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 17th and 18th 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.