is also affected by things we, as active observers contribute. Things such as our expectations, world knowledge, attitudes and many other factors contribute to perception. We've called the first of these things bottom-up information and the second top-down information.

In addition to learning about normal perception, we've also seen just how complicated perception is by examining disruptions in perception. These disruptions make it clear that perception is much more than simply hearing or seeing.

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.

7a | Introduction to Concepts and Categorization

We're going to begin this module by discussing some of the key definitions that you'll need to understand in order to grasp the remaining material of this section. Then we're going to talk about a couple of examples of categorization in the real world. Specifically, we're going to look at medical diagnoses and selecting a major in university. Then we're going to talk about the classical view of categorization, and some problems with this classical view.

So, first let's look at a couple definitions. So, what is a concept? Well, a concept is a mental representation of some object, event, or pattern that has stored in it much of the knowledge typically thought relevant to that object, event, or pattern. So, any piece of factual knowledge that you have stored, any sort of object that you know anything about – that is a concept. Think about, for example, a Ferrari. Well, if you know what a Ferrari is, you know that it's a car, you know that it's fast, you know that it's Italian, and you know that it's expensive. All those attributes stored together with that object is what we can think of as a concept. As another example of a concept – and I might be dating myself here a little bit – but think about grunge music. Well, if you know anything about grunge music, you know that it started in Seattle, you know that it was a heavier style of music, and it contained bands such as Nirvana, Pearl Jam, and Soundgarden. All that information, again, is stored together in what your concept of grunge music might be. And again, the key thing with concepts and categories is that everyone's concepts and categories and groups of things, they're all different, because not everybody has the exact same experience. So, everybody's concepts are going to be different, and they're going to be based on the individual experience that every individual has.

Now, what is categorization? Well, categorization is the process by which we place things into groups, called categories. So, for example, how is it that we place objects into groups of cars, into groups of music genres? All these things are what the process of categorization is about.

And finally, what is a category? Well, a category can be thought of as a class or group of similar things, objects, or entities. So, for example, fruit, vegetables, cars, fish, mammals – all these things are categories, and they're based all on how we can actually group objects or things together into groups.

So, what role, then, do categories and concepts form in our mental life? Well, I'm going to take this quote right from Smith and Medin, 1981, from your textbook, and what is says here is that "Without concepts, mental life would be chaotic. If we perceived each entity as unique, we'd be overwhelmed by the sheer diversity of what we experience, and unable to remember more than a minute fraction of what we encounter. And if each individual entity needed a distinct name, our language would be staggeringly complex, and communication virtually impossible." Fortunately, though, we do not perceive, remember, and talk about each object and event as a unique entity, but rather, as an instance of a class or concept that we already know something about. This quote highlights some of the main functions of categorization. First off, understanding individual cases you have not seen before, and allows you to make inferences about them. So, for example, consider a Duck-billed Platypus. You might not have ever seen a duck-billed platypus before, but if somebody told you they were a mammal, then, what you would know is that this duck-billed platypus likely has lungs, and it likely breathes air. Consider, also, the Green Sandpiper. Well, you might not have ever heard about a Green Sandpiper before, but if I told you it was a bird, then you'd be able to infer from that that this object, this thing, could fly, and again, that is based on your knowledge of birds, the category of birds.

So, as you can see from these examples, here, having categories and concepts of objects helps you reduce complexity in the environment. You don't have to store each and every bit of information with each specific example of bird. Rather, you can have concepts and categories that help you organize and store that information, which, in turn, requires less learning and memorization. And, finally, having the knowledge of a specific category of an object helps guide you to the appropriate action. So, for example, if you see a four-legged creature with a tail coming toward you, your classification of it as either a dog or a wolf has implications for whether you'll want to call it, run away, pet it, or shout out for help.

So, in summary, concepts help us to establish order in our knowledge base. They allow us to categorize, giving up mental buckets in which to sort the things we encounter, letting us treat new, never before encountered things in the same way we treat familiar things that we perceive to be in the same set, and categorization allows us to make predictions and act accordingly.

7b | Theoretical Descriptions of the Nature of Concepts

We're now going to discuss different theoretical descriptions of the nature of concepts. So, here we're going to concentrate on different ways in which it is thought that concepts and categories might be represented in the mind. We're going to cover five different views: the classical view, the prototype view, the exemplar view, the schemata view, and the knowledge-based view.

First, let's consider the classical view of categories. Now, here, category membership is thought to be determined by a set of defining properties, and when we say defining properties, what we mean are those properties that are deemed necessary and sufficient. These two attributes, that of necessity, and sufficiency, are a little bit different to dissociate, but it's important to understand them, as they are a key property to the classical view. So, in order to get a good grasp of them, let's look at table 7.1. Here, along the top, what we see are different categories, so bachelor, triangle, uncle, and prime minister, and then we have the concepts and features associated with them. So, let's take a look at the category "triangle." The features listed along "triangle" are three-sided and planar. So, how might these relate to the concepts of necessity and sufficiency? Well, to say that a feature is individually necessary is to say that each example must have that feature if it is to be regarded as a member of that category. So, three-sided is a necessary feature of the concept "triangle." Things that do not have tree sides are automatically disqualified from being triangles. Now, what about sufficiency? So, to say that a set of features – now, the key thing here is "a set," meaning more than one feature – is collectively sufficient, is to say that anything with each feature in the set is automatically an instance of the concept. For example, the set of features "three-sided and planar" are sufficient to specify "triangle." Anything that has both of these features is a triangle. Now, since this is such a key aspect of the principle of categorization, I would suggest that you take a look at the other categories in table 7.1 and think about how the concepts of necessity and sufficiency map on to those features.

There are a number of assumptions put forth by proponents of the classical view of categorization. First off, concepts are not thought to be representations of specific examples, but a list of characteristics. So, for example, you won't have a specific example of a dog or a cat represented in your mind as a member of a category. Rather, what you'll have is you'll just have a list of characteristics, and what you do is, you just simply look at a new instance and match it to those lists of characteristics. Secondly, membership in a category is clear-cut – it's all or none, black or white. There are no grey areas at all; either an object is a member of a category, or it is not a member of a category. And there are no better or worse examples of a category. So, again, for example, take the instance of the category "dog:" a German Sheppard, a Beagle, a Chihuahua – they are all equally represented within the category of "dog."

As you can probably imagine, when looking at the assumptions for the classical view of categorization, researchers have taken issue with a lot of them. So, for example, there are some categories where there don't appear to be any real defining features. So, to take a quote from Wittgenstein, 1953: "Consider, for example, the precedings we call "games" – I mean board games, card games, ball games, Olympic games, and so on. For, if you look at them, you will see nothing really in common at all – but similarities, relationships, and a whole series of them, at that." The point here is that there are a number of things out there in the environment that belong to categories where it is very difficult to come up with a set of defining features. So, just to think about a couple of others, here, how about "dog" or "cat?" Well, for a dog, what would be a defining feature? Well, one of the first things that might come to mind is that it has four legs. But what about that poor and unfortunate dog that got into an accident and lost one of its legs? Does that three-legged dog, did it lose it's category membership, and can no longer be called a dog? I think not. How about "cat?" one of the first categories that might come to mind is "has fur." Well, if you owned a hairless Sphinx, you would think otherwise. The important point here is that the assumption of defining features doesn't fit with all the categories that come to mind.

The second problem with the classical view of categorization concerns its assumption that category membership is all or none. So, again, recall that the classical view holds that if an object or an instance has the defining features, it will be a member of the category. There are no good or worse members of categories. Well, a number of researchers, including Eleanor Rosch and her colleagues, have found that people judge different members of a category as varying in goodness. For example, most people in North America consider a robin and a sparrow to be good examples of a bird, but find other examples, such as chickens, penguins, and ostriches, to be not as good. Evidence for this more graded membership was also found in a number of simple reaction-time tasks. So, for example, participants in a sentence-verifications task were faster to respond to a sentence such as "A robin is a bird," than to a sentence such as "A chicken is a bird." And, in semantic priming studies, highly typical instances often led to better priming than less typical instances. And, like we've seen in other sections of this course, we can use reaction time as an index to how the cognitive machinery is working. Here, faster reaction times likely mean that this information, or this member of a category, is a better member of a category than that which is judged slower.

So, in response to the obvious limitations to the classical view of categorization, Rosch and colleagues came up with what is termed the prototype view. Now, this is very similar to what we've talked about in the perception section a number of modules ago. So what a prototype is, is its an idealized representation of a class of objects. It includes features that are characteristic that are typically, rather than necessary or sufficient, and it's thought to be formed by averaging the category members we have encountered in the past. So, If you think about it this way, what it really means is that you've experienced, throughout your lifetime, a number of examples of a specific category. So again, let's just go back to our friend the dog. So, you may have had experiences with Labradors, with Chihuahuas, with Bulldogs, with all these things, but what we have in our mind is we have a prototype which is more of a fuzzy representation of the most characteristic features of all these animals. And the key thing is that this takes into account, too, each of our own individual and unique experiences. Everybody might have a very different prototype in their mind. This also gets around the problem with the classical view to do with all or none membership. Here, members within a category can differ in terms of protoypicality. For example, let's go back to the dog again, you can have highly prototypical dogs, like, for example, the Lab, and less prototypical dos, like, for example, the Chihuahua. And again, everyone's own experience would determine the prototypicality of the instances within memory.

The prototyping of concepts and categories often refers to the family resemblance structure of concepts, and it uses this structure as a means of explaining typicality and prototypicality. Family resemblance can be thought of as a structure in which each member has a number of features, sharing different features with different members. Few, if any, features are shared by every single member of the category, however, the more features a member possesses, the more typical it is. A good example of the family resemblance principle and how to think about it can be found in figure 7.1. This is a figure of who are known as the Smith brothers. Note that they have several shared features – light hair, bushy moustache, large ears, and eyeglasses - and not every Smith brother has every feature. But, the brother in the middle, having them all, would be likely to be judged by the Smiths' friends as the most typical Smith of the bunch. Note that he shares big ears, the eyeglasses, the light hair, with the brother in ten o'clock position, and the moustache and big ears with the seven o'clock brother. Different pairs of brothers share different features, but not all of them have a single, necessary, defining feature. The prototype view of concepts explains typicality effects by reference to this family resemblance principle. The idea is that the more characteristic features an instance of a concept has, the stronger the family resemblance between that instance and other instances, and therefore, the more typical an instance is.

Returning now to our dog example, a Labrador is probably thought of as a more typical dog than a Chihuahua, because the Labrador possesses more characteristic dog features. Even with well-defined concepts, like bachelor, like we talked about in table 7.1, some examples seem more bachelor-like than others. So again, if you'd just look at the defining features which we all probably agree with, the defining features for a bachelor, are adult, unmarried, and human. Is the Pope a bachelor? Or how about an eighteen year old high school student? The point here is that both people may meet the technical definition of a bachelor – they're adult, unmarried, and human – but neither is such a good example, as someone such as, say, George Clooney. So, the prototype view seems to do a pretty good job at explaining why certain members of a category are seen as more typical than others. It also explains why people have a hard time providing strict definitions of their concepts, that is, because stict definitions do not exist, at least as far as the prototype view is concerned. And, finally, the prototype view can explain why some classifications are especially easy to make, and others are a little more unclear – the clarity being determined by the number of shared features between categories. The more shared features between categories, the harder the classification, the less shared features between categories, and the more shared features within categories, the easier the classification.

Now, we've kind of painted a pretty rosy picture of the prototype view, but that's not to say that there aren't some problems with it. So, a couple problems I'm just going to highlight, here, are, one, variable categories. The prototype view is pretty unconstrained, so, if you take again the example of games, where do you draw the line? What determines category membership and not? Again, you could have paintball, poker, basketball – again, the list goes on. A second issue with the prototype view is that the typicality of a certain instance of a category can depend on context, again, so typicality is not fixed. If you think about a robin, a robin might be a typical bird you might find in a park in the city, but a less typical bird on a farm, where maybe a chicken might be the more typical example.

The previous two views of categorization that we've talked about held that concepts were some sort of mental abstraction, or summary of information. For example, the classical view held that we had stored lists of defining features that were necessary and sufficient. The prototype view held that we had some sort of abstract representation that was a summary of previous experiences. Were going to talk about the exemplar based view now, which makes just the opposite assumption of that. It asserts that concepts include actual representations of some real instances that we've experienced in the past. Here, when you categorize an object, or you categorize a new instance that you see, you do this by comparing this new instance to some representation of previously stored instances, or exemplars. Now, similar to the prototype view, the exemplar view assumes that there are no defining features that are associated with specific categories. It also explains why some objects or items are more difficult to categorize than others. Recall when we were talking about the prototype view, categorization was difficult when you had an object that shared features with multiple categories. Again, the key thing with the prototype view is that objects to be categorized in the same category needed to share more features with other objects within the category than between categories. A similar thing is thought to be going on with the exemplar view. However, here, categorization becomes difficult when an instance that you're trying to categorize is similar to exemplars from multiple categories. Take, for example, the tomato – now that's a difficult one to categorize, and the reason it's difficult to categorize is because it's similar to both fruit exemplars, such as oranges and apples, and to vegetable examples, such as beets or squash. And, like the prototype view, the exemplar view can explain the typicality effect. So, recall when we talked about the prototype view before, the typicality effect was determined in part by the number of shared features that specific example that you're trying to categorize shares with the prototype. The more features that example shares with the prototype – the more feature overlap there is – the more typical that example is, and the faster you'll be able to respond to it. Well, a similar thing goes on with the exemplar view. Here, typical instances are thought to be more likely to be stored than less typical ones, or, to be more similar to stored examples. So, this explains why people are faster to process information about typical examples.

Now that you have a pretty good idea about how the exemplar view explains categorization, it would be a good idea to go through the experiment by Allan and Brooks, 1991, that we present in the textbook, and that's referred to in figure 7.2. You'll want to read it carefully because there's a lot of very key details in that experiment that you'll need to understand in order to fully grasp their findings. Now, the key thing is, with that experiment, is they show that physical similarity to previously stored exemplars influences categorization despite participants having a simple and sufficient rule to follow. Put another way, here, previously stored exemplars were the most powerful cue used by these participants to categorize new instances. And participants, even though they had access to some simple rule to use, they pretty much ignored that rule. They just stuck to using the previously stored examples in memory. The other interesting thing with this view is that, oftentimes, people will make use of these previously stored exemplars, without even being consciously aware of it.

And, of course, like all the views we've talked about so far, there are problems with the exemplar view. The big problem, just like the prototype view, is that people do argue that it is a little bit unconstrained, so it's hard to define where category boundaries are, and, why some objects, or some things, will be stored as exemplars, and others will not. Plus, it requires that we store lots of exemplars. So, the classical view of categorization is pretty economical, in that we only store certain features, stored with general classes of objects . The prototype view argues, again, that we have these prototypes, which are generalized representations of objects . The exemplar view, however, argues that we store exemplars: specific instances of objects that we've experienced in our lives. This requires that we store lots of exemplars, and, as we know from different sections of this course, we don't have an infinite storage capacity, so how is it that we can store limitless amounts of experiences that we all have?

The final two views of categorization that we're going to talk about, the schemata view and the knowledge-based view, are a little bit more abstract, and perhaps a little bit more difficult to grasp, because of that. We're only going to discuss them briefly, however. The schemata view of concepts is that concepts are a form of schemata – they're frameworks of knowledge that have roles, slots, variables, and so on. This is very much related to what we talked about before, in the earlier modules on memory, so, for example, how you might have stored information about more general classes of things, more general classes of objects. So, for example, you might have a schema for a car accident, and within that schema you might have things like, well, there's broken glass, well, there's police, well, there's all these things together. Also, schemata may involve both abstractions across distances, like we talked about in the prototype view, and it may involve information about actual, specific examples that we've experienced, like we talked about in the exemplar view. As you've probably gathered, from our brief coverage of the topic, here, and from reading through the section in the textbook, the main problem with the schemata view is that it is really ill-defined, and since it's so ill-defined, it's very difficult to empirically test it.

The final view of categorization that we're going to talk about in this module is knowledge-based view. Now, here, the argument is that people don't just look at specific instances or examples and compare them to stored, previous examples, or to prototypes, or to look at defining features. Rather, they use their knowledge of how the concept is organized to justify the classification and explain why certain instances happen to go together in the same category. The key thing here is that a category only becomes coherent or meaningful when you know what the purpose of the category is. So, consider the following items: children, pets, photo albums, family heirlooms, cash. So, on the face of it, these things just seem to be all from disparate categories, however, when a home is about to be engulfed in flames, well, that new situation would create a new category, or a new meaning: things to save. Note that each one of those objects mentioned is probably precious to the owner, and probably irreplaceable. Notice here that the category only becomes coherent and meaningful once we know the purpose of that category.

This view highlights, again, the flexibility of categorization, and the individuality of it, as well, because it depends on each individual's knowledge of how concepts are organized, the purpose of the category, and people's own individual theories about the world in which they're trying to categorize. And, it addresses the limitations of the prototype and exemplar view, that, remember in those views, it was hard to answer the question of how things actually came together in a category – what defined category boundaries or category membership. Well, here, it's the purpose of that category that actually defines what the category membership is.

So, we've just covered five different views of categorization. And you might be wondering, why do we need five different views? Is the prototype view correct, and the exemplar view wrong? Is the deifning features, or classical view, of categorization right, and the others, wrong? Well the answer's not that simple. I think the best way to think about it is that they're all probably used, and they're used depending on the type of objects, or types of things that we're trying to categorize. So, take for instance, shapes. Well, when we're talking about shapes, like a triangle, well, those have defining features, so we'd probably use a simple rule of classification based on that classical defining features model. For other things, like naturally-occurring things in our environment, like animals, like mammals, we may be more likely to use something like the prototype view. The key thing to take out of this is that our minds, our categorization system, our categorization machinery, is highly flexible, and it likely uses a number of these tools at its disposal when trying to classify and categorize objects in the environment.

7c | Forming New Concepts and Classifying New Instances

For the remainder of this module, we're going to look at how it is that people can form new concepts. And this is a pretty remarkable feat when you think about it. It requires that people have some basis for generalization. It also requires that people figure out which attributes or features are important or critical for categorization, and which are not. In this section, we're going to first look at explicit forms of categorization, and concept attainment – that is, things that people do at a conscious level. Then, we're going to look at what happens in the brain when people acquire concepts, and then we're going to finish of this section by looking at implicit concept attainment, that is, learning concepts without participants' conscious awareness of the riles.

One of the earliest and most influential studies in concept attainment was conducted by Bruner, Goodnow, and Austin, in 1956. So, Bruner and colleagues, they studied the ways that people attain concepts using card depicting different geometric figures. Examples of these cards can be found in the following figure. Note that the cards each could vary along three dimensions: it could have one of three shapes, being a circle, a square, or a cross, one of three colours, being a black, white, or striped, and one of three borders, one, two, or three. In this task, participants were simple told that the experimenter had in mind a certain concept, such as black circles, or all cards containing two borders and striped figures. Participants were then shown one card at a time that illustrated the concept – in other words, a positive instance. The participants' task was simply to test the cards one at a time to see of they conformed to the rule. They were to do this to determine as efficiently as possible what the rule was. So, just to re-clarify that, the researcher would simply present them with a single card that would follow the rule. The researcher did not tell them what the rule was. So, the participants' job was to simply select cards, and by getting feedback from the researcher, determine what the rule was.

Importantly, the main thing that Bruner and colleagues were interested in were the strategies that people used to test for the rule. They found that participants used three different types of strategies. The first one was simultaneous scanning. Now, in this strategy, participants would test multiple hypotheses at the same time, so, for example, white circles. Notice here that the colour "white" and the shape "circles" requires that participants simultaneously test for two different dimensions of the task, and in doing so, places heavy demands on working memory. A second strategy that Bruner and colleagues found was that some participants used what was called successive scanning. Here, a participant tested one hypothesis at a time. So, rather than testing multiple hypotheses, like in simultaneous scanning, the participant just picks one hypothesis and selects cards, based on that one hypothesis until they are reasonably confident that they figured out what that one rule was. This strategy is relatively inefficient, as it is quite time-consuming, but it does have low demands on working memory. Whereas the former two strategies, simultaneous scanning and successive scanning, are strategies based on testing hypotheses, the final strategy, conservative focussing, focuses more on the card attributes. Here, a participant chooses cards that vary in only one respect from the positive instance focus card. For example, if the focus card had two black crosses, and one border, the participant might next select one of the following cards: a card with two black circles and one border, a card with one black cross and one border, a card with two black crosses and two borders, or a card with two white crosses and one border. If any of these cards was a member of the category, then the participant would logically eliminate the changed attribute as being relevant to the concept. For example, if the card with two white crosses and one border was also a member of the category, then the participant knew that colour did not define the concept. As you can see, this strategy places very low demands on working memory, as it doesn't really require you to hold onto a hypothesis and test it systematically. However, this strategy, unlike the other two that we've talked about, doesn't guarantee a solution. And, when adopting this strategy, you run the risk of just going in circles, and not really every finding the rule. The key thing to take away from this study is that there are multiple different strategies people can adopt to learn a concept. And the strategy that you adopt typically involves a trade-off between the amount of working memory resources required and the efficiency of that strategy. The more efficient strategies typically involve more working memory resources than less efficient strategies.

As we've seen so far in a number of different sections of this course, functional brain imaging can be a useful tool in helping us uncover some of the mechanisms underlying cognitive processes. One area where this has become clearly evident is in that of concept learning. I'm going to uncover one of my favourite brain imaging studies right now, one that I think really helps underlie how it is that people can actually acquire concepts. This is a little bit of a complicated study, and in order to grasp the data, and to really truly understand what it's telling us, it's important to clearly understand the methodologies, and, most critically, the stimuli used in this experiment. The basic gist of this task is that participants were asked to respond to a series of what were thought to be abstract paintings, and they were supposed to respond to them as being done by either the painter Smith or Jones. You can see on the figure where the prototypes for the Smith and Jones paintings are. Importantly, however, participants never received these two paintings. Rather, they judged a series of exemplars. These exemplars were formed by changing the colour of each square with a 7% probability. By doing so, that generated a series of exemplars which were extremely close to one of the prototypes and not to the other. What would happen then is, through practice, participants would learn to distinguish and differentiate between these two categories of paintings and be able to respond to them appropriately. Through a series of trials, it didn't take participants very long to learn these rules, and to be able to correctly classify them. However, what the most interesting part of these data are, are not in those behavioural data, but in the functional brain images. So, if you look at the brain images, what we have it broken down to here are the right hemisphere and the left hemisphere, and early versus late in learning. So, let's first just focus on early learning, that is, at the beginning parts of this task, before they actually reached ceiling performance. And what you see here, is we basically see activations isolated to the right prefrontal and right parietal cortices, and there's really not much going on on the left side of the brain. This is likely due to the idea that the early classification of these stimuli mainly involves the processing of visual patterns of information, without the application of any sort of formal rule. And, when we talk about application of a rule, typically, we think about some sort of verbal mediation of that rule, which, again, we know is the realm of the left hemisphere. And this is precisely what we see that happens later on in training. So, for example, as learning progresses, what we see is that the regions of the left hemisphere begin to become recruited, specifically, the left parietal lobe, and the left dorsolateral prefrontal cortex. So, this shift from more right-hemisphere processing to left hemisphere processing may be the result of the formulation and application of rules. I think this is a nice example of how functional brain imaging provides us with some unique information about the mechanisms underlying cognitive processes that would have been very difficult to acquire without the technology.

We just covered a couple studies, one behavioural, by Bruner and colleagues, and one functional brain imaging, by Seger and colleagues, looking at how it is that people acquire new concepts, to categorize new objects. Those were both examples of explicit categorization, or explicit concept learning, in that participants were consciously making use of cues to try to categorize the objects. A lot of concept learning, however, is more implicit in nature, in that participants are not explicitly using knowledge about category membership to make different discriminations. Rather, they are implicitly, or unconsciously, using that information. And there are numerous examples in the real world that follow more of this implicit learning. For example, learning a grammatical structure in a language. There's a lot of grammatical rules that we might not be consciously aware of that we follow on a day-to-day basis, and don't have to actually consciously think of them, or consciously conjure them up. In situations like that, when the underlying rules are so complex, sometimes its better just to be presented with a bunch of examples, and what will happen is you will unconsciously, or implicitly, acquire the rule, and be able to apply it without really being consciously aware of what the rule is.

So we've just covered how category learning can occur both explicitly and implicitly. The degree to which explicit or implicit processing occurs depends, to a large extent, on the type of task. For example, if it's a very simple task where the rules to be learned are rather simple, a more explicit strategy is probably going to be employed. However, if the task is much more complex, and the rules much more varied, then, a more implicit strategy will be employed. That is, as in pretty much every other area of cognitive psychology that we've been talking about so far, the way that people will go about processing this information, or categorizing this information, again, is very, very flexible, and it's going to vary depending on the situation at hand.

7c1 | The Seger Experiment

I thought it would be useful to look at a short little video clip that shows how the stimuli were presented in the Seger et al experiment where they looked at how the brain changes as a function of category learning. This clip is a shortened version, as the actual experiment took several minutes, and I just wanted to give you a sense of how the stimuli would look on the screen.   So, like we mentioned before, while participants were in the scanner, what they did is they received a bunch of these different stimuli on the screen, and responded to them whether they thought they were a painting of Smith or Jones. And what you'll see in this clip is that the stimuli was on the screen for 2.5 seconds, and then a participant had to respond quickly to that, and then afterwards they received feedback whether it was actually a Smith or a Jones painting, so that they could learn to distinguish between these two different types of images. I made up this little clip so that it has exactly those specific time parameters that were used in the actual experiment. Also, the reason I wanted to show this little clip is just because it kind of highlights again how FMRI experiments need to have appropriate baseline conditions. Now, we talked about that a little bit in the very first module of this course. In this experiment, after participants received twelve different stimuli to classify as either Smith or Jones paintings, they then received twelve different displays of a simple checkerboard, followed by the word "board." When the received the checkerboard, all they did was press the left or right button randomly. Now, the reason it's so important to have that checkerboard condition, or that baseline condition, as we call it, is that that screen will activate a lot of the same sorts of regions in the brain as the critical stimuli will activate. For example, regions that are associated with processing colours or shapes. That way, when the researchers want to determine the critical regions that are responsible for categorization, they can subtract out those regions that are involved in basic visual perception, and thus be able to isolate those regions that are just involved with category learning. So take a quick look at that short little video that I made, and again, it's just to show you again how the stimuli might appear to the actual participant when they're in the FMRI machine. I only included a couple examples, just to give you a flavour for the task.

8a | Introduction to Visual Imagery and Spatial Cognition

Let's begin this unit with a thought experiment. Think about the street or the block where your current home is located. Including your own, how many buildings are located on your side of the street?

This question forces you to use memory, but a special kind of memory. That is, it is very unlikely that you have the fact, "there are six houses on my block," stored in memory. Instead, in order to answer this question, it is likely that you used a different kind of memory process.

Most likely, you drew a mental map in your mind's eye of your street or block and counted out the houses you saw. You may have even mentally walked past the houses while you were counting. Moreover, you might even be able to name the colours of the buildings as you walk by.

The mental map, or visual image, that you may have used to solve this problem, is the focus of this unit. We will examine how we use these images in order to improve memory, as a kind of mnemonic. Mnemonics are simply techniques used to improve memory and a lot of them include the use of visual memories, or imagery.

We will discuss the nature of these imagery representations, and how we can manipulate them in our minds. This sheds some important light on how information is stored in memory. As we will see, researchers have devised some very clever ways in order to determine how we can process images in our minds.

These experiments also tell us a great deal about how visual/spatial information is stored in memory, which has for a long time been a matter of contention between competing theorists. For instance, do we actually store in memory a picture of our living room that we can recall in order to answer our question about the layout of the furniture, or the number of lamps in the room, or do we store a verbal description, from which we extract the information that we need? This question is at the heart of what is known as the analog versus propositional debate.

Finally, we will consider neuropsychological findings involving imagery. As in the earlier units, we can learn a great deal about imagery from this type of investigation.

8b | Visual Imagery and Memory

You may have already used specialized techniques to improve memory-maybe to memorize vocabulary items for a foreign language class. These are called mnemonics. The ones that we will discuss now involve the construction and use of mental pictures, or images.

Imagine, for a moment, that you are expecting four friends for dinner tonight. You know what you want to serve, and you also know that you don't have any of it at home. You don't have a pen with you, or, amazingly enough, a phone with text capabilities. How will you be able to remember everything you need when you get to the store?

One of the best techniques in this kind of situation is the Method of Loci. The critical framework that one needs to use for the Method of Loci to be successful is a series of well-known places that you encounter in a structured order.

For instance, imagine in detail the trip up your driveway, into the house, and ending in the kitchen. In order to use this technique successfully, you would associate one grocery item with each important location along your journey. After you have made your associations, you would recall your list by re-tracing your steps, exactly as you first performed them, and see, in your mind's eye all of the items that you've stored along the way.

The figure in front of you shows a short memory list along with a series of images you might use as a basis to remember them. This technique can also be supplemented by the use of interactive imagery. For instance, instead of merely imaging hot dogs lying on your driveway, imagine them rolling down the driveway and being covered with pebbles. Interactive images are especially powerful memory aids.

A second imagery-based mnemonic that works very well under certain conditions is the pegword method. This method requires that you first learn a list of ordered paired cues, like those seen in the panel in front of you (one-bun; two-shoe, so on and so forth). These cues are all chosen to rhyme, and you will notice that the first word in each pair is a number, whereas the second is a concrete noun. Each of the items that you wish to remember needs to be associated in an image with the paired cues. For instance, to remember that you have a dentist appointment, you might form the following memory bundle: one is a bun, and imagine yourself biting into a bun and hurting a tooth so that you want to see the dentist. To remember that you have bills to pay, you might encode: three is a tree and form an image of bills hanging in the tree just like leaves. As was the case with the Method of Loci, your memory will be even better if you are able to form interactive images, rather than static ones.

Note that with both Method of Loci and the pegword method, there is an initial investment to be made. That is, if you haven't learned a specific route of locations to use in the Method of Loci or invested the time learn the cue word pairings in the pegword method, they will not be useful techniques for improving memory.

Why do these visually based mnemonics work, and what does their success tell us about how things are stored in memory? University of Western Ontario researcher Alan Pavio hypothesized that visual images are beneficial to memory because they allow information to be stored, or coded in memory in two distinct ways. Let's try a short experiment to investigate this. On the next slide, you will see a list of words. Read through this list with the intent of memorizing them. When you are satisfied that you have learned them, grab a sheet of paper and write down all the words you studied, in their proper order.

Not spoken- Justice; honesty; love; respect; malice; freedom; truth; courage; valor; integrity

Now let's do the same thing with the following list of words:

Not spoken-Cake; table; student; tulip; pizza; pencil; book; sneaker; picture; dolphin

Were you able to recall more words from the second list than from the first? Pavio would predict yes, because according to his Dual Code hypothesis you are able to store the words in the second list using both verbal codes, which are their abstract, linguistic meanings, and image-based codes, you can picture what those things look like. In contrast, the words I chose for list one don't afford dual coding as well. You can encode verbal labels for concepts like justice and honesty, but how well can you form an image of what those concepts look like? Pavio states that having a dual code improves memory over a single code. If you remember back to the units on memory, you will remember that the more retrieval cues that we have available to recall information will lead to better memory. Indeed, it is well-established that people typically do a much better job at recalling concrete items as compared to abstract ones.

Not all theorists agree with Pavio, however, and some have stated that memory for concrete items is superior to that for abstract items not because we can form a visual based memory for concrete items, but because we can generate more detailed verbal descriptions for them. As you see, this debate centers around the nature of representation in memory. Is it the case that we can actually store visual images in memory, and manipulate them just as we would as if the item were in front of us? Or are we limited to only abstract, verbal descriptions? This is the heart of the analog versus propositional debate. Pavio's theory is an example of an analog point of view, and the fact that memory is better for concrete items is consistent with that analog view.

Is there any other evidence that is consistent with the hypothesis that we can store useable visual codes in memory?

8c | Manipulating Visual Images

We've all had the experience of seeing in our mind's eye. But does that mean those images are useful memory codes? Shephard and Metzler published a series of experiments that gave credence to the hypothesis that people can form mental images, and can manipulate them in much the same way that we can manipulate actual objects in our environment.

Imagine that I present you with two complex shapes, perhaps put together out of Lego, and I ask you to tell me if they are the same shape or not? Imagine that instead of putting the shapes in front of you so that they are aligned in exactly the same way, I have the one on the right hand side rotated a bit in a clockwise direction. In order to make sure your decision is correct, you might reach out to one of the shapes and turn it so that its orientation is identical to the comparison shape. If we measured the time for you to make the comparison and respond, we would find that your response time would be longer the greater the difference in orientation or rotation between the two shapes. Shepard and Metzler used this logic in an experiment with mental imagery to see if the same premise held true. That is, when making a comparison of two images, would we mentally rotate one of the objects or images in order to aid in a correct response?

The panel in front of you shows some examples of the shapes used by Sheperd and Metzler. These shapes were not physically provided to the observers, they were only shown on a slide. Shephard and Metzler presented the pairs of shapes so that they varied either in picture-plane, or in depth, and in both cases, they manipulated how many degrees of rotation separated the orientation of the two shapes. Critically, as you see in this figure, the observers' response times varied directly as a function of the number of degrees of rotation separating the two shapes! This is the same pattern of data we observe when people manipulate physical shapes that are actually placed before them, and it supports the idea that observers are actually performing mental rotation on these images in their minds' eye.

Stephen Kosslyn and colleagues extended this research by showing parallel results in a series of image scanning experiments. To understand the logic of the experiments, pretend that I have placed a map of Canada in front of you. I ask you to put your finger on the city of Montreal. Imagine I then ask you a question about the city of Winnipeg, or the city of Vancouver, that requires you to look at that area of the map. We know that it will take you longer to sweep your eyes and your finger across the map to answer the question about Vancouver than it will to answer the question about Winnipeg. Would the same hold true for images of maps?

To test this hypothesis, Kosslyn presented his observers with maps like you see in the panel in front of you. Observers were asked to study the map until they had it committed to memory. The map was then taken away, and observers were asked to form a mental image of the map they had just seen. Once they had formed the image, they were then given a starting point, say the tiki hut in the bottom left hand corner of the map. From that point, they were then asked a question about a place on the map that was relatively near to the tiki hut, like the tree, or a place that was relatively far from the tiki hut, like the rock. Consistent with the results of Shepard and Metzler, and with the hypothesis that we scan mental maps much like we scan actual maps, Kosslyn and his colleagues found that it took longer for observers to answer questions about places further away from their starting points than it did to answer questions about places closer to their starting points.

Taken together, these types of results appear to provide strong support for the analog view of imagery- that mental images are useful codes in memory- and challenge the propositional view that we store only abstract linguistic codes in memory. It is difficult to see why there should be differences in response time that vary according to the physical separation of items on an imaginary map if all we store are verbal descriptions of these items. The proponents of the propositional point of view, however, suggest that these differences are actually due to demand characteristics. That is, everyone knows that it should take longer to respond to two things that are further from one another and in order to do the right thing in the experiment, observers tailor their responses accordingly.

We'll return to the analog versus propositional debate a bit later in this unit, but next, we'll discuss the properties of visual images as important codes in memory.

8d | Imagery Debate

Finke, in 1989, outlined important qualities that are inherent in visual images. The first is implicit, or non-intentional encoding. This means that without overtly encoding that information, it is possible to access the image in memory and retrieve it. In order to understand this, form an image of a block letter "F". It should look like this. Now, close your eyes and form an image of the F you just saw. Starting at the upper left hand corner of the F, I would like you to scan the F in a clockwise manner, and at every corner you encounter, respond yes if that corner is at the extreme top or bottom of the F, and no if it is not at the extreme top or bottom./

Your responses should have been this: yes, yes, no, no, no, no, no, no, yes, yes.

The fact that you were able to do this means that you were able to retrieve from the image information that you probably never consciously thought about before. This is part of an experiment that was done by Lee Brook at McMaster University, and we'll return to the rest of the experiment in just a moment.

The second property of visual images that sets them apart from mere abstract propositions is perceptual equivalence. That is, imagery, and manipulating those images, should activate similar brain and mental systems as does actual perception of the physical item. The mental rotation and map scanning experiments we talked about earlier are consistent with this. To really make this point, however, we will try one more condition from the experiment reported by Brooks in 1968. For this condition, you will need to reform the image of the block letter F that you used just a few minutes ago. Your task is going to be exactly the same as before. That is, you are going to begin in the upper left hand corner of the letter, and travel clockwise, indicating at each corner whether that corner is at the extreme top or the extreme bottom of the letter. Instead of responding by saying yes or no, however, I have provided a response sheet for you. On the next slide, you will see 10 rows that each contain a Y and an N, one for each corner of the F. In order to respond, I would like you to start at the top row, touch either the Y or the N to indicate your first response, and then respond to the second corner on the second row, and so forth until you have responded to all the corners and your finger ends at the bottom of the screen.

You probably found this task much more difficult than the first. Brooks argued that this is the case because you need to use your spatial processing skills both to examine and move around the image of the letter F, and to find the proper response row and letter. If you remember back to our attention unit, this is a clear case where we are seeing interference from two controlled processes that are trying to use the same processing resources.

Finke's third principle is spatial equivalence, which states that the spatial relations in images should correspond to spatial relations in the actual physical space. Kosslyn's map scanning results provide strong support for this principle.

The fourth principle, that of transformational equivalence, was demonstrated when we talked about Shepard and Metzler's mental rotation experiments. That is, our performance in mental rotation, or image transformation, was very similar to performance in transforming or rotating actual objects.

The final principle advanced by Finke was that of structural equivalence, which means that images should be organized much like physical objects. Results consistent with this principle have been shown in studies like those of Kosslyn and colleagues. They showed that it took people far longer to form more complex images than simpler images, much like the two pictures of the alligator in part (A). Interestingly, the time to form the same image was also shown to vary according to how it was described. Observers shown the object in panel (B) took longer to form an image of it if was described as five connected boxes than did those observers who were told that that object was two overlapping rectangles.

To summarize, Finke's principles are important in outlining the qualities that visual images should have in order to be important codes in memory. These principles are consistent with the qualities held important by the analog view of visual imagery, as well. As we'll see, however, not all theorists believe that visual images should be considered useful representations in memory.

We've already spent quite a bit of time talking about results that are consistent with the analog view. That is, that visual images are actual visually-based codes stored in memory, that closely resemble the original object. Even more importantly, there is evidence that we can manipulate these so-called pictures in the head much like we manipulate actual objects.

Not everyone agrees that images are useful representations in visual memory, however. That doesn't necessarily mean that these theorists dispute the fact that we can form images, but they do not believe that images per se are true memory representations. Instead, these theorists argue that images are merely by-products of abstract verbal or propositional codes. We may form images as a consequence of activating an abstract verbal code, but we do not process them or operate on them as we would operate on a physical object.

What about the results that we've discussed earlier that seem to indicate that we do process images in much the same way as we process visual objects? Proponents of the propositional point of view, led by Zenon Pylyshyn of the University of Western Ontario, argue that many of those results can be explained by the concept of demand characteristics and by the fact that we have a lot of implicit knowledge about the world. That is, as we discussed earlier, people know that it should take longer to move between two points that are further apart, and that it should take longer to rotate an object the further that the object has to be rotated. Pylyshyn says with this knowledge in hand people behave accordingly.

Pylyshyn also raises a second interesting point. That is, you can look at a picture that you've never seen before and determine what it is. Can you do the same thing with an image? That is, do you ever examine an image in your mind without first knowing what it is? Pylyshyn argues no, because images are by-products of verbal descriptions.

This debate was hotly contested in the 1970s and 80s. Recent advances in technology, however, and the advent of neuropsychological case studies have pushed the weight of the evidence in favour of the analog point of view, as we will see in the next section./

As noted earlier, although we all had the experience of seeing in our mind's eye, or seeing an image, that does not necessarily mean that information is stored in memory as a visual image, or that these images are actual memory codes that can be processed and manipulated. This issue is the center of the analog versus propositional debate.

Recent advances in technology and the use of neuropsychological case studies have provided evidence to help clarify this debate. For instance, Martha Farah and colleagues used a method developed by Stephen Kosslyn to provide a clever demonstration that processing images appears to recruit the same brain areas as does processing actual visual space.

Kosslyn asked observers to imagine an animal at its normal size- for example a mouse. Once the observer had this image formed, Kosslyn asked him or her to "mentally walk towards" the mouse. Observers reported that the size of the image grew as they got closer to it, until they reached the point at which it overflowed their visual field. Kosslyn asked them to estimate how far away they were from the animal when its image overflowed the visual field. Observers in these experiments reported that the visual field was completely filled at a distance further from the animal when the animal was larger than when it was smaller. This is the same thing that we would experience if we approached real animals. In other words, an entire elephant would overflow your visual field before an entire mouse would, as you moved towards the two.

The occipital lobe of the brain is primarily associated with vision, and it is well known that if part of one's occipital lobe is removed, the field of vision decreases.

Farah cleverly combined the experimental work of Kosslyn, and our knowledge about the effect of the occipital lobe on determining the size of one's visual field in a case study. A woman by the initials MGS had part of her right occipital lobe removed as treatment for epilepsy. Before surgery, Farah had MGS perform Kosslyn's mental walk task that we just discussed, and she recorded the estimated distance that MGS reported for overflow of the images of various animals.

These same tests were repeated after surgery, and Farah found that MGS's reported distances of overflow were much smaller than before surgery! That is, removal of part of the occipital lobe not only reduces our physical field of view, but our field of view for images, as well! It is hard to account for such a finding by way of a propositional view of visual imagery.

DeVreese in 1991 also made the important discovery that people who have lost the ability to see colour due to brain damage are also unable to create colours through imagery!

Finally, the work of Bisiach and Luzzatti that we discussed in our attention unit also supports the view that we process visual images much like physical objects. Specifically, their patients suffering from unilateral neglect ignored not only the left side of space when processing items in the real world, but also when processing visual images of their home towns.

Generally, then, advances in neuroscience have bolstered the experimental results that suggest that the analog view is closer to the truth with regards to visual imagery.

8e | Summary of Visual Imagery and Spatial Recognition

Visual images are mental representations of our perceptual experiences. As such, they are important codes that we store in long term memory and can process in working, or short-term memory.

Images can also play an important role as mnemonic, or memory enhancing, devices. Techniques such as the Method of Loci, the use of interactive images, and the Pegword Method have all been shown to help promote memory, and it is quite likely that they do so because they provide two distinct ways that to-be-remembered items can be stored in and retrieved from memory, the so-called Dual Code theory.

We've discussed important evidence concerning mental imagery from studies using mental rotation, imagine scanning, and more recent neuropsychological work. Taken together, these results have allowed us to name important principles of mental images, including implicit encoding, perceptual equivalence, spatial equivalence, transformational equivalence, and structural equivalence. Mental images therefore prove to be an important memory representation- we can store information in visual form, and we can also process and retrieve information from those images.

9a | Introduction to Language and Cognition

In this unit, we will explore one of the most complex, and, uniquely human, cognitive abilities. Your ability to comprehend and produce language, whether it be spoken or written, is a phenomenal achievement, one that you no doubt take for granted. Our ability to use language draws upon all of the units that we've covered to date, from basic perception and attention to the storage and retrieval of concepts, meanings, spellings and pronunciations in memory. Moreover, think about how hearing that ad for a Caribbean holiday in the dead of winter leads you to conjure up an image of crystal clear water, white sand, and a gentle breeze. The units that we cover after this one, the higher-order cognitive skills like reasoning and decision making draw heavily on language. In short, it is an integral part of human cognition.

Is language uniquely human, though? Clearly, other animals can communicate, and many do so with quite a lot of complexity. For instance, when it is time to find a new nest, there is a species of ant that send envoys out to scout for a new location. Having done their best to find a new living place, these scouts then return and communicate to the rest of the ants about the new home so that the entire colony can make a decision. Unlike human language, however, this communication is only about the location of the potential nest. The ants cannot describe what they saw along the way, what the weather was like, or anything else. Therefore, although other species seem to have what are sometimes sophisticated methods of communication, and these methods are often quite structured, which is a requirement of a language, they do not seem to have language per se.

Two aspects of human language set it apart. First, it is arbitrary. That is, there is no direct link between a word that represents a concept and that concept. The word brown does not look like brown. Hungry doesn't feel like hungry. These are arbitrary words chosen to represent concepts. That is not the case with other animal communication.

Perhaps most importantly, human language gives us an ability that makes human life incredibly enjoyable. Our language is generative. That is, every single one of us can state, write or sing something that no one has ever said before.

Thus, language is an incredible feat. In this unit we'll spend some time talking about the structure of language- all languages have structures, and as masters of a language, we are masters of its structure, even if we cannot explain all the rules.

We will also then talk about both language comprehension and production. Obviously these are related topics, but we will also see that they can be done quite independently.

Finally, by examining some of the neuropsychological work that has been done on language, we will reinforce our knowledge about its structure, and we will also see that comprehension and production are separate abilities, recruiting distinct brain areas.

9b | The Structure of Language

When we speak about the structure of language, we will identify a number of different systems that work together, and it is probably not surprising that different systems are invoked depending on whether one is discussing auditory or visual language.

Think about the most basic elements of auditory language as you listen to my voice right now. The first stage in understanding what I am saying is to perceive the sounds I am speaking to you. These are called phonemes, and different languages have different phonemes (and different numbers of phonemes). Phonemes are the smallest unit of sound that makes a meaningful difference in a language. For instance, substituting the phoneme "m" for "c" changes "cat" to "mat." Phonology is the study of how phonemes can be combined in a language.

Phonemes are assembled to create morphemes, which are the smallest units of meaning in a language. In the word cats, "cat" is a morpheme, as it means the concept of a furry house pet, but "s" constitutes a morpheme, as well. In this case, it means more than one cat. Morphemes need to be assembled in some manner that makes sense, and this is called the syntax of the utterance. Syntax is the structure of our language. Having proper syntax is not enough to communicate an idea, however, as the utterance must be semantically meaningful. Finally, in order for communication to be complete, there must be some form of give and take between the participants. We call this the pragmatics of the language. We'll talk about each of these in a bit more detail now.

Even if you speak and read only one language, you no doubt know that different languages make use of different phonemes. German, for instance, uses phonemes that are not used in English, and one of the difficulties of mastering a new language is being able to produce new phonemes as a native would. The table in front of you gives examples of some of the phonemes in the English language. As you try to produce some of these phonemes, notice that your mouth takes on different shapes, your tongue meets the back of your teeth or the roof of your mouth in a different manner, and air is forced from your mouth in a different way. These are regular and important differences that characterize these different phonemes.

As we noted briefly earlier, there are explicit rules for how phonemes can be combined to form an utterance- some combinations of phonemes are not legal, for instance beginning a word with two consonants is only possible when they are certain consonants. Interestingly, although you probably never think about these rules, you would notice a violation of the rules almost instantly.

As we noted earlier, morphemes are the units in our language that convey meaning. Many morphemes are words, but not all are. As you study this unit, you already know that "study" is a morpheme. If you remove the "y" and add an "ied" however, you have added a morpheme, because the meaning of the word has changed from something you are about to do, to something you have done. Word endings, prefixes, tense markers and the like are all morphemes.

How do we combine these morphemes into a form that makes sense? Syntax refers to the arrangement of words within sentences, or their structure. English is primarily what we refer to as an SVO or subject-verb-object language. You may have vague memories from studying grammar, or the syntax of your language in grade school, and may even be vaguely familiar with tree diagrams like that shown here. These diagrams allow us to identify the component parts of a sentence. These diagrams also allow us to see how parts of sentences can be meaningfully rearranged. For instance, the original sentence, seen in the Figure, is The poodle will chase the red ball. It is also possible to reverse the order of the two noun phrases in the diagram, and make a small change to the verb phrase, and be left with an utterance that means essentially the same thing. That is, "The red ball will be chased by the poodle." This is known as preposing, and in this case it is possible. It is not always possible, however. For instance, the utterance "Martha stood up her blind date" cannot be modified in the same way. Up her blind date, Martha stood, simply does not work.

This raises an interesting distinction, that is: we have way more implicit understanding of our language than we are able to explicitly state. Everyone of us can reject as illegal the second utterance, yet that doesn't mean we can explain why.

This also raises another issue, and that is the issue of what a linguist means when he or she says an utterance is grammatically or syntactically correct. Although your grade 8 grammar teacher would likely tell you that it is improper to state, "I ain't gonna do my homework anymore," a linguist would find that a completely legal, albeit perhaps shortsighted statement. That is, a linguist speaks of how utterances must be constructed in order to follow the rules of English, not whether the utterance is particularly proper or polite.

Having a syntactically correct utterance, however, does not mean that it will serve its purpose. Language is meant to communicate, and without proper semantic content, an utterance is useless for that purpose.

The semantics, or meaning, in language, explains many interesting things. For instance, the concept of anomaly- why "Coffee ice-cream can take dictation" is meaningless, the concept of self-contradiction- as illustrated in "my dog is not an animal." When I say that I need to go to the bank, am I speaking about a financial institution or the side of the river? Many words in English are semantically ambiguous, and we need context to disambiuguate them. Likewise, English is rife with synonymous statements, so it is clear to all of us that having someone tell you that you are too young to do something means the same as saying that you aren't old enough. Finally, we are able to derive much more from an utterance that what is explicitly stated. For instance, if I were to tell you that Pat was my uncle, you would know that Pat is a male.

The key to understanding the meaning of an utterance, then, begins with understanding each of the words, but also requires that we be able to understand the syntax, or the way that the utterance is constructed, and the truth value of each part of the utterance.

To this point, we've been able to get a grasp on how one can construct an utterance that informs, which is the point of language. This is only part of the story, however, because to communicate with someone else, you also need to follow a fourth set of rules- the social rules of a language, or its pragmatics.

Pragmatics are the practical rules that we use in maintaining conversations- things like using proper etiquette. We understand that conversation must have give and take, and that we should wait for a response before interrupting and continuing with our point of view. Moreover, our understanding of pragmatics ensures that we speak to our elders and employers in a way that is different from how we might speak to a friend over a beer.

With a general understanding of the many layers of structure that are part of human language, we'll turn now to a closer examination of how we comprehend and produce language.

9c | Language Comprehension and Production

Just as you're able to see the form, colours, texture and shape in front of you as a coffee mug, you must be able to transform raw data in order to comprehend language. One of the most awe inspiring (yet rarely considered) skill that human comprehenders have is speech comprehension. We've spent a bit of time earlier talking about the elemental sounds in the language, the phones, and the smallest sounds that carry meaning, the phonemes. This might lead you to believe, then, that comprehending speech means being able to "hear" each of these phonemes. That is, that we perceive each of these sounds one at a time, using the pauses between the sounds to help us identify when one ends and when the next begins.

This is not the case, however, our ability to comprehend language relies on something much more complex. First, speech is continuous. The Figure in front of you shows a speech spectrogram of a person uttering a phrase. A spectrogram is a physical representation of the frequency of sound plotted over time. As you can see from the spectrogram, speech is not distinct, but is continuous. Where in the spectrogram would you say the individual is saying the word "a?" A second problem with the discrete comprehension view is that an individual phoneme can sound very different, depending on the other phonemes that are around it. Think of the phoneme associated with the letter "p" when it begins a word such as pumpkin, as compared to when it begins a word such as phone.

Given these challenges, how is it that we can process speech so readily, and seemingly without effort? One theory is that we process speech in a categorical manner, meaning that we are "hard wired" to efficiently, without awareness or intention, force sounds into discrete categories. Interestingly, it has been shown that distinctions in sound that we can hear as infants can no longer be made by us once we have learned English. From that point on, we perceive sounds in categories that fit with the phonemes of our language. This is true not just of English speakers, but of speakers of other languages, as well. For instance, speakers of the Cantonese dialect of Chinese cannot distinguish between the English phonemes r and L, although they can do so as infants.

Clearly, then, our ability to comprehend spoken language is complex. What about our ability to produce it?

One of the more interesting areas of study in speech production centers on speech errors. Speech errors are often of a specific type. In one case, we might substitute one phoneme for another, as in "sue keeps food in her vesk." Other times, a phoneme might be shifted from the proper location to a second location. "Keep your cotton-pickin' hands off my weet speas." We also sometimes shift a combination of phonemes, or a more complex sound, as in "got a lot of pons and pats to wash." Finally, other speech errors result from the exchange of complete words or morphemes, as in "We'll sit around the song and sing fires." Notice that in each of these cases the errors are not random, but in their own way they obey the laws of the language. That is, they involve transposing entire phonemes, or more complex sounds, or even morphemes and words. Even our mistakes, then, appear sensitive to the rules of the language.

9d | Neuropsychological Views and Evidence

Our introduction to the concepts of language structure- namely it's meaning and syntax- and our ability to both comprehend it and produce it alluded to the fact that these are separable facets of language. That is, it is possible to utter a meaningful utterance in a syntactically incorrect manner, and it is possible to comprehend language without being able to produce it, and vice versa. In fact, our ability to comprehend language develops much earlier than our ability to produce it, as the parent of any toddler can attest to.

We will now turn to a closer look at neuropsychological evidence that underscores the separability of syntax and semantics, of comprehension and production. As in earlier units, much of this work has relied on the case-study methodology- the in depth study of language in an individual who has suffered some form of brain injury.

There is a special term for a collective deficit in language that results from brain damage, and that is aphasia. We will now discuss some of the aphasias, focusing on two- Broca's aphasia and Wernicke's aphasia.

Broca's aphasia, also called expressive aphasia, was named after the French surgeon Paul Broca. He had encountered a patient, who had been nicknamed "Tan" because he had lost his ability to speak any words except for "tan." After the patient's death, Broca performed an autopsy, and discovered a lesion in the left frontal lobe. This became known as Broca's area, as seen in the Figure. Broca's aphasia is characterized by halting, agrammatic speech. These individuals generally can express semantics, as in nouns and verbs, but the function words, or the connectors that hold our syntactically correct utterances together, are missing. Generally, then, we say that an individual with Broca's aphasia has fairly intact semantics, but badly impaired syntax. Moreover, they have fairly intact comprehension, but badly impaired production. An important limit is present in their comprehension, however. They can comprehend sentence such as, "The dog bit the boy." but make errors on sentences such as "The boy was bit by the dog." These are called reversed sentences, and notice that in order to understand them, you need to rely a little more heavily on your knowledge of syntax.

The following clip shows an individual with Broca's aphasia being interviewed by a psychologist. Notice how he seems to be tracking the conversation and his responses, although short and syntactically impaired, are appropriate for the conversation.

We'll contrast his behaviour with the individual we see in the next clip.

In contrast to Broca's aphasia, which affects one's ability to produce language most dramatically, Wernicke's aphasia has been termed receptive aphasia, but these individuals produce relatively fluent speech that is meaningless. That is, for them, semantics are greatly impaired although syntax is relatively intact. Moreover, their ability to produce language is spared (aside from the fact that it has no meaning), but they cannot comprehend it. Even simple commands such as "touch your knee" will generally not be comprehended and executed by an individual suffering from Wernicke's aphasia. Like Broca's aphasia, Wernicke's aphasia was named after the surgeon who discovered damage to the temporal lobe of the left hemisphere of an individual suffering from it.

An interesting way to conceptualize the difference between Broca's aphasia and Wernicke's aphasia is the following. Imagine you are a first time visitor to a country whose language you do not speak. If you were to run into an individual suffering from Broca's aphasia on the street, you would immediately realize that something was wrong with him or her. In contrast, you would not be able to make the same discrimination about an individual suffering from Wernicke's aphasia. His or her word salad would sound ok to you, because all utterances in that language are meaningless. Here is an example of a patient suffering from Wernicke's aphasia speaking in English.

Just as we noted that there were many forms of agnosia in our unit on perception, it is also the case that there are many forms of aphasia. There are several forms of anomia, which are typically difficulties in naming objects, forms of alexia, which are visual language impairments (dyslexia itself is a large class of alexia), agraphia, which is the inability to write, and interestingly, alexia without agraphia. These individuals can write, but cannot read what they have just written!

An important contribution that the study of language impairment has made is that it has clearly demonstrated the separability of semantics and syntax (meaning and structure) and comprehension and production. These areas are served by different parts of the brain, and it is clearly the case that language, in humans, is strongly lateralized. That is, for the most part, language in right handed individuals resides most strongly in the left hemisphere of the brain.

9e | Summary of Language and Cognition

As we have seen, language is a complex and phenomenal skill- one that is uniquely human. We've discussed five levels of structure- including phonology, morphology, syntax, semantics and pragmatics, and successful language relies on all of these.

As we have seen repeatedly throughout this course, context strongly affects language, just as it affects perception and memory.

We have seen that language is conducted by a number of specialized, independent brain regions. This means that not are the different language processes subserved by different areas of the brain, but it is also possible to have some abilities preserved while others are damaged by some form of brain accident.

Finally, the key to what makes human language unique is two-fold:

First, that you get the gist of what I am saying right now is remarkable given that the words I use to convey this message are arbitrary. They bear no physical resemblance to the concepts that they represent. Second, you can tell your roommate the story of language and do so in a unique way. Human language is generative!

10a | Introduction to Thinking, Problem Solving, and Reasoning

In this section of the course, we're going to be talking about thinking, problem solving, and reasoning. In this module, we're just going to really talk about what thinking really is – how we can go about defining it. In later modules in this section, we're going to cover more specific problem solving techniques, then move on to some blocks in problem solving, so, what sorts of cognitive processes might stop you or halt you from solving a specific problem, and then move on to reasoning.

So, what is thinking? Well, here are a couple examples. Imagine your favourite restaurant. What is its name? Where is it? What are its best dishes? What makes it your favourite? Those all examples, however simple they may seem, are examples of thinking. Here's another example. So, look at the following figure. Create unusual, but appropriate titles for the drawings. For example, for the one on the left, A, you might come up with "Giant Egg on a Baseball Diamond," or, simply, "Xs and Os." Those two examples we just talked about are very different, and they highlight the broad range of tasks that might be subsumed under the title "thinking." They also show how it's difficult to come up with a precise definition of "thinking." It's something we all know something about, and we all can provide our own sort of definitions for it. Here are a couple definitions that we've come up with by scouring through the literature. So Bruner, 1957, defined thinking as "going beyond the information given." Bartlett, 1958, defined thinking as "complex and high-level skill; fills up gaps in the evidence." Newell and Simon, 1972, define thinking as "the process of searching through a problem-space." And finally, Baron, 1994, defined thinking as "what we do when we are in doubt about how to act, what to believe, or what to desire."

As you can see by these definitions, "thinking" is used to refer to more than one specific activity, and what this also suggests is that since we have such a vast array of tasks that can be subsumed under the title "thinking," there are likely several different types of thinking. And indeed, most researchers do believe that there are different types of thinking. One distinction that we'll talk about a little bit in this module is that between focussed and unfocussed thinking. So, here, focussed thinking, pretty much as the name suggests, involves thinking that has a clear starting point and has a specific goal. An example of that would be trying to figure out a way, how to get to the Air Canada Centre in Toronto to go see a concert. You have a definite goal in mind – that is, getting to the concert – and there are a clear number of steps along the way that you could help solve that goal. The key think here with focussed thinking is that your mind is definitely focussed on the task at hand, and you're deliberately working through the problem. Unfocussed thinking, on the other hand, has the characteristic of being not on task. So, for example, daydreaming, unintentional thinking, and even some forms of creative thinking might involve more unfocussed thinking processes. We're going to be primarily spending our attention talking about focussed thinking in this task. Indeed, the vast majority of research in thinking, and problem solving, and reasoning, is done looking at more focussed thinking processes.

This is also a good time of the course to think again about how it is that we can go about measuring cognitive activities. So, one thing that we've looked at throughout the course, and what we've used throughout the course have been responses, accuracy, reaction times, and looking at what goes on in the brain when people are doing specific tasks. When it comes to reasoning, problem solving, and decision making, researchers have also relied quite a bit on what is termed "introspection." Introspection is the detailed, concurrent, and non-judgemental observation of the contents of your own consciousness as you work on a problem. You might be able to do this online, thinking aloud while you're doing a task, or be asked to judge or respond to what you think you were doing retrospectively after you do the task. Of course, there are a lot of problems with this technique, for example, how can you actually externally validate this process – again, we don't have privileged access into the minds of others – nonetheless, it has been shown to be a very powerful tool. This would probably be a good time to take a look at box 10.1 in your textbook. It goes through some of the specific instructions for introspecting. To maximize what you can get out of this section of the course, you might want to work through some of the problems in the textbook that we provide, and use the technique of introspection while you're solving the problem. That will give you some good first-hand experience in trying to understand and uncover some of the thinking processes that are involved in completing some of these tasks.

There are two more key definitions that we need to talk about before we can move on in this section of the course. That has to do with the types of problems that we are trying to solve. There are at least two different classes of problems. There are well-defined problems, and these are problems that have a clear goal. They have a beginning and an end, and you can use rules of guidelines to solve the problem. A good example of a well-defined problem might be games or puzzles. Take, for example, the Rubik's cube. There is a clear end state to that game, or that puzzle, where you have to have each side having its own colour. And there are a number of steps that you can complete where you have to follow specific rules to get to that end state. As another example, consider chess, highlighted by this picture of Bobby Fisher. There is a clear beginning state, a clear goal, and a number of rules that you need to follow in order to achieve that goal.

In contrast to well-defined problems, there are ill-defined problems, and the definition of an ill-defined problem is basically the opposite of a well-defined problem. There may be no clear goal, very little starting information, and they don't have many rules or steps clearly laid out for you. An example of an ill-defined problem might be if you had to write a difficult, sensitive letter to somebody. You might find yourself sitting, staring blankly at a computer screen, not knowing quite sure how to start the message, or, how to finish it, for that matter. And there are no clear rules at your disposal on how to get from the starting point to the end point.

As we talked about moments ago, cognitive psychologists have mainly spent their time researching focussed thinking, and, perhaps not surprisingly, cognitive psychologists have also focussed most of their research attention on well-defined problems. Now, there are several reasons for this. First-off, they're just simply easier to present. That is, it's easier to come up with and present a series of well-defined problems than it is to come up with and generate a bunch of ill-defined problems. And, plus, we know that well-defined problems can be solved relatively shortly, whereas, the ill-defined problem, some participants may never solve it. Scoring is another issue. Scoring an algebra problem, or a simple problem solving task like the Rubik's cube, for instance, is relatively straight-forward: they either solve it or they don't. An ill-defined problem, on the other hand, is very difficult to score, and that is largely due to the fact that for many ill-defined problems, there really is no clear goal state, so there might be not a clear right or wrong answer to the problem. And finally, well-defined problems are easy to modify and change – that is, you can change some aspect of the problem, some small aspect of the problem, while leaving the remainder of the problem intact. So, unfortunately, because of the preponderance of research on well-defined problems, there is very little work that has been done on ill-defined problems to date. As such, for the remaining modules of this section, we're going to be focussing our attention on focussed thinking with well-defined problems. It is assumed by researchers that problem solving for ill-defined problems works in very similar ways to problem solving for well-defined problems.

10b | Problem Solving Techniques

In the previous section, we provided some definitions about what we really mean by problem solving and thinking. In this section, what we're going to be doing now is talk about some general problem solving techniques. What we mean by general problem solving techniques is techniques that could work for a variety of different classes of problems. This can be contrasted with domain-specific problem solving techniques – those that might only work with specific types of problems. In this module, we're going to talk about four different domain-general problem solving techniques: the generate and test technique, means-ends analysis, working backwards, and reasoning by analogy.

First, we'll talk about the generate and test technique. As the name suggests, the generate and test technique involves we generate a number of potential solutions and then test to see if those solutions fit. For example, consider the task of generating as many foods as you can that begin with the letter C. In the following figure, there's a couple examples here, for example, cream, cheese, candy, cookies, celery, carrots, cantaloupe, cheese, cocoa, cereal, and so on and so on. In this example, you may have generated a number of words that actually didn't start with the letter c, for example, ketchup. In addition, you might have generated some words that start with the letter c, but that might not be food, for example, commute. So, in the second step, when you were verifying which of the words actually truly fit, you would have eliminated those examples. As you can probably see by this example, it's a pretty simple strategy, but it's only really useful if there is a limited number of possibilities. If there are a large number of possibilities, this strategy would not be a very useful problem solving technique. This can also be problematic due to, again, the limited cognitive capacity that we have. This point has come up over and over again in this course, in that we have a finite processing capacity, and when you look at working memory capacity, again, we can only hold so much information in our mind. As this technique requires us to hold in mind the number of alternatives, this can again easily surpass that limited capacity that we have,

The next technique we're going to talk about is called means-ends analysis. Now, this is a very popular technique, and very powerful as well. So, first, in order to think about means-ends analysis, let's think of an example. So, let's just suppose that what your goal in life, your ultimate goal in life, is to become a cognitive psychologist. Well, how would you go about doing that? Well, first off, you might think to yourself "Well, I should think about taking Psych207 and I should try to do very well in that class. Then, maybe after 207, I might move on to a third year class, and take an advanced lab class in cognitive psychology. And, if I'm still passionate about cognitive psychology at that point, I might do an honours thesis, and then send off all my applications to graduate school. Once I get all my acceptance letters, and I pick a good graduate school, and I'm well on my way to becoming a cognitive psychologist. After a few years, I'll have my PhD in hand." Now, I just made that sound very simple, didn't I? Well, it's a little bit more work than that, I skipped a couple steps, but at least I gave you a good idea of how means-ends analysis works. You look, you have an initial state, and that is the conditions at the beginning of a problem, you'll have a goal state, those the conditions at the end of the problem, and again here, it's getting that PhD in cognitive psychology and becoming a cognitive psychologist, thee are intermediate states, those are conditions that exist along the way, pathways between the initial and the goal state, that is, all those courses that I might want to take along the way to becoming a PhD in cognitive psychology, and then there are operators: permissible moves, that would basically be some of the rules that you have to follow along the way. This would be a good point in the module to take a close look at the tower of Hanoi problem. There are numerous fun examples of this problem online that you can try for yourself, or, you might be lucky enough to have a manual, physical version of this at home. In this task you need to determine a sequence of moves to transfer the discs from the first to the third peg, moving only one disc at a time and never placing a bigger disc on tip of a smaller one. So, try this task a few times, and see how efficient you can get at it – and efficiency, here, is determined by how few moves you can complete the task in. This task, the tower of Hanoi, could also be solved by working backwards. Here, this involves creating a series of sub-goals and reducing the differences between the current state and the goal state, like means-ends analysis, however, the sub-goals are created by working backwards from the goal state. So, considering the tower of Hanoi problem, you can create, in your mind, what the goal state looks like – those three discs sitting on the third peg – and generate sub-goals from that goal state until you arrive at your initial state.

So, think back, now, how you went about solving the tower of Hanoi task. Did you solve it using means-ends analysis, by working forward from the initial state to the goal state, or, did you find it more efficient to work backwards, trying to generate sub-goals from the end state, the goal state, to the initial state? Another good example of working backwards, and one that might be relevant to a student taking a class in cognitive psychology, is how you might improve your grade on a test. So, let's just consider the case where you didn't do quite as well on the last test as you would liked to have. Well, so your problem, your goal state, is "How can I get an A on the next test?" Your first sub-goal might be, "well, before I do better, I need to have a better understanding of the material. In order to have a better understanding of the material, I need to have more efficient study strategies." Then, you might look through your cognitive psychology notes and see if you can find any sort of hints about how better to encode information so that you will be able to retrieve it better at the time of testing.

The final problem-solving technique that we're going to talk about in this module is reasoning by analogy, and what we're going to do in this section is we're going to actually work through a problem ourselves, because I think that's one of the better ways to really, truly understand how powerful this technique is. So, take a look at box 10.3 in your textbook: the story of the general. A small country was ruled from a strong fortress by a dictator. The fortress was situated in the middle of a country, surrounded by farms and villages. Many roads led to the fortress through the countryside. A rebel general vowed to capture the fortress. The general knew that an attack by his entire army would capture the fortress. He gathered his army at the head of one of the roads, ready to launch a full-scale direct attack. However, the general then learned the dictator had planted mines on each of the roads. The mines were set so that the small bodies of men could pass over them safely, since the ditator needed to move his troops and workers to and from the fortress. However, any large force would detonate the mines. Not only would this blow up the road, but it would also destroy many neighbouring villages. It therefore seemed impossible to capture the fortress. However, the general devised a simple plan. He divided his army into small groups and dispatched each group to the head of a different road. When all was ready, he gave the signal, and each group marched down a different road. Each group continued down its road to the fortress so that the entire army arrived together at the fortress at the same time. In this way, the general captured the fortress and overthrew the dictator.

Alright, now let's move past that, admittedly, very dramatic, story, to another problem: the tumour problem. Given a human being with an inoperable stomach tumour, and rays that destroy organic tissue at sufficient intensity, by what procedure can one free him of the tumour by these rays, and, at the same time, avoid destroying the healthy tissue that surrounds it? You might want to pause here and think about this problem for a moment. Once you generate a solution to this tumour problem that you think will work, then we'll continue.

Now that you're back, I'm going to give you a hint. What if I told you that the general problem can be used to help you solve the tumour problem? So, think back to the general problem, now, and look through it, and think if there is any information in there that might help you solve this new problem. You might want to pause the program here, again, just so you can have some time to think through this.

Okay, now it's time for the solution. The solution to the tumour problem is to send weak rays of radiation from several angles, such that all rays converge at the site of the tumour. So, although the radiation from any one ray would not be strong enough to destroy the tumour, or the healthy tissue in its path, the convergence of the rays will be strong enough. As you can see here, now, the tumour problem and the problem of the general, although they differ in what is called "surface features," share a common underlying, or analogical, structure. The components of one correspond, at least roughly, with the components of the other. So, the army is analogous to the rays, the capturing of enemy forces is analogous to the destruction of the tumour, the convergence of soldiers at the fortress is analogous to the convergence of rays at the site of the tumour. So, in order to solve the new problem by using the analogous problem, you need to be able to automatically abstract that abstract relationship between those two different domains. Now, don't feel bad if you weren't able to abstract that analogical relationship between those two different domains. In a study by Dick and Holyoak in 1980, they found that only 30% of individuals in their experiments not told about the analogy noticed the analogy, and even when given an explicit hint that the general story could be used to solve the tumour problem, then, 75% of individuals were able to extract the analogy between the two different domains. So, as you can see, this isn't an easy problem. Analogies can be a very powerful problem solving tool. In fact, if you look to the history of science, you'll find that a number of discoveries that have been made have been linked to the effective use of analogies. For example, William Harvey likening the circulatory system to a water pump. Or, more close to our own hearts here in cognitive psychology, thinking about attention as a spotlight.

Perhaps the most famous analogy of them all is that of the relationship between the structure of the hydrogen atom and the solar system. In this analogy, the sun and the planets of the solar system domain are analogous to the nucleus and electron in the atom domain. This example highlights another important role for analogy: that in education and teaching. Many of us may have learned the structure of the atom by comparing it to our solar system. By doing so, it makes it easier to understand and more concrete, by taking something we already know something about, and comparing it to something that we do not.

10c | Blocks to Problem Solving

In the previous section, we covered a number of different problem solving strategies. These strategies are useful because many problems that we have to solve can't be solved in a single step. In addition, many problems have barriers that hinder us from successfully solving a problem. What we're going to talk about now are some of the classic blocks, some of the classic things that hinder us from successfully solving a problem. Before we do this, I'm going to present to you a couple problems that highlight this phenomenon. When I present you with the problem, what I want you to do is press pause on the module, so that you can work on it a little bit before you move on to see the actual solution. The first two problems I want you to try are called the nine dot and the six matches problem. So, first, take a look at the nine dot problem. So, what you see here are a series of dots, and what the task is, is to draw four straight lines that pass through each of the nine dots, without removing your pencil from the paper. The six matches problem is a similar type of task, and what this task requires you to do is to arrange the six matches so that they form four triangles will all sides equal to the length of one match. So, press pause now, and try to work on this problem for a couple of minutes, and then resume play so that you can see what the solutions are.

Welcome back. Now, take a look at the solution to those two problems. First, take a look at the nine-dot problem on the left. As you can see, the problem is easily solvable, as long as you draw the lines outside of the box. Most people aren't able to solve this problem, because they make the faulty assumption that the four lines must stay within the borders of the dots. So, literally, in this example, you have to think outside the box in order to solve the problem. Now, look at the matchstick problem. As you can see, the solution to this problem requires that you think in three dimensions, and create a three-dimensional object. Most people, however, constrain themselves to creating the four triangles in a two-dimensional plane, and thus, cannot solve this problem. Both of these problems illustrate how people typically go into a problem – or often go into a problem, anyways – with faulty assumptions, and these faulty assumptions, of faulty rules about the problem, hinder successful problem solving. There are a couple other examples in the textbook: the string problem, and the candle problem, which I'd also recommend you try out. These blocks to problem solving highlight what is called "mental set." Now, mental set is the tendency to adopt a certain framework, strategy, or procedure, or, more generally, to see things in a certain way instead of in another, equally plausible way. It can be induced by short amounts of practice, and it causes people to make certain unwarranted assumptions, without being aware of making them. So, for example, when you look at the matchstick problem, by looking at that original picture, where all the matches are sitting in a two-dimensional space, people typically make the unwarranted assumption that the final object, or the final image that they create, must also be in two dimensions. However, this is not stated at all anywhere in the rule. Mental set can also be induced by what is called functional fixedness. Now, here, this is an adoption of a rigid mental set towards an object. If you looked at the string problem in the textbook, what you'd find is a perfect example of functional fixedness. To solve that problem, what you'd need to do is to attach the screwdriver to one of the strings to swing it like a pendulum. People typically don't discover that solution because the fail to think that a screwdriver can have other functions besides screwing in screws.

So far, we've talked about mental set as a block to problem solving. Well, there's other blocks as well. One is the lack of problem-specific knowledge or expertise. So, most of the problems studied by cognitive psychologists are about equally unfamiliar to everyone, and people go about solving them in basically the same way. Other kinds of problems, for example, those in chess, or other skilled games, textbook problems in physics, geometry, and electronics, computer programming, and problems in diagnosis, for example, medical diagnosis, seem to be different in kind from the puzzles we have been talking about so far. Perhaps, not surprisingly, experts and novices have been found to approach most such problems differently. Here, the familiarity within a domain of knowledge seems to change the way one solves problems within that frame of reference. There have been numerous studies done comparing experts and novices in a number of domains. For example, Chase and Simon compared novice and expert chess players, and they found that expert chess players were able to extract much more information from a brief exposure to a chess board than novices. In addition, they found that experts could recall more items from a brief exposure than novices. However, these expert-novice differences were only evident when the pieces of the chessboard were configured to depict a possible chess game. When the chess pieces were random, no differences were evident. Presumably, these differences occurred because when experts were presented with a meaningfully configuration, they were able to draw on their extensive memories of past plays, and past games. Now, since novices don't have that extensive long-term memory base of past pays and past moves, they are forced to simply try to maintain the information in their working memory.

Another area where researchers have found extensive differences in the way that experts and novices solve problems is in physics. Here, Chi and colleagues, 1981, found that experts, when given a series of problems to categorize, tended to organize the problems in terms of principles, so, underlying structures of the problem – for example, Newton's first law of motion – whereas novices, on the other hand, focussed on the superficial features of the problems, so, for example, was there an incline plane present, or, was there a frictionless surface? To reiterate, here, experts focussed on underlying principles, underlying deep structures of the problems, whereas novices were cued into the superficial features of the problem, and did not see the underlying structure. What you can see here is that there is a commonality between the expert-novice differences in chess and in physics. For example, in both cases, experts see and represent the problem in their domain at a deeper and more principled level than do novices, who tend to represent information more superficially. An important point to remember about these studies, however, is that experts excel in their own domain of expertise, that is, their knowledge is domain-specific. For example, you take the expert chess player and you ask him to partake in the experiment on physics, then chances are, unless, of course, he's an expert in physics as well, he will behave like the novices, and represent and code the information superficially in that domain, whereas he will still encode and represent the information in a deeper domain within chess. So, to reiterate, expertise, and the degree to which someone will encode, store, and retrieve information at a deeper, structural level, or at a more shallow, superficial level, depends entirely if it is within the individual's domain of expertise. For example, take the professional chess player. Although he will reveal very deep, structured processing in the chess environment, unless he's also an expert in physics, when tested in the physics environment, he will behave like a novice – that is, he will reveal superficial problem solving strategies that is focussed on the surface features of the problem, and not the deeper, structural features.

10d | Reasoning

In the last section of this module, we're going to be talking about reasoning, and you might wonder, well, how is reasoning different than thinking? Well, the term "reason" is often used interchangeably with the term "thinking," so therefore, you're going to notice a great deal of overlap between the types of processes that we talk about within reasoning, and those within thinking. However, researchers that consider themselves working on problems of reasoning typically have specific areas in mind. So, when reasoning, we typically have one or more particular goal in mind. That is, our thinking is very focussed. Reasoning also includes inferences or conclusions drawn form other information. Now, there are two main forms of reasoning that we're going to be talking about. These are deductive reasoning and inductive reasoning.

First, consider deductive reasoning. Now, in deductive reasoning, the information goes from the general to the specific. So, consider the following example: All college students like pizza. Kerri is a college student; therefore, Kerri likes pizza. The final conclusion necessarily follows from the initial premises. Inductive reasoning, on the other hand, goes from the specific to the general, that is, it takes specific information and allows one to make inferences that are more generalized. For example, consider the following syllogism: Brian is a university student. Brian lives in a dormitory; therefore, all university students live in dormitories.

We're going to focus our attention now on deductive reasoning. Now, there are a number of different types of deductive reasoning processes that researchers have focussed on. The two that we're going to talk about are conditional reasoning and categorical reasoning. One of the most well-researched tasks within conditional reasoning is called the Wason selection task. So, let's work through this problem – this is in your textbook as well. So, consider this: you have been hired as a clerk. Your job is to make sure that a set of documents is marked correctly according to the following rule: if the document has an A on one side, then it must have a 4 on the other. You've been told that there are some errors in the coding of the documents, and that you need to find the errors. Each document has a letter written on one side, and a numerical code on the other. Here are the four documents: which documents do you need to turn over to check for errors? You might want to pause, now, for a little bit, and try this problem on your own, and then press play again and then we'll work through it together. So, how about the A card? Well, most people correctly assume that you need to turn over the A card, because, again, you need to check to see if there if there is a 4 on the other. The D card is completely irrelevant on this one, because the rule says nothing about cards that have a D on one side. How about the 4 card? A lot of people mistakenly select the 4 card, thinking that the statement "If the document has an A on one side, then it must have a four on the other" means that if a document has a 4 on one side, it must have an A on the other. Importantly, however, the conditional statement "If the document has an A on one side, then it must have a 4 on the other," says nothing about whether a 4 card must have an A. This is a common error that people often make when reasoning conditionally, in that they assume that a conditional statement is bi-conditional. And, finally, how about the 7 card? The 7 card also needs to be turned over, but most people neglect to do this. The 7 card is required to check to see if the rule is violated. If you turn over the 7 card, and there is an A on the other side, then the conditional statement "If the document has an A on one side, then it must have a 4 on the other," would be violated. If you didn't select the A and the 7 card, don't feel bad. Only a small percentage of people actually do select those cards correctly. Although I'm not going to specifically go through them in this module, it would be a good idea to look through the examples of inferences, rules, and fallacies in the textbook. For example, the modus ponens, the modus tollens, denying the antecedent, and affirming the consequent, to see if they map onto these selections in the Wason selection task.

Now, let's consider that same problem, however, this time, we're going to put meaningful content to it. So, consider this problem: You've been hired as a bouncer in a bar, and you must enforce the following rule: if a person is drinking beer, then he must be over 19 years old. The cards above have information about four people in the bar. One side of each card lists a person's age, and the other side shows what he or she is drinking. Which card, or cards, do you need to turn over, to be sure that no-one is breaking the law? Here, the task feels very transparent, and is very easy. You need to turn over the beer card, to make sure the person is of age, and you need to turn over the card of the 16 year old, to see what they're drinking. Both of these cards are necessary to check to see if the rule has been followed. You probably got a sense from this task that this is much, much easier than the preceding problem. In fact, researchers have found that the majority of university students can correctly solve this problem. However, the previous one I showed you is very difficult , and very, very few people actually solve it correctly. This is what is called a content effect, where the content of a problem can facilitate the logical reasoning process. Griggs and Cox in 1982 were the original researchers to look at this problem, and they came up with what is called the memory cueing explanation. And what they argued was that certain contents of the problem cue, or call to mind, personal experiences that are relevant to the rule. The authors argued that university students did very well on this task because of their own personal experience with drinking age laws, and, perhaps, with violations of those laws. The same participants would have had no relevant experience reasoning about vowels and numbers, and so, performance on that task could not be facilitated by personal experience.

The preceding problems that we just talked about dealt with conditional statements. A second class of problems that researchers have focussed on have been to do with categorical statements. These are often called syllogisms or categorical syllogisms, and in these problems, people are presented with premises that deal with classes of entities. Quantifiers provide information about how many members of a class are under consideration, whether that be all, none, or some. Take a look at the examples provided in the textbook. So, for example, syllogisms like "all red books are astronomy books, all astronomy books are large, therefore, all red books are large," are relatively easy. However, syllogisms that contain "somes" or negatives are much more difficult, and people are typically much slower at responding to them and make many more errors. Just like conditional syllogisms, there are content effects as well, too, in categorical syllogisms – that is, the content of the syllogism can significantly impact logical processing. One content effect that has probably received more research attention than any other in deductive reasoning is the believability effect. Here, people are much more likely to accept a conclusion as valid if the conclusion is believable, irrespective of if it logically follows from the premises.

We're now going to move from deductive reasoning to inductive reasoning. Inductive reasoning is reasoning about conclusions that are likely, but not guaranteed to be true. It's an inferential process that expands knowledge in the face of uncertainty, and it often involves categorization and formation of rules or hypotheses. A famous task designed to look at inductive reasoning is the Wason 2-4-6 task. In this task, participants are given the following triplet: 2, 4, 6, and they are told that the triplet conforms to a particular rule, and the task is to determine what the rule is. But, you may not ask direct questions about the rule, you have to offer examples of triplets, and for each one you give, you'll be told by the experimenter whether it follows the rule or not. And, you should not try to guess the rule, you should only announce the rule when you are confident you know what it is. You might want to pause here and give this a try. What triplets did you come up with? Was it, 4, 6, 8? 10, 12, 14? I, 3,5? All of those triplets would conform to the rule, and most people, when given this task, generate those sorts of triplets. What if I told you that what the rule was , was any three numbers in ascending order? Would you have guessed that? Well, of the 29 original participants in this study, only six discovered the correct rule, without first making any incorrect guesses. Thirteen others made one wrong guess, nine reached two or more incorrect conclusions, and one reached no conclusion at all. What typically happens here is that people come up with an original hypothesis, like, for example, any two numbers increasing by two, and then construct examples that follow that rule. What they fail to do is to test that rule by constructing a counter-example – a triplet that, if the rule is correct, won't receive a "yes" answer from the experimenter. That is, if the participant believes that the rule is "any two numbers increased by two" they will continue to generate triplets that conform to that rule, and they won't try a simpler triplet, like any two numbers that increase by one, or, try to test to see if any numbers that decrease will violate the rule. This is an example of what is termed a "confirmation bias," that is, participants seem to be trying to confirm that the rule is true, rather than trying to test the rule.

We've just spent some time talking about a number of different reasoning tasks. As with the other areas of cognitive psychology that we've talked about, researchers typically try to come up with a broad theoretical framework that explains the cognitive performance. We're going to briefly talk about two major theoretical approaches to the study of reasoning. These are the rules-based approaches, and the mental models approach. The rules-based approach basically argues that people rely on special-purpose mental rules which we have implicit access to – that means we can't consciously think about them – to draw conclusions. They can be sensitive to context, and they can be domain-specific. That is, they could be adapted to solve specific problems that we might encounter. An alternative to the rule-based approach is the mental models approach. Proponents of this approach deny that reasoning consists of using special-purpose rules of inference. Rather, they argue that reasoning consists of constructing mental models to depict the premises. A mental model might be a quasi-pictoral representation of the relationship between the information in the premises and the conclusion. Effective reasoning is thought to occur when the reasoner checks to be sure that his or her first idea of the conclusion might be is assessed by an attempt to construct alternative models consistent with the premises but inconsistent with the hypothesized conclusion. So, which theoretical approach is correct, and which better captures reasoning performance? Well, the jury is still out on that, and, actually, recent neuroimaging research by Goel and colleagues at York University have found evidence for both rule-based and mental models-based approaches, depending on the problem. They found evidence for reliance on more rule-based mechanisms when reasoning with content-laden material, that is, like the drinking age problem we talked about before, and more visual-spatial mental model bases mechanisms when reasoning with abstract material, that is, material that you can't rely on your past experience and knowledge.

10e | Summary of Thinking, Problem Solving, and Reasoning

In summary, in this module, we talked about thinking, problem solving, and reasoning, and the general definition we gave of thinking is really just any sort of cognitive process or mental process that goes beyond the information given. We covered several different distinctions among types of problems, these could be well-defined or ill-defined ones, and among types of thinking, for example, could be focussed thinking versus unfocussed thinking. Cognitive psychologists typically focus on focussed thinking with well-defined problems. We then discussed four different domain-general problem solving strategies, and when I say domain-general, I mean problem solving strategies that can be used across a wide variety of problems. Here, we talked about the generate and test technique, means-ends analysis, working backwards, and reasoning by analogies. And people can use these, again, in a wide variety of situations, independent of the context. We then moved on to talk about several different blocks to problem solving. These can be though of as barriers and constraints that prevent, or at least seriously interfere with, finding a successful solution to a problem. Here, we talked about mental set and lack of problem-specific expertise. We then finished off by talking about two types of reasoning: deductive, going from general to specific, and inductive, going from specific to general. Within deductive reasoning, we talked about categorical and conditional reasoning. We completed our discussion on deductive reasoning by covering two main theoretical approaches, that is, the rule-based approach, and the mental models approach.

11a – Introduction to Decision Making

In this section we're going to be talking about making decisions. We're going to begin by introducing the topic to you by talking about some of the main pieces of information that people use when making decisions. We're then going to move on to a very big area in the area of decision making, called heuristics. Heuristics can be thought of as mental shortcuts that help you arrive at a decision faster. Often, however, these mental shortcuts could cause the reasoner to arrive at an erroneous conclusion. We're then going to briefly talk about some of the main models of decision making, and then finish by talking about some recent work looking at decision making in the brain.

Let's begin by talking about some of the main sources of difficulty in making a decision. Oftentimes many decisions involve conflict and uncertainty. So first off, when we talk about conflict what we is, is that a decision maker must make trade-offs across different dimensions. So, for example, consider the case of shopping for a car. Well, you might look at the trade-off between a car's power versus its gas mileage, or, its options versus its price. In addition to conflict, there is often uncertainty, that is, the outcome of a decision often depends on uncertain variables. I think a good example of uncertainty in decision making in the real world is investing in the stock market. One can't be certain whether the stock that you've just invested in will grow dramatically, will fall dramatically, or will perform somewhere in the middle. This second source of difficulty, that of uncertainty, highlights one of the main aspects of decision making, that is, that many decisions involve uncertain events with unknown probabilities. This being the case, often researchers have focussed on probabilistic reasoning when looking at decision making, and we will as well, when we talk about some studies throughout this section of the course. Specifically, we'll be talking about how it is that we estimate probabilities, what strategies do we use, what information influences us, and the big question out of all of this is are we rational decision makers? Here, we define rationality in terms of following some sort of objective rule in judging probabilities – that is, not letting our beliefs or our expectations get in the way.

Interestingly, decision making is one of the areas in cognitive psychology where there is a large amount of research done in the applied world. For example, people have been studying how people make decisions in business, in medicine, in law, in countless areas. One example that's highlighted in the textbook is the research that's being conducted at the DRDC in Toronto. There are a number of applied researchers at that centre who are interested in issues of decision making. For example, they are examining how fatigue due to sleep loss affects decision making performance under a wide variety of conditions.

11b – Heuristics in Decision Making

One of the most popular areas in the field of decision making has to do with the examination of heuristics and biases, that is, ways that people go about solving problems and making decisions that can lead to systematic errors. You can think about these biases in decision making in much the same way as we thought about biases in perception, that is, these are errors of cognition that come about for understandable reasons, and that they provide us with information relevant to understanding normal functioning. So, the systematic biases that people have in decision making tell us a bit about how people go about making decisions in general.

We're going to briefly talk about six different heuristics in decision making: availability, representativeness, anchoring, illusory correlation, confirmation bias, and overconfidence. Let's start with the availability heuristic. Consider the following problem: in of four pages in a novel, how many words would you expect to find having the following form, that is, ending in "–ing," or having "n" as the second-last letter in the word. Think about this for a second, and then arrive at your answer. When given this problem, most people choose the first option, that is, words ending in "–ing." However, this is incorrect. Words ending in "–ing" cannot be more prevalent than words having the letter "n" as the second to last letter in the word, that is because words ending in "–ing" also have the letter "n" as the second-to-last letter in the word, so there will be at least as many words with the letter "n" as the second to last letter in the word as there are words ending in "–ing," and again, likely much more. However, people judge words ending in "–ing" as being more prevalent because they are easier to come to mind, and people use this ease of coming to mind, that is, they can think of words relatively easily ending in "–ing," as a measure of how probable that word is.

Let's now move on to a second heuristic, called the representativeness heuristic. So, consider the following problem: of all families having exactly six children, in what percentage do you think the exact birth order of boys and girls would be? Would it be a) boy, boy, boy, girl, girl, girl, or b) girl, boy, boy, girl, boy, girl. Most people given this problem intuitively select option b, and they do so because option b looks like it has less of a pattern, like it's more random. In fact however, both of these options, a and b, are equally likely to occur. The problem here is that most people general expect the random process, that is, whether you're going to have a boy or a girl, will always produce results that are relatively random looking. This is also related to what's known as the gambler's fallacy. Here, people mistakenly believe that each roll of a dice or each flip of a coin is dependent on the other. However, each one of these events is completely independent of the previous one. So, if you flip a coin five times and it comes up heads five times, the sixth coin still has an equal chance of coming up heads or tails.

The next heuristic that we're going to talk about is called anchoring. So, imagine an experiment where you're in a classroom of people, and you ask everyone with the last name to solve the following equation, 8x7x6x5x4x3x2x1, in less than five seconds. Conversely, those with last names ending from N-Z solve the problem 1x2x3x4x5x6x7x8, again, in less than five seconds. Now, even though these two problems would result in the identical answer, that is, 40 320, those given the first equation that started with 8 would have a larger estimation, in general, than those given the second equation that started with 1. What happens here is the first part of the problem serves as an anchor, and determines, to some degree, what the final answer will look like. Tversky and Kahneman, in 2000, explain these results in this way: They argue that people tend to perform the first few steps of multiplication and then extrapolate. So, those who started with 1x2x3 would begin with a smaller value than those who began with 8x7x6. So this first group would more severely underestimate the final result than the latter group.

Another prevalent heuristic is that of illusory correlation. That is where people see a relationship that one expects to see, even when no relationship exists. Take a look at the following table that can be found in your textbook. This table notes the frequency of those that were found to twist their hair with their fingers, versus not twist their hair with their fingers, and those that were deemed to be under stress, and those deemed to be not under stress. Now, looking at this table, try to determine what you think the relationship is between the likelihood that someone is going to twist their hair and be under stress. More often than not, people will look at this table and judge that there is a moderate relationship between the two. However, when you do the math, you basically would find out that people were just as likely to be a hair-twister or not a hair-twister when they were under stress or not under stress, that is, a quarter of those under stress and a quarter of those not under stress were hair-twisters. The point is that you might expect those who are under stress to be more likely to twist their hair than those that are not under stress, so people would typically see that relationship in those data, even though it does not exist. Put more generally, the associations that we bring to a situation often colour our judgement to such an extent that we see them even if they are not really there.

Another example of a heuristic is the confirmation bias, and I'm not going to go into depth, here, on this, because we talked about this previously when we talked about inductive reasoning in the previous section. I just want to highlight again, here, that the confirmation bias is the tendency to search only for information that will confirm one's own initial hunch or hypothesis, and to overlook or ignore other information. So, in the 2-4-6 task, when people generate triplets, what they typically do is they generate triplets that confirm their original rule that they have in mind, rather than trying to generate triplets that disconfirm their rule.

The final heuristic I want to talk about is that of overconfidence. Take a look at the following trivia questions. For each one choose one answer and rate your confidence in your answer on a scale from 0.5, which would be just guessing, to 1, completely certain. You might want to pause here a bit, just to work through these problems. The following figure is a typical example of how people's confidence is related to their performance or accuracy in that task. The diagonal dotted line depicts what the data would look like if people were perfectly calibrated, that is, if their confidence accurately measured or accurately tracked with their accuracy in the task. The degree to which the confidence-accuracy calibration deviates below this diagonal line indicates the degree of overconfidence that participants have. Here, confidence ratings are higher than actual accuracy. What these data highlight is that people's impressions of their own accuracy on a task are typically inflated.

I just finished introducing to you six different heuristics and biases. This is a very incomplete list, as there are many more heuristics and biases that have been found in literature. These heuristics and biases are an important area of research as understanding how and why the cognitive system goes wrong sometimes can help us understand how the mind works.

11c – Utility Models of Decision Making

In the preceding sections, we talked about how decision making often involves making decisions where pieces of information are in conflict – it typically involves information about probabilities, and also we talked about a number of heuristics and biases that show how decision making often goes awry. As in many areas of cognitive psychology, researchers have developed models that try to capture what it is that people do in these tasks. We're going to talk about expected utility theory, image theory, and recognition primed decision making.

Expected utility theory is a normative model of decision making. What that means is that it defines ideal performance under ideal circumstances. Because of this, it's mathematical in nature. It is often expressed or compared to a gamble. That is, making a decision, such a choosing a major in high school or university, can be compared to a gamble. For example, in most gambles you win or lose particular amounts of money depending on certain outcomes, and probability theory tells us – assuming fair coins, decks of cards, and the like – what the odds are of any outcome. The dollar amount won, or lost, tells us the monetary worth of each outcome, or, put another way, the expected value of that outcome. To derive the expected value, all you need to do is you multiply the probability of each outcome by the amount of money won or lost for that outcome, and summing these values over all possible outcomes. We can do this for all possible alternative gambles. Presumably, then, if offered a choice between two gambles, one would choose the better one by calculating the expected value of each one and choosing the gamble with the higher expected value. That would be the rational thing to do. Researchers in decision making have adopted the term expected utility, rather than expected value, because we often care about other aspects of life, rather than money, so utility can be a more general term that captures ideas like happiness, pleasure, and the satisfaction that comes from achieving one or more personal goals. You can apply this simple equation, where expected utility equals the sum of the probability of an event, multiplied by the utility of an event, over all events.

Let's work through some examples, here. So, take a look at the following table: here is an example of expected utility calculations for the decision of selecting a major in selective subjects. What you see in the first column is a list of a bunch of different majors: art, Asian studies, biology, chemistry, economics, and so on. The column next to that, you see probability of success. Here you have to use your imagination a little bit, and try to predict the probability of success in each of these majors. And, let's just say, for example, in this hypothetical situation, you determine that the probability of success for you, as an art major, would be quite high at 0.75, similarly, for sociology, quite high at 0.8, however, your success for mathematics would be quite low at 0.05, and physics, 0.01. And again, the other majors sit somewhere in between those extremes. You then multiply the probability of your success in these majors by the utility that each of these professions or each of these majors would afford you, that is, how much you would value this profession or this major. Then, to arrive at the expected utility of each major, you multiply the probability of success of each major by the utility for success, and then you add to that the probability of failure of that major to the utility of failure for that major.

Let's just work though a couple of examples here, just to make sure this is clear. Let's calculate the expected utility for art. So, the probability of success for art, as an art major, is 0.75. The utility for success is 10, and the utility for failure is 0. So, what we do, is to determine the value for the probability for success and utility for success, we take the 0.75 multiplied by 10. Now, that gives us a value of 7.5. And then what we do is we add to that the probability of failure with the utility of failure. And to do that we say okay, if the probability of success if 0.75, well then that means by definition the probability of failure is 0.25. So, we take the 0.25, multiplied by 0, which is going to be 0. So then we take the 7.5, plus 0, which gives us an expected utility value of 7.5. Let's just work through one more of these. So, let's look at biology, now. So, the probability of success for biology is 0.3. The utility for success is 25, and the utility for failure is 5, which means utility still, so this participant judged that even if they failed in biology, they still wouldn't feel that bad about it. Alrighty, so then what we would do, is we take the probably of success, which is 0.3, multiplied by the utility for success, which is 25, that gives us a value of 7.5. Then what we do is we multiply the probability of failure by the utility for failure. Now, here again, since the probability of success is 0.3, the probability for failure should be 0.7. So, we take 0.7, multiplied by the utility for failure, which is 5, which gives us a value of 3.5. Then we simply sum those two values, we sum the 7.5 with the 3.5, and that gives us an expected utility of 11. Now, once we've calculated expected utility for all of the majors, we can simply look down the column and find out which one has the largest value. And here, what it looks like, it is chemistry, and if we are purely rational decision makers we would declare chemistry as our major. The idea being is that chemistry should offer us the largest utility or the biggest utility, and thus we should be happiest with that choice.

As you can probably imagine, expected utility theory has been critiques on a number of grounds, the main issue being, is that although it's a normative account – that is, an idealized way in which people should make decisions, or could make decisions, to optimize utility – people rarely go through such a process. In contrast to expected utility theory, other theories have arisen that seem to be a little bit more realistic in terms of how people actually go about making decisions. One such theory is image theory, and the basic idea behind this view is that people typically whittle down their choices to a small few before they do any active consideration. And this again related back to the recurring theme throughout this course, is that we have a very limited amount of cognitive capacity, and that we can only handle a certain, small amount of information at any given time. Proponents of this view argue that most of the decision making work is done during pre-choice screen of options. This pre-screening allows people to make more deliberate and conscious decisions on a small number of alternatives, rather than trying to weigh the utilities of all options. They do this by asking themselves whether a new goal, plan, or alternative is compatible with three images: the value image, that's containing the decision maker's values, morals, and principles, the trajectory image, that contains the decision maker's goals and aspirations for the future, and the strategic image, that is the way in which the decision maker plans to attain his or her goals. According to image theory, options that are judged incompatible with any three of these images are automatically dropped from further consideration. Ideally what happens then is that the reasoner is left with only one or two options to give careful consideration.

The final decision making theory that I'm going to talk about is recognition primed decision making. This area of research has borrowed much from the area of expertise. Here, when experts are making decisions from within their own domain of expertise, they rely more on intuition, mental simulation, or making metaphors or analogies and recalling or creating stories about previous experiences that they've had in that domain. That is, with a lot of experience in a specific domain, the requirement to use conscious, deliberate, or utility-type strategies diminishes, and this gets replaced with a more intuitive , unconscious-like decision making process. In addition, as a decision maker takes stock of a new situation, they compare it to other situations they've previously encountered in the past and make direct analogies between them. Of course, as we've seen in the previous section, when we talked about heuristics and biases, this can be problematic. Specifically, one's intuitions and expectations may lead to erroneous decision making.

11d – Decision Making, Emotions and the Brain

In this last section, we're going to be talking about decision making, emotions, and the brain, and I just want to highlight the field of neuroeconomics, as this is a field that really focuses in on this. And this is a new field that examines how the brain interacts with the environment to enable us to make complex decisions. What some scientists have argued is that you can't really fully grasp how human beings make decisions in the world without acknowledging the role of emotion. Well, what brain regions are involved with decision making? Well, it probably doesn't surprise you that the frontal lobes play a huge part in decision making. This has been known for a number of years, at least as early as the case of Phineas Gage. Since that time, numerous studies have examined the brain regions that underlie decision making. I'm going to highlight one study here that I think really highlights how cognition and emotion interact when we're making decisions. In this task, Sanfey and colleagues presented participants with a task called the ultimatum game. In this task, you are to imagine that you are working with a partner, and you have the opportunity to split $10 with that partner. You'll receive a one-time offer from your partner, and then you have the opportunity to either accept or reject this offer. If you accept the offer made by your partner, you split the money as determined. If it is rejected, you both go home with nothing. So, if the partner offers you $4, if you accept the $4, you get $4, the partner gets $6. If you reject the $4, you get nothing, and your partner gets nothing. So, think about this for a moment. What would you do if your partner offered you $5? Would you accept that offer and split it, $5 each? How about if the partner offered you $1? Would you take that dollar and let your partner have $9? Well, rationally, if you think about it, one dollar is better than no dollars – if you reject that $1 offer, you will get nothing. What Sanfey found was that many participants actually would reject these unfair offers, that is, they would rather leave with nothing and ensure that their partner had nothing, than leave with $1 when they knew that that was an unfair offer. In addition, these unfair offers were followed by activations in the insula cortex and the dorsolateral prefrontal cortex. The insula has been predominately indicated in response to negative emotional states, such as anger and disgust. So, even though the rational brain, perhaps the prefrontal cortex, should be telling these participants to accept, no matter what the offer is, because any money is better than no money, the insula gets in the way, and in some ways, this emotional response trumps the cognitive response and determines how the decision will be made. Numerous studies have also converged on this idea that complex decision making involving real-world problems often involves this interplay between emotion and those regions of the brain that subserve emotion and cognition. A summary of some of these brain regions can be found in the following figure. In the previous study we discussed the prefrontal cortex and the insula. Other neuroimaging studies of decision making have also found that the anterior cinglulate cortex, that is, a region of the brain found to be involved in error detection and conflict monitoring, as well as the amygdala, which is also known to be involved in processing emotion, work together to help us make decisions in the real world.

11e - Summary

In summary, we began our discussion of decision making by talking about how decisions are often made under conflict and about uncertain variables or events. We then moved on and discussed how there are many heuristics and biases that we use when making decisions. We discussed six of them: the availability heuristic, the representativeness heuristic, anchoring, illusory correlation, confirmation bias and overconfidence. The key thing to remember with these heuristics and biases are that they typically work well for us, and again, they typically serve us well in that they allow us to make decisions efficiently. However, they can lead to erroneous responses. After discussing heuristics and biases, we talked about three utility models of decision making. Specifically, we talked about the expected utility theory, and again, this is the normative model of decision making. We then talked about image theory, and recognition primed decision making – these are more descriptive accounts, in that they describe, more or less, what people actually do when making decisions, not the ideal thing that people should do. We ended our discussion on decision making by talking about the role of emotions, cognition, and the brain. Here, I highlighted how the field of neuroeconomics has recently emerged as a discipline that examines how emotion and cognition jointly contribute to real-life decisions, and we talked about some of the key brain regions that subserve this interplay between cognition and emotion.

12a | Introduction to Individual, Aging, and Gender Differences in Cognition

We've spent an entire term talking about human cognitive processes. You now have a better understanding of the myriad of amazing things your mind does, most of the time without you even thinking about it, or realizing it.

In talking about these fantastic abilities, however, we did so assuming that they are more or less the same for everyone. Other than those instances in which we discussed individual case studies, we talked about cognitive processes that are general to everyone. Even when we talked about case studies, part of our interest was in learning what they said about human cognition, in general. As we noted earlier, the bulk of the experimental work in cognition is based on testing university students, like yourselves, and making generalizations to the larger population. Although there is a lot of merit in this approach, for instance, we do know that cognitive processes unfold pretty similarly for most people, it is also the case that this approach selectively ignores another important area of study.

That is, generalizing to large populations can often ignore the fact that there are, within any group, individual differences. Although cognitive processes may be similar within a group, there are still differences in ability, and in development. There are psychologists who are interested in studying individual differences and the underlying causes.

In this unit, we will discuss three major sources of individual differences in cognitive skills- intelligence, the role of practice and expertise, and bilingualism. These are 3 of the most studied areas associated with individual differences.

We will discuss another factor that leads to differences in cognitive abilities- and this one is associated with changes in cognition within an individual. There are clear effects of aging on cognitive abilities, and researchers are interested in understanding why these arise./

Finally, we will talk about another large source of individual differences in cognition, and this is the role of gender. In examining these differences, we will also try to determine whether the differences are associated with sex- the fact that we are born male or female- or are of gender and our socialization as male or female.

12b | Individual Differences in Cognition

Everyone has some notion of what it means to be intelligent. We can think of individuals that we believe are very intelligent, and those that are less so. That is, we know that there are clear and important differences in intelligence across a population, and that these differences are often associated with differences in achievement. When we speak of intelligence, though, what exactly are we talking about?

Is intelligence one general mental ability that promotes us doing well or less well on all kinds of tasks and processes? Or is intelligence something more complex? Are there multiple intelligences? We'll think about this issue when we discuss differences in intelligence.

Generally speaking, more intelligent people are said to be those that can carry out a basic cognitive process more efficiently. Keating and Bobbitt demonstrated in 1978, as you see in the figure in front of you, that higher-ability children and adults were better able to acquire, store, and manipulate basic information than were same-age, normal-ability peers. That is, our ability to do things like retrieve information from memory improves as we age, but even within an age group there are differences in ability that are associated with intelligence. So, what then is this thing called intelligence?

In their book called the Bell Curve, Hernstein and Murray argued that there is a general cognitive ability, and that this ability is relatively stable over the course of a person's lifetime. More crucially, they argue that this ability is what we are actually talking about when we talk about someone's score on a standardized test of academic aptitude, like an IQ test. They believe that if an IQ test is properly administered, it does not bias against social, economic, ethnic or racial groups and that intelligence is something that is largely inherited from our parents.

In contrast, Gardner takes a view that is very different. His view is that there is not one global concept called intelligence, but that people can express intelligence on at least 6 different dimensions. As you see in the Figure in front of you, these dimensions include linguistic intelligence, logical-mathematical intelligence, musical intelligence, bodily-kinesthetic intelligence, spatial intelligence, interpersonal intelligence, intrapersonal intelligence, naturalist intelligence, and existential intelligence. This makes intuitive sense, as we have all known someone who really seems to excel in one or two of these areas, perhaps they are very strong students in math and very musical, but seem to struggle more in other areas, such as writing or speaking. Gardner claims that these differences are real and measurable, and that we would even do well to tailor our career choices to our individual strengths.

There is still a great deal of debate about what, exactly, intelligence is, and whether standardized tests really tell us anything at all about it.

We've already talked about the role of practice earlier in the course. We all know that practice typically makes us better at something, and in extreme cases, lots of practice can push our performance into the area of expert performance. When we discuss expert performance, do we mean performance that is quantitatively different from normal performance, or is there something special, or qualitiatively different, about expert performance.

Eyal Reingold at the University of Toronto, and his colleagues, have extensively studied expert performance in chess players. Reingold showed that expertise in chess is associated not just with going faster, but with being able to use memory in a way that is very different from how non-experts use memory.

In their experiments, expert chess players and non experts were given very brief views of chess boards, somewhere mid-game, with a considerable number of pieces on them. After a 5-second view, the participants were given a blank chess board, and were asked to reconstruct the board they had just viewed. Experts were able to reconstruct the positions of about 65% of the chess pieces, compared to about 20% for the non-experts. In terms of our unit on memory, it is believed that the experts were able to chunk the chess pieces into meaningful groups, whereas the novices could not. This was further supported by the finding that when chess pieces were scattered in a non-meaningful way, or were randomly placed on the board, experts performed no better than non-experts. In that case, there was no benefit from chunking in memory.

Later research by Reingold in which he actually monitored the eye movements of the experts and novices while they were examining the chess board showed that they actually pay attention to different areas of the board during the 5-second view.

Thus, it appears that experts are better able to recruit their cognitive processes in order to perform a task than are non-experts.

One of the notable things about Canada is that it is officially a bilingual nation, and many of its citizens have experience in two languages. What do we know about how bilingualism affects cognitive abilities?

If you remember back to our unit on attention, you'll remember that part of successful behaviour is not only responding to the information one is supposed to respond to, but also being able to ignore the information that we are not supposed to process. Bilingualism can be considered a massive exercise in just such a thing. That is, a person proficient in multiple languages must always exercise control in responding with the appropriate language. A word spelled in English will not be meaningful if one attempts to read it in French, for instance.

Ellen Bialystok of York University is a leader in the study of bilingualism. She has shown that the ability to attend selectively to relevant information, and to ignore distracting information, develops earlier in bilingual, than in monolingual children. As shown in the Figure of the RAT_MAN in front of you, she has also shown that when appropriate, bilinguals are more successful than monolinguals at seeing multiple possibilities from a common stimulus. That is, bilinguals shown the Rat-man in the far left part of the figure are better able to see it both as a rat (center part of the figure) and as a man (far right part of the figure) than are monolinguals. Bilinguals appear, then, to be more flexible when appropriate.

It is clear, then, that being bilingual confers an advantage in terms of attentional control. From an early age, on, bilinguals are better at directing their behaviour to relevant stimuli, and this advantage continues on until older age (although it is diminished somewhat in the prime of adulthood). But, being bilingual does not come without costs. It has also been shown that bilinguals, when compared to monolinguals on a single language, do not do as well with things like retrieving individual words from memory. This makes sense when one understands that a bilingual, being proficient in multiple languages, likely does not spend as much time on any one language as does a monolingual.

12c | Effects of Aging and Cognition

One of the facts of life is that we all age. We understand that as we age our bodies will change, and we do not expect to run as quickly or to be able to lift as much weight at age 70 as we can at age 20. What about mental abilities? What can we expect as we age?

There are profound changes that can come about with aging such as seen in Alzheimer's disease, but what about normal aging? How will memory be affected by normal aging? There is good news, and bad news. First, our semantic memory generally increases with increasing age. As we live longer, experience more things, learn more things, we are able to store that information away, leading to richer semantic memory later in life. Our ability to access memory in an implicit manner remains relatively stable across life. What can change, however, is our ability to explicitly access a particular episode. As we build up more life experiences, it sometimes gets more difficult to remember exactly which experience was associated with what time.

This decline in remembering which experience was associated with which event is a decline in what we referred to as episodic memory. Episodic memory relies heavily on the frontal lobes, and research has shown that later in life we don't encode information or retrieve it as well as we did when we were younger. Interestingly, we often have a specific difficulty with what we call source memory. That is, we may remember that we heard or saw something, but we may not remember exactly who told us, or where we saw it.

Research has shown that although changes in memory are somewhat inevitable, we can help postpone them or lessen them by keeping ourselves physically and mentally healthy. Proper diet, regular exercise- both mental and physical- and increased reliance on memory strategies can all be helpful.

It is clear that we can document changes in mental abilities, like memory, with advancing age. Why do these occur? There are a number of possibilities that have been advanced by theorists. One general argument is that we just get slower in terms of the speed of our mind. Slower processing can have all kinds of implications. One possibility is that if we are processing something, other information that we might also need might decay in the extra time it takes to process the first bit of information.

A second interesting possibility is that aging is associated with a decline in inhibitory processes. This means that as we get older, it is increasingly difficult to determine what we should pay attention to, and what we should not pay attention to. There have been sad, and informative, reports of elderly individuals overdosing on medication, possibly because they have been confused by seeing take"20 mg 2x per day" and taking 20 pills. In that case, they possibly were not able to inhibit the interpretation that 20 refers to a number of pills, rather than a dosage.

This possible change in inhibitory processes is also associated with a general decline in the availability of attentional resources. It has been shown that not only do we need resources to focus attention on something we want to process, but also to avoid processing, or shut-out, something we do not want to process. If those resources are lacking, we might have more difficulty blocking out the irrelevant stuff and have too little resources to fully activate the things we want to process.

Finally, there has been a specific model, called HAROLD, that associates changes with aging with changes in the frontal lobe of the brain. This model says that the types of executive processes that become impaired as we get older are housed in the frontal lobes. As the frontal lobes deteriorate, so do the processes they are responsible for.

The take home message here, however, is hopeful. We can all benefit from the old adage use it or lose it. Practice and exercise (and overall good health) have been shown to help ameliorate the changes associated with aging. In addition, they make for a happier here and now!

12d | Gender Differences in Cognitive Abilities

The final source of individual differences that we'll discuss is gender. Before we talk about where these differences appear, however, we'll briefly talk about what they might mean. That is, if we say that women generally perform better on some task than do men, we do not necessarily mean that every woman will out-perform every man. There are a number of ways that mean scores can differ, and this needs to be considered as well. Moreover, it is often too simple to say that one gender outperforms another on some task, because those differences can be associated with developmental differences, and once both genders mature, those differences might not be present. So, when discussing gender differences, or any individual differences, it is important to think about what is really being argued.

Having said that, there are some cognitive areas that have revealed pretty consistent individual differences that can be seen between men and women. For instance, men typically outperform women on some visual-spatial tasks, such as mental rotation- we talked about that task in our imagery unit, and spatial relation tasks- but women outperform men on visual tasks requiring observers to determine when the location of an object has changed.

Verbal, or language-based, tasks have also been studied extensively. Generally speaking, language skills develop in females earlier than they do in males, and women typically stay more verbally fluent than males throughout their lifespans. This obviously does not mean that men are linguistically deficient, however. There are many excellent male writers and debaters. One interesting possibility is that the sex based individual differences that we observe are associated with documented differences in brain organization between men and women. Generally speaking, it is known that female brains tend to be less lateralized then are male brains. This means that whereas men's brains are highly specialized in terms of undertaking certain processes in specific areas, this is less the case with women. Because certain tasks tend to be more spread out in women, they often show better recovery than men following brain injury. This is specifically the case with language. Because women's language is less lateralized than men's recovery of language after stroke is often better for women than for men.

12e | Summary of Individual, Aging and Gender Differences in Cognition

We've seen in this unit that despite the fact that there is a lot we can say about general cognitive functioning, we can learn a lot by investigating individual differences in cognition.

Individual differences are seen in intelligence. Whether this indicates a differences in one general ability that affects many tasks and processes, or indicates many different sets of abilities is still of robust debate.

Intelligent, or expert, behaviour in any domain involves better recruitment and use of cognitive skills in the so-called expert behaviour. Some of this might indicate an innate ability- being born with a predisposition towards a particular skill- but hours of practice likely play a very large role, as well.

Bilingualism is also a source of important and documented individual differences. Bilinguals, from an early age, show superior abilities at attentional control tasks than do monolinguals.

We have also discussed individual differences that occur within the individual- the way in which our cognitive skills change as we age. The most profound age-related deficits are associated with tests of episodic memory. As we collect more information, it seems more difficult to be able to sort through it. This change might be associated with overall slowing, with the lost ability to inhibit irrelevant information, with decreased attentional capacity, and has been shown to be associated with brain changes in the frontal lobes.

Finally, we closed the unit thinking about individual differences that are associated with whether we are male or female. There are documented differences in both visuo-spatial and verbal tasks, and it remains to be seen how much of any difference can be accounted for by the fact that we are born male vs. female and how much should be attributed to whether we are raised male or female.

Taken together, our unit on individual differences gives us a more nuanced view on all the material that we've covered throughout the term. We talk about general truths, but can also learn from how we differ from one another.