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.

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.