COGNITIVE PSYCHOLOGY

PSYCH

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COLLEGE OF THE CANYONS

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Chapter 1 - History of Cognitive Psychology

Definition of Cognitive Psychology

Imagine all of your thoughts as if they were physical entities, swirling rapidly inside your mind. How is it possible that the brain is able to move from one thought to the next in an organized, orderly fashion? The brain is endlessly perceiving, processing, planning, organizing, and remembering—it is always active. Yet, you don't notice most of your brain's activity as you move throughout your daily routine. This is only one facet of the complex processes involved in cognition. Simply put, cognition is thinking, and it encompasses the processes associated with perception, knowledge, problem solving, judgment, language, and memory. Scientists who study cognition are searching for ways to understand how we integrate, organize, and utilize our conscious cognitive experiences without being aware of all of the unconscious work that our brains are doing (for example, Kahneman, 2011).

Cognition

Upon waking each morning, you begin thinking—contemplating the tasks that you must complete that day. In what order should you run your errands? Should you go to the bank, the cleaners, or the grocery store first? Can you get these things done before you head to class or will they need to wait until school is done? These thoughts are one example of cognition at work. Exceptionally complex, cognition is an essential feature of human consciousness, yet not all aspects of cognition are consciously experienced.

Cognitive psychology is the field of psychology dedicated to examining how people think. It attempts to explain how and why we think the way we do by studying the interactions among human thinking, emotion, creativity, language, and problem solving, in addition to other cognitive processes. Cognitive psychologists strive to determine and measure different types of intelligence, why some people are better at problem solving than others, and how emotional intelligence affects success in the workplace, among countless other topics. They also sometimes focus on how we organize thoughts and information gathered from our environments into meaningful categories of thought, which will be discussed later.

Historical Roots: History of Cognition

"Cognition" is a term for a wide swath of mental functions that relate to knowledge and information processing.

LEARNING OBJECTIVES

- **Name major figures in the history of cognition.**

KEY TAKEAWAYS

Key Points

- **Cognition is the set of all mental abilities and processes related to knowledge, including attention, memory, judgment, reasoning, problem solving, decision making, and a host of other vital processes.**
- **Aristotle, Descartes, and Wundt are among the earliest philosophers who dealt specifically with the act of cognition.**
- **Cognitive processes can be analyzed through the lenses of many different fields, including linguistics, anesthesia, neuroscience, education, philosophy, biology, computer science, and psychology.**

Key Terms

- **cognition: The set of all mental abilities and processes related to knowledge.**
- **cognitive science: An interdisciplinary field that analyses mental functions and processes.**

Cogito Ergo Sum

Maybe you've heard the phrase *I think , therefore I am*, or perhaps even the Latin version: *Cogito ergo sum*. This simple expression is one of enormous philosophical importance, because it is about the act of thinking. Thought has been of fascination to humans for many centuries, with questions like *What is thinking?* and *How do people think?* and *Why do people think?* troubling and intriguing many philosophers, psychologists, scientists, and others.

The word "cognition" is the closest scientific synonym for thinking. It comes from the same root as the Latin word *cogito*, which is one of the forms of the verb "to know." Cognition is the set of all mental abilities and processes related to knowledge, including attention, memory, judgment, reasoning, problem solving, decision making, and a host of other vital processes.

Human cognition takes place at both conscious and unconscious levels. It can be concrete or abstract. It is intuitive, meaning that nobody has to learn or be taught how to think. It just happens as part of being human. Cognitive processes use existing knowledge but are capable of generating new knowledge through logic and inference.

History of Cognition

People have been studying knowledge in various ways for centuries. Some of the most important figures in the study of cognition are:

Aristotle (384–322 BCE)

The study of human cognition began over two thousand years ago. The Greek philosopher Aristotle was interested in many fields, including the inner workings of the mind and how they affect the human experience. He also placed great importance on ensuring that his studies and ideas were based on empirical evidence (scientific information that is gathered through observation and careful experimentation).

Descartes (1596–1650)

René Descartes was a seventeenth-century philosopher who coined the famous phrase *I think, therefore I am* (albeit in French). The simple meaning of this phrase is that the act of thinking proves that a thinker exists. Descartes came up with this idea when trying to prove whether anyone could truly know anything despite the fact that our senses sometimes deceive us. As he explains, "We cannot doubt of our existence while we doubt."

Wilhelm Wundt (1832–1920)

Wilhelm Wundt is considered one of the founding figures of modern psychology; in fact, he was the first person to call himself a psychologist. Wundt believed that scientific psychology should focus on introspection, or analysis of the contents of one's own mind and experience. Though today Wundt's methods are recognized as being subjective and unreliable, he is one of the important figures in the study of cognition because of his examination of human thought processes.

Cognition, Psychology, and Cognitive Science

The term "cognition" covers a wide swath of processes, everything from memory to attention. These processes can be analyzed through the lenses of many different fields: linguistics, anesthesia, neuroscience, education, philosophy, biology, computer science, and of course, psychology, to name a few. Because of the number of disciplines that study cognition to some degree, the term can have different meanings in different contexts. For example, in psychology, "cognition" usually refers to processing of neural information; in social psychology the term "social cognition" refers to attitudes and group attributes. These numerous approaches to the analysis of cognition are synthesized in the relatively new field of cognitive science, the interdisciplinary study of mental processes and functions.

Mnemonic Devices

What is the nature of thought/how is it organized?

Concepts and Prototypes

The human nervous system is capable of handling endless streams of information. The senses serve as the interface between the mind and the external environment, receiving stimuli and translating it into nervous impulses that are transmitted to the brain. The brain then processes this information and uses the relevant pieces to create thoughts, which can then be expressed through language or stored in memory for future use. To make this process more complex, the brain does not gather information from external environments only. When thoughts are formed, the brain also pulls information from emotions and memories. Emotion and memory are powerful influences on both our thoughts and behaviors.

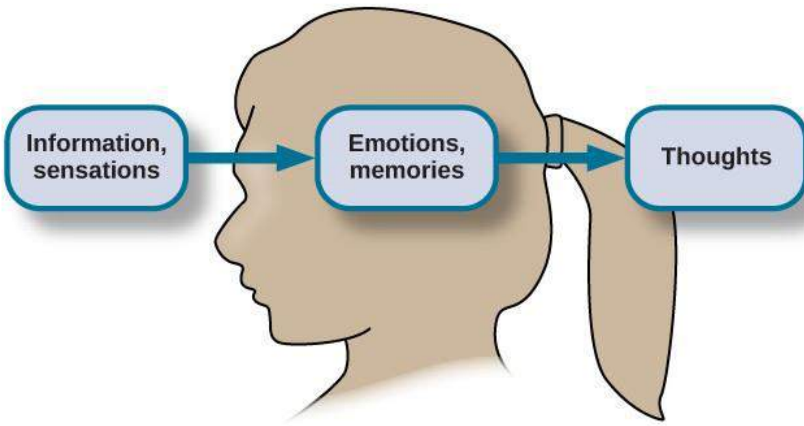


Figure 1. Sensations and information are received by our brains, filtered through emotions and memories, and processed to become thoughts.

In order to organize this staggering amount of information, the brain has developed a file cabinet of sorts in the mind. The different files stored in the file cabinet are called concepts. Concepts are categories or groupings of linguistic information, images, ideas, or memories, such as life experiences. Concepts are, in many ways, big ideas that are generated by observing details, and categorizing and combining these details into cognitive structures. You use concepts to see the relationships among the different elements of your experiences and to keep the information in your mind organized and accessible.

Concepts are informed by our semantic memory (you learned about this concept when you studied memory) and are present in every aspect of our lives; however, one of the easiest places to notice concepts is inside a classroom, where they are discussed explicitly. When you study United States history, for example, you learn about more than just individual events that have happened in America's past. You absorb a large quantity of information by listening to and participating in discussions, examining maps, and reading first-hand accounts of people's lives. Your brain analyzes these details and develops an overall understanding of American history. In the process, your brain gathers details that inform and refine your understanding of related concepts like democracy, power, and freedom.

Concepts can be complex and abstract, like justice, or more concrete, like types of birds. In psychology, for example, Piaget's stages of development are abstract concepts. Some concepts, like tolerance, are agreed upon by many people, because they have been used in various ways over many years. Other concepts, like the characteristics of your ideal friend or your family's birthday traditions, are personal and individualized. In this way, concepts touch every aspect of our lives, from our many daily routines to the guiding principles behind the way governments function.

Another technique used by your brain to organize information is the identification of prototypes for the concepts you have developed. A prototype is the best example or representation of a concept. For example, for the category of civil disobedience, your prototype could be Rosa Parks. Her peaceful resistance to segregation on a city bus in Montgomery, Alabama, is a recognizable example of civil disobedience. Or your prototype could be Mohandas Gandhi, sometimes called Mahatma Gandhi ("Mahatma" is an honorific title).

Figure 2. In 1930, Mohandas Gandhi led a group in peaceful protest against a British tax on salt in India.

Mohandas Gandhi served as a nonviolent force for independence for India while simultaneously demanding that Buddhist, Hindu, Muslim, and Christian leaders—both Indian and British—collaborate peacefully. Although he was not always successful in preventing violence around him, his life provides a steadfast example of the civil disobedience prototype (Constitutional Rights Foundation, 2013). Just as concepts can be abstract or concrete, we can make a distinction between concepts that are functions of our direct experience with the world and those that are more artificial in nature.

Natural and Artificial Concepts

In psychology, concepts can be divided into two categories, natural and artificial. Natural concepts are created "naturally" through your experiences and can be developed from either direct or indirect experiences. For example, if you live in Essex Junction, Vermont, you have probably had a lot of direct experience with snow. You've watched it fall from the sky, you've seen lightly falling snow that barely covers the windshield of your car, and you've shoveled out 18 inches of fluffy white snow as you've thought, "This is perfect for skiing." You've thrown snowballs at your best friend and gone sledding down the steepest hill in town. In short, you know snow. You know what it looks like, smells like, tastes like, and feels like. If, however, you've lived your whole life on the island of Saint Vincent in the Caribbean, you may never have actually seen snow, much less tasted, smelled, or touched it. You know snow from the indirect experience of seeing pictures of falling snow—or from watching films that feature snow as part of the setting. Either way, snow is a natural concept because you can construct an understanding of it through direct observations or experiences of snow.

(a) (b)

Figure 3. (a) Our concept of snow is an example of a natural concept—one that we understand through direct observation and experience. (b) In contrast, artificial concepts are ones that we know by a specific set of characteristics that they always exhibit, such as what defines different basic shapes. (credit a: modification of work by Maarten Takens; credit b: modification of work by "Shayan (USA)"/Flickr)

An artificial concept, on the other hand, is a concept that is defined by a specific set of characteristics. Various properties of geometric shapes, like squares and triangles, serve as useful examples of artificial concepts. A triangle always has three angles and three sides. A square always has four equal sides and four right angles. Mathematical formulas, like the equation for area (length × width) are artificial concepts defined by specific sets of characteristics that are always the same. Artificial concepts can enhance the understanding of a topic by building on one another. For example, before learning the concept of "area of a square" (and the formula to find it), you must understand what a square is. Once the concept of "area of a square" is understood, an understanding of area for other geometric shapes can be built upon the original understanding of area. The use of artificial concepts to define an idea is crucial to communicating with others and engaging in complex thought. According to Goldstone and Kersten (2003), concepts act as building blocks and can be connected in countless combinations to create complex thoughts.

Schemata

A schema is a mental construct consisting of a cluster or collection of related concepts (Bartlett, 1932). There are many different types of schemata, and they all have one thing in common: schemata are a method of organizing information that allows the brain to work more efficiently. When a schema is activated, the brain makes immediate assumptions about the person or object being observed.

There are several types of schemata. A role schema makes assumptions about how individuals in certain roles will behave (Callero, 1994). For example, imagine you meet someone who introduces himself as a firefighter. When this happens, your brain automatically activates the "firefighter schema" and begins making assumptions that this person is brave, selfless, and community-oriented. Despite not knowing this person, already you have unknowingly made judgments about him. Schemata also help you fill in gaps in the information you receive from the world around you. While schemata allow for more efficient information processing, there can be problems with schemata, regardless of whether they are accurate: Perhaps this particular firefighter is not brave, he just works as a firefighter to pay the bills while studying to become a children's librarian.

An event schema, also known as a cognitive script, is a set of behaviors that can feel like a routine. Think about what you do when you walk into an elevator. First, the doors open and you wait to let exiting passengers leave the elevator car. Then, you step into the elevator and turn around to face the doors, looking for the correct button to push. You never face the back of the elevator, do you? And when you're riding in a crowded elevator and you can't face the front, it feels uncomfortable, doesn't it? Interestingly, event schemata can vary widely among different cultures and countries. For example, while it is quite common for people to greet one another with a handshake in the United States, in Tibet, you greet someone by sticking your tongue out at them, and in Belize, you bump fists (Cairns Regional Council, n.d.)

Figure 4. What event schema do you perform when riding in an elevator? (credit: "Gideon"/Flickr)

Because event schemata are automatic, they can be difficult to change. Imagine that you are driving home from work or school. This event schema involves getting in the car, shutting the door, and buckling your seatbelt before putting the key in the ignition. You might perform this script two or three times each day. As you drive home, you hear your phone's ring tone. Typically, the event schema that occurs when you hear your phone ringing involves locating the phone and answering it or responding to your latest text message. So without thinking, you reach for your phone, which could be in your pocket, in your bag, or on the passenger seat of the car. This powerful event schema is informed by your pattern of behavior and the pleasurable stimulation that a phone call or text message gives your brain. Because it is a schema, it is extremely challenging for us to stop reaching for the phone, even though we know that we endanger our own lives and the lives of others while we do it (Neyfakh, 2013).

Figure 5.Texting while driving is dangerous, but it is a difficult event schema for some people to resist.

Remember the elevator? It feels almost impossible to walk in and *not* face the door. Our powerful event schema dictates our behavior in the elevator, and it is no different with our phones. Current research suggests that it is the habit, or event schema, of checking our phones in many different situations that makes refraining from checking them while driving especially difficult (Bayer & Campbell, 2012). Because texting and driving has become a dangerous epidemic in recent years, psychologists are looking at ways to help people interrupt the "phone schema" while driving. Event schemata like these are the reason why many habits are difficult to break once they have been acquired. As we continue to examine thinking, keep in mind how powerful the forces of concepts and schemata are to our understanding of the world.

Summary

In this section, you were introduced to cognitive psychology, which is the study of cognition, or the brain's ability to think, perceive, plan, analyze, and remember. Concepts and their corresponding prototypes help us quickly organize our thinking by creating categories into which we can sort new information. We also develop schemata, which are clusters of related concepts. Some schemata involve routines of thought and behavior, and these help us function properly in various situations without having to "think twice" about them. Schemata show up in social situations and routines of daily behavior.

Self Check Questions

Critical Thinking Questions

1. Describe a social schema that you would notice at a sporting event.
2. Explain why event schemata have so much power over human behavior.

Personal Application Question

3. Describe a natural concept that you know fully but that would be difficult for someone else to understand and explain why it would be difficult.

Answers

1. Answers will vary. When attending a basketball game, it is typical to support your team by wearing the team colors and sitting behind their bench.
2. Event schemata are rooted in the social fabric of our communities. We expect people to behave in certain ways in certain types of situations, and we hold ourselves to the same social standards. It is uncomfortable to go against an event schema—it feels almost like we are breaking the rules.

Glossary

- **Artificial Concept:** concept that is defined by a very specific set of characteristics
- **Cognition:** thinking, including perception, learning, problem solving, judgment, and memory
- **Cognitive Psychology:** field of psychology dedicated to studying every aspect of how people think
- **Concept:** category or grouping of linguistic information, objects, ideas, or life experiences
- **Cognitive Script:** set of behaviors that are performed the same way each time; also referred to as an event schema
- **Event Schema:** set of behaviors that are performed the same way each time; also referred to as a cognitive script
- **Natural Concept:** mental groupings that are created "naturally" through your experiences
- **Prototype:** best representation of a concept
- **Role Schema:** set of expectations that define the behaviors of a person occupying a particular role
- **Schema:** (plural = schemata) mental construct consisting of a cluster or collection of related concepts

Early Psychology—Structuralism and Functionalism

LEARNING OBJECTIVES

- **Define structuralism and functionalism and the contributions of Wundt and James to the development of psychology**

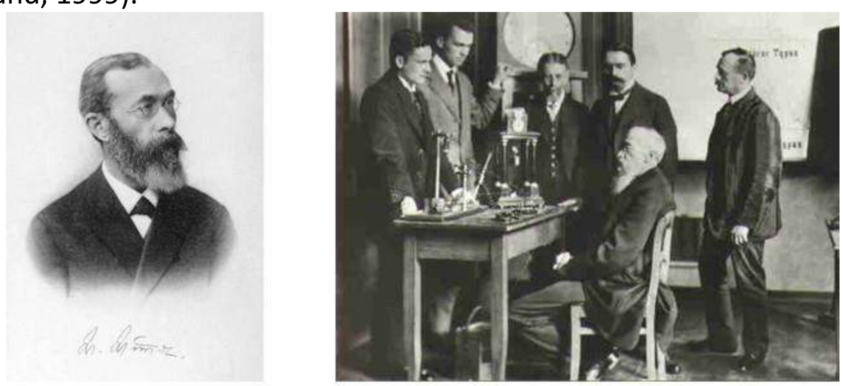
Psychology is a relatively young science with its experimental roots in the 19th century, compared, for example, to human physiology, which dates much earlier. As mentioned, anyone interested in exploring issues related to the mind generally did so in a philosophical context prior to the 19th century. Two men, working in the 19th century, are generally credited as being the founders of psychology as a science and academic discipline that was distinct from philosophy. Their names were Wilhelm Wundt and William James.

School of psychology	**Description**	**Important contributors**
Structuralism	Uses the method of introspection to identify the basic elements or "structures" of psychological experience	Wilhelm Wundt, Edward B. Titchener
Functionalism	Attempts to understand why animals and humans have developed the particular psychological aspects that they currently possess	William James
Psychodynamic	Focuses on the role of our unconscious thoughts, feelings, and memories and our early childhood experiences in determining behavior	Sigmund Freud, Carl Jung, Alfred Adler, Erik Erickson
Behaviorism	Based on the premise that it is not possible to objectively study the mind, and therefore that psychologists should limit their attention to the study of behavior itself	John B. Watson, B. F. Skinner
Cognitive	The study of mental processes, including perception, thinking, memory, and judgments	Hermann Ebbinghaus, Sir Frederic Bartlett, Jean Piaget
Social-cultural	The study of how the social situations and the cultures in which people find themselves influence thinking and behavior	Fritz Heider, Leon Festinger, Stanley Schachter

Table 1. The Most Important Approaches (Schools) of Psychology

Wundt and Structuralism

Wilhelm Wundt (1832–1920) was a German scientist who was the first person to be referred to as a psychologist. His famous book entitled *Principles of Physiological Psychology* was published in 1873. Wundt viewed psychology as a scientific study of conscious experience, and he believed that the goal of psychology was to identify components of consciousness and how those components combined to result in our conscious experience. Wundt used introspection (he called it "internal perception"), a process by which someone examines their own conscious experience as objectively as possible, making the human mind like any other aspect of nature that a scientist observed. Wundt's version of introspection used only very specific experimental conditions in which an external stimulus was designed to produce a scientifically observable (repeatable) experience of the mind (Danziger, 1980). The first stringent requirement was the use of "trained" or practiced observers, who could immediately observe and report a reaction. The second requirement was the use of repeatable stimuli that always produced the same experience in the subject and allowed the subject to expect and thus be fully attentive to the inner reaction. These experimental requirements were put in place to eliminate "interpretation" in the reporting of internal experiences and to counter the argument that there is no way to know that an individual is observing their mind or consciousness accurately, since it cannot be seen by any other person. This attempt to understand the structure or characteristics of the mind was known as **structuralism**. Wundt established his psychology laboratory at the University at Leipzig in 1879. In this laboratory, Wundt and his students conducted experiments on, for example, reaction times. A subject, sometimes in a room isolated from the scientist, would receive a stimulus such as a light, image, or sound. The subject's reaction to the stimulus would be to push a button, and an apparatus would record the time to reaction. Wundt could measure reaction time to one-thousandth of a second (Nicolas & Ferrand, 1999).



(a) (b)

Figure 6. (a) Wilhelm Wundt is credited as one of the founders of psychology. He created the first laboratory for psychological research. (b) This photo shows him seated and surrounded by fellow researchers and equipment in his laboratory in Germany. However, despite his efforts to train individuals in the process of introspection, this process remained highly subjective, and there was very little agreement between individuals. As a result, structuralism fell out of favor with the passing of Wundt's student, Edward Titchener, in 1927 (Gordon, 1995).

Follow the link for a deeper look at Structuralism & Functionalism

James and Functionalism

William James (1842–1910) was the first American psychologist who espoused a different perspective on how psychology should operate. James was introduced to Darwin's theory of evolution by natural selection and accepted it as an explanation of an organism's characteristics. Key to that theory is the idea that natural selection leads to organisms that are adapted to their environment, including their behavior. Adaptation means that a trait of an organism has a function for the survival and reproduction of the individual, because it has been naturally selected. As James saw it, psychology's purpose was to study the function of behavior in the world, and as such, his perspective was known as **functionalism**. Functionalism focused on how mental activities helped an organism fit into its environment. Functionalism has a second, more subtle meaning in that functionalists were more interested in the operation of the whole mind rather than of its individual parts, which were the focus of structuralism. Like Wundt, James believed that introspection could serve as one means by which someone might study mental activities, but James also relied on more objective measures, including the use of various recording devices, and examinations of concrete products of mental activities and of anatomy and physiology (Gordon, 1995).

Figure 7. William James, shown here in a self-portrait, was the first American psychologist.

GLOSSARY

- **Functionalism:** focused on how mental activities helped an organism adapt to its environment
- **Structuralism:** understanding the conscious experience through introspection

Ecological Validity

One important challenge researchers face when designing a study is to find the right balance between ensuring **internal validity**, or the degree to which a study allows unambiguous causal inferences, and **external validity**, or the degree to which a study ensures that potential findings apply to settings and samples other than the ones being studied (Brewer, 2000). Unfortunately, these two kinds of validity tend to be difficult to achieve at the same time, in one study. This is because creating a controlled setting, in which all potentially influential factors (other than the experimentally-manipulated variable) are controlled, is bound to create an environment that is quite different from what people naturally encounter (e.g., using a happy movie clip to promote helpful behavior). However, it is the degree to which an experimental situation is comparable to the corresponding real-world situation of interest that determines how generalizable potential findings will be. In other words, if an experiment is very far-off from what a person might normally experience in everyday life, you might reasonably question just how useful its

findings are.
Because of the incompatibility of the two types of validity, one is often—by design—prioritized over the other. Due to the importance of identifying true causal relationships, psychology has traditionally emphasized internal over external validity. However, in order to make claims about human behavior that apply across populations and environments, researchers complement traditional laboratory research, where participants are brought into the lab, with field research where, in essence, the psychological laboratory is brought to participants. Field studies allow for the important test of how psychological variables and processes of interest "behave" under real-world circumstances (i.e., what *actually does happen* rather than what *can happen*). They can also facilitate "downstream" operationalizations of constructs that measure life outcomes of interest *directly* rather than indirectly.

Take, for example, the fascinating field of psychoneuroimmunology, where the goal is to understand the interplay of psychological factors - such as personality traits or one's stress level - and the immune system. Highly sophisticated and carefully controlled experiments offer ways to isolate the variety of neural, hormonal, and cellular mechanisms that link psychological variables such as chronic stress to biological outcomes such as immunosuppression (a state of impaired immune functioning; Sapolsky, 2004). Although these studies demonstrate impressively how psychological factors can affect health-relevant biological processes, they—because of their research design—remain mute about the degree to which these factors actually do undermine people's everyday health in real life. It is certainly important to show that laboratory stress can alter the number of natural killer cells in the blood. But it is equally important to test to what extent the levels of stress that people experience on a day-to-day basis result in them catching a cold more often or taking longer to recover from one. The goal for researchers, therefore, must be to complement traditional laboratory experiments with less controlled studies under real-world circumstances. The term **ecological validity** is used to refer the degree to which an effect has been obtained under conditions that are typical for what happens in everyday life (Brewer, 2000). In this example, then, people might keep a careful daily log of how much stress they are under as well as noting physical symptoms such as headaches or nausea. Although many factors beyond stress level may be responsible for these symptoms, this more correlational approach can shed light on how the relationship between stress and health plays out outside of the laboratory.

Behaviorism

How do we act?

Learning theories focus on how we respond to events or stimuli rather than emphasizing what motivates our actions. These theories provide an explanation of how experience can change what we are capable of doing or feeling.

Classical Conditioning and Emotional Responses

Classical Conditioning theory helps us to understand how our responses to one situation become attached to new situations. For example, a smell might remind us of a time when we were a kid (elementary school cafeterias smell like milk and mildew!). If you went to a new cafeteria with the same smell, it might evoke feelings you had when you were in school. Or a song on the radio might remind you of a memorable evening you spent with your first true love. Or, if you hear your entire name (John Wilmington Brewer, for instance) called as you walk across the stage to get your diploma and it makes you tense because it reminds you of how your father used to use your full name when he was mad at you, you've been classically conditioned!

Classical conditioning explains how we develop many of our emotional responses to people or events or our "gut level" reactions to situations. New situations may bring about an old response because the two have become connected. Attachments form in this way. Addictions are affected by classical conditioning, as anyone who's tried to quit smoking can tell you. When you try to quit, everything that was associated with smoking makes you crave a cigarette.

Pavlov

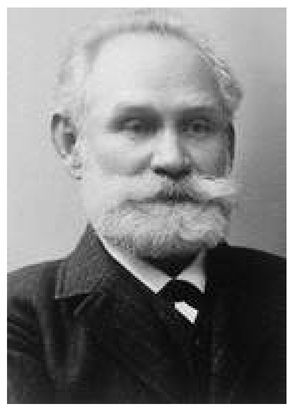


Figure 8. Ivan Pavlov

Ivan Pavlov (1880-1937) was a Russian physiologist interested in studying digestion. As he recorded the amount of salivation his laboratory dogs produced as they ate, he noticed that they actually began to salivate before the food arrived as the researcher walked down the hall and toward the cage. "This," he thought, "is not natural!" One would expect a dog to automatically salivate when food hit their palate, but BEFORE the food comes? Of course, what had happened was . . . you tell me. That's right! The dogs knew that the food was coming because they had learned to associate the footsteps with the food. The key word here is "learned". A learned response is called a "conditioned" response. Pavlov began to experiment with this "psychic" reflex. He began to ring a bell, for instance, prior to introducing the food. Sure enough, after making this connection several times, the dogs could be made to salivate to the sound of a bell. Once the bell had become an event to which the dogs had learned to salivate, it was called a conditioned stimulus. The act of salivating to a bell was a response that had also been learned, now termed in Pavlov's jargon, a conditioned response. Notice that the response, salivation, is the same whether it is conditioned or unconditioned (unlearned or natural). What changed is the stimulus to which the dog salivates. One is natural (unconditioned) and one is learned (conditioned). Well, enough of Pavlov's dogs. Who cares?

Let's think about how classical conditioning is used on us. One of the most widespread applications of classical conditioning principles was brought to us by the psychologist, John B. Watson.

Watson and Behaviorism

Watson believed that most of our fears and other emotional responses are classically conditioned. He had gained a good deal of popularity in the 1920s with his expert advice on parenting offered to the public. He believed that parents could be taught to help shape their children's behavior and tried to demonstrate the power of classical conditioning with his famous experiment with an 18 month old boy named "Little Albert". Watson sat Albert down and introduced a variety of seemingly scary objects to him: a burning piece of newspaper, a white rat, etc. But Albert remained curious and reached for all of these things. Watson knew that one of our only inborn fears is the fear of loud noises so he proceeded to make a loud noise each time he introduced one of Albert's favorites, a white rat. After hearing the loud noise several times paired with the rat, Albert soon came to fear the rat and began to cry when it was introduced. Watson filmed this experiment for posterity and used it to demonstrate that he could help parents achieve any outcomes they desired, if they would only follow his advice. Watson wrote columns in newspapers and in magazines and gained a lot of popularity among parents eager to apply science to household order. Parenting advice was not the legacy Watson left us, however. Where he really made his impact was in advertising. After Watson left academia, he went into the world of business and showed companies how to tie something that brings about a natural positive feeling to their products to enhance sales. Thus the union of sex and advertising! So, let's use a much more interesting example than Pavlov's dogs to check and see if you understand the difference between conditioned and unconditioned stimuli and responses. In the experiment with Little Albert, identify the unconditioned stimulus, the unconditioned response, and, after conditioning, the conditioned stimulus and the conditioned response.

Operant Conditioning and Repeating Actions

Operant Conditioning is another learning theory that emphasizes a more conscious type of learning than that of classical conditioning. A person (or animal) does something (operates something) to see what effect it might bring. Simply said, operant conditioning describes how we repeat behaviors because they pay off for us. It is based on a principle authored by a psychologist named Thorndike (1874-1949) called the law of effect. The law of effect suggest that we will repeat an action if it is followed by a good effect.

Skinner and Reinforcement

Watch a pigeon learn through the concept reinforcement:

B.F. Skinner (1904-199 expanded on Thorndike's principle and outlined the principles of operant conditioning. Skinner believed that we learn best when our actions are reinforced. For example, a child who cleans his room and is reinforced (rewarded) with a big hug and words of praise is more likely to clean it again than a child whose deed goes unnoticed. Skinner believed that almost anything could be reinforcing. A reinforcer is anything following a behavior that makes it more likely to occur again. It can be something intrinsically rewarding (called intrinsic or primary reinforcers), such as food or praise, or it can be rewarding because it can be exchanged for what one really wants (such as using money to buy a cookie). Such reinforcers are referred to as secondary reinforcers or extrinsic reinforcers.

Figure 9. B. F. Skinner (1950)

Positive and negative reinforcement

Sometimes, adding something to the situation is reinforcing as in the cases we described above with cookies, praise and money. Positive reinforcement involves adding something to the situation to encourage a behavior. Other times, taking something away from a situation can be reinforcing. For example, the loud, annoying buzzer on your alarm clock encourages you to get up so that you can turn it off and get rid of the noise. Children whine in order to get their parents to do something and often, parents give in just to stop the whining. In these instances, negative reinforcement has been used.

Operant conditioning tends to work best if you focus on trying to encourage a behavior or move a person into the direction you want them to go rather than telling them what not to do. Reinforcers are used to encourage a behavior; punishers are used to stop behavior. A punisher is anything that follows an act and decreases the chance it will reoccur. But often a punished behavior doesn't really go away. It is just suppressed and may reoccur whenever the threat of punishment is removed. For example, a child may not cuss around you because you've washed his mouth out with soap, but he may cuss around his friends. Or a motorist may only slow down when the trooper is on the side of the freeway. Another problem with punishment is that when a person focuses on punishment, they may find it hard to see what the other does right or well. And punishment is stigmatizing; when punished, some start to see themselves as bad and give up trying to change.

Reinforcement can occur in a predictable way, such as after every desired action is performed, or intermittently, after the behavior is performed a number of times or the first time it is performed after a certain amount of time. The schedule of reinforcement has an impact on how long a behavior continues after reinforcement is discontinued. So a parent who has rewarded a child's actions each time may find that the child gives up very quickly if a reward is not immediately forthcoming. A lover who is warmly regarded now and then may continue to seek out his or her partner's attention long after the partner has tried to break up. Think about the kinds of behaviors you may have learned through classical and operant conditioning. You may have learned many things in this way. But sometimes we learn very complex behaviors quickly and without direct reinforcement. Bandura explains how.

Gestalt Psychology

LEARNING OBJECTIVES

By the end of this section, you will be able to:

- **Explain the figure ground relationship**
- **Define Gestalt principles of grouping**
- **Describe how perceptual set is influenced by an individual's characteristics and mental state**

In the early part of the 20th century, Max Wertheimer published a paper demonstrating that individuals perceived motion in rapidly flickering static images—an insight that came to him as he used a child's toy tachistoscope. Wertheimer, and his assistants Wolfgang Köhler and Kurt Koffka, who later became his partners, believed that perception involved more than simply combining sensory stimuli. This belief led to a new movement within the field of psychology known as Gestalt psychology. The word *gestalt* literally means form or pattern, but its use reflects the idea that the whole is different from the sum of its parts. In other words, the brain creates a perception that is more than simply the sum of available sensory inputs, and it does so in predictable ways. Gestalt psychologists translated these predictable ways into principles by which we organize sensory information. As a result, Gestalt psychology has been extremely influential in the area of sensation and perception (Rock & Palmer, 1990).

One Gestalt principle is the figure-ground relationship. According to this principle, we tend to segment our visual world into figure and ground. Figure is the object or person that is the focus of the visual field, while the ground is the background. As **[link]** shows, our perception can vary tremendously, depending on what is perceived as figure and what is perceived as ground. Presumably, our ability to interpret sensory information depends on what we label as figure and what we label as ground in any particular case, although this assumption has been called into question (Peterson & Gibson, 1994; Vecera & O'Reilly, 1998).

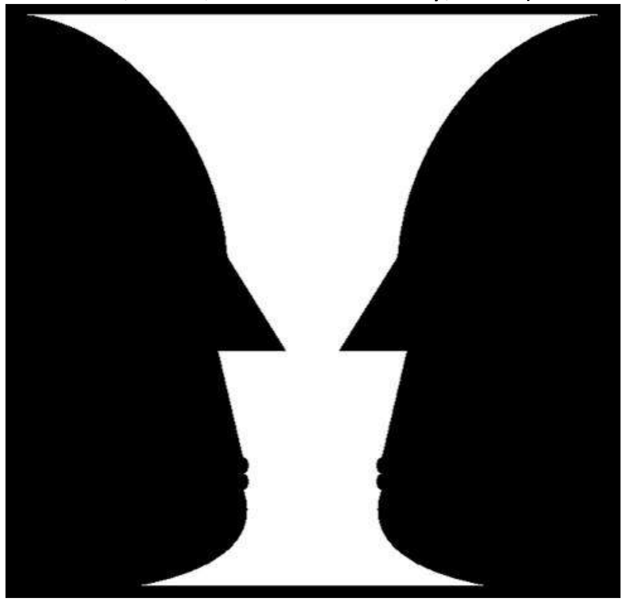


Figure 10. The concept of figure-ground relationship explains why this image can be perceived either as a vase or as a pair of faces.

Another Gestalt principle for organizing sensory stimuli into meaningful perception is proximity. This principle asserts that things that are close to one another tend to be grouped together, as is illustrated in the image below.

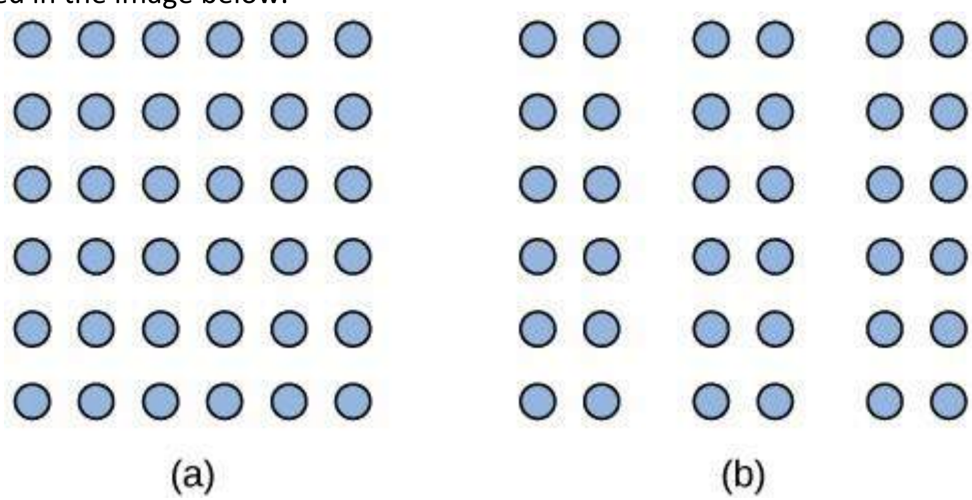


Figure 11. The Gestalt principle of proximity suggests that you see (a) one block of dots on the left side and (b) three columns on the right side.

How we read something provides another illustration of the proximity concept. For example, we read this sentence like this, notl iket hiso rt hat. We group the letters of a given word together because there are no spaces between the letters, and we perceive words because there are spaces between each word. Here are some more examples: Cany oum akes enseo ft hiss entence? What doth es e wor dsmea n?

We might also use the principle of similarity to group things in our visual fields. According to this principle, things that are alike tend to be grouped together. For example, when watching a football game, we tend to group individuals based on the colors of their uniforms. When watching an offensive drive, we can get a sense of the two teams simply by grouping along this dimension.

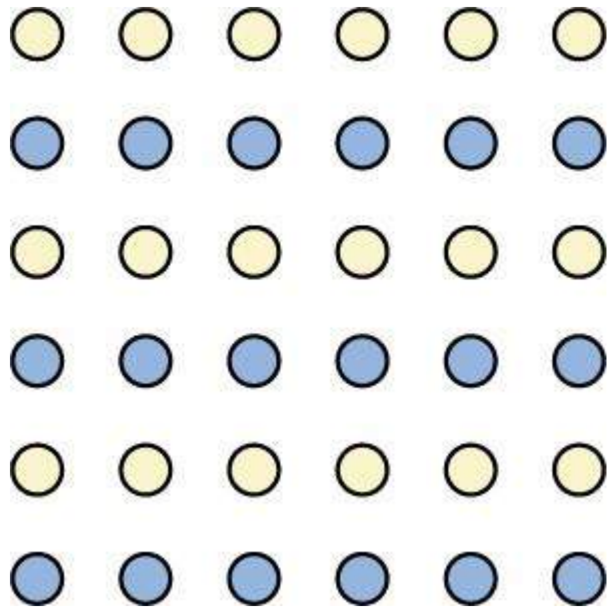


Figure 12. When looking at this array of dots, we likely perceive alternating rows of colors. We are grouping these dots according to the principle of similarity.

Two additional Gestalt principles are the law of continuity (or good continuation) and closure. The law of continuity suggests that we are more likely to perceive continuous, smooth flowing lines rather than jagged, broken lines. The principle of closure states that we organize our perceptions into complete objects rather than as a series of parts.

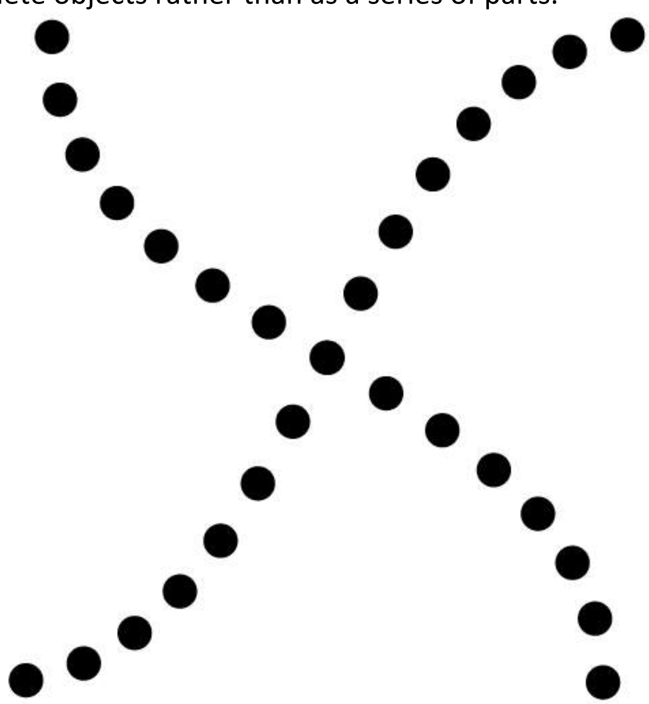


Figure 13. Good continuation would suggest that we are more likely to perceive this as two overlapping lines, rather than four lines meeting in the center.

Figure 14. Closure suggests that we will perceive a complete circle and rectangle rather than a series of segments.

Link to Learning

Watch this video showing real world illustrations of Gestalt principles.

According to Gestalt theorists, pattern perception, or our ability to discriminate among different figures and shapes, occurs by following the principles described above. You probably feel fairly certain that your perception accurately matches the real world, but this is not always the case. Our perceptions are based on perceptual hypotheses: educated guesses that we make while interpreting sensory information. These hypotheses are informed by a number of factors, including our personalities, experiences, and expectations. We use these hypotheses to generate our perceptual set. For instance, research has demonstrated that those who are given verbal priming produce a biased interpretation of complex ambiguous figures (Goolkasian & Woodbury, 2010).

Dig Deeper: The Depths of Perception: Bias, Prejudice, and Cultural Factors

In this chapter, you have learned that perception is a complex process. Built from sensations, but influenced by our own experiences, biases, prejudices, and cultures, perceptions can be very different from person to person. Research suggests that implicit racial prejudice and stereotypes affect perception. For instance, several studies have demonstrated that non Black participants identify weapons faster and are more likely to identify non weapons as weapons when the image of the weapon is paired with the image of a Black person (Payne, 2001; Payne, Shimizu, & Jacoby, 2005). Furthermore, White individuals' decisions to shoot an armed target in a video game is made more quickly when the target is Black (Correll, Park, Judd, & Wittenbrink, 2002; Correll, Urland, & Ito, 2006). This research is important, considering the number of very high profile cases in the last few decades in which young Blacks were killed by people who claimed to believe that the unarmed individuals were armed and/or represented some threat to their personal safety.

Summary

Gestalt theorists have been incredibly influential in the areas of sensation and perception. Gestalt principles such as figure-ground relationship, grouping by proximity or similarity, the law of good continuation, and closure are all used to help explain how we organize sensory information. Our perceptions are not infallible, and they can be influenced by bias, prejudice, and other factors.

SELF CHECK QUESTIONS

Critical Thinking Question

1. The central tenet of Gestalt psychology is that the whole is different from the sum of its parts. What does this mean in the context of perception?
2. Take a look at the following figure. How might you influence whether people see a duck or a rabbit?

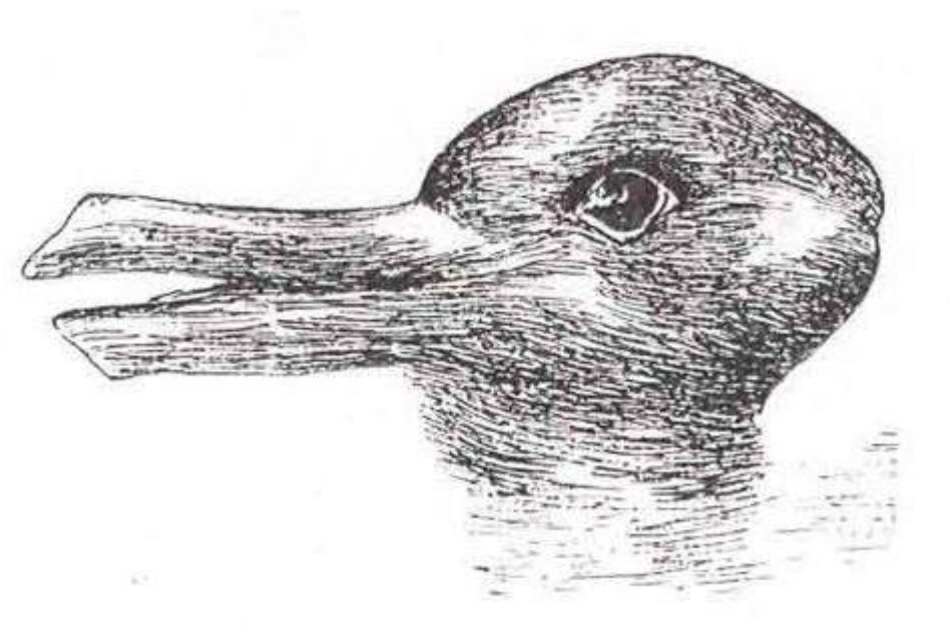


Figure 15.

Personal Application Question

3. Have you ever listened to a song on the radio and sung along only to find out later that you have been singing the wrong lyrics? Once you found the correct lyrics, did your perception of the song change?

ANSWERS

1. This means that perception cannot be understood completely simply by combining the parts. Rather, the relationship that exists among those parts (which would be established according to the principles described in this chapter) is important in organizing and interpreting sensory information into a perceptual set.
2. Playing on their expectations could be used to influence what they were most likely to see. For instance, telling a story about Peter Rabbit and then presenting this image would bias perception along rabbit lines.

GLOSSARY

- **Closure:** organizing our perceptions into complete objects rather than as a series of parts
- **Figure-ground Relationship:** segmenting our visual world into figure and ground
- **Gestalt Psychology:** field of psychology based on the idea that the whole is different from the sum of its parts
- **Good Continuation:** (also, continuity) we are more likely to perceive continuous, smooth flowing lines rather than jagged, broken lines
- **Pattern Perception:** ability to discriminate among different figures and shapes
- **Perceptual Hypothesis:** educated guess used to interpret sensory information
- **Principle of Closure:** organize perceptions into complete objects rather than as a series of parts
- **Proximity:** things that are close to one another tend to be grouped together
- **Similarity:** things that are alike tend to be grouped together

Contributions to Cognitive Psychology "Birth"

Behaviorism's emphasis on objectivity and focus on external behavior had pulled psychologists' attention away from the mind for a prolonged period of time. The early work of the humanistic psychologists redirected attention to the individual human as a whole, and as a conscious and self-aware being. By the 1950s, new disciplinary perspectives in linguistics, neuroscience, and computer science were emerging, and these areas revived interest in the mind as a focus of scientific inquiry. This particular perspective has come to be known as the cognitive revolution (Miller, 2003). By 1967, Ulric Neisser published the first textbook entitled *Cognitive Psychology*, which served as a core text in cognitive psychology courses around the country (Thorne & Henley, 2005).

Although no one person is entirely responsible for starting the cognitive revolution, Noam Chomsky was very influential in the early days of this movement. Chomsky (1928–), an American linguist, was dissatisfied with the influence that behaviorism had had on psychology. He believed that psychology's focus on behavior was short-sighted and that the field had to re-incorporate mental functioning into its purview if it were to offer any meaningful contributions to understanding behavior (Miller, 2003).

Figure 16. Noam Chomsky was very influential in beginning the cognitive revolution. In 2010, this mural honoring him was put up in Philadelphia, Pennsylvania. (credit: Robert Moran)

European psychology had never really been as influenced by behaviorism as had American psychology; and thus, the cognitive revolution helped reestablish lines of communication between European psychologists and their American counterparts. Furthermore, psychologists began to cooperate with scientists in other fields, like anthropology, linguistics, computer science, and neuroscience, among others. This interdisciplinary approach often was referred to as the cognitive sciences, and the influence and prominence of this particular perspective resonates in modern-day psychology (Miller, 2003).

Noam Chomsky

In the middle of the 20th century, American linguist Noam Chomsky explained how some aspects of language could be innate. Prior to this time, people tended to believe that children learn language soley by imitating the adults around them. Chomsky agreed that individual words must be learned by experience, but he argued that genes could code into the brain categories and organization that form the basis of grammatical structure. We come into the world ready to distinguish different grammatical classes, like nouns and verbs and adjectives, and sensitive to the order in which words are spoken. Then, using this innate sensitivity, we quickly learn from listening to our parents about how to organize our own language [5] [6] For instance, if we grow up hearing Spanish, we learn that adjectives come after nouns (*el gato amarillo*, where *gato* means "cat" and *amarillo* is "yellow"), but if we grow up hearing English, we learn that adjectives come first ("the yellow cat"). Chomsky termed this *innate sensitivity that allows infants and young children to organize the abstract categories of language* the ***language acquisition device (LAD)***.

According to Chomsky's approach, each of the many languages spoken around the world (there are between 6,000 and 8,000) is an individual example of the same underlying set of procedures that are hardwired into human brains. Each language, while unique, is just a set of variations on a small set of possible rule systems that the brain permits language to use.

Chomsky’s account proposes that children are born with a knowledge of general rules of grammar (including phoneme, morpheme, and syntactical rules) that determine how sentences are constructed.

Although there is general agreement among psychologists that babies are genetically programmed to learn language, there is still debate about Chomsky’s idea that a universal grammar can account for all language learning. Evans and Levinson [7] surveyed the world’s languages and found that none of the presumed underlying features of the language acquisition device were entirely universal. In their search they found languages that did not have noun or verb phrases, that did not have tenses (e.g., past, present, future), and some that did not have nouns or verbs at all, even though a basic assumption of a universal grammar is that all languages should share these features. Other psychologists believe that early experience can fully explain language acquisition, and Chomsky’s language acquisition device is unnecessary. Nevertheless, Chomsky’s work clearly laid out the many problems that had to be solved in order to adequately explain how children acquire language and why languages have the structures that they do.

Connectionism – Parallel Distributive Processing

Connectionism was based on principles of associationism, mostly claiming that elements or ideas become associated with one another through experience and that complex ideas can be explained through a set of simple rules. But connectionism further expanded these assumptions and introduced ideas like distributed representations and supervised learning and should not be confused with associationism.

Connectionism and Network Models

Network models of memory storage emphasize the role of connections between stored memories in the brain. The basis of these theories is that neural networks connect and interact to store memories by modifying the strength of the connections between neural units. In network theory, each connection is characterized by a weight value that indicates the strength of that particular connection. The stronger the connection, the easier a memory is to retrieve. Network models are based on the concept of connectionism. Connectionism is an approach in cognitive science that models mental or behavioral phenomena as the emergent processes of interconnected networks that consist of simple units. Connectionism was introduced in the 1940s by Donald Hebb, who said the famous phrase, “Cells that fire together wire together.” This is the key to understanding network models: neural units that are activated together strengthen the connections between themselves.

There are several types of network models in memory research. Some define the fundamental network unit as a piece of information. Others define the unit as a neuron. However, network models generally agree that memory is stored in neural networks and is strengthened or weakened based on the connections between neurons. Network models are not the only models of memory storage, but they do have a great deal of power when it comes to explaining how learning and memory work in the brain, so they are extremely important to understand.

Parallel Distributed Processing Model

The parallel distributed processing (PDP) model is an example of a network model of memory, and it is the prevailing connectionist approach today. PDP posits that memory is made up of neural networks that interact to store information. It is more of a metaphor than an actual biological theory, but it is very useful for understanding how neurons fire and wire with each other.

Taking its metaphors from the field of computer science, this model stresses the parallel nature of neural processing. “Parallel processing” is a computing term; unlike serial processing (performing one operation at a time), parallel processing allows hundreds of operations to be completed at once—in parallel. Under PDP, neural networks are thought to work in parallel to change neural connections to store memories. This theory also states that memory is stored by modifying the strength of connections between neural units. Neurons that fire together frequently (which occurs when a particular behavior or mental process is engaged many times) have stronger connections between them. If these neurons stop interacting, the memory’s strength weakens. This model emphasizes learning and other cognitive phenomena in the creation and storage of memory.

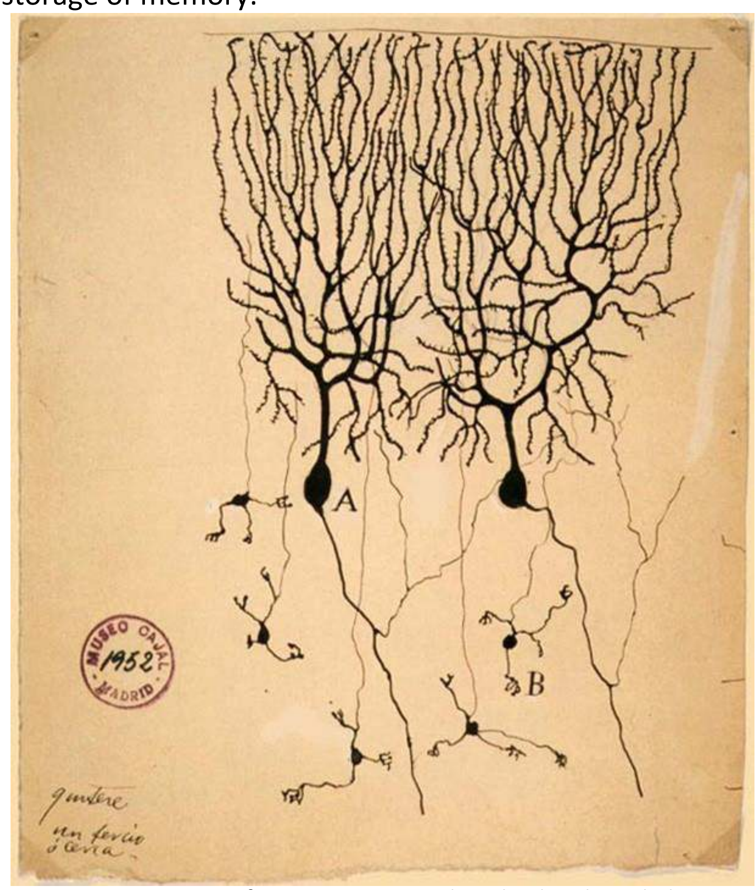


Figure 17. Neural connections: As neurons form connections with each other through their many dendrites, they can form complex networks. Network models propose that these connections are the basis of storing and retrieving memories.

Chapter 2 – The Brain

The picture you have in your mind of the nervous system probably includes the **brain**, the nervous tissue contained within the cranium, and the **spinal cord**, the extension of nervous tissue within the vertebral column. That suggests it is made of two organs—and you may not even think of the spinal cord as an organ—but the nervous system is a very complex structure. Within the brain, many different and separate regions are responsible for many different and separate functions. It is as if the nervous system is composed of many organs that all look similar and can only be differentiated using tools such as the microscope or electrophysiology. In comparison, it is easy to see that the stomach is different than the esophagus or the liver, so you can imagine the digestive system as a collection of specific organs.

The Central and Peripheral Nervous Systems

The nervous system can be divided into two major regions: the central and peripheral nervous systems. The **central nervous system (CNS)** is the brain and spinal cord, and the **peripheral nervous system (PNS)** is everything else (Figure 1). The brain is contained within the cranial cavity of the skull, and the spinal cord is contained within the vertebral cavity of the vertebral column. It is a bit of an oversimplification to say that the CNS is what is inside these two cavities and the peripheral nervous system is outside of them, but that is one way to start to think about it. In actuality, there are some elements of the peripheral nervous system that are within the cranial or vertebral cavities. The peripheral nervous system is so named because it is on the periphery—meaning beyond the brain and spinal cord. Depending on different aspects of the nervous system, the dividing line between central and peripheral is not necessarily universal.

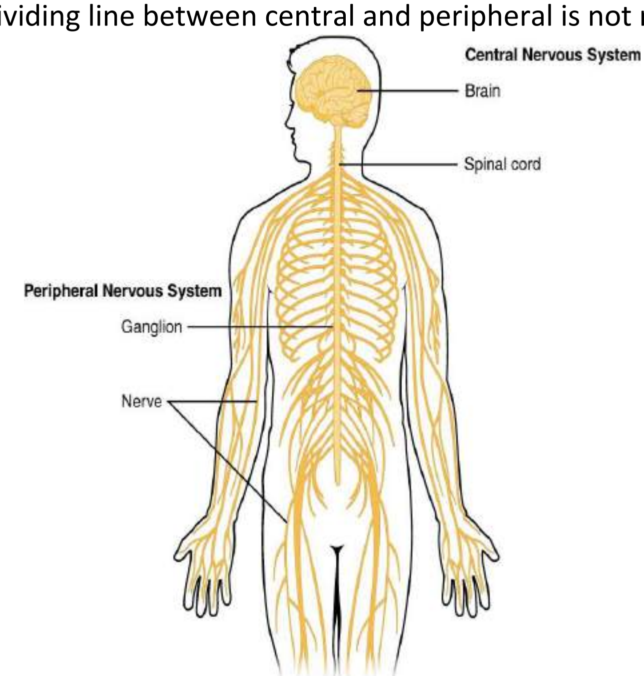


Figure 1. Central and Peripheral Nervous System. The structures of the PNS are referred to as ganglia and nerves, which can be seen as distinct structures. The equivalent structures in the CNS are not obvious from this overall perspective and are best examined in prepared tissue under the microscope.

Nervous tissue, present in both the CNS and PNS, contains two basic types of cells: neurons and glial cells. A **glial cell** is one of a variety of cells that provide a framework of tissue that supports the neurons and their activities. The **neuron** is the more functionally important of the two, in terms of the communicative function of the nervous system. To describe the functional divisions of the nervous system, it is important to understand the structure of a neuron. Neurons are cells and therefore have a **soma**, or cell body, but they also have extensions of the cell; each extension is generally referred to as a **process**. There is one important process that every neuron has called an **axon**, which is the fiber that connects a neuron with its target. Another type of process that branches off from the soma is the **dendrite**. Dendrites are responsible for receiving most of the input from other neurons.

Looking at nervous tissue, there are regions that predominantly contain cell bodies and regions that are largely composed of just axons. These two regions within nervous system structures are often referred to as **gray matter** (the regions with many cell bodies and dendrites) or **white matter** (the regions with many axons). Figure 2 demonstrates the appearance of these regions in the brain and spinal cord. The colors ascribed to these regions are what would be seen in "fresh," or unstained, nervous tissue. Gray matter is not necessarily gray. It can be pinkish because of blood content, or even slightly tan, depending on how long the tissue has been preserved. But white matter is white because axons are insulated by a lipid-rich substance called **myelin**. Lipids can appear as white ("fatty") material, much like the fat on a raw piece of chicken or beef. Actually, gray matter may have that color ascribed to it because next to the white matter, it is just darker—hence, gray.

The distinction between gray matter and white matter is most often applied to central nervous tissue, which has large regions that can be seen with the unaided eye. When looking at peripheral structures, often a microscope is used and the tissue is stained with artificial colors. That is not to say that central nervous tissue cannot be stained and viewed under a microscope, but unstained tissue is most likely from the CNS—for example, a frontal section of the brain or cross section of the spinal cord.

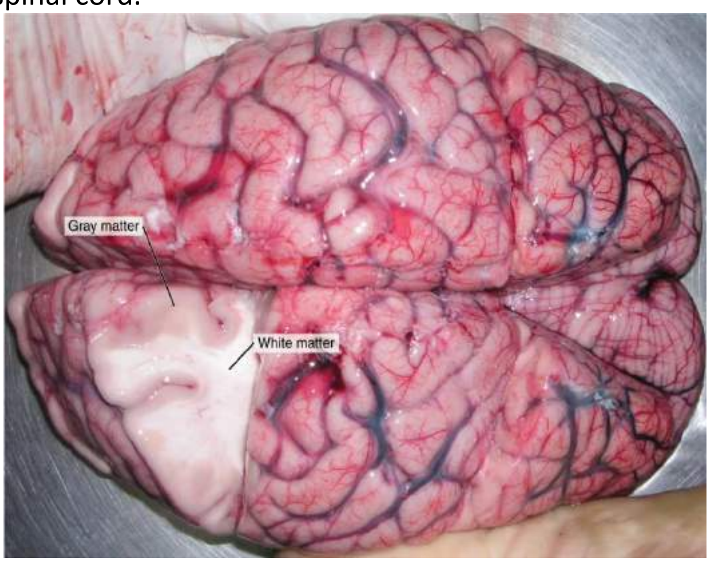


Figure 2. Gray Matter and White Matter. A brain removed during an autopsy, with a partial section removed, shows white matter surrounded by gray matter. Gray matter makes up the outer cortex of the brain. (credit: modification of work by

"Suseno"/Wikimedia Commons)

Regardless of the appearance of stained or unstained tissue, the cell bodies of neurons or axons can be located in discrete anatomical structures that need to be named. Those names are specific to whether the structure is central or peripheral. A localized collection of neuron cell bodies in the CNS is referred to as a **nucleus**. In the PNS, a cluster of neuron cell bodies is referred to as a **ganglion**. Figure 3 indicates how the term nucleus has a few different meanings within anatomy and physiology. It is the center of an atom, where protons and neutrons are found; it is the center of a cell, where the DNA is found; and it is a center of some function in the CNS. There is also a potentially confusing use of the word ganglion (plural = ganglia) that has a historical explanation. In the central nervous system, there is a group of nuclei that are connected together and were once called the basal ganglia before "ganglion" became accepted as a description for a peripheral structure. Some sources refer to this group of nuclei as the "basal nuclei" to avoid confusion.

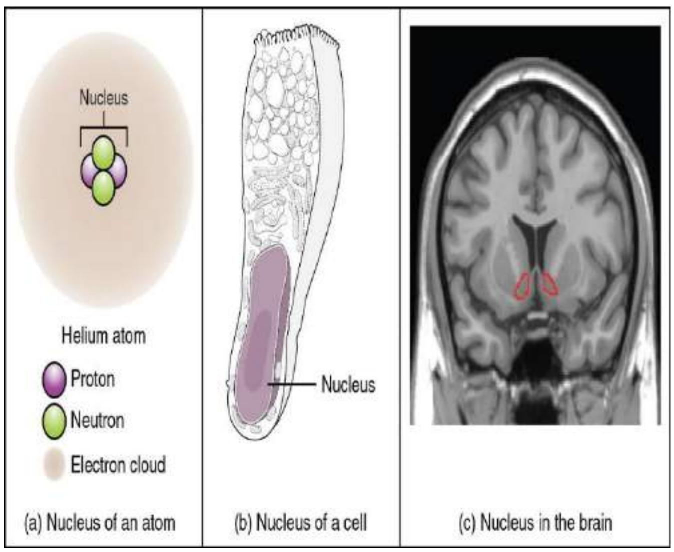


Figure 3. What Is a Nucleus? (a) The nucleus of an atom contains its protons and neutrons. (b) The nucleus of a cell is the organelle that contains DNA. (c) A nucleus in the CNS is a localized center of function with the cell bodies of several neurons, shown here circled in red. (credit c: "Was a bee"/Wikimedia Commons)

Terminology applied to bundles of axons also differs depending on location. A bundle of axons, or fibers, found in the CNS is called a **tract** whereas the same thing in the PNS would be called a **nerve**. There is an important point to make about these terms, which is that they can both be used to refer to the same bundle of axons. When those axons are in the PNS, the term is nerve, but if they are CNS, the term is tract. The most obvious example of this is the axons that project from the retina into the brain. Those axons are called the optic nerve as they leave the eye, but when they are inside the cranium, they are referred to as the optic tract. There is a specific place where the name changes, which is the optic chiasm, but they are still the same axons (Figure 4). A similar situation outside of science can be described for some roads. Imagine a road called "Broad Street" in a town called "Anyville." The road leaves Anyville and goes to the next town over, called "Hometown." When the road crosses the line between the two towns and is in Hometown, its name changes to "Main Street." That is the idea behind the naming of the retinal axons. In the PNS, they are called the optic nerve, and in the CNS, they are the optic tract. Table 1 helps to clarify which of these terms apply to the central or peripheral nervous systems.

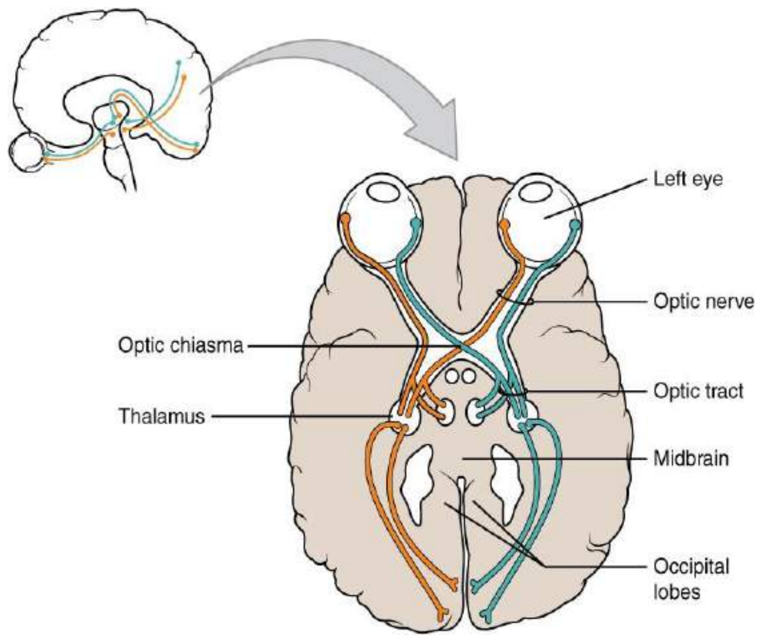


Figure 4. Optic Nerve Versus Optic Tract. This drawing of the connections of the eye to the brain shows the optic nerve extending from the eye to the chiasm, where the structure continues as the optic tract. The same axons extend from the eye to the brain through these two bundles of fibers, but the chiasm represents the border between peripheral and central.

Structures of the CNS and PNS (Table 1)		
	CNS	**PNS**
Group of Neuron Cell Bodies (i.e., gray matter)	Nucleus	Ganglion
Bundle of Axons (i.e., white matter)	Tract	Nerve

Table 2.

Visit the Nobel Prize web site to play an interactive game that demonstrates the use of this technology and compares it with other types of imaging technologies.
In 2003, the Nobel Prize in Physiology or Medicine was awarded to Paul C. Lauterbur and Sir

Peter Mansfield for discoveries related to magnetic resonance imaging (MRI). This is a tool to see the structures of the body (not just the nervous system) that depends on magnetic fields associated with certain atomic nuclei. The utility of this technique in the nervous system is that fat tissue and water appear as different shades between black and white. Because white matter is fatty (from myelin) and gray matter is not, they can be easily distinguished in MRI images. Visit the Nobel Prize [web site](#) to play an interactive game that demonstrates the use of this technology and compares it with other types of imaging technologies. Also, the results from an MRI session are compared with images obtained from X-ray or computed tomography. How do the imaging techniques shown in this game indicate the separation of white and gray matter compared with the freshly dissected tissue shown earlier?

How Much of Your Brain Do You Use?

Have you ever heard the claim that humans only use 10 percent of their brains? Maybe you have seen an advertisement on a website saying that there is a secret to unlocking the full potential of your mind—as if there were 90 percent of your brain sitting idle, just waiting for you to use it. If you see an ad like that, don't click. It isn't true.

An easy way to see how much of the brain a person uses is to take measurements of brain activity while performing a task. An example of this kind of measurement is functional magnetic resonance imaging (fMRI), which generates a map of the most active areas and can be generated and presented in three dimensions (Figure 6). This procedure is different from the standard MRI technique because it is measuring changes in the tissue in time with an experimental condition or event.

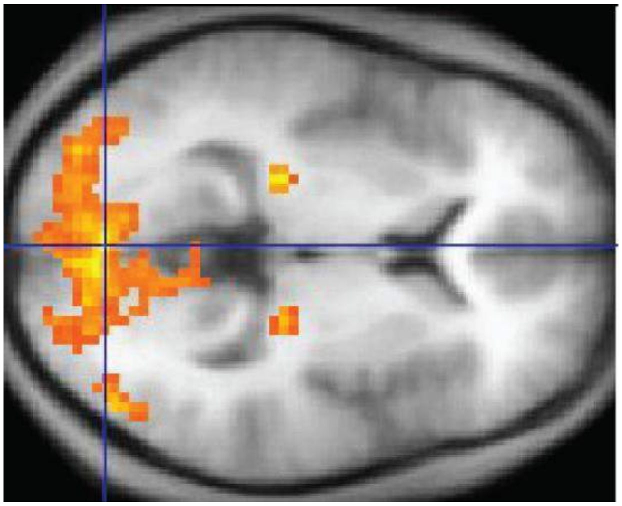


Figure 5. fMRI. This fMRI shows activation of the visual cortex in response to visual stimuli. (credit: "Superborsuk"/Wikimedia Commons)

The underlying assumption is that active nervous tissue will have greater blood flow. By having the subject perform a visual task, activity all over the brain can be measured. Consider this possible experiment: the subject is told to look at a screen with a black dot in the middle (a fixation point). A photograph of a face is projected on the screen away from the center. The subject has to look at the photograph and decipher what it is. The subject has been instructed to push a button if the photograph is of someone they recognize. The photograph might be of a celebrity, so the subject would press the button, or it might be of a random person unknown to the subject, so the subject would not press the button.

In this task, visual sensory areas would be active, integrating areas would be active, motor areas responsible for moving the eyes would be active, and motor areas for pressing the button with a finger would be active. Those areas are distributed all around the brain and the fMRI images would show activity in more than just 10 percent of the brain (some evidence suggests that about 80 percent of the brain is using energy—based on blood flow to the tissue—during well-defined tasks similar to the one suggested above). This task does not even include all of the functions the brain performs. There is no language response, the body is mostly lying still in the MRI machine, and it does not consider the autonomic functions that would be ongoing in the background.

Lower-Level Structures of the Brain

The brain’s lower-level structures consist of the brain stem, the spinal cord, and the cerebellum.

LEARNING OBJECTIVE

- **Outline the location and functions of the lower level structures of the brain**

KEY POINTS

- The brain’s lower-level structures are the oldest in the brain, and are more geared towards basic bodily processes than the higher-level structures.
- Except for the spinal cord, the brain’s lower-level structures are largely located within the hindbrain, diencephalon (or interbrain), and midbrain.
- The hindbrain consists of the medulla oblongata, the pons, and the cerebellum, which control respiration and movement among other functions.
- The midbrain is interposed between the hindbrain and the forebrain. Its ventral areas are dedicated to motor function while the dorsal regions are involved in sensory information circuits.
- The thalamus and hypothalamus are located within the diencephalon (or “interbrain”), and are part of the limbic system. They regulate emotions and motivated behaviors like sexuality and hunger.
- The spinal cord is a tail-like structure embedded in the vertebral canal of the spine, and is involved in transporting sensorimotor information and controlling nearby organs.

TERMS

- **Proprioception** The sense of the position of parts of the body relative to neighbouring parts of the body.
- **Ventral** On the front side of the human body, or the corresponding surface of an animal, usually the lower surface.
- **Dorsal** With respect to, or concerning the side in which the backbone is located, or the analogous side of an invertebrate.

The brain's lower-level structures consist of the **brain stem** and spinal cord, along with the cerebellum. With the exception of the spinal cord, these structures are largely located within the hindbrain, diencephalon (or interbrain), and midbrain. These lower dorsal structures are the oldest parts of the brain, having existed for much of its evolutionary history. As such they are geared more toward basic bodily processes necessary to survival. It is the more recent layers of the brain (the forebrain) which are responsible for the higher-level **cognitive** functioning (language, reasoning) not strictly necessary to keep a body alive.

The Hindbrain

The hindbrain, which includes the medulla oblongata, the pons, and the cerebellum, is responsible some of the oldest and most primitive body functions. Each of these structures is described below.

Medulla Oblongata

The medulla oblongata sits at the transition zone between the brain and the spinal cord. It is the first region that formally belongs to the brain (rather than the spinal cord). It is the control center for respiratory, **cardiovascular**, and digestive functions.

Pons

The pons connects the medulla oblongata with the midbrain region, and also relays **signals** from the forebrain to the cerebellum. It houses the control centers for respiration and inhibitory functions. The cerebellum is attached to the dorsal side of the pons.

Cerebellum

The cerebellum is a separate region of the brain located behind the medulla oblongata and pons. It is attached to the rest of the brain by three stalks (called *pedunculi*), and coordinates skeletal muscles to produce smooth, graceful motions. The cerebellum receives information from our eyes, ears, muscles, and joints about the body's current positioning (referred to as proprioception). It also receives output from the **cerebral cortex** about where these body parts should be. After processing this information, the cerebellum sends motor impulses from the brain stem to the skeletal muscles so that they can move. The main function of the cerebellum is this muscle coordination. However, it is also responsible for balance and **posture**, and it assists us when we are learning a new motor skill, such as playing a sport or musical instrument.

Recent research shows that apart from motor functions the cerebellum also has some role in emotional sensitivity.

Human and shark brains

The shark brain diverged on the evolutionary tree from the human brain, but both still have the "old" structures of the hindbrain and midbrain dedicated to autonomic bodily processes.

The Midbrain

The midbrain is located between the hindbrain and forebrain, but it is actually part of the brain stem. It displays the same basic functional composition found in the spinal cord and the hindbrain. Ventral areas control motor function and convey motor information from the cerebral cortex. Dorsal regions of the midbrain are involved in sensory information circuits. The substantia nigra, a part of the brain that plays a role in reward, addiction, and movement (due to its high levels of dopaminergic neurons) is located in the midbrain. In Parkinson's disease, which is characterized by a deficit of **dopamine**, death of the substantia nigra is evident.

The Diencephalon ("Interbrain")

The diencephalon is the region of the embryonic vertebrate **neural tube** that gives rise to posterior forebrain structures. In adults, the diencephalon appears at the upper end of the brain stem, situated between the **cerebrum** and the brain stem. It is home to the limbic system, which is considered the seat of emotion in the human brain. The diencephalon is made up of four distinct components: the thalamus, the subthalamus, the hypothalamus, and the epithalamus.

Thalamus

The thalamus is part of the limbic system. It consists of two lobes of grey matter along the bottom of the cerebral cortex. Because nearly all sensory information passes through the thalamus it is considered the sensory "way station" of the brain, passing information on to the cerebral cortex (which is in the forebrain). **Lesions** of, or stimulation to, the thalamus are associated with changes in emotional reactivity. However, the importance of this structure on the regulation of emotional behavior is not due to the activity of the thalamus itself, but to the connections between the thalamus and other limbic-system structures.

Limbic system, brain stem, and spinal cord

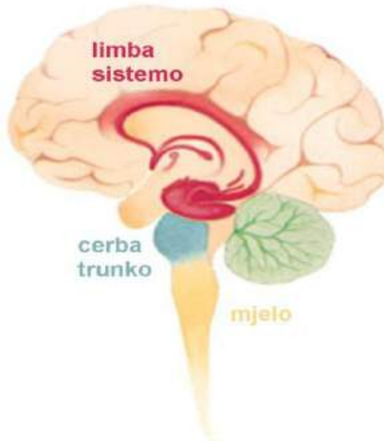


Figure 6. (https://commons.wikimedia.org/wiki/File:Limba_sistemo.jpg)

Hypothalamus

The hypothalamus is a small part of the brain located just below the thalamus. Lesions of the hypothalamus interfere with motivated behaviors like sexuality, combativeness, and hunger. The hypothalamus also plays a role in emotion: parts of the hypothalamus seem to be involved in pleasure and rage, while the central part is linked to aversion, displeasure, and a tendency towards uncontrollable and loud laughing. When external **stimuli** are presented (for example, a dangerous stimuli), the hypothalamus sends signals to other limbic areas to trigger feeling states in response to the stimuli (in this case, fear).

The Spinal Cord

The spinal cord is a tail-like structure embedded in the vertebral canal of the spine. The adult spinal cord is about 40 cm long and weighs approximately 30 **g**. The spinal cord is attached to the underside of the medulla oblongata, and is organized to serve four distinct tasks:

1. to convey (mainly sensory) information to the brain;
2. to carry information generated in the brain to peripheral targets like skeletal muscles;
3. to control nearby organs via the **autonomic** nervous system;
4. to enable sensorimotor functions to control posture and other fundamental movements.

Lobes: Cerebral Hemispheres and Lobes of the Brain

The brain is divided into two hemispheres and four lobes, each of which specializes in a different function.

LEARNING OBJECTIVE

- **Outline the structure and function of the lobes and hemispheres of the**

KEY POINTS

- The left hemisphere is dominant with regard to language and logical processing, while the right hemisphere handles spatial perception.
- The brain is separated into the frontal, temporal, occipital, and parietal lobes.
- The frontal lobe is associated with executive functions and motor performance.
- The temporal lobe is associated with the retention of short- and and long term memories. It processes sensory input, including auditory information, language comprehension, and naming.
- The occipital lobe is the visual processing center of the brain.
- The parietal lobe is associated with sensory skills.

TERMS

- **corpus callosum** A wide, flat bundle of neural fibers beneath the cortex that connects the left and right cerebral hemispheres and facilitates interhemispheric communication.
- **lateralization** Localization of a function, such as speech, to the right or left side of the brain.
- **visuospatial** Of or pertaining to the visual perception of spatial relationships.

Brain Lateralization

The brain is divided into two halves, called hemispheres. There is evidence that each brain hemisphere has its own distinct functions, a phenomenon referred to as lateralization. The left hemisphere appears to dominate the functions of speech, language processing and comprehension, and logical reasoning, while the right is **more** dominant in spatial tasks like vision-independent object recognition (such as identifying an object by touch or another nonvisual sense). However, it is easy to exaggerate the differences between the functions of the left and right hemispheres; both hemispheres are involved with most processes. Additionally, **neuroplasticity** (the ability of a brain to adapt to experience) enables the brain to compensate for damage to one hemisphere by taking on extra functions in the other half, especially in young brains.

Corpus Callosum

The two hemispheres communicate with one another through the **corpus callosum**. The corpus callosum is a wide, flat bundle of neural fibers beneath the cortex that connects the left and right cerebral hemispheres and facilitates interhemispheric communication. The corpus callosum is sometimes implicated in the cause of seizures; patients with **epilepsy** sometimes undergo a corpus callostomy, or the removal of the corpus callosum.

The Lobes of The Brain
The brain is separated into four lobes: the frontal, temporal, occipital, and parietal lobes.

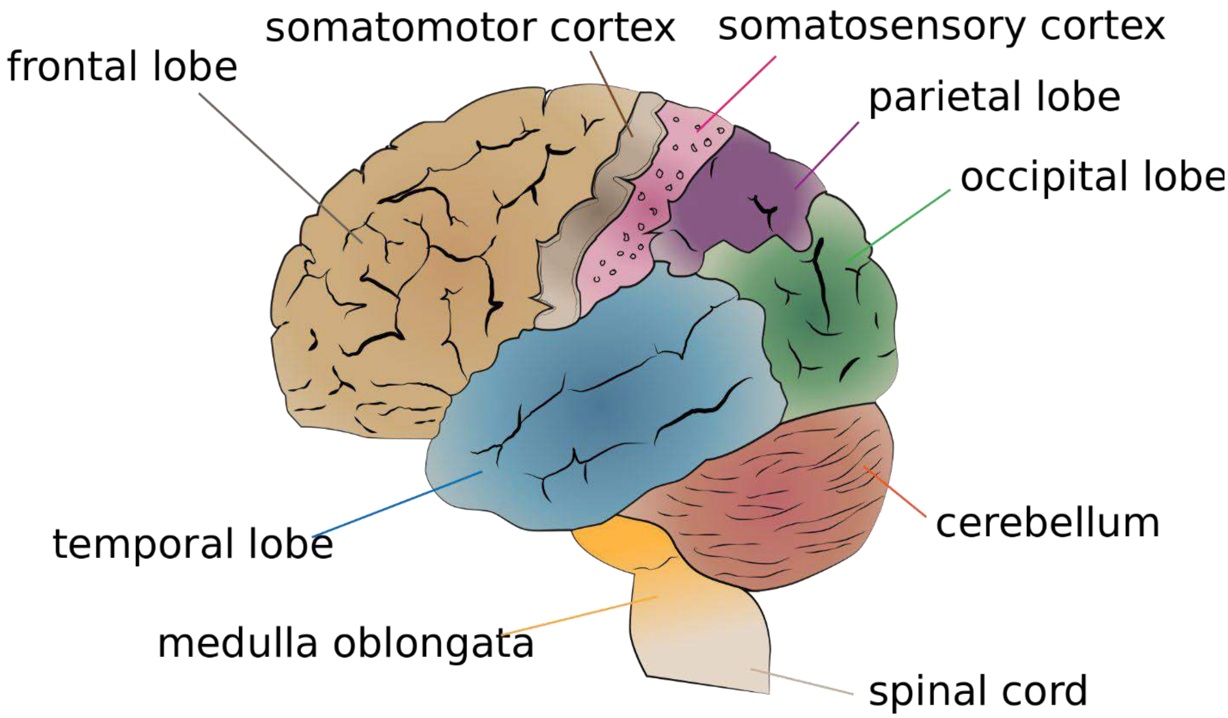


Figure 7. (https://commons.wikimedia.org/wiki/File:Cerebrum_lobes.svg)

Lobes of the brain
The brain is divided into four lobes, each of which is associated with different types of mental processes. Clockwise from left: The frontal lobe is in blue, the parietal lobe in yellow, the occipital lobe in red, and the temporal lobe in green.

The Frontal Lobe
The frontal lobe is associated with executive functions and motor performance. Executive functions are some of the highest-order **cognitive** processes that humans have. Examples include:

- planning and engaging in goal-directed behavior;
- recognizing future consequences of current actions;
- choosing between good and bad actions;
- overriding and suppressing socially unacceptable responses;
- determining similarities and differences between objects or situations.

The frontal lobe is considered to be the moral center of the brain because it is responsible for advanced decision-making processes. It also plays an important role in retaining emotional memories derived from the **limbic system**, and modifying those **emotions** to fit socially accepted **norms**.

The Temporal Lobe

The temporal lobe is associated with the retention of short- and long-term memories. It processes sensory input including auditory information, language comprehension, and naming. It also creates emotional responses and controls biological **drives** such as aggression and **sexuality**.

The temporal lobe contains the **hippocampus**, which is the memory center of the brain. The hippocampus plays a key role in the formation of emotion-laden, long-term memories based on emotional input from the **amygdala**. The left temporal lobe holds the primary auditory cortex, which is important for processing the **semantics** of speech.

One specific portion of the temporal lobe, Wernicke's area, plays a key role in speech comprehension. Another portion, Broca's area, underlies the ability to produce (rather than understand) speech. Patients with damage to Wernicke's area can speak clearly but the words make no sense, while patients with damage to Broca's area will fail to form words properly and speech will be halting and slurred. These disorders are known as Wernicke's and Broca's **aphasia** respectively; an aphasia is an inability to speak.

Broca's and Wernicke's areas

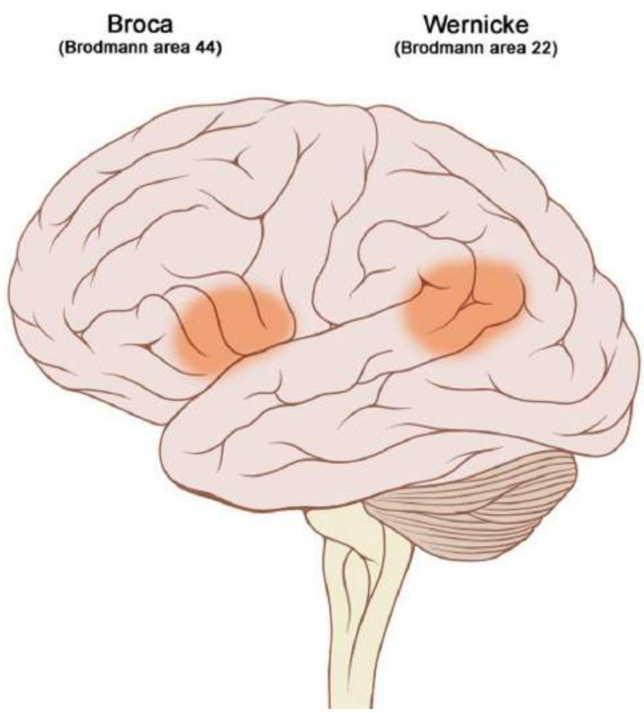


Figure 8. The locations of Broca's and Wernicke's areas in the brain. (https://radiopaedia.org/cases/brocas-and-wernickes-areas-illustration)

The Occipital Lobe

The occipital lobe contains most of the visual cortex and is the visual processing center of the brain. Cells on the posterior side of the occipital lobe are arranged as a spatial map of the retinal field. The visual cortex receives raw sensory information through sensors in the **retina** of the eyes, which is then conveyed through the optic tracts to the visual cortex. Other areas of the occipital lobe are specialized for different visual tasks, such as **visuospatial** processing, color discrimination, and **motion perception**. Damage to the primary visual cortex (located on the surface of the posterior occipital lobe) can cause blindness, due to the holes in the visual map on the surface of the cortex caused by the **lesions**.

The Parietal Lobe

The parietal lobe is associated with sensory skills. It integrates different types of sensory information and is particularly useful in spatial processing and navigation. The parietal lobe plays an important role in integrating sensory information from various parts of the body, understanding numbers and their relations, and manipulating objects. Its also processes information related to the sense of touch.

The parietal lobe is comprised of the somatosensory cortex and part of the visual system. The somatosensory cortex consists of a "map" of the body that processes sensory information from specific areas of the body. Several portions of the parietal lobe are important to language and visuospatial processing; the left parietal lobe is involved in symbolic functions in language and mathematics, while the right parietal lobe is specialized to process images and **interpretation** of maps (i.e., spatial relationships).

(https://courses.lumenlearning.com/teachereducationx92x1/chapter/cerebral-hemispheres-and-lobes-of-the-brain/)

Limbic System and Other Brain Areas

LEARNING OBJECTIVES

- **Identify and describe the role of the parts of the limbic system, the midbrain, and hindbrain**

Areas of the Forebrain

Other areas of the **forebrain** (which includes the lobes that you learned about previously), are the parts located beneath the cerebral cortex, including the thalamus and the limbic system. The **thalamus** is a sensory relay for the brain. All of our senses, with the exception of smell, are routed through the thalamus before being directed to other areas of the brain for processing (Figure 1).

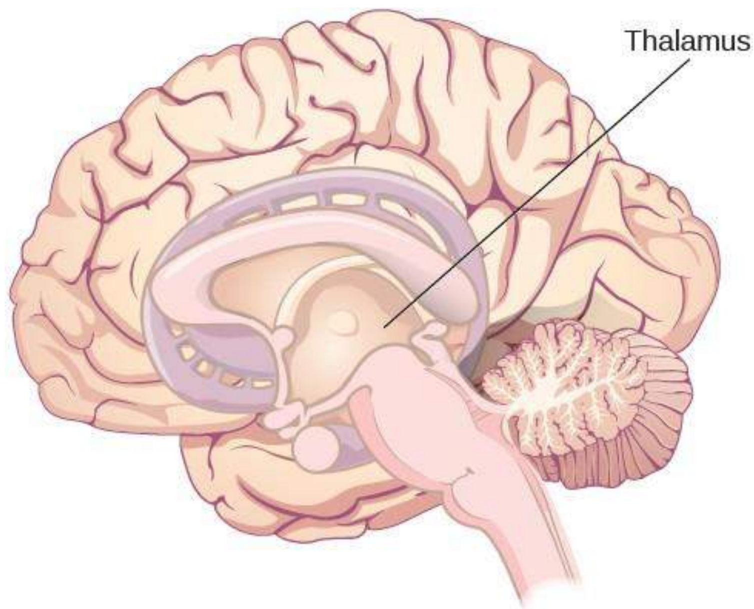


Figure 9. The thalamus serves as the relay center of the brain where most senses are routed for processing.

The **limbic system** is involved in processing both emotion and memory. Interestingly, the sense of smell projects directly to the limbic system; therefore, not surprisingly, smell can evoke emotional responses in ways that other sensory modalities cannot. The limbic system is made up of a number of different structures, but three of the most important are the hippocampus, the amygdala, and the hypothalamus (Figure 2). The **hippocampus** is an essential structure for learning and memory. The **amygdala** is involved in our experience of emotion and in tying emotional meaning to our memories. The **hypothalamus** regulates a number of homeostatic processes, including the regulation of body temperature, appetite, and blood pressure. The hypothalamus also serves as an interface between the nervous system and the endocrine system and in the regulation of sexual motivation and behavior.

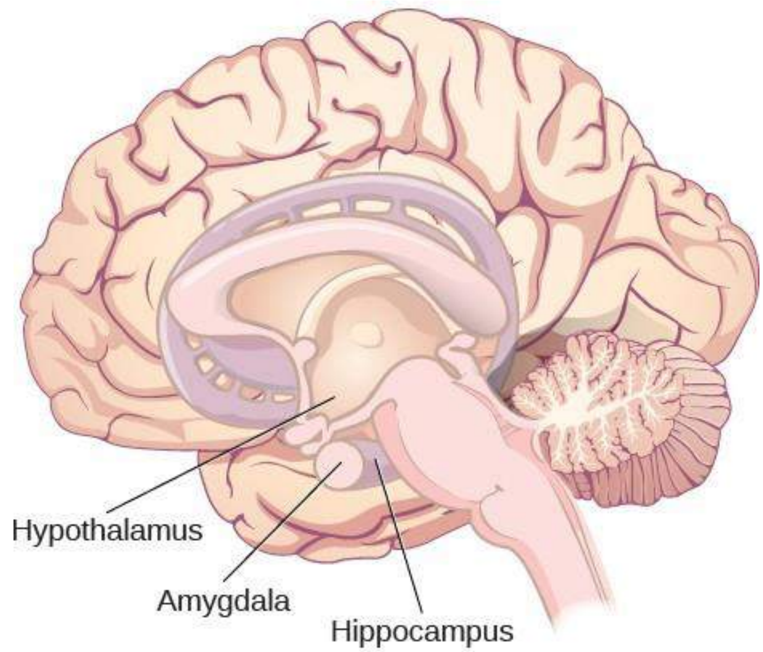


Figure 10. The limbic system is involved in mediating emotional response and memory.

THE CASE OF HENRY MOLAISON (H.M.)

In 1953, Henry Gustav Molaison (H. M.) was a 27-year-old man who experienced severe seizures. In an attempt to control his seizures, H. M. underwent brain surgery to remove his hippocampus and amygdala. Following the surgery, H.M's seizures became much less severe, but he also suffered some unexpected—and devastating— consequences of the surgery: he lost his ability to form many types of new memories. For example, he was unable to learn new facts, such as who was president of the United States. He was able to learn new skills, but afterward he had no recollection of learning them. For example, while he might learn to use a computer, he would have no conscious memory of ever having used one. He could not remember new faces, and he was unable to remember events, even immediately after they occurred. Researchers were fascinated by his experience, and he is considered one of the most studied cases in medical and psychological history (Hardt, Einarsson, & Nader, 2010; Squire, 2009). Indeed, his case has provided tremendous insight into the role that the hippocampus plays in the consolidation of new learning into explicit memory.

LINK TO LEARNING

Clive Wearing, an accomplished musician, lost the ability to form new memories when his hippocampus was damaged through illness. Check out the first few minutes of this **documentary video** for an introduction to this man and his condition.

Midbrain and Hindbrain Structures

The **midbrain** is comprised of structures located deep within the brain, between the forebrain and the hindbrain. The **reticular formation** is centered in the midbrain, but it actually extends up into the forebrain and down into the hindbrain. The reticular formation is important in regulating the sleep/wake cycle, arousal, alertness, and motor activity.

The **substantia nigra** (Latin for "black substance") and the **ventral tegmental area (VTA)** are also located in the midbrain (Figure 3). Both regions contain cell bodies that produce the neurotransmitter dopamine, and both are critical for movement. Degeneration of the substantia nigra and VTA is involved in Parkinson's disease. In addition, these structures are involved in mood, reward, and addiction (Berridge & Robinson, 1998; Gardner, 2011; George, Le Moal, & Koob, 2012).

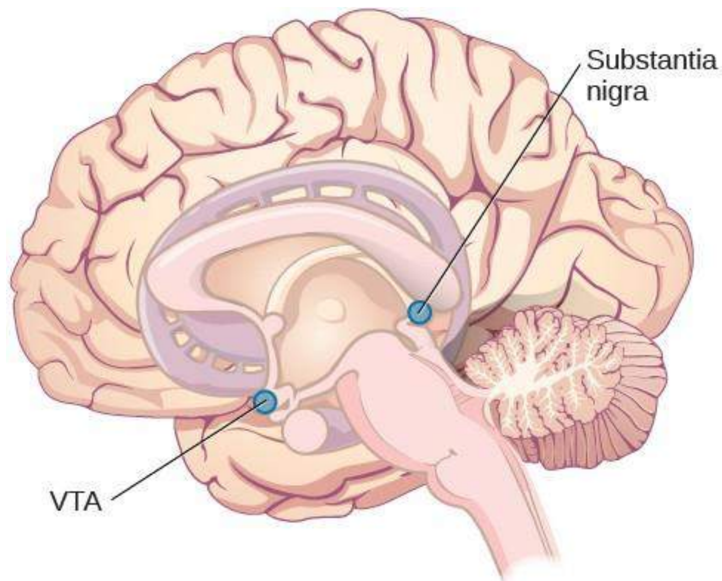


Figure 11. The substantia nigra and ventral tegmental area (VTA) are located in the midbrain.

The **hindbrain** is located at the back of the head and looks like an extension of the spinal cord. It contains the medulla, pons, and cerebellum (Figure 4). The **medulla** controls the automatic processes of the autonomic nervous system, such as breathing, blood pressure, and heart rate. The word **pons** literally means "bridge," and as the name suggests, the pons serves to connect the brain and spinal cord. It also is involved in regulating brain activity during sleep. The medulla, pons, and midbrain together are known as the brainstem.

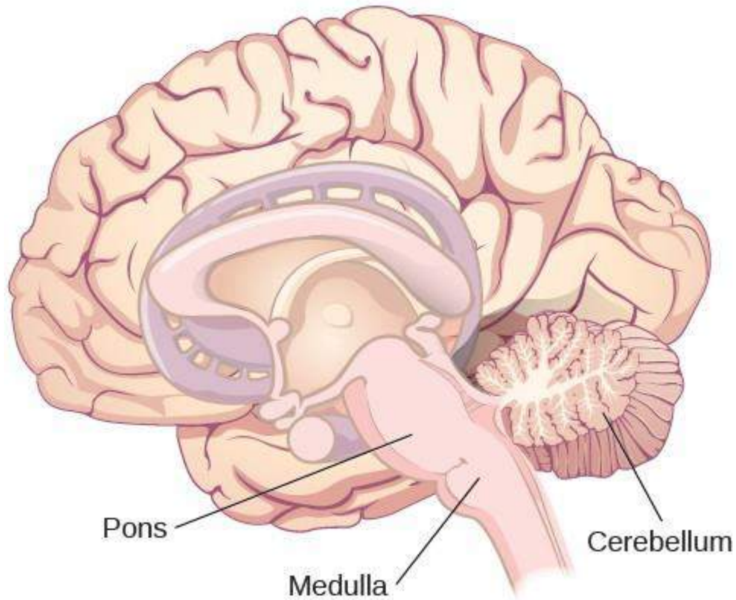


Figure 12. The pons, medulla, and cerebellum make up the hindbrain.

The **cerebellum** (Latin for "little brain") receives messages from muscles, tendons, joints, and structures in our ear to control balance, coordination, movement, and motor skills. The cerebellum is also thought to be an important area for processing some types of memories. In particular, procedural memory, or memory involved in learning and remembering how to perform tasks, is thought to be associated with the cerebellum. Recall that H. M. was unable to form new explicit memories, but he could learn new tasks. This is likely due to the fact that H. M.'s cerebellum remained intact.

LINK TO LEARNING

Click on the link below to review each part of the brain and its purpose through the PsychSim Tutorial. The tutorial is only intended for practice. Please disregard the final screen that requests you submit answers to your instructor.

Brain and Behavior

For a fun recap of the parts of the brain, watch the following short clip from the old cartoon***, Pinky and the Brain*:**

WHAT DO YOU THINK?: BRAIN DEAD AND ON LIFE SUPPORT

What would you do if your spouse or loved one was declared brain dead but his or her body was being kept alive by medical equipment? Whose decision should it be to remove a feeding tube? Should medical care costs be a factor?

On February 25, 1990, a Florida woman named Terri Schiavo went into cardiac arrest, apparently triggered by a bulimic episode. She was eventually revived, but her brain had been deprived of oxygen for a long time. Brain scans indicated that there was no activity in her

cerebral cortex, and she suffered from severe and permanent cerebral atrophy. Basically, Schiavo was in a vegetative state. Medical professionals determined that she would never again be able to move, talk, or respond in any way. To remain alive, she required a feeding tube, and there was no chance that her situation would ever improve.
On occasion, Schiavo's eyes would move, and sometimes she would groan. Despite the doctors' insistence to the contrary, her parents believed that these were signs that she was trying to communicate with them.

After 12 years, Schiavo's husband argued that his wife would not have wanted to be kept alive with no feelings, sensations, or brain activity. Her parents, however, were very much against removing her feeding tube. Eventually, the case made its way to the courts, both in the state of Florida and at the federal level. By 2005, the courts found in favor of Schiavo's husband, and the feeding tube was removed on March 18, 2005. Schiavo died 13 days later.
Why did Schiavo's eyes sometimes move, and why did she groan? Although the parts of her brain that control thought, voluntary movement, and feeling were completely damaged, her brainstem was still intact. Her medulla and pons maintained her breathing and caused involuntary movements of her eyes and the occasional groans. Over the 15-year period that she was on a feeding tube, Schiavo's medical costs may have topped $7 million (Arnst, 2003).

These questions were brought to popular conscience 25 years ago in the case of Terri Schiavo, and they persist today. In 2013, a 13-year-old girl who suffered complications after tonsil surgery was declared brain dead. There was a battle between her family, who wanted her to remain on life support, and the hospital's policies regarding persons declared brain dead. In another complicated 2013–14 case in Texas, a pregnant EMT professional declared brain dead was kept alive for weeks, despite her spouse's directives, which were based on her wishes should this situation arise. In this case, state laws designed to protect an unborn fetus came into consideration until doctors determined the fetus unviable.
Decisions surrounding the medical response to patients declared brain dead are complex. What do you think about these issues?

THINK IT OVER

You read about H. M.'s memory deficits following the bilateral removal of his hippocampus and amygdala. Have you encountered a character in a book, television program, or movie that suffered memory deficits? How was that character similar to and different from H. M.?

GLOSSARY

- **Amygdala:** structure in the limbic system involved in our experience of emotion and tying emotional meaning to our memories
- **Cerebellum:** hindbrain structure that controls our balance, coordination, movement, and motor skills, and it is thought to be important in processing some types of memory
- **Cerebral cortex:** surface of the brain that is associated with our highest mental capabilities

- **Forebrain:** largest part of the brain, containing the cerebral cortex, the thalamus, and the limbic system, among other structures
- **Hindbrain:** division of the brain containing the medulla, pons, and cerebellum
- **Hippocampus:** structure in the temporal lobe associated with learning and memory
- **Hypothalamus:** forebrain structure that regulates sexual motivation and behavior and a number of homeostatic processes; serves as an interface between the nervous system and the endocrine system
- **Limbic system:** collection of structures involved in processing emotion and memory
- **Medulla:** hindbrain structure that controls automated processes like breathing, blood pressure, and heart rate
- **Midbrain:** division of the brain located between the forebrain and the hindbrain; contains the reticular formation
- **Pons:** hindbrain structure that connects the brain and spinal cord; involved in regulating brain activity during sleep
- **Reticular formation:** midbrain structure important in regulating the sleep/wake cycle, arousal, alertness, and motor activity
- **Thalamus:** sensory relay for the brain
- **Ventral tegmental area (VTA):** midbrain structure where dopamine is produced: associated with mood, reward, and addiction

Somatosensory and Motor Cortex

Cortical Processing

As described earlier, many of the sensory axons are positioned in the same way as their corresponding receptor cells in the body. This allows identification of the position of a stimulus on the basis of which receptor cells are sending information. The cerebral cortex also maintains this sensory topography in the particular areas of the cortex that correspond to the position of the receptor cells. The somatosensory cortex provides an example in which, in essence, the locations of the somatosensory receptors in the body are mapped onto the somatosensory cortex. This mapping is often depicted using a **sensory homunculus** (Figure 13).

The term homunculus comes from the Latin word for "little man" and refers to a map of the human body that is laid across a portion of the cerebral cortex. In the somatosensory cortex, the external genitals, feet, and lower legs are represented on the medial face of the gyrus within the longitudinal fissure. As the gyrus curves out of the fissure and along the surface of the parietal lobe, the body map continues through the thighs, hips, trunk, shoulders, arms, and hands. The head and face are just lateral to the fingers as the gyrus approaches the lateral sulcus. The representation of the body in this topographical map is medial to lateral from the lower to upper body. It is a continuation of the topographical arrangement seen in the dorsal column system, where axons from the lower body are carried in the fasciculus gracilis, whereas axons from the upper body are carried in the fasciculus cuneatus. As the dorsal column system continues into the medial lemniscus, these relationships are maintained. Also, the head and neck axons running from the trigeminal nuclei to the thalamus run adjacent to the upper body fibers. The connections through the thalamus maintain topography such that the anatomic information is preserved. Note that this correspondence does not result in a perfectly miniature scale version of the body, but rather exaggerates the more sensitive areas of the body, such as the fingers and lower face. Less sensitive areas of the body, such as the shoulders and back, are mapped to smaller areas on the cortex.

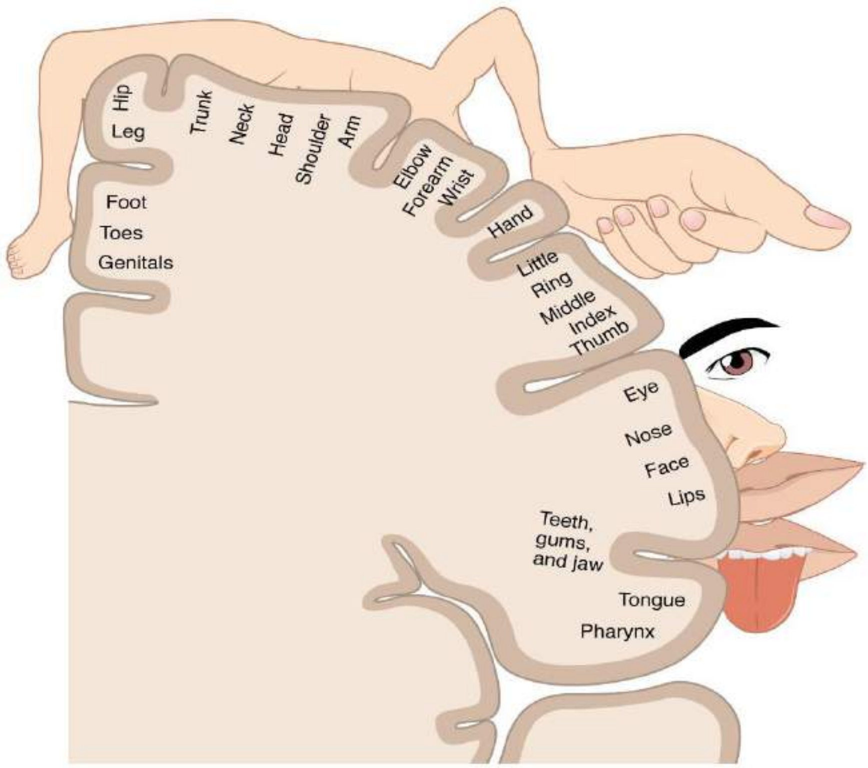


Figure 13. The Sensory Homunculus. A cartoon representation of the sensory homunculus arranged adjacent to the cortical region in which the processing takes place.

The cortex has been described as having specific regions that are responsible for processing specific information; there is the visual cortex, somatosensory cortex, gustatory cortex, etc. However, our experience of these senses is not divided. Instead, we experience what can be referred to as a seamless percept. Our perceptions of the various sensory modalities—though distinct in their content—are integrated by the brain so that we experience the world as a continuous whole.

In the cerebral cortex, sensory processing begins at the **primary sensory cortex**, then proceeds to an **association area**, and finally, into a **multimodal integration area**. For example, somatosensory information inputs directly into the primary somatosensory cortex in the post-central gyrus of the parietal lobe where general awareness of sensation (location and type of sensation) begins. In the somatosensory association cortex details are integrated into a whole. In the highest level of association cortex details are integrated from entirely different modalities to form complete representations as we experience them.

Motor Responses

The defining characteristic of the somatic nervous system is that it controls skeletal muscles. Somatic senses inform the nervous system about the external environment, but the response to that is through voluntary muscle movement. The term "voluntary" suggests that there is a conscious decision to make a movement. However, some aspects of the somatic system use voluntary muscles without conscious control. One example is the ability of our breathing to switch to unconscious control while we are focused on another task. However, the muscles that are responsible for the basic process of breathing are also utilized for speech, which is entirely voluntary.

Hemispheres

LEARNING OBJECTIVES

- **Explain the two hemispheres of the brain, lateralization and plasticity**

The central nervous system (CNS), consists of the brain and the spinal cord.

The Brain

The brain is a remarkably complex organ comprised of billions of interconnected neurons and glia. It is a bilateral, or two-sided, structure that can be separated into distinct lobes. Each lobe is associated with certain types of functions, but, ultimately, all of the areas of the brain interact with one another to provide the foundation for our thoughts and behaviors.

The Spinal Cord

It can be said that the spinal cord is what connects the brain to the outside world. Because of it, the brain can act. The spinal cord is like a relay station, but a very smart one. It not only routes messages to and from the brain, but it also has its own system of automatic processes, called reflexes.

The top of the spinal cord merges with the brain stem, where the basic processes of life are controlled, such as breathing and digestion. In the opposite direction, the spinal cord ends just below the ribs—contrary to what we might expect, it does not extend all the way to the base of the spine.

The spinal cord is functionally organized in 30 segments, corresponding with the vertebrae. Each segment is connected to a specific part of the body through the peripheral nervous system. Nerves branch out from the spine at each vertebra. Sensory nerves bring messages in;

motor nerves send messages out to the muscles and organs. Messages travel to and from the brain through every segment.

Some sensory messages are immediately acted on by the spinal cord, without any input from the brain. Withdrawal from heat and knee jerk are two examples. When a sensory message meets certain parameters, the spinal cord initiates an automatic reflex. The signal passes from the sensory nerve to a simple processing center, which initiates a motor command. Seconds are saved, because messages don't have to go the brain, be processed, and get sent back. In matters of survival, the spinal reflexes allow the body to react extraordinarily fast.

The spinal cord is protected by bony vertebrae and cushioned in cerebrospinal fluid, but injuries still occur. When the spinal cord is damaged in a particular segment, all lower segments are cut off from the brain, causing paralysis. Therefore, the lower on the spine damage is, the fewer functions an injured individual loses.

The Two Hemispheres

The surface of the brain, known as the **cerebral cortex**, is very uneven, characterized by a distinctive pattern of folds or bumps, known as **gyri** (singular: gyrus), and grooves, known as **sulci** (singular: sulcus), shown in Figure 1. These gyri and sulci form important landmarks that allow us to separate the brain into functional centers. The most prominent sulcus, known as the longitudinal fissure, is the deep groove that separates the brain into two halves or hemispheres: the left hemisphere and the right hemisphere.

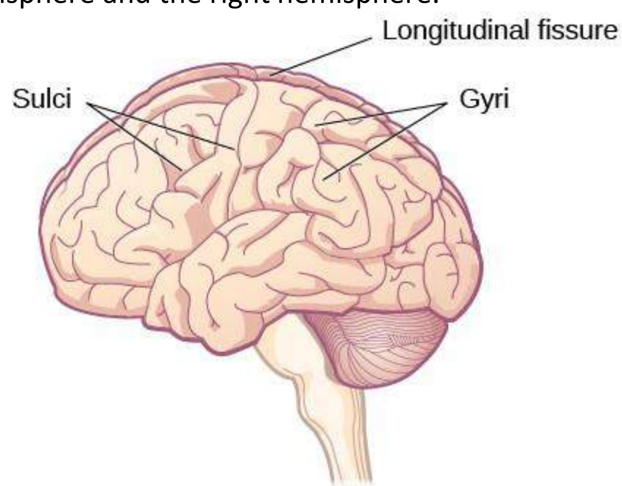


Figure 14. The surface of the brain is covered with gyri and sulci. A deep sulcus is called a fissure, such as the longitudinal fissure that divides the brain into left and right hemispheres. (credit: modification of work by Bruce Blaus)

There is evidence of some specialization of function—referred to as **lateralization**—in each hemisphere, mainly regarding differences in language ability. Beyond that, however, the differences that have been found have been minor. What we do know is that the left hemisphere controls the right half of the body, and the right hemisphere controls the left half of the body.

The two hemispheres are connected by a thick band of neural fibers known as the **corpus callosum**, consisting of about 200 million axons. The corpus callosum allows the two hemispheres to communicate with each other and allows for information being processed on one side of the brain to be shared with the other side.

Normally, we are not aware of the different roles that our two hemispheres play in day-to-day functions, but there are people who come to know the capabilities and functions of their two hemispheres quite well. In some cases of severe epilepsy, doctors elect to sever the corpus callosum as a means of controlling the spread of seizures (Figure 2). While this is an effective treatment option, it results in individuals who have split brains. After surgery, these split-brain patients show a variety of interesting behaviors. For instance, a split-brain patient is unable to name a picture that is shown in the patient's left visual field because the information is only available in the largely nonverbal right hemisphere. However, they are able to recreate the picture with their left hand, which is also controlled by the right hemisphere. When the more verbal left hemisphere sees the picture that the hand drew, the patient is able to name it (assuming the left hemisphere can interpret what was drawn by the left hand).

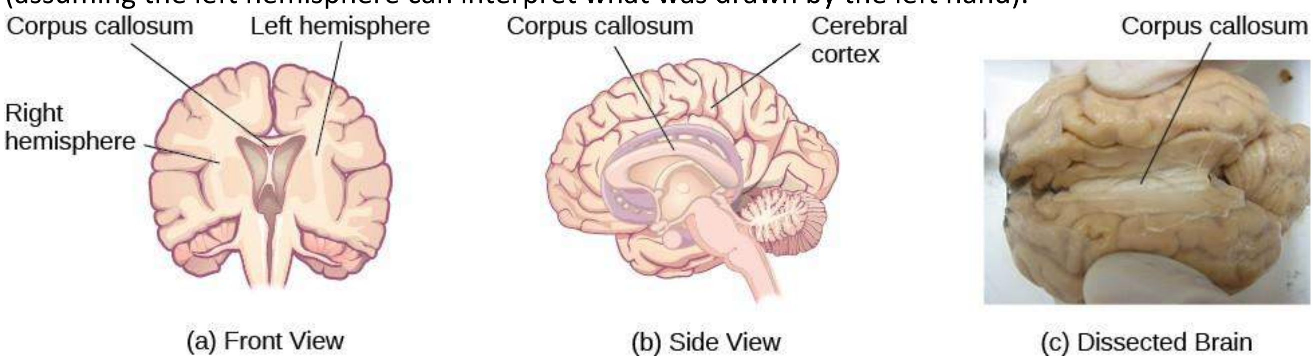


Figure 15. (a, b) The corpus callosum connects the left and right hemispheres of the brain. (c) A scientist spreads this dissected sheep brain apart to show the corpus callosum between the hemispheres. (credit c: modification of work by Aaron Bornstein)

LINK TO LEARNING

This interactive animation from the Nobel Prize website walks users through the hemispheres of the brain.

Much of what we know about the functions of different areas of the brain comes from studying changes in the behavior and ability of individuals who have suffered damage to the brain. For example, researchers study the behavioral changes caused by strokes to learn about the functions of specific brain areas. A stroke, caused by an interruption of blood flow to a region in the brain, causes a loss of brain function in the affected region. The damage can be in a small area, and, if it is, this gives researchers the opportunity to link any resulting behavioral changes to a specific area. The types of deficits displayed after a stroke will be largely dependent on where in the brain the damage occurred.

Consider Theona, an intelligent, self-sufficient woman, who is 62 years old. Recently, she suffered a stroke in the front portion of her right hemisphere. As a result, she has great difficulty moving her left leg. (As you learned earlier, the right hemisphere controls the left side of the body; also, the brain's main motor centers are located at the front of the head, in the frontal lobe.) Theona has also experienced behavioral changes. For example, while in the produce section of the grocery store, she sometimes eats grapes, strawberries, and apples directly from their bins before paying for them. This behavior—which would have been very embarrassing to her before the stroke—is consistent with damage in another region in the frontal lobe—the prefrontal cortex, which is associated with judgment, reasoning, and impulse control.

LINK TO LEARNING

Watch this video to see an incredible example of the challenges facing a split-brain patient shortly following the surgery to sever her corpus callosum.
Watch this second video about another patient who underwent a dramatic surgery to prevent her seizures. You'll learn more about the brain's ability to change, adapt, and reorganize itself, also known as brain plasticity.

GLOSSARY

- **Corpus callosum:** thick band of neural fibers connecting the brain's two hemispheres
- **Gyrus** (plural: gyri): bump or ridge on the cerebral cortex
- **Hemisphere:** left or right half of the brain
- **Lateralization:** concept that each hemisphere of the brain is associated with specialized functions
- **Longitudinal fissure:** deep groove in the brain's cortex
- **Sulcus** (plural: sulci) depressions or grooves in the cerebral cortex

Split-Brain Measures-severing the corpus callosum

Neuroplasticity, Neurogenesis, and Brain Lateralization

Learning Objectives

- **Explain and define the concepts brain neuroplasticity, neurogenesis, and brain lateralization.**

The control of some bodily functions, such as movement, vision, and hearing, is performed in specific areas of the cortex, and if an area is damaged, the individual will likely lose the ability to perform the corresponding function. For instance, if an infant suffers damage to facial recognition areas in the temporal lobe, it is likely that he or she will never be able to recognize faces. [1] However, the brain is not divided in an entirely rigid way. The brain's neurons have a remarkable capacity to reorganize and extend themselves to carry out particular functions in response to the needs of the organism and to repair damage. As a result, the brain constantly creates new neural communication routes and rewires existing ones. ***Neuroplasticity*** is *the brain's ability to change its structure and function in response to experience or damage*. Neuroplasticity enables us to learn and remember new things and adjust to new experiences.

Our brains are the most "plastic" when we are young children, as it is during this time that we learn the most about our environment. And neuroplasticity continues to be observed even in adults. [2] The principles of neuroplasticity help us understand how our brains develop to reflect our experiences. For instance, accomplished musicians have a larger auditory cortex compared with the general population [3] and also require less neural activity to play their instruments than do novices. [4] These observations reflect the changes in the brain that follow our experiences.

Plasticity is also observed when damage occurs to the brain or to parts of the body that are represented in the motor and sensory cortexes. When a tumor in the left hemisphere of the brain impairs language, the right hemisphere begins to compensate to help the person recover the ability to speak. [5] And if a person loses a finger, the area of the sensory cortex that previously received information from the missing finger begins to receive input from adjacent fingers, causing the remaining digits to become more sensitive to touch. [6]
Although neurons cannot repair or regenerate themselves as skin and blood vessels can, new evidence suggests that the brain can engage in ***neurogenesis***, *the forming of new neurons*. [7] These new neurons originate deep in the brain and may then migrate to other brain areas where they form new connections with other neurons. [8] This leaves open the possibility that someday scientists might be able to "rebuild" damaged brains by creating drugs that help grow neurons.

Unique Functions of the Left and Right Hemispheres Using Split-Brain Patients

We learned that the left hemisphere of the brain primarily senses and controls the motor movements on the right side of the body, and vice versa. This fact provides an interesting way to study brain lateralization—the idea that the left and the right hemispheres of the brain are specialized to perform different functions. Gazzaniga, Bogen, and Sperry [9] studied a patient, known as W. J., who had undergone an operation to relieve severe seizures. In this surgery, the region that normally connects the two halves of the brain and supports communication between the hemispheres, known as the corpus callosum, is severed. As a result, the patient essentially becomes a person with two separate brains. Because the left and right hemispheres are separated, each hemisphere develops a mind of its own, with its own sensations, concepts, and motivations.[10]
In their research, Gazzaniga and his colleagues tested the ability of W. J. to recognize and respond to objects and written passages that were presented to only the left or to only the right brain hemispheres. The researchers had W. J. look straight ahead and then flashed, for a fraction of a second, a picture of a geometric shape to the left of where he was looking. By

doing so, they assured that—because the two hemispheres had been separated—the image of the shape was experienced only in the right brain hemisphere (remember that sensory input from the left side of the body is sent to the right side of the brain). Gazzaniga and his colleagues found that W. J. was able to identify what he had been shown when he was asked to pick the object from a series of shapes, using his left hand, but that he could not do so when the object was shown in the right visual field. Conversely, W. J. could easily read written material presented in the right visual field (and thus experienced in the left hemisphere) but not when it was presented in the left visual field.

Visual and Verbal Processing in the Split-Brain Patient

The information presented on the left side of our field of vision is transmitted to the right brain hemisphere, and vice versa. In split-brain patients, the severed corpus callosum does not permit information to be transferred between hemispheres, which allows researchers to learn about the functions of each hemisphere.

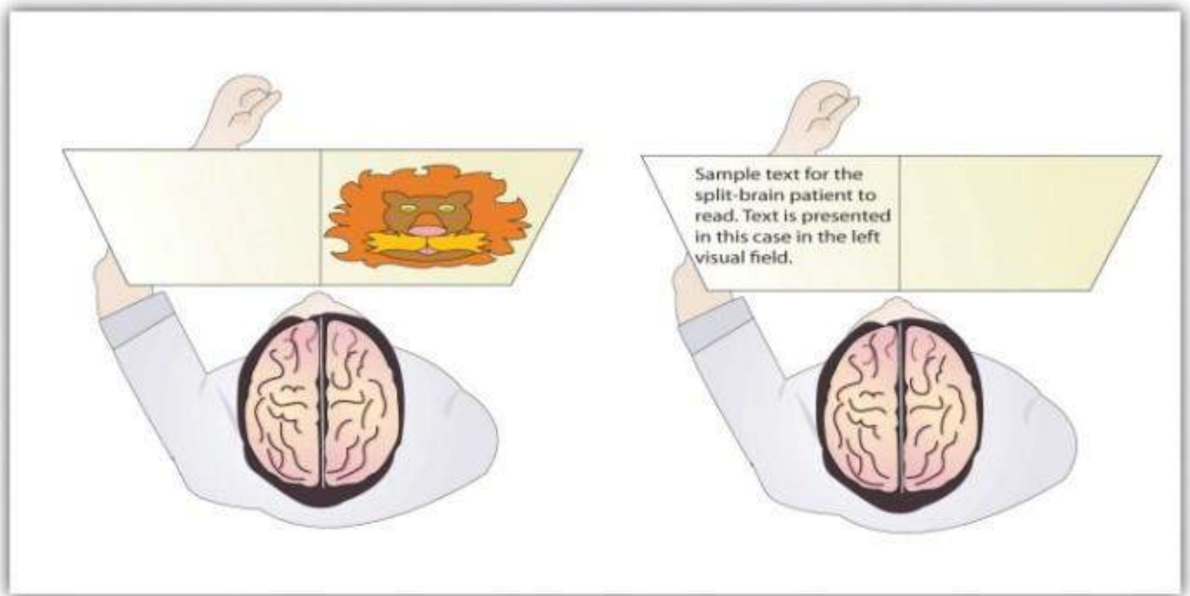


Figure 16. In the sample on the left, the split-brain patient could not choose which image had been presented because the left hemisphere cannot process visual information. In the sample on the right, the patient could not read the passage because the right brain hemisphere cannot process language. From Flat World Knowledge, Introduction to Psychology, v1.0, CC-BY-NC-SA.

This research, and many other studies following it, demonstrated that the two brain hemispheres specialize in different abilities. In most people, the ability to speak, write, and understand language is located in the left hemisphere. This is why W. J. could read passages that were presented on the right side and thus transmitted to the left hemisphere, but could not read passages that were only experienced in the right brain hemisphere. The left hemisphere is also better at math and at judging time and rhythm. It is also superior in coordinating the order of complex movements—for example, lip movements needed for speech. The right hemisphere has only limited verbal abilities, and yet it excels in perceptual skills. The right hemisphere is able to recognize objects, including faces, patterns, and melodies, and it can put a puzzle together or draw a picture. This is why W. J. could pick out the image

when he saw it on the left, but not the right, visual field.
Although Gazzaniga's research demonstrated that the brain is in fact lateralized, such that the two hemispheres specialize in different activities, this does not mean that when people behave in a certain way or perform a certain activity they are using only one hemisphere of their brains at a time. That would be drastically oversimplifying the concept of brain differences. We normally use both hemispheres at the same time, and the difference between the abilities of the two hemispheres is not absolute. [11]

Trauma

Cortical Responses

Let's start with sensory stimuli that have been registered through receptor cells and the information relayed to the CNS along ascending pathways. In the cerebral cortex, the initial processing of sensory perception progresses to associative processing and then integration in multimodal areas of cortex. These levels of processing can lead to the incorporation of sensory perceptions into memory, but more importantly, they lead to a response. The completion of cortical processing through the primary, associative, and integrative sensory areas initiates a similar progression of motor processing, usually in different cortical areas.
Whereas the sensory cortical areas are located in the occipital, temporal, and parietal lobes, motor functions are largely controlled by the frontal lobe. The most anterior regions of the frontal lobe—the prefrontal areas—are important for **executive functions**, which are those cognitive functions that lead to goal-directed behaviors. These higher cognitive processes include **working memory**, which has been called a "mental scratch pad," that can help organize and represent information that is not in the immediate environment. The prefrontal lobe is responsible for aspects of attention, such as inhibiting distracting thoughts and actions so that a person can focus on a goal and direct behavior toward achieving that goal.

The functions of the prefrontal cortex are integral to the personality of an individual, because it is largely responsible for what a person intends to do and how they accomplish those plans. A famous case of damage to the prefrontal cortex is that of Phineas Gage, dating back to 1848. He was a railroad worker who had a metal spike impale his prefrontal cortex (Figure 1). He survived the accident, but according to second-hand accounts, his personality changed drastically. Friends described him as no longer acting like himself. Whereas he was a hardworking, amiable man before the accident, he turned into an irritable, temperamental, and lazy man after the accident. Many of the accounts of his change may have been inflated in the retelling, and some behavior was likely attributable to alcohol used as a pain medication. However, the accounts suggest that some aspects of his personality did change. Also, there is new evidence that though his life changed dramatically, he was able to become a functioning stagecoach driver, suggesting that the brain has the ability to recover even from major trauma such as this.

Phineas Gage

The victim of an accident while working on a railroad in 1848, Phineas Gage had a large iron rod impaled through the prefrontal cortex of his frontal lobe. After the accident, his personality appeared to change, but he eventually learned to cope with the trauma and lived as a coach

driver even after such a traumatic event.

Figure 17. (credit b: John M. Harlow, MD)

Figure 18. Phineas Gage. The victim of an accident while working on a railroad in 1848, Phineas Gage had a large iron rod impaled through the prefrontal cortex of his frontal lobe. After the accident, his personality appeared to change, but he eventually learned to cope with the trauma and lived as a coach driver even after such a traumatic event. (credit b: John M. Harlow, MD)

Chapter 3 – Methods of Research

Learning Objectives

1. **Describe a general model of scientific research in psychology and give specific examples that fit the model.**
2. **Explain who conducts scientific research in psychology and why they do it.**
3. **Distinguish between basic research and applied research.**

A Model of Scientific Research in Psychology

Figure 1 presents a more specific model of scientific research in psychology. The researcher (who more often than not is really a small group of researchers) formulates a research question, conducts a study designed to answer the question, analyzes the resulting data, draws conclusions about the answer to the question, and publishes the results so that they become part of the research literature. Because the research literature is one of the primary sources of new research questions, this process can be thought of as a cycle. New research leads to new questions, which lead to new research, and so on. Figure 1 also indicates that research questions can originate outside of this cycle either with informal observations or with practical problems that need to be solved. But even in these cases, the researcher would start by checking the research literature to see if the question had already been answered and to refine it based on what previous research had already found.

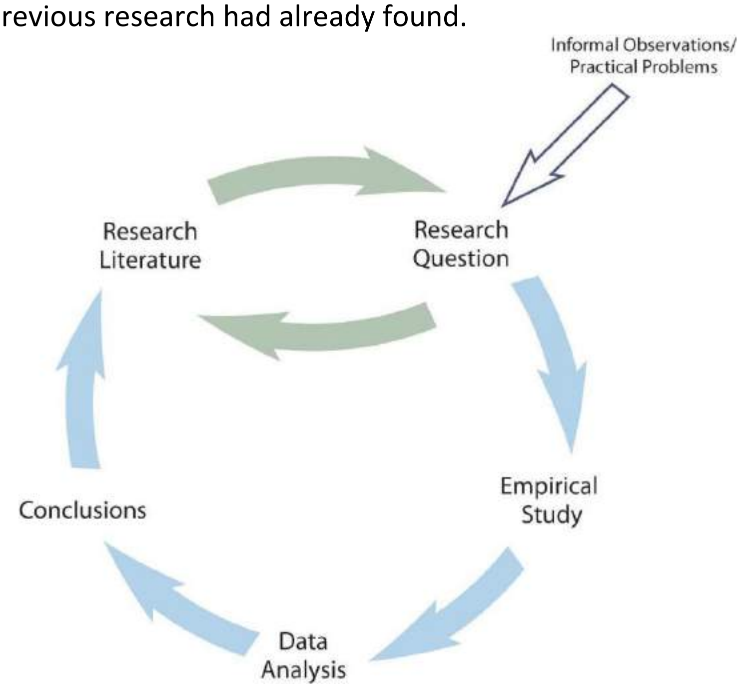


Figure 1. A Simple Model of Scientific Research in Psychology

The research by Mehl and his colleagues is described nicely by this model. Their question—whether women are more talkative than men—was suggested to them both by people's stereotypes and by published claims about the relative talkativeness of women and men. When they checked the research literature, however, they found that this question had not been adequately addressed in scientific studies. They conducted a careful empirical study, analyzed the results (finding very little difference between women and men), and published their work so that it became part of the research literature. The publication of their article is not the end of the story, however, because their work suggests many new questions (about the reliability of the result, about potential cultural differences, etc.) that will likely be taken up by them and by other researchers inspired by their work.

Figure 2. Scientific research has confirmed that cell phone use impairs a variety of driving behaviors. Indiana Stan *– CC BY-NC 2.0.*

As another example, consider that as cell phones became more widespread during the 1990s, people began to wonder whether, and to what extent, cell phone use had a negative effect on driving. Many psychologists decided to tackle this question scientifically (Collet, Guillot, & Petit, 2010). It was clear from previously published research that engaging in a simple verbal task impairs performance on a perceptual or motor task carried out at the same time, but no one had studied the effect specifically of cell phone use on driving. Under carefully controlled conditions, these researchers compared people's driving performance while using a cell phone with their performance while not using a cell phone, both in the lab and on the road. They found that people's ability to detect road hazards, reaction time, and control of the vehicle were all impaired by cell phone use. Each new study was published and became part of the growing research literature on this topic.

Who Conducts Scientific Research in Psychology?

Scientific research in psychology is generally conducted by people with doctoral degrees (usually the doctor of philosophy [PhD]) and master's degrees in psychology and related fields, often supported by research assistants with bachelor's degrees or other relevant training. Some of them work for government agencies (e.g., the National Institute of Mental Health), for nonprofit organizations (e.g., the American Cancer Society), or in the private sector (e.g., in product development). However, the majority of them are college and university faculty, who often collaborate with their graduate and undergraduate students. Although some researchers are trained and licensed as clinicians—especially those who conduct research in clinical psychology—the majority are not. Instead, they have expertise in one or more of the many other subfields of psychology: behavioral neuroscience, cognitive psychology, developmental psychology, personality psychology, social psychology, and so on. Doctoral-level researchers might be employed to conduct research full-time or, like many college and university faculty members, to conduct research in addition to teaching classes and serving their institution and community in other ways.

Of course, people also conduct research in psychology because they enjoy the intellectual and technical challenges involved and the satisfaction of contributing to scientific knowledge of human behavior. You might find that you enjoy the process too. If so, your college or university might offer opportunities to get involved in ongoing research as either a research assistant or a participant. Of course, you might find that you do not enjoy the process of conducting scientific research in psychology. But at least you will have a better understanding of where scientific knowledge in psychology comes from, an appreciation of its strengths and limitations, and an awareness of how it can be applied to solve practical problems in psychology and everyday life.

Scientific Psychology Blogs

A fun and easy way to follow current scientific research in psychology is to read any of the many excellent blogs devoted to summarizing and commenting on new findings.
Among them are the following:

- Child Psych, http://www.child psych.org
- PsyBlog, http://www.spring.org.uk
- Research Digest, http://bps research digest.blogspot.com
- Social Psychology Eye, http://socialpsychologyeye.wordpress.com
- We're Only Human, http://www.psychologicalscience.org/onlyhuman

You can also browse to http://www.researchblogging.org, select psychology as your topic, and read entries from a wide variety of blogs.

The Broader Purposes of Scientific Research in Psychology

People have always been curious about the natural world, including themselves and their behavior. (In fact, this is probably why you are studying psychology in the first place.) Science grew out of this natural curiosity and has become the best way to achieve detailed and accurate knowledge. Keep in mind that most of the phenomena and theories that fill psychology textbooks are the products of scientific research. In a typical introductory psychology textbook, for example, one can learn about specific cortical areas for language and perception, principles of classical and operant conditioning, biases in reasoning and judgment, and people's surprising tendency to obey authority. And scientific research continues because what we know right now only scratches the surface of what we *can* know.

Scientific research is often classified as being either basic or applied. Basic research in psychology is conducted primarily for the sake of achieving a more detailed and accurate understanding of human behavior, without necessarily trying to address any particular practical problem. The research of Mehl and his colleagues falls into this category. Applied research is conducted primarily to address some practical problem. Research on the effects of cell phone use on driving, for example, was prompted by safety concerns and has led to the enactment of laws to limit this practice. Although the distinction between basic and applied research is convenient, it is not always clear-cut. For example, basic research on sex differences in talkativeness could eventually have an effect on how marriage therapy is practiced, and applied research on the effect of cell phone use on driving could produce new insights into basic processes of perception, attention, and action.

Key Takeaways

- Research in psychology can be described by a simple cyclical model. A research question based on the research literature leads to an empirical study, the results of which are published and become part of the research literature.
- Scientific research in psychology is conducted mainly by people with doctoral degrees in psychology and related fields, most of whom are college and university faculty members. They do so for professional and for personal reasons, as well as to contribute to scientific knowledge about human behavior.
- Basic research is conducted to learn about human behavior for its own sake, and applied research is conducted to solve some practical problem. Both are valuable, and the distinction between the two is not always clear-cut.

Exercises

1. Practice: Find a description of an empirical study in a professional journal or in one of the scientific psychology blogs. Then write a brief description of the research in terms of the cyclical model presented here. One or two sentences for each part of the cycle should suffice.
2. Practice: Based on your own experience or on things you have already learned about psychology, list three basic research questions and three applied research questions of interest to you.

Chapter 4 - Memory

Memory and the Brain

Neural Correlates of Memory Consolidation

The hippocampus, amygdala, and cerebellum play important roles in the consolidation and manipulation of memory.

LEARNING OBJECTIVES

Analyze the role each brain structure involved in memory formation and consolidation

KEY TAKEAWAYS

Key Points

- **Memory consolidation is a category of processes that stabilize a memory trace after its initial acquisition.**
- **The hippocampus is essential for the consolidation of both short term and long term memories. Damage to this area of the brain can render a person incapable of making new memories and may even affect older memories that have not been fully consolidated.**
- **The amygdala has been associated with enhanced retention of memory. Because of this, it is thought to modulate memory consolidation. The effect is most pronounced in emotionally charged events.**
- **The cerebellum is associated with creativity and innovation. It is theorized that all processes of working memory are adaptively modeled by the cerebellum.**

Key Terms

- **declarative memory**: The type of long term memory that stores facts and events; also known as conscious or explicit memory.
- **encoding**: The process of converting information into a construct that can be stored within the brain.
- **consolidation**: The act or process of turning short term memories into more permanent, long term memories.

Memory consolidation is a category of processes that stabilize a memory trace after its initial acquisition. Like encoding, consolidation affects how well a memory will be remembered after it is stored: if it is encoded and consolidated well, the memory will be easily retrieved in full detail, but if encoding or consolidation is neglected, the memory will not be retrieved or may not be accurate.

Consolidation occurs through communication between several parts of the brain, including the hippocampus, the amygdala, and the cerebellum.

The Hippocampus

While psychologists and neuroscientists debate the exact role of the hippocampus, they generally agree that it plays an essential role in both the formation of new memories about experienced events and declarative memory (which handles facts and knowledge rather than motor skills). The hippocampus is critical to the formation of memories of events and facts.

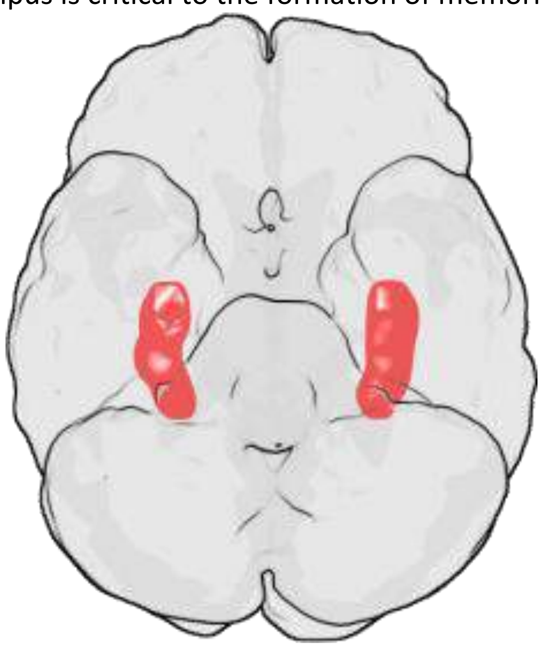


Figure 1. The hippocampus: The hippocampus is integral in consolidating memories from short-term to long-term memory.

Information regarding an event is not instantaneously stored in long-term memory. Instead, sensory details from the event are slowly assimilated into long-term storage over time through the process of consolidation. Some evidence supports the idea that, although these forms of memory often last a lifetime, the hippocampus ceases to play a crucial role in the retention of memory after the period of consolidation.

Damage to the hippocampus usually results in difficulties forming new memories, or anterograde amnesia, and normally also brings about problems accessing memories that were created prior to the damage, or retrograde amnesia. A famous case study that made this theory plausible is the story of a patient known as HM: After his hippocampus was removed in an effort to cure his epilepsy, he lost the ability to form memories. People with damage to the hippocampus may still be able to learn new skills, however, because those types of memory are non-declarative. Damage may not affect much older memories. All this contributes to the idea that the hippocampus may not be crucial in memory retention in the post-consolidation stages.

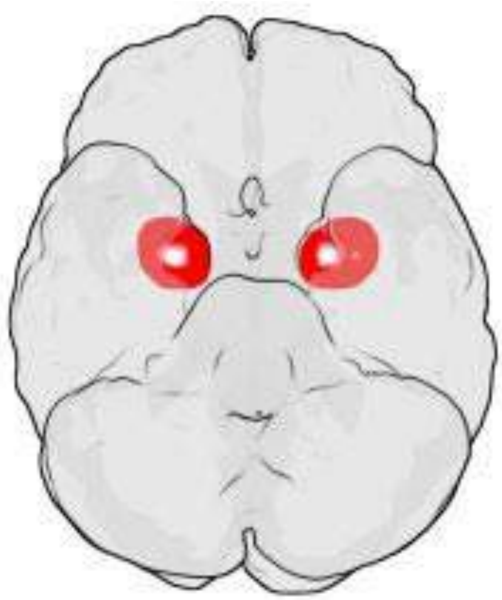


Figure 2. The amygdala: The amygdala is involved in enhancing the consolidation of emotional memories.

The Amygdala

The amygdala is involved in memory consolidation—specifically, in how consolidation is modulated. “Modulation” refers to the strength with which a memory is consolidated. In particular, it appears that emotional arousal following an event influences the strength of the subsequent memory. Greater emotional arousal following learning enhances a person’s retention of that stimulus.

The amygdala is involved in mediating the effects of emotional arousal on the strength of the memory of an event. Even if the amygdala is damaged, memories can still be encoded. The amygdala is most helpful in enhancing the memories of emotionally charged events, such as recalling all of the details on a day when you experienced a traumatic accident.

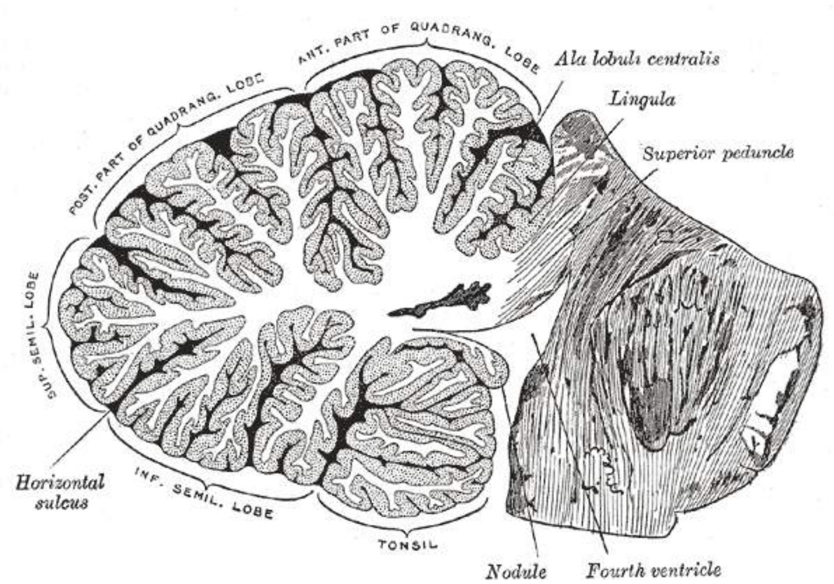


Figure 3. The cerebellum: A vertical cross-section of the human cerebellum, showing the folding pattern of the cortex, and interior structures.

The Cerebellum

The cerebellum plays a role in the learning of procedural memory (i.e., routine, "practiced" skills), and motor learning, such as skills requiring coordination and fine motor control. Playing a musical instrument, driving a car, and riding a bike are examples of skills requiring procedural memory. The cerebellum is more generally involved in motor learning, and damage to it can result in problems with movement; specifically, it is thought to coordinate the timing and accuracy of movements, and to make long-term changes (learning) to improve these skills. A person with hippocampal damage might still be able to remember how to play the piano but not remember facts about their life. But a person with damage to their cerebellum would have the opposite problem: they would remember their declarative memories, but would have trouble with procedural memories like playing the piano.

Memory Processes

Although the physical location of memory remains relatively unknown, it is thought to be distributed in neural networks throughout the brain.

LEARNING OBJECTIVES

- Discuss the physical characteristics of memory storage

KEY TAKEAWAYS

Key Points

- **It is theorized that memories are stored in neural networks in various parts of the brain associated with different types of memory, including short term memory, sensory memory, and long-term memory.**
- **Memory traces, or engrams, are physical neural changes associated with memories. Scientists have gained knowledge about these neuronal codes from studies on neuroplasticity.**
- **Encoding of episodic memory involves lasting changes in molecular structures, which alter communication between neurons. Recent functional imaging studies have detected working-memory signals in the medial temporal lobe and the prefrontal cortex.**
- **Both the frontal lobe and prefrontal cortex are associated with long and short term memory, suggesting a strong link between these two types of memory.**
- **The hippocampus is integral in consolidating memories but does not seem to store memories itself.**

Key Terms

- **engram: A postulated physical or biochemical change in neural tissue that represents a memory; a memory trace.**
- **neuroplasticity: The state or quality of the brain that allows it to adapt to experience through physical changes in connections.**

Many areas of the brain have been associated with the processes of memory storage. Lesion studies and case studies of individuals with brain injuries have allowed scientists to determine which areas of the brain are most associated with which kinds of memory. However, the actual physical location of memories remains relatively unknown. It is theorized that memories are stored in neural networks in various parts of the brain associated with different types of memory, including short-term memory, sensory memory, and long-term memory. Keep in mind, however, that it is not sufficient to describe memory as solely dependent on specific brain regions, although there are areas and pathways that have been shown to be related to certain functions.

Memory Traces

Memory traces, or *engrams*, are the physical neural changes associated with memory storage. The big question of how information and mental experiences are coded and represented in the brain remains unanswered. However, scientists have gained much knowledge about neuronal codes from studies on neuroplasticity, the brain's capacity to change its neural connections.

Most of this research has been focused on simple learning and does not clearly describe changes involved in more complex examples of memory.
Encoding of working memory involves the activation of individual neurons induced by sensory input. These electric spikes continue even after the sensation stops. Encoding of episodic memory (i.e., memories of experiences) involves lasting changes in molecular structures that alter communication between neurons. Recent functional-magnetic-resonance-imaging (fMRI) studies detected working memory signals in the medial temporal lobe and the prefrontal cortex. These areas are also associated with long-term memory, suggesting a strong relationship between working memory and long-term memory.

Brain Areas Associated with Memory

Imaging research and lesion studies have led scientists to conclude that certain areas of the brain may be more specialized for collecting, processing, and encoding specific types of memories. Activity in different lobes of the cerebral cortex have been linked to the formation of memories.

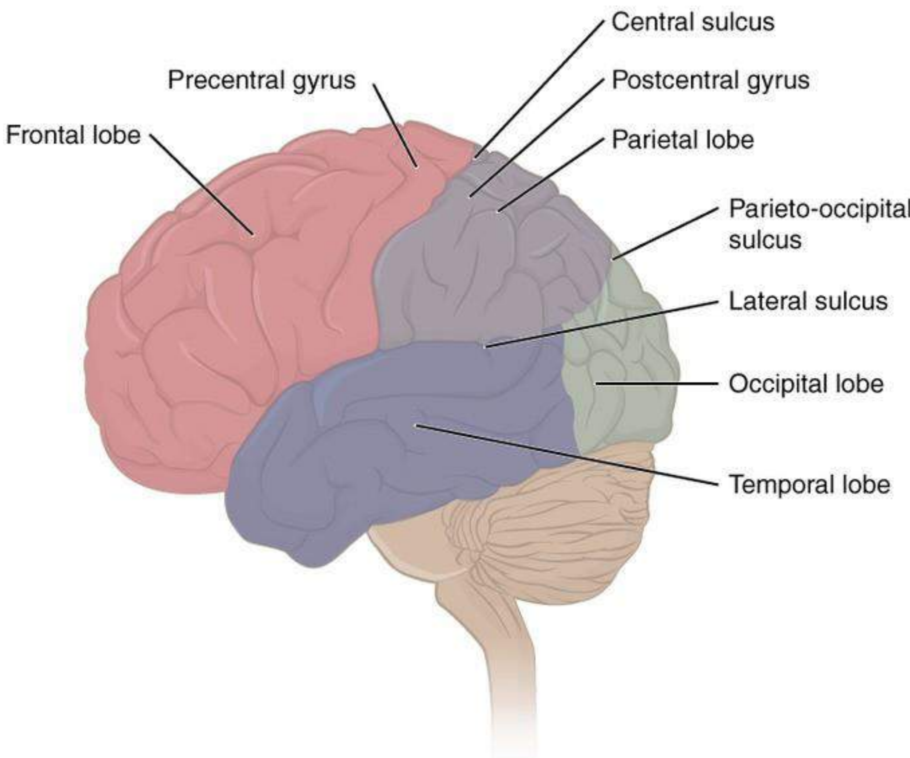


Figure 4. ***Lobes of the cerebral cortex****: While memory is created and stored throughout the brain, some regions have been shown to be associated with specific types of memory. The temporal lobe is important for sensory memory, while the frontal lobe is associated with both short- and long-term memory.*

Sensory Memory

The temporal and occipital lobes are associated with sensation and are thus involved in sensory memory. Sensory memory is the briefest form of memory, with no storage capability. Instead, it is a temporary "holding cell" for sensory information, capable of holding information for seconds at most before either passing it to short-term memory or letting it disappear.

Short-Term Memory

Short-term memory is supported by brief patterns of neural communication that are dependent on regions of the prefrontal cortex, frontal lobe, and parietal lobe. The hippocampus is essential for the consolidation of information from short-term to long-term memory; however, it does not seem to store information itself, adding mystery to the question of where memories are stored. The hippocampus receives input from different parts of the cortex and sends output to various areas of the brain. The hippocampus may be involved in changing neural connections for at least three months after information is initially processed. This area is believed to be important for spatial and declarative (i.e., fact-based) memory as well.

Long-Term Memory

Long-term memory is maintained by stable and permanent changes in neural connections spread throughout the brain. The processes of consolidating and storing long-term memories have been particularly associated with the prefrontal cortex, cerebrum, frontal lobe, and medial temporal lobe. However, the permanent storage of long-term memories after consolidation and encoding appears to depend upon the connections between neurons, with more deeply processed memories having stronger connections.

Three Stages of the Learning/Memory Process

Psychologists distinguish between three necessary stages in the learning and memory process: **encoding**, **storage**, and **retrieval** (Melton, 1963). Encoding is defined as the initial learning of information; storage refers to maintaining information over time; retrieval is the ability to access information when you need it. If you meet someone for the first time at a party, you need to encode her name (Lyn Goff) while you associate her name with her face. Then you need to maintain the information over time. If you see her a week later, you need to recognize her face and have it serve as a cue to retrieve her name. Any successful act of remembering requires that all three stages be intact. However, two types of errors can also occur. Forgetting is one type: you see the person you met at the party and you cannot recall her name. The other error is misremembering (false recall or false recognition): you see someone who looks like Lyn Goff and call the person by that name (false recognition of the face). Or, you might see the real Lyn Goff, recognize her face, but then call her by the name of another woman you met at the party (misrecall of her name).

Whenever forgetting or misremembering occurs, we can ask, at which stage in the learning/memory process was there a failure?—though it is often difficult to answer this question with precision. One reason for this inaccuracy is that the three stages are not as discrete as our description implies. Rather, all three stages depend on one another. How we encode information determines how it will be stored and what cues will be effective when we try to retrieve it. And too, the act of retrieval itself also changes the way information is subsequently remembered, usually aiding later recall of the retrieved information. The central point for now is that the three stages—encoding, storage, and retrieval—affect one another, and are inextricably bound together.

Encoding

Memory encoding allows an item of interest to be converted into a construct that is stored in the brain, which can later be recalled.

Memory encoding allows information to be converted into a construct that is stored in the brain indefinitely. Once it is encoded, it can be recalled from either short- or long-term memory. At a very basic level, memory encoding is like hitting "Save" on a computer file. Once a file is saved, it can be retrieved as long as the hard drive is undamaged. "Recall" refers to retrieving previously encoded information.

The process of encoding begins with perception, which is the identification, organization, and interpretation of any sensory information in order to understand it within the context of a particular environment. Stimuli are perceived by the senses, and related signals travel to the thalamus of the human brain, where they are synthesized into one experience. The hippocampus then analyzes this experience and decides if it is worth committing to long-term memory.

Encoding is achieved using chemicals and electric impulses within the brain. Neural pathways, or connections between neurons (brain cells), are actually formed or strengthened through a process called long-term potentiation, which alters the flow of information within the brain. In other words, as a person experiences novel events or sensations, the brain "rewires" itself in order to store those new experiences in memory.

Encoding refers to the initial experience of perceiving and learning information. Psychologists often study recall by having participants study a list of pictures or words. Encoding in these situations is fairly straightforward. However, "real life" encoding is much more challenging. When you walk across campus, for example, you encounter countless sights and sounds—friends passing by, people playing Frisbee, music in the air. The physical and mental environments are much too rich for you to encode all the happenings around you or the internal thoughts you have in response to them. So, an important first principle of encoding is that it is selective: we attend to some events in our environment and we ignore others. A second point about encoding is that it is prolific; we are always encoding the events of our lives—attending to the world, trying to understand it. Normally this presents no problem, as our days are filled with routine occurrences, so we don't need to pay attention to everything. But if something does happen that seems strange—during your daily walk across campus, you see a giraffe—then we pay close attention and try to understand why we are seeing what we are seeing.

Figure 5. A giraffe in the context of a zoo or its natural habitat may register as nothing more than ordinary, but put it in another setting - in the middle of a campus or a busy city - and its level of distinctiveness increases dramatically. Distinctiveness is a key attribute to remembering events. [Image: Colin J Babb, https://goo.gl/Cci2yl, CC BY-SA 2.0, https://goo.gl/jSSrcO]

Right after your typical walk across campus (one without the appearance of a giraffe), you would be able to remember the events reasonably well if you were asked. You could say whom you bumped into, what song was playing from a radio, and so on. However, suppose someone asked you to recall the same walk a month later. You wouldn't stand a chance. You would likely be able to recount the basics of a typical walk across campus, but not the precise details of that particular walk. Yet, if you had seen a giraffe during that walk, the event would have been fixed in your mind for a long time, probably for the rest of your life. You would tell your friends about it, and, on later occasions when you saw a giraffe, you might be reminded of the day you saw one on campus. Psychologists have long pinpointed **distinctiveness**—having an event stand out as quite different from a background of similar events—as a key to remembering events (Hunt, 2003).

In addition, when vivid memories are tinged with strong emotional content, they often seem to leave a permanent mark on us. Public tragedies, such as terrorist attacks, often create vivid memories in those who witnessed them. But even those of us not directly involved in such events may have vivid memories of them, including memories of first hearing about them. For example, many people are able to recall their exact physical location when they first learned about the assassination or accidental death of a national figure. The term **flashbulb memory** was originally coined by Brown and Kulik (1977) to describe this sort of vivid memory of finding out an important piece of news. The name refers to how some memories seem to be captured in the mind like a flash photograph; because of the distinctiveness and emotionality of the news, they seem to become permanently etched in the mind with exceptional clarity

compared to other memories.
Take a moment and think back on your own life. Is there a particular memory that seems sharper than others? A memory where you can recall unusual details, like the colors of mundane things around you, or the exact positions of surrounding objects? Although people have great confidence in flashbulb memories like these, the truth is, our objective accuracy with them is far from perfect (Talarico & Rubin, 2003). That is, even though people may have great confidence in what they recall, their memories are not as accurate (e.g., what the actual colors were; where objects were truly placed) as they tend to imagine. Nonetheless, all other things being equal, distinctive and emotional events are well-remembered.

Details do not leap perfectly from the world into a person's mind. We might say that we went to a party and remember it, but what we remember is (at best) what we encoded. As noted above, the process of encoding is selective, and in complex situations, relatively few of many possible details are noticed and encoded. The process of encoding always involves **recoding**—that is, taking the information from the form it is delivered to us and then converting it in a way that we can make sense of it. For example, you might try to remember the colors of a rainbow by using the acronym ROY G BIV (red, orange, yellow, green, blue, indigo, violet). The process of recoding the colors into a name can help us to remember. However, recoding can also introduce errors—when we accidentally add information during encoding, then remember that *new* material as if it had been part of the actual experience (as discussed below).

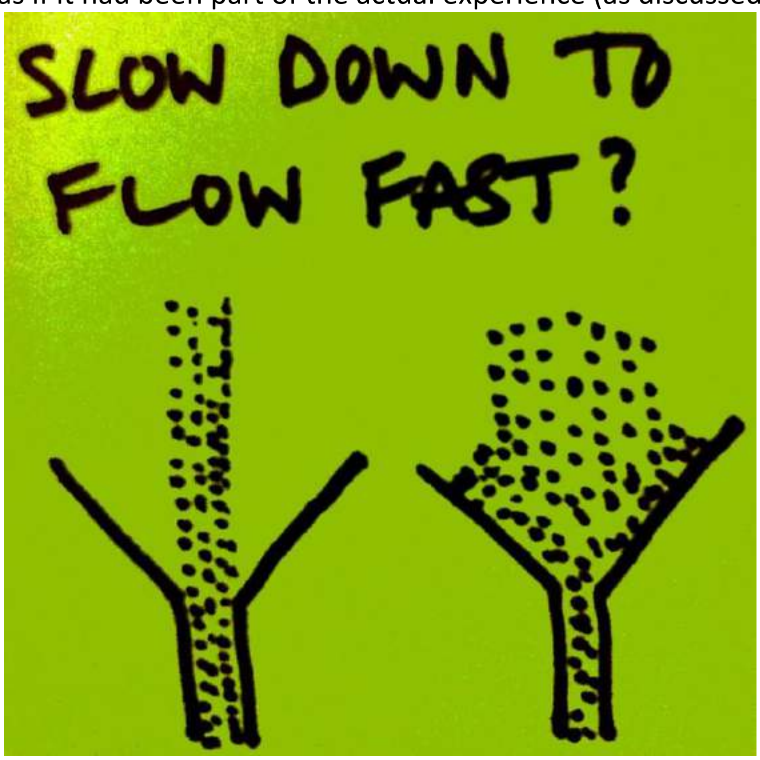


Figure 6. Although it requires more effort, using images and associations can improve the process of recoding. [Image: psd, https://goo.gl/9xjcDe, CC BY 2.0, https://goo.gl/9uSnqN]

Psychologists have studied many recoding strategies that can be used during study to improve retention. First, research advises that, as we study, we should think of the meaning of the events, and we should try to relate new events to information we already know. This helps us form associations that we can use to retrieve information later. Second, imagining events also makes them more memorable; creating vivid images out of information (even verbal information) can greatly improve later recall. Creating imagery is part of the technique Simon Reinhard uses to remember huge numbers of digits, but we can all use images to encode information more effectively. The basic concept behind good encoding strategies is to form distinctive memories (ones that stand out), and to form links or associations among memories to help later retrieval. Using study strategies such as the ones described here is challenging, but the effort is well worth the benefits of enhanced learning and retention.

We emphasized earlier that encoding is selective: people cannot encode all information they are exposed to. However, recoding can add information that was not even seen or heard during the initial encoding phase. Several of the recoding processes, like forming associations between memories, can happen without our awareness. This is one reason people can sometimes remember events that did not actually happen—because during the process of recoding,details got added. One common way of inducing false memories in the laboratory employs a word-list technique. Participants hear lists of 15 words, like *door, glass, pane, shade, ledge, sill, house, open, curtain, frame, view, breeze, sash, screen,* and *shutter.* Later, participants are given a test in which they are shown a list of words and asked to pick out the ones they'd heard earlier. This second list contains some words from the first list (e.g., *door, pane, frame*) and some words not from the list (e.g., *arm, phone, bottle*). In this example, one of the words on the test is *window*, which—importantly—does not appear in the first list, but which is related to other words in that list. When subjects were tested, they were reasonably accurate with the studied words (*door*, etc.), recognizing them 72% of the time. However, when *window* was on the test, they falsely recognized it as having been on the list 84% of the time. The same thing happened with many other lists the authors used. This phenomenon is referred to as the DRM (for Deese-Roediger-McDermott) effect. One explanation for such results is that, while students listened to items in the list, the words triggered the students to think about *window*, even though *window*was never presented. In this way, people seem to encode events that are not actually part of their experience.

Because humans are creative, we are always going beyond the information we are given: we automatically make associations and infer from them what is happening. But, as with the word association mix-up above, sometimes we make false memories from our inferences—remembering the inferences themselves as if they were actual experiences. To illustrate this, Brewer gave people sentences to remember that were designed to elicit *pragmatic inferences*. Inferences, in general, refer to instances when something is not explicitly stated, but we are still able to guess the undisclosed intention. For example, if your friend told you that she didn't want to go out to eat, you may infer that she doesn't have the money to go out, or that she's too tired. With *pragmatic* inferences, there is usually *one* particular inference you're likely to make. Consider the statement Brewer gave her participants: "The karate champion hit the cinder block." After hearing or seeing this sentence, participants who were given a memorytest tended to remember the statement as having been, “The karate champion *broke* the cinder block.” This remembered statement is not necessarily a *logical* inference (i.e., it is perfectly reasonable that a karate champion could hit a cinder block without breaking it). Nevertheless, the *pragmatic* conclusion from hearing such a sentence is that the block was likely broken. The participants remembered this inference they made while hearing the sentence in place of the actual words that were in the sentence.

Encoding—the initial registration of information—is essential in the learning and memory process. Unless an event is encoded in some fashion, it will not be successfully remembered later. However, just because an event is encoded (even if it is encoded well), there’s no guarantee that it will be remembered later.

Storage

Memory storage allows us to hold onto information for a very long duration of time—even a lifetime.

Memory Storage

Memories are not stored as exact replicas of experiences; instead, they are modified and reconstructed during retrieval and recall. Memory storage is achieved through the process of encoding, through either short- or long-term memory. During the process of memory encoding, information is filtered and modified for storage in short-term memory. Information in short-term memory deteriorates constantly; however, if the information is deemed important or useful, it is transferred to long-term memory for extended storage. Because long-term memories must be held for indefinite periods of time, they are stored, or consolidated, in a way that optimizes space for other memories. As a result, long-term memory can hold much more information than short-term memory, but it may not be immediately accessible.

The way long-term memories are stored is similar to a digital compression. This means that information is filed in a way that takes up the least amount of space, but in the process, details of the memory may be lost and not easily recovered. Because of this consolidation process, memories are more accurate the sooner they are retrieved after being stored. As the retention interval between encoding and retrieval of the memory lengthens, the accuracy of the memory decreases.

Short-Term Memory Storage

Short-term memory is the ability to hold information for a short duration of time (on the order of seconds). In the process of encoding, information enters the brain and can be quickly forgotten if it is not stored further in the short-term memory. George A. Miller suggested that the capacity of short-term memory storage is approximately seven items plus or minus two, but modern researchers are showing that this can vary depending on variables like the stored items’ phonological properties. When several elements (such as digits, words, or pictures) are held in short-term memory simultaneously, their representations compete with each other for recall, or degrade each other. Thereby, new content gradually pushes out older content, unless the older content is actively protected against interference by rehearsal or by directing attention to it.

Information in the short-term memory is readily accessible, but for only a short time. It continuously decays, so in the absence of rehearsal (keeping information in short-term memory by mentally repeating it) it can be forgotten.

Long-Term Memory Storage

In contrast to short-term memory, long-term memory is the ability to hold semantic information for a prolonged period of time. Items stored in short-term memory move to long-term memory through rehearsal, processing, and use. The capacity of long-term memory storage is much greater than that of short-term memory, and perhaps unlimited. However, the duration of long-term memories is not permanent; unless a memory is occasionally recalled, it may fail to be recalled on later occasions. This is known as forgetting.

Long-term memory storage can be affected by traumatic brain injury or lesions. Amnesia, a deficit in memory, can be caused by brain damage. Anterograde amnesia is the inability to store new memories; retrograde amnesia is the inability to retrieve old memories. These types of amnesia indicate that memory does have a storage process.

Figure 7. Memory traces, or engrams, are NOT perfectly preserved recordings of past experiences. The traces are combined with current knowledge to reconstruct what we think happened in the past. [Simon Bierdwald, https://goo.gl/JDhdCE, CC BY-NC-SA 2.0, https://goo.gl/jSSrcO]

Every experience we have changes our brains. That may seem like a bold, even strange, claim at first, but it’s true. We encode each of our experiences within the structures of the nervous system, making new impressions in the process—and each of those impressions involves changes in the brain. Psychologists (and neurobiologists) say that experiences leave **memory traces**, or **engrams** (the two terms are synonyms). Memories have to be stored somewhere in the brain, so in order to do so, the brain biochemically alters itself and its neural tissue. Just like you might write yourself a note to remind you of something, the brain "writes" a memory trace, changing its own physical composition to do so. The basic idea is that events (occurrences in our environment) create engrams through a process of **consolidation**: the neural changes that occur after learning to create the memory trace of an experience. Although neurobiologists are concerned with exactly what neural processes change when memories are created, for psychologists, the term *memory trace* simply refers to the physical change in the nervous system (whatever that may be, exactly) that represents our experience.

Although the concept of engram or memory trace is extremely useful, we shouldn't take the term too literally. It is important to understand that memory traces are not perfect little packets of information that lie dormant in the brain, waiting to be called forward to give an accurate report of past experience. Memory traces are not like video or audio recordings, capturing experience with great accuracy; as discussed earlier, we often have errors in our memory, which would not exist if memory traces were perfect packets of information. Thus, it is wrong to think that remembering involves simply "reading out" a faithful record of past experience. Rather, when we remember past events, we reconstruct them with the aid of our memory traces—but also with our current belief of what happened. For example, if you were trying to recall for the police who started a fight at a bar, you may not have a memory trace of who pushed whom first. However, let's say you remember that one of the guys held the door open for you. When thinking back to the start of the fight, this knowledge (of how one guy was friendly to you) may unconsciously influence your memory of what happened in favor of the nice guy. Thus, memory is a construction of what you actually recall and what you believe happened. In a phrase, remembering is reconstructive (we reconstruct our past with the aid of memory traces) not reproductive (a perfect reproduction or recreation of the past).

Retrieval

Memory retrieval, including recall and recognition, is the process of remembering information stored in long-term memory.

LEARNING OBJECTIVES

- **Outline the ways in which recall can be cued or fail**

KEY TAKEAWAYS

Key Points

- **Retrieval cues can facilitate recall. Cues are thought to be most effective when they have a strong, complex link with the information to be recalled.**
- **Memories of events or items tend to be recalled in the same order in which they were experienced, so by thinking through a list or series of events, you can boost your recall of successive items.**
- **The primacy and recency effects show that items near the beginning and end of a list or series tend to be remembered most frequently.**
- **Retroactive interference is when new information interferes with remembering old information; proactive interference is when old information interferes with remembering new information.**
- **The tip of the tongue phenomenon occurs when an individual can almost recall a word but cannot directly identify it. This is a type of retrieval failure; the memory cannot be accessed, but certain aspects of it, such as the first letter or similar words, can.**

Key Terms

- **working memory: The system that actively holds multiple pieces of information in the mind for execution of verbal and nonverbal tasks and makes them available for further information processing.**
- **tip of the tongue phenomenon: The failure to retrieve a word from memory combined with partial recall and the feeling that retrieval is imminent.**
- **retrieval: The cognitive process of bringing stored information into consciousness.**

Memory retrieval is the process of remembering information stored in long-term memory. Some theorists suggests that there are three stores of memory: sensory memory, long-term memory (LTM), and short-term memory (STM). Only data that is processed through STM and encoded into LTM can later be retrieved. Overall, the mechanisms of memory are not completely understood. However, there are many theories concerning memory retrieval. There are two main types of memory retrieval: recall and recognition. In recall, the information must be retrieved from memories. In recognition, the presentation of a familiar outside stimulus provides a cue that the information has been seen before. A cue might be an object or a scene—any stimulus that reminds a person of something related. Recall may be assisted when retrieval cues are presented that enable the subject to quickly access the information in memory.

Patterns of Memory Retrieval

Memory retrieval can occur in several different ways, and there are many things that can affect it, such as how long it has been since the last time you retrieved the memory, what other information you have learned in the meantime, and many other variables. For example, the *spacing effect* allows a person to remember something they have studied many times spaced over a longer period of time rather than all at once. The *testing effect* shows that practicing retrieval of a concept can increase the chance of remembering it.

Some effects relate specifically to certain types of recall. There are three main types of recall studied in psychology: serial recall, free recall, and cued recall.

Serial Recall

People tend to recall items or events in the order in which they occurred. This is called serial recall and can be used to help cue memories. By thinking about a string of events or even words, it is possible to use a previous memory to cue the next item in the series. Serial recall helps a person to remember the order of events in his or her life. These memories appear to exist on a continuum on which more recent events are more easily recalled.

When recalling serial items presented as a list (a common occurrence in memory studies), two effects tend to surface: the *primacy effect* and the *recency effect*. The primacy effect occurs when a participant remembers words from the beginning of a list better than the words from the middle or end. The theory behind this is that the participant has had more time to rehearse these words in working memory. The recency effect occurs when a participant remembers words from the end of a list more easily, possibly since they are still available in short-term memory.

Free Recall

Free recall occurs when a person must recall many items but can recall them in any order. It is another commonly studied paradigm in memory research. Like serial recall, free recall is subject to the primacy and recency effects.

Cued Recall

Cues can facilitate recovery of memories that have been “lost.” In research, a process called cued recall is used to study these effects. Cued recall occurs when a person is given a list to remember and is then given cues during the testing phase to aid in the retrieval of memories. The stronger the link between the cue and the testing word, the better the participant will recall the words.

Interference with Memory Retrieval

Interference occurs in memory when there is an interaction between the new material being learned and previously learned material. There are two main kinds of interference: proactive and retroactive.

Proactive Interference

Proactive interference is the forgetting of information due to interference from previous knowledge in LTM. Past memories can inhibit the encoding of new memories. This is particularly true if they are learned in similar contexts and the new information is similar to previous information. This is what is happening when you have trouble remembering your new phone number because your old one is stuck in your head.

Retroactive Interference

Retroactive interference occurs when newly learned information interferes with the encoding or recall of previously learned information. If a participant was asked to recall a list of words, and was then immediately presented with new information, it could interfere with remembering the initial list. If you learn to use a new kind of computer and then later have to use the old model again, you might find you have forgotten how to use it. This is due to retroactive interference.

Retrieval Failure

Sometimes a person is not able to retrieve a memory that they have previously encoded. This can be due to decay, a natural process that occurs when neural connections decline, like an unused muscle.

Occasionally, a person will experience a specific type of retrieval failure called tip-of-the-tongue phenomenon. This is the failure to retrieve a word from memory, combined with partial recall and the feeling that retrieval is imminent. People who experience this can often recall one or more features of the target word such as the first letter, words that sound similar, or words that have a similar meaning. While this process is not completely understood, there are two theories as to why it occurs. The first is the *direct-access perspective*, which states that the memory is not strong enough to retrieve but strong enough to trigger the state. The *inferential perspective* posits that the state occurs when the subject infers knowledge of the target word, but tries to piece together different clues about the word that are not accessible in memory.

Modal Model of Memory

The three major classifications of memory that the scientific community deals with today are as follows: sensory memory, short-term memory, and long-term memory. Information from the world around us begins to be stored by sensory memory, making it possible for this information to be accessible in the future. Short-term memory refers to the information processed by the individual in a short period of time. Working memory performs this processing. Long-term memory allows us to store information for long periods of time. This information may be retrieved consciously (explicit memory) or unconsciously (implicit memory).

Sensory Memory

"Sensory memory is the capacity for briefly retaining the large amounts of information that people encounter daily" (Siegler and Alibali, 2005). There are three types of sensory memory: echoic memory, iconic memory, and haptic memory. Iconic memory retains information that is gathered through sight, echoic memory retains information gathered through auditory stimuli and haptic memory retains data acquired through touch.

Scientific research has focused mainly on iconic memory; information on echoic and haptic memory is comparatively scarce. Iconic memory retains information from the sense of sight with an approximate duration of 1 second. This reservoir of information then passes to short-term vision memory (which is analogous, as we shall see shortly, to the visuospatial sketchpad with which working memory operates).

Di Lollo's model (Di Lollo, 1980) is the most widely accepted model of iconic memory. Therein, he considered iconic memory a storehouse constituted by two components: the persistence of vision and information.

a) Persistence of vision. Iconic memory corresponds to the pre-categorical representation image/visual. It is sensitive to physical parameters, such that it depends on retinal photoreceptors (rods and cones). It also depends on various cells in the visual system and on retinal ganglion cells M (transition cells) and P (sustained cells). "The occipital lobe is responsible for processing visual information".
b) Persistence of information. Iconic memory is a storehouse of information that lasts 800 miliseconds and that represents a codified and already categorized version of the visual image. It plays the role of storehouse for post-categorical memory, which provides visual short-term memory with information to be consolidated.

Subsequent research on visual persistence from Coltheart (Coltheart, 1983) and Sperling's studies (Sperling, 1960) on the persistence of information led to the definition of three characteristics pertaining to iconic memory: a large capacity, a short duration, and a pre-categorical nature.

Regarding short-term, Sperling interpreted the results of the partial report as due to the rapid decline of the visual sign and reaffirmed this short duration by obtaining a decrease in the number of letters reported by the subject in delaying the audio signal for choosing a row to remember in the presentation. Averbach and Coriell's experiments (Averbach and Coriell, 1961) corroborated Sperling's conclusion; they presented a variety of letters for a certain period of time to the subject. After each letter, and in the same position, they showed a particular visual sign. The participant's task was to name the letter that occupied the position of the visual sign. When the visual sign appeared immediately after the letters, participants could correctly name the letter that occupied the position of the sign, however, as the presentation of the sign became more delayed, participant performance worsened. These results also show the rapid decline of visual information.

In the Atkinson-Shiffrin model, stimuli from the environment are processed first in sensory memory: storage of brief sensory events, such as sights, sounds, and tastes. It is very brief storage—up to a couple of seconds. We are constantly bombarded with sensory information. We cannot absorb all of it, or even most of it. And most of it has no impact on our lives. For example, what was your professor wearing the last class period? As long as the professor was dressed appropriately, it does not really matter what she was wearing. Sensory information about sights, sounds, smells, and even textures, which we do not view as valuable information, we discard. If we view something as valuable, the information will move into our short-term memory system.

One study of sensory memory researched the significance of valuable information on short-term memory storage. J. R. Stroop discovered a memory phenomenon in the 1930s: you will name a color more easily if it appears printed in that color, which is called the Stroop effect. In other words, the word “red” will be named more quickly, regardless of the color the word appears in, than any word that is colored red. Try an experiment: name the colors of the words you are given in **the picture**. Do not read the words, but say the color the word is printed in. For example, upon seeing the word “yellow” in green print, you should say “green,” not “yellow.” This experiment is fun, but it’s not as easy as it seems.

Figure 8. The Stroop effect describes why it is difficult for us to name a color when the word and the color of the word are different.

Methods of studying-whole report and partial report techniques:-

Miller’s Magic Number

A factoid is a snippet of information (usually taken out of context) that's assumed to be factual because it's repeated often. A favorite pop-psychology factoid, repeated in textbooks and popular media, is that human short-term memory is limited to 7, plus or minus 2, items (called "chunks"). While there is some truth to it, this factoid offers little as a pedagogical tool beyond stressing the need to break problems into manageable chunks for novices. The full story behind the "magic" number seven, however, provides a fascinating look into Psychology's quest to understand the differences between experts and novices.

The number seven, called "Miller's Magic Number," comes from a 1956 article by the psychologist George A. Miller title "The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information." In this celebrated and highly-readable article, Miller considers two kinds of situations:

- A person must correctly distinguish between very similar items (e.g., high/low-pitched tones, shades of green), and
- A person must recall items presented in a sequence.

In the first kind of situation, called **absolute judgement**, subjects are exposed to a stimulus that varies along a single dimension, such as the pitch of a tone, the green-ness of a color, or the concentration of salt in a cup of water. Across many different kinds of stimuli, people can consistently distinguish about six distinct stimulus levels without making mistakes.

The second kind of situation is used to measure the span of **immediate memory**. Here, the subject must retain a select number of chunks in their short-term memory, and recall as many items as possible at the end of a trial. Across a handful of simple domains, such as decimal digits, letters of the alphabet, and monosyllabic words, people are able to hold anywhere from five to nine chunks in short-term without making mistakes. While it is tempting to assume that the limits of absolute judgement and immediate memory are related, Miller **did not** believe this to be the case.

The Game of Simon

A helpful way to understand the difference between absolute judgement and immediate memory span is with the electronic game Simon by Milton Bradley. This simple game device has four colored buttons, each associated with a distinct tone. In each round, *Simon* plays a sequence of tones, and the player must repeat the sequence back by pressing the appropriate buttons. The game gets progressively harder as the length of the sequence grows.

Figure 9. A Simon Circle

A player is exercising absolute judgement when distinguishing between *Simon's* tones. The number of distinct tones is fixed at four, well within a safe "no mistakes" range for most people. *Simon's* increasing sequence length, however, is meant to strain immediate memory capacity. Based on Miller's article, one would expect it to be quite difficult for players to repeat back a sequence of nine or more tones, yet expert players have managed nearly ten times that. How are they able to do this?

Shortcomings of the Magic Number

The span of short-term memory as reported by Miller in 1956 (7 ± 2 chunks) is where the pop-psychology factoid usually stops. Since that time, however, researchers have cast doubt on the magic number itself as well as its cross-domain applicability. Research with chess experts, for example, has suggested a span limit of 3 to 5 chunks; nearly half the magic number! In the domain of language, it has been found that phonological similarity and spoken word length are much better predictors of how many words a person can hold in short-term memory (less-similar and longer words are harder to retain). Things have even changed for absolute judgement: subjects in one experiment were only able to distinguish about 7 colors until they were given a broader vocabulary (i.e., "pale blueish green"). With little training, they were then able to discriminate around 36 colors.

What does it mean for short-term memory to have a limited capacity in the first place? A key insight is that traditional means of measuring absolute judgement and short-term memory span require blocking **recoding** -- the process of grouping or relating chunks. To block recoding, experimenters must use non-sensical or unrelated stimuli, such as made-up words or random decimal digits. Under these artificial conditions, we see something resembling a strict capacity limit, but this limit increases or even seems to disappear when subjects are able to find some higher-order meaning in the stimuli. For example, one famous subject in a random decimal digit memorization experiment found he could remember more digits at a time by mentally recoding them as mile times (he was an avid runner).

Recoding is Magical

In the real world, people are constantly recoding stimuli. Because of this, it is difficult to define precisely what a "chunk" is. Cross-domain research with experts suggests that they retain the same short-term capacity limits as novices, but the content of their chunks is far greater. In addition to denser chunks, experts have invested in building intricate networks of chunks in their long-term memories, ensuring that relevant chunks are always readily available. As Miller and many psychologists since have shown, recoding is truly where the action lies.

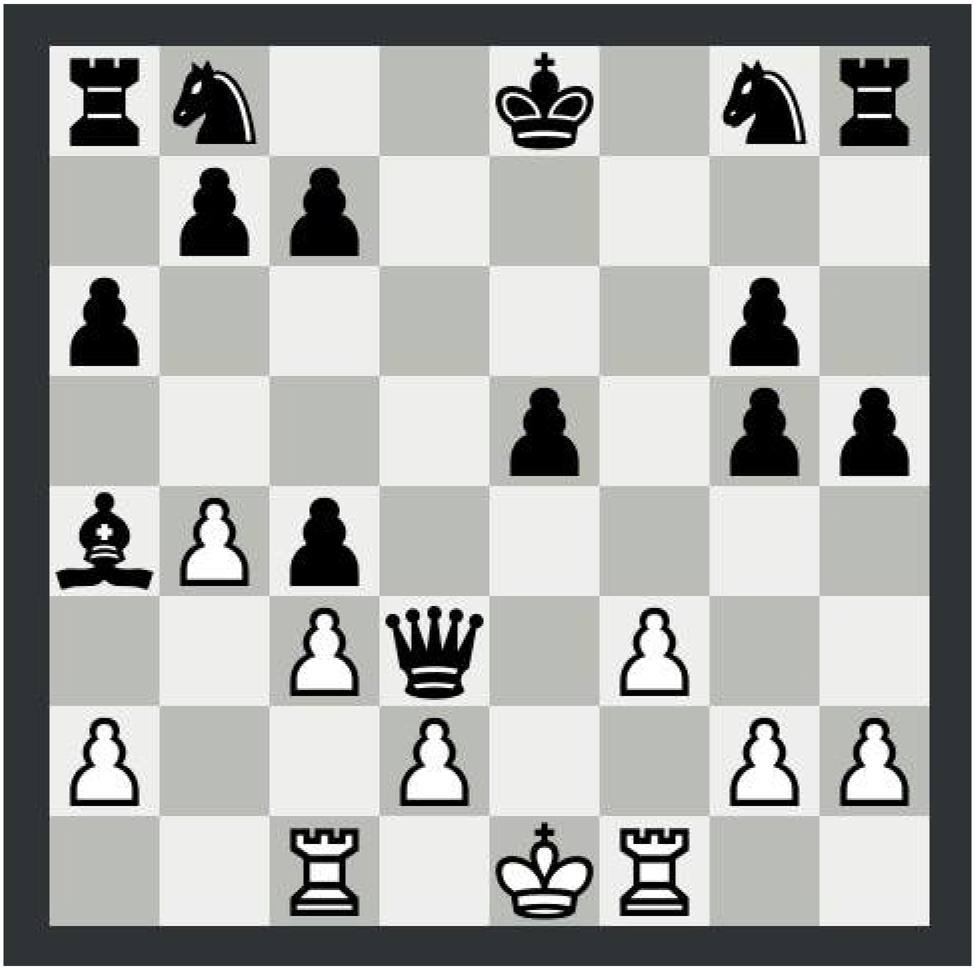


Figure 10. An in play chessboard

If stimuli can be recoded relative to one's background knowledge, then using Miller's magic number alone to judge the cognitive burden of something may or may not be helpful. When the chunk sizes are known, it becomes possible to use short-term capacity limits as a predictor of cognitive burden and complexity. In an ingenious experiment with chess players, subjects were asked to copy the positions of all pieces from one chessboard to another. By placing the boards far apart, subjects were forced to turn their heads to focus on either board.
The experimenters were thus able to use the number of piece positions copied on every turn as an estimate of the subjects' chunk size, and were able to show that the performance difference between grand masters and novices was slim when random board positions were used.
A similar experiment was done with programmers copying code by hand, and the same kind of results were found (experts were no better at remember code with shuffled lines than novices).

The Big Picture

Miller's magic number is a fun factoid, but it is only the beginning. In the search for a fixed short-term memory limit, we have found something much more interesting: an understanding of domain expertise. Experts do not exceed the limitations of the average human mind, they have "simply" built a vast, complex network of domain-specific chunks that allows them to rarely end up in unfamiliar territory. We can still see experts' capacity limits in the lab, but they are much more difficult to spot in the wild.

Chunking

Chunking refers to a phenomenon whereby individuals group items together when performing a memory task to improve the performance of sequential memory.
The word “Chunking,” a phenomenon whereby individuals group items together when performing a memory task, was initiated by (Miller, 1956). (Lindley, 1966) showed that groups produced by chunking have concept meanings to the participant. Therefore, this strategy makes it easier for an individual to maintain and recall information in memory. For example, when recalling a number sequence 01122014, if we group the numbers as 01, 12, and 2014, mnemonic meanings for each group as a day, a month and a year are created. Furthermore, studies found evidence that the firing event of a single cell is associated with a particular concept, such as personal names of Bill Clinton or Jennifer Aniston (Kreiman et al., 2000, 2001).

Psychologists believe that chunking plays as an essential role in joining the elements of a memory trace together through a particular hierarchical memory structure (Tan and Soon, 1996; Edin et al., 2009). At a time when information theory started to be applied in psychology, Miller claimed that short-term memory is not rigid but open to strategies (Miller, 1956) such as chunking that can expand the memory capacity (Gobet et al., 2001). According to this information, it is possible to increase short-term memory capacity by effectively recoding a large amount of low-information-content items into a smaller number of high-information-content items (Cowan, 2001; Chen and Cowan, 2005). Therefore, when chunking is evident in recall tasks, one can expect a higher number of correct recalls. Patients with Alzheimer's disease typically experience working memory deficits; chunking is also an effective method to improve patients' verbal working memory performance (Huntley et al., 2011).

Ebbinghaus

Hermann Ebbinghaus (1850–1909) was a pioneer of the study of memory. In this section we consider three of his most important findings, each of which can help you improve your memory. In his research, in which he was the only research participant, Ebbinghaus practiced memorizing lists of nonsense syllables, such as the following:
DIF, LAJ, LEQ, MUV, WYC, DAL, SEN, KEP, NUD

You can imagine that because the material that he was trying to learn was not at all meaningful, it was not easy to do. Ebbinghaus plotted how many of the syllables he could remember against the time that had elapsed since he had studied them. He discovered an important principle of memory: Memory decays rapidly at first, but the amount of decay levels off with time. Although Ebbinghaus looked at forgetting after days had elapsed, the same effect occurs on longer and shorter time scales. Bahrick (1984) found that students who took a Spanish language course forgot about one half of the vocabulary that they had learned within three years, but that after that time their memory remained pretty much constant. Forgetting also drops off quickly on a shorter time frame. This suggests that you should try to review the material that you have already studied right before you take an exam; that way, you will be more likely to remember the material during the exam.

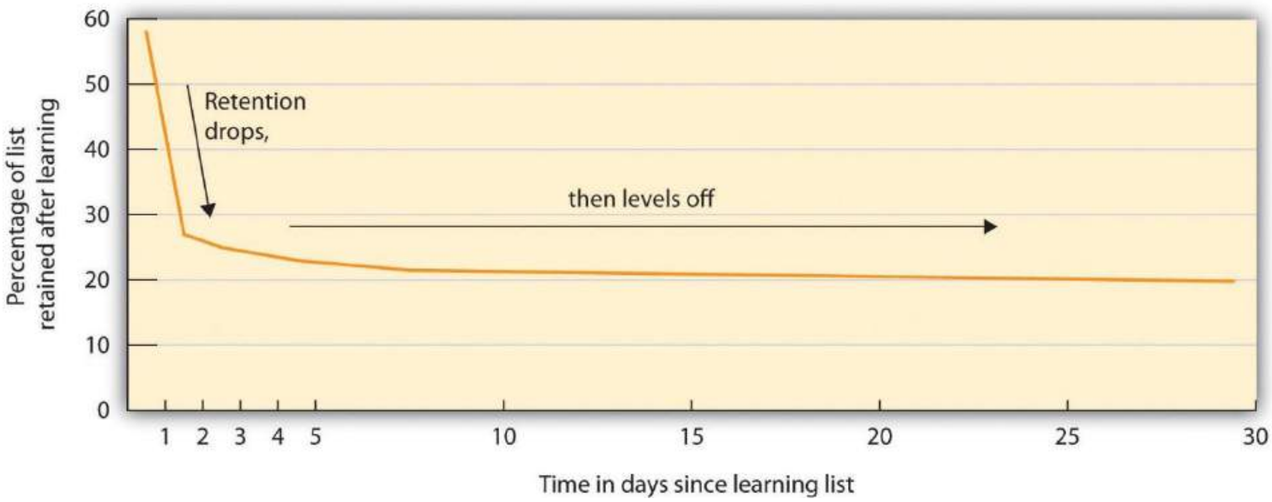


Figure 11. Ebbinghaus Forgetting Curve - Hermann Ebbinghaus found that memory for information drops off rapidly at first but then levels off after time.

Ebbinghaus also discovered another important principle of learning, known as the *spacing effect*. The spacing effect refers to *the fact that learning is better when the same amount of study is spread out over periods of time than it is when it occurs closer together or at the same time*. This means that even if you have only a limited amount of time to study, you'll learn more if you study continually throughout the semester (a little bit every day is best) than if you wait to cram at the last minute before your exam. Another good strategy is to study and then wait as long as you can before you forget the material. Then review the information and again wait as long as you can before you forget it. (This probably will be a longer period of time than the first time.) Repeat and repeat again. The spacing effect is usually considered in terms of the difference between *distributed practice* (practice that is spread out over time) and *massed practice* (practice that comes in one block), with the former approach producing better memory.

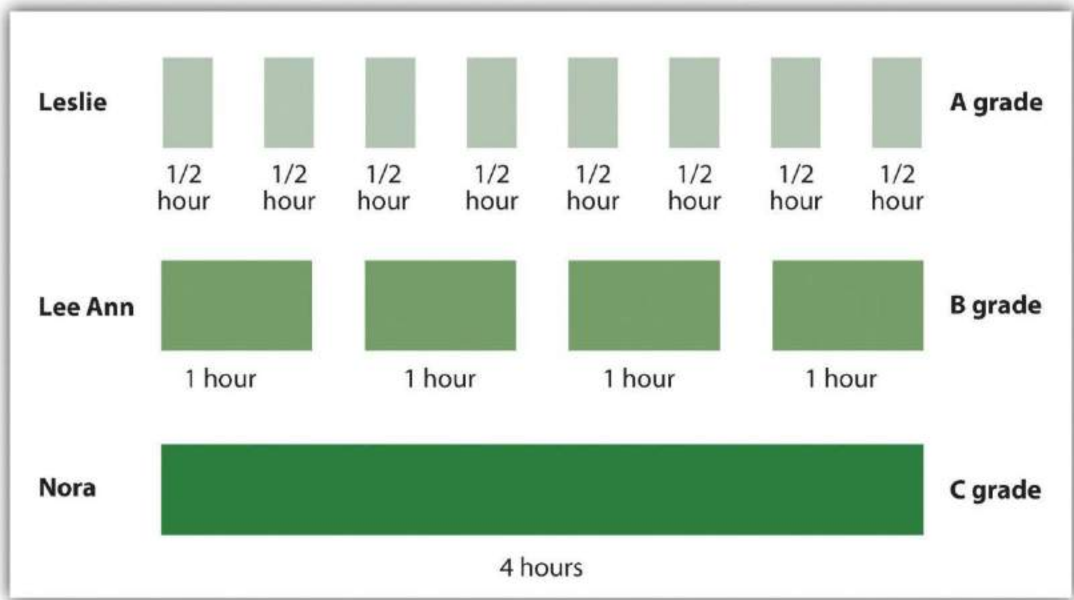


Figure 12. Effects of Massed Versus Distributed Practice on Learning The spacing effect refers to the fact that memory is better when it is distributed rather than massed. Leslie, Lee Ann, and Nora all studied for four hours total, but the students who spread out their learning into smaller study sessions did better on the exam.

Ebbinghaus also considered the role of *overlearning*—that is, continuing to practice and study even when we think that we have mastered the material. Ebbinghaus and other researchers have found that overlearning helps encoding (Driskell, Willis, & Copper, 1992). Students frequently think that they have already mastered the material but then discover when they get to the exam that they have not. The point is clear: Try to keep studying and reviewing, even if you think you already know all the material.

William James: isolating Short-term and Long-term memory

An issue discussed during 1960s was weather human memory system has one or two components. Some authors like **Arthur Melton** [8)] argued that both short term memory (STM) and long-term memory (LTM) are just two subcomponents dependent on the same system. He justified his views by proofs of activation of the LTM in STM experiments. His work was very influential, yet during the years more and more evidence of at least two separate memory systems have accumulated.

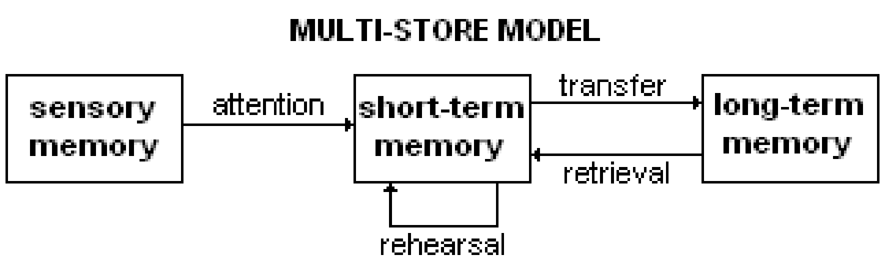


Figure 13.

The first more influential two component memory model was introduced in **1968** by **Richard Atkinson** and **Richard Shiffrni** [9)] . Their model called *Multi-store model*consisted of long-term and working or short-term memory model and was later improved by an additional component, the ***sensory memory***. Sensory memory contains one register for each sense and serves as an short lasting buffer-zone before the information can enter short-term memory. Short-term memory is a temporal storage for new information before it enters long-term memory, but is also used for cognitive tasks, understanding and learning.
The thesis of two separate memory systems: the **long-term memory** and the **short-term memory** is today considered to be true. This thesis is supported by differences in:

- **capacity** (small for STM and large or unlimited for LTM),
- **duration limits** (items in STM decay as a function of time, which is not a characteristic of LTM),
- **retention speed** (very high for STM and possibly lower for LTM),
- **time to acquire information** (short for STM and longer for LTM),
- **information encoding** (semantic for LTM and acoustic or visual for STM), and
- type of memory affected by physical injuries in patients.

Another term should be clarified here: the working memory, which is often mistaken for the short-term memory. The main difference between these two is that working memory usually includes the structure and processes performed by a system in control of the short-term memory.

Serial Position Curve

Variations in the ability to retrieve information are also seen in the *serial position curve*. When we give people a list of words one at a time (e.g., on flashcards) and then ask them to recall them, the results look something like those in Figure 14 "The Serial Position Curve". People are able to retrieve more words that were presented to them at the beginning and the end of the list than they are words that were presented in the middle of the list. This pattern, known as the serial position curve, is caused by two retrieval phenomenon: The **primacy effect** refers to *a tendency to better remember stimuli that are presented early in a list*. The **recency effect** refers to *the tendency to better remember stimuli that are presented later in a list*.

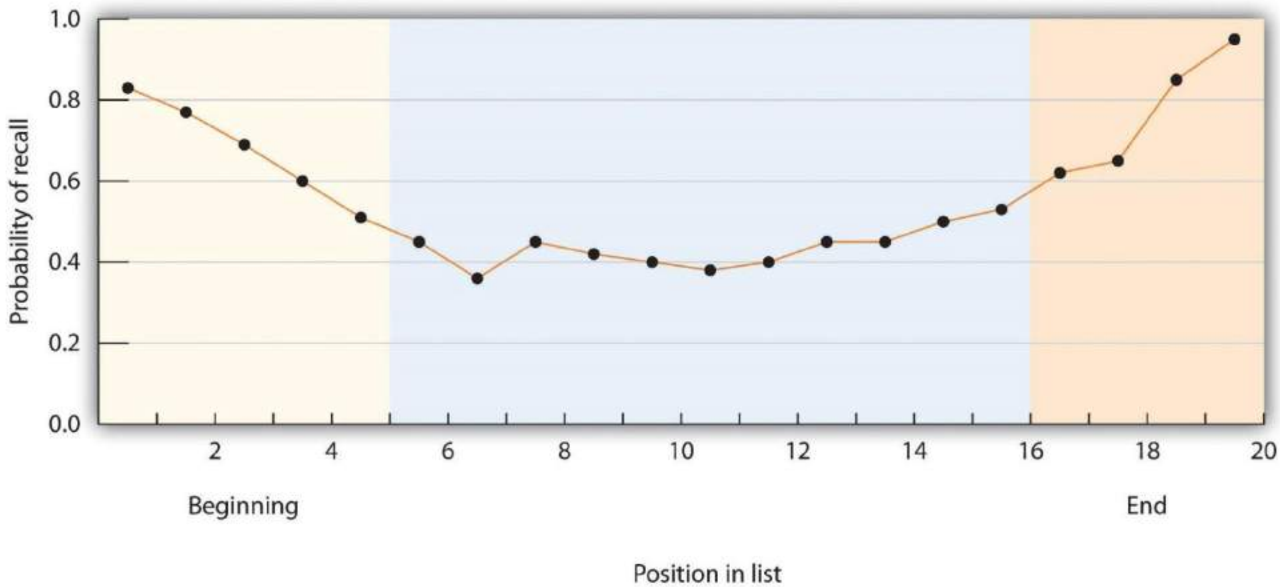


Figure 14. The serial position curve is the result of both primacy effects and recency effects.

There are a number of explanations for primacy and recency effects, but one of them is in terms of the effects of rehearsal on short-term and long-term memory (Baddeley, Eysenck, & Anderson, 2009). Because we can keep the last words that we learned in the presented list in short-term memory by rehearsing them before the memory test begins, they are relatively easily remembered. So the recency effect can be explained in terms of maintenance rehearsal in short-term memory. And the primacy effect may also be due to rehearsal—when we hear the first word in the list we start to rehearse it, making it more likely that it will be moved from short-term to long-term memory. And the same is true for the other words that come early in the list. But for the words in the middle of the list, this rehearsal becomes much harder, making them less likely to be moved to LTM.

Recency Effects and Primary Effects

People tend to recall items or events in the order in which they occurred. This is called serial recall and can be used to help cue memories. By thinking about a string of events or even words, it is possible to use a previous memory to cue the next item in the series. Serial recall helps a person to remember the order of events in his or her life. These memories appear to exist on a continuum on which more recent events are more easily recalled.

When recalling serial items presented as a list (a common occurrence in memory studies), two effects tend to surface: the *primacy effect* and the *recency effect*. The primacy effect occurs when a participant remembers words from the beginning of a list better than the words from the middle or end. The theory behind this is that the participant has had more time to rehearse these words in working memory. The recency effect occurs when a participant remembers words from the end of a list more easily, possibly since they are still available in short-term memory.

Short Term memory

Short-term memory (STM) is a temporary storage system that processes incoming sensory memory; sometimes it is called working memory. Short-term memory takes information from sensory memory and sometimes connects that memory to something already in long-term memory. Short-term memory storage lasts about 20 seconds. George Miller (1956), in his research on the capacity of memory, found that most people can retain about 7 items in STM. Some remember 5, some 9, so he called the capacity of STM 7 plus or minus 2.

Think of short-term memory as the information you have displayed on your computer screen—a document, a spreadsheet, or a web page. Then, information in short-term memory goes to long-term memory (you save it to your hard drive), or it is discarded (you delete a document or close a web browser). This step of rehearsal, the conscious repetition of information to be remembered, to move STM into long-term memory is called memory consolidation.

You may find yourself asking, "How much information can our memory handle at once?" To explore the capacity and duration of your short-term memory, have a partner read the strings of random numbers out loud to you, beginning each string by saying, "Ready?" and ending each by saying, "Recall," at which point you should try to write down the string of numbers from memory.

9754	68259	913825	5316842	86951372	719384273
6419	67148	648327	5963827	51739826	163875942

Figure 15. Series of Numbers

Work through this series of numbers using the recall exercise explained above to determine the longest string of digits that you can store.

Note the longest string at which you got the series correct. For most people, this will be close to 7, Miller's famous 7 plus or minus 2. Recall is somewhat better for random numbers than for random letters (Jacobs, 1887), and also often slightly better for information we hear (acoustic encoding) rather than see (visual encoding) (Anderson, 1969).

Chapter 5 – Working Memory

The difference between Working Memory and Short-Term Memory

Today, many theorists use the concept of working memory (WM) to replace the concept of Short Term Memory. This new model of STM "shifted the focus from memory structure to memory processes and functions". To put it another way, WM refers to both structures and processes used for storing and manipulating information.
To sum up, STM refers to the ability to hold information in mind over a brief period of time. As concept of STM has expanded and it includes more than just the temporary storage of information, psychologists have created new terminology, working memory. The term WM is now commonly used to refer to a broader system that both stores information and manipulates it. However, STM and WM are sometimes used interchangeably.

Components of Memory: Central Executive, Phonological Loop, Visuospatial Sketchpad

Baddeley's model of working memory

Based on experiments demonstrating connections between LTM and STM, as well as experiments indicating that STM consists of more components, **Alan Baddeley** and **Graham Hitch** proposed a multi-component *working memory* model in **1974**. The new term *working memory* was supposed to emphasize the importance of this system in cognitive processing. Baddeley and Hitch suggested working memory is composed of three parts: the **central executive**, a system that controls the **phonological loop** (a subsystem for remembering phonological information such as language by constant refreshing through repetition in the loop), and the **visuospatial sketch pad** (a subsystem for storing visual information).

This model was later revised and improved by Baddeley but also contributed by other authors, which resulted in additional component of **episodic buffer** in year **2000** and more detailed functions and analysis of other components, as described in table below.

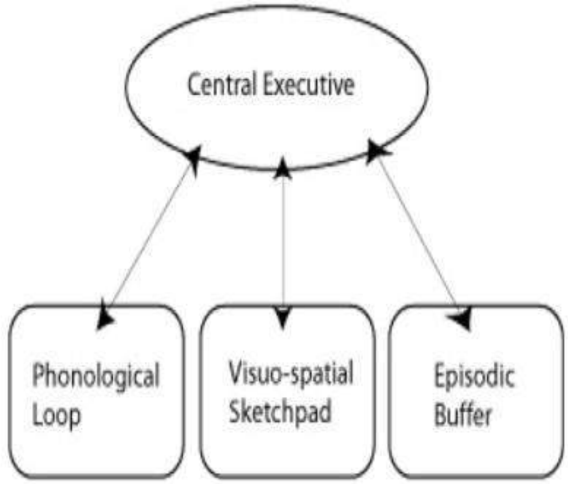


Figure 1. Schematic of Baddeley's model.

Central executive	It is still unclear whether it is a single system or more systems working together. Central executive's functions include **attention** and focusing, **active inhibition** of stimuli, planning and decision-making, sequencing, **updating**, **maintenance** and **integration of information** from phonological loop and visuospatial sketchpad. These functions also include communication with long-term memory and connections to language understanding and production centers.
Episodic buffer	Episodic buffer has the role of **integrating the information** from phonological loop and visuospatial sketchpad, but also from long-term memory. It serves as the **storage component of central executive**, or otherwise information integration wouldn't be possible.
Phonological loop	According to Baddeley, phonological loop consists of **two components**: a sound **storage** which lasts just a few seconds and an **articulatory processor** which maintains sound information in the storage by **vocal or sub vocal repetition**. Verbal information seems to be automatically processed by phonological loop and it also plays an important, maybe even key role in language learning and speech production. It can also help in memorizing information from the visuospatial sketchpad. (For example, repeating "A red car is on the lawn.")
Visuospatial sketchpad	This construct according to Baddeley enables temporary storing, maintaining and manipulating of visuospatial information. It is important in **spatial orientation** and solving **visuospatial problems**. Studies have indicated that visuospatial sketchpad might actually be containing two different systems: one for spatial information and processes and the other for visual

	information and processes.

Table 1.

Long –Term Memory

If information makes it past STM it may enter ***long-term memory (LTM)***, *memory storage that can hold information for days, months, and years*. The capacity of long-term memory is large, and there is no known limit to what we can remember. Although we may forget at least some information after we learn it, other things will stay with us forever.

Long-term memory (LTM) is the continuous storage of information. Unlike short-term memory, the storage capacity of LTM has no limits. It encompasses all the things you can remember that happened more than just a few minutes ago to all of the things that you can remember that happened days, weeks, and years ago. In keeping with the computer analogy, the information in your LTM would be like the information you have saved on the hard drive. It isn't there on your desktop (your short-term memory), but you can pull up this information when you want it, at least most of the time. Not all long-term memories are strong memories. Some memories can only be recalled through prompts. For example, you might easily recall a fact— "What is the capital of the United States?"—or a procedure—"How do you ride a bike?"—but you might struggle to recall the name of the restaurant you had dinner when you were on vacation in France last summer. A prompt, such as that the restaurant was named after its owner, who spoke to you about your shared interest in soccer, may help you recall the name of the restaurant.

Long-term memory is divided into two types: **explicit and implicit**. Understanding the different types is important because a person's age or particular types of brain trauma or disorders can leave certain types of LTM intact while having disastrous consequences for other types. Explicit memories are those we consciously try to remember and recall. For example, if you are studying for your chemistry exam, the material you are learning will be part of your explicit memory. (Note: Sometimes, but not always, the terms explicit memory and declarative memory are used interchangeably.)

Implicit memories are memories that are not part of our consciousness. They are memories formed from behaviors. Implicit memory is also called non-declarative memory.

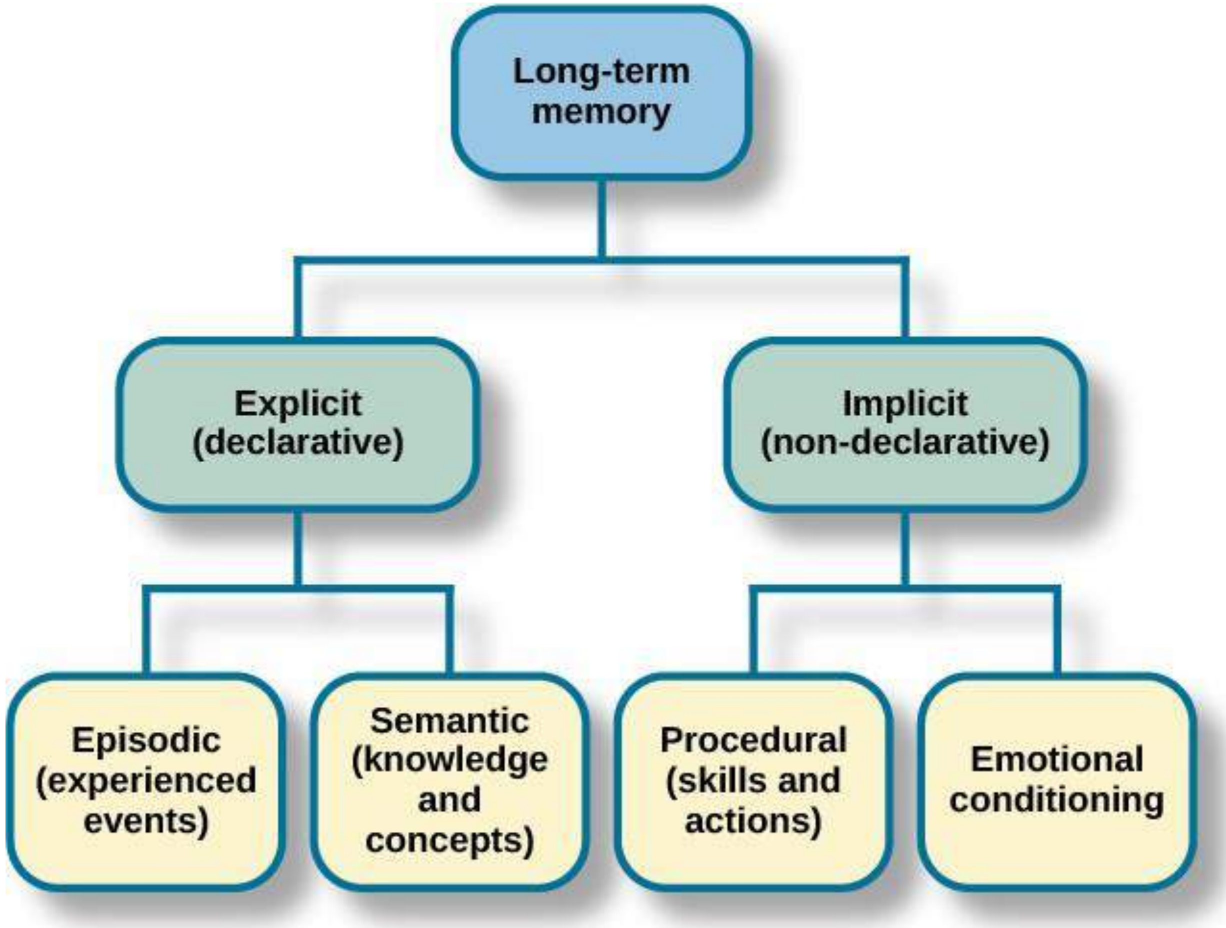


Figure 2. There are two components of long-term memory: explicit and implicit. Explicit memory includes episodic and semantic memory. Implicit memory includes procedural memory and things learned through conditioning.

Procedural memory is a type of implicit memory: it stores information about how to do things. It is the memory for skilled actions, such as how to brush your teeth, how to drive a car, how to swim the crawl (freestyle) stroke. If you are learning how to swim freestyle, you practice the stroke: how to move your arms, how to turn your head to alternate breathing from side to side, and how to kick your legs. You would practice this many times until you become good at it. Once you learn how to swim freestyle and your body knows how to move through the water, you will never forget how to swim freestyle, even if you do not swim for a couple of decades. Similarly, if you present an accomplished guitarist with a guitar, even if he has not played in a long time, he will still be able to play quite well.

Declarative memory has to do with the storage of facts and events we personally experienced. Explicit (declarative) memory has two parts: semantic memory and episodic memory. Semantic means having to do with language and knowledge about language. An example would be the question "what does *argumentative* mean?" Stored in our semantic memory is knowledge about words, concepts, and language-based knowledge and facts. For example, answers to the following questions are stored in your semantic memory:

- Who was the first President of the United States?
- What is democracy?
- What is the longest river in the world?

Episodic memory is information about events we have personally experienced. The concept of episodic memory was first proposed about 40 years ago (Tulving, 1972). Since then, Tulving and others have looked at scientific evidence and reformulated the theory. Currently, scientists believe that episodic memory is memory about happenings in particular places at particular times, the what, where, and when of an event (Tulving, 2002). It involves recollection of visual imagery as well as the feeling of familiarity (Hassabis & Maguire, 2007).

Explicit Memory

When we assess memory by asking a person to consciously remember things, we are measuring *explicit memory*. Explicit memory refers to *knowledge or experiences that can be consciously remembered*. As you can see in Figure 8.2 "Types of Memory", there are two types of explicit memory: *episodic* and *semantic*. Episodic memory refers to *the firsthand experiences that we have had* (e.g., recollections of our high school graduation day or of the fantastic dinner we had in New York last year). Semantic memory refers to *our knowledge of facts and concepts about the world* (e.g., that the absolute value of −90 is greater than the absolute value of 9 and that one definition of the word "affect" is "the experience of feeling or emotion").

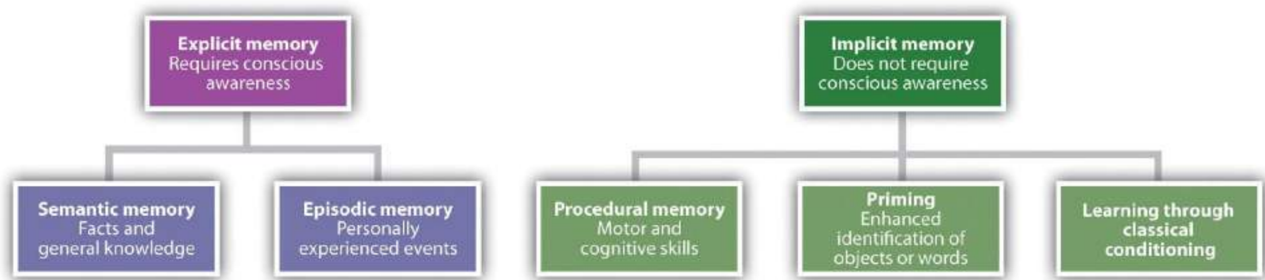


Figure 3. Types of Memory

Explicit memory is assessed using measures in which the individual being tested must consciously attempt to remember the information. A recall memory test is *a measure of explicit memory that involves bringing from memory information that has previously been remembered*. We rely on our recall memory when we take an essay test, because the test requires us to generate previously remembered information. A multiple-choice test is an example of a recognition memory test, *a measure of explicit memory that involves determining whether information has been seen or learned before*.

Your own experiences taking tests will probably lead you to agree with the scientific research finding that recall is more difficult than recognition. Recall, such as required on essay tests, involves two steps: first generating an answer and then determining whether it seems to be the correct one. Recognition, as on multiple-choice test, only involves determining which item from a list seems most correct (Haist, Shimamura, & Squire, 1992). Although they involve different processes, recall and recognition memory measures tend to be correlated. Students who do better on a multiple-choice exam will also, by and large, do better on an essay exam (Bridgeman & Morgan, 1996).

A third way of measuring memory is known as *relearning* (Nelson, 1985). Measures of relearning (or savings) *assess how much more quickly information is processed or learned when it is studied again after it has already been learned but then forgotten*. If you have taken some French courses in the past, for instance, you might have forgotten most of the vocabulary you learned. But if you were to work on your French again, you'd learn the vocabulary much faster the second time around. Relearning can be a more sensitive measure of memory than either recall or recognition because it allows assessing memory in terms of "how much" or "how fast" rather than simply "correct" versus "incorrect" responses. Relearning also allows us to measure memory for procedures like driving a car or playing a piano piece, as well as memory for facts and figures.

Implicit Memory

While explicit memory consists of the things that we can consciously report that we know, implicit memory refers to knowledge that we cannot consciously access. However, implicit memory is nevertheless exceedingly important to us because it has a direct effect on our behavior. Implicit memory refers to *the influence of experience on behavior, even if the individual is not aware of those influences*. There are three general types of implicit memory: procedural memory, classical conditioning effects, and priming.

Procedural memory refers to *our often unexplainable knowledge of how to do things*. When we walk from one place to another, speak to another person in English, dial a cell phone, or play a video game, we are using procedural memory. Procedural memory allows us to perform complex tasks, even though we may not be able to explain to others how we do them. There is no way to tell someone how to ride a bicycle; a person has to learn by doing it. The idea of implicit memory helps explain how infants are able to learn. The ability to crawl, walk, and talk are procedures, and these skills are easily and efficiently developed while we are children despite the fact that as adults we have no conscious memory of having learned them.

A second type of implicit memory is classical conditioning effects, in which we learn, often without effort or awareness, to associate neutral stimuli (such as a sound or a light) with another stimulus (such as food), which creates a naturally occurring response, such as enjoyment or salivation. The memory for the association is demonstrated when the conditioned stimulus (the sound) begins to create the same response as the unconditioned stimulus (the food) did before the learning.

The final type of implicit memory is known as priming, or *changes in behavior as a result of experiences that have happened frequently or recently*. Priming refers both to the activation of knowledge (e.g., we can prime the concept of "kindness" by presenting people with words related to kindness) and to the influence of that activation on behavior (people who are primed with the concept of kindness may act more kindly).

One measure of the influence of priming on implicit memory is the *word fragment test*, in which a person is asked to fill in missing letters to make words. You can try this yourself: First, try to complete the following word fragments, but work on each one for only three or four seconds. Do any words pop into mind quickly?

_ i b _ a _ y
_ h _ s _ _ i _ n
_ o _ k
_ h _ i s _

Now read the following sentence carefully:
"He got his materials from the shelves, checked them out, and then left the building."

Then try again to make words out of the word fragments.

I think you might find that it is easier to complete fragments 1 and 3 as "library" and "book," respectively, after you read the sentence than it was before you read it. However, reading the sentence didn't really help you to complete fragments 2 and 4 as "physician" and "chaise." This difference in implicit memory probably occurred because as you read the sentence, the concept of "library" (and perhaps "book") was primed, even though they were never mentioned explicitly. Once a concept is primed it influences our behaviors, for instance, on word fragment tests.

Our everyday behaviors are influenced by priming in a wide variety of situations. Seeing an advertisement for cigarettes may make us start smoking, seeing the flag of our home country may arouse our patriotism, and seeing a student from a rival school may arouse our competitive spirit. And these influences on our behaviors may occur without our being aware of them.

Research Focus: Priming Outside Awareness Influences Behavior

One of the most important characteristics of implicit memories is that they are frequently formed and used *automatically*, without much effort or awareness on our part. In one demonstration of the automaticity and influence of priming effects, John Bargh and his colleagues (Bargh, Chen, & Burrows, 1996) conducted a study in which they showed college students lists of five scrambled words, each of which they were to make into a sentence. Furthermore, for half of the research participants, the words were related to stereotypes of the elderly.

These participants saw words such as the following:
in Florida retired live people
bingo man the forgetful plays

The other half of the research participants also made sentences, but from words that had

nothing to do with elderly stereotypes. The purpose of this task was to prime stereotypes of elderly people in memory for some of the participants but not for others.
The experimenters then assessed whether the priming of elderly stereotypes would have any effect on the students' behavior—and indeed it did. When the research participant had gathered all of his or her belongings, thinking that the experiment was over, the experimenter thanked him or her for participating and gave directions to the closest elevator. Then, without the participants knowing it, the experimenters recorded the amount of time that the participant spent walking from the doorway of the experimental room toward the elevator. Participants who had made sentences using words related to elderly stereotypes took on the behaviors of the elderly—they walked significantly more slowly as they left the experimental room.

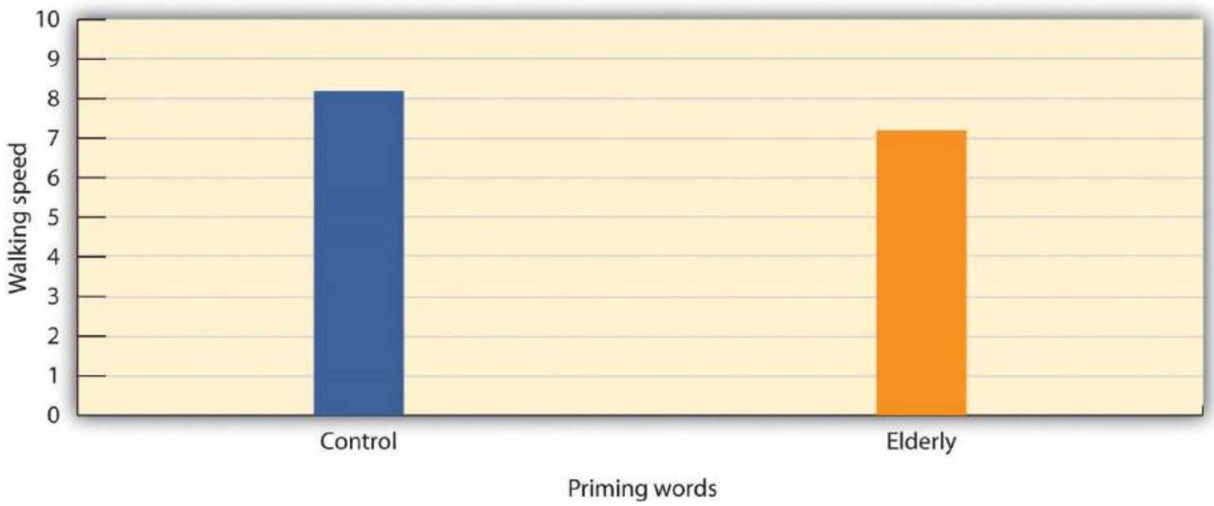


Figure 4. Results From Bargh, Chen, and Burrows, 1996

Bargh, Chen, and Burrows (1996) found that priming words associated with the elderly made people walk more slowly.

To determine if these priming effects occurred out of the awareness of the participants, Bargh and his colleagues asked still another group of students to complete the priming task and then to indicate whether they thought the words they had used to make the sentences had any relationship to each other, or could possibly have influenced their behavior in any way. These students had no awareness of the possibility that the words might have been related to the elderly or could have influenced their behavior.

Decay vs. Interference

Psychologists refer to the time between learning and testing as the retention interval. Memories can consolidate during that time, aiding retention. However, experiences can also occur that undermine the memory. For example, think of what you had for lunch yesterday—a pretty easy task. However, if you had to recall what you had for lunch 17 days ago, you may well fail (assuming you don't eat the same thing every day). The 16 lunches you've had since that one have created **retroactive interference**. Retroactive interference refers to new activities (i.e., the subsequent lunches) during the retention interval (i.e., the time between the lunch 17 days ago and now) that interfere with retrieving the specific, older memory (i.e., the lunch details from 17 days ago). But just as newer things can interfere with remembering older things, so can the opposite happen. *Proactive interference* is when past memories interfere with the encoding of new ones. For example, if you have ever studied a second language, often times the grammar and vocabulary of your native language will pop into your head, impairing your fluency in the foreign language.

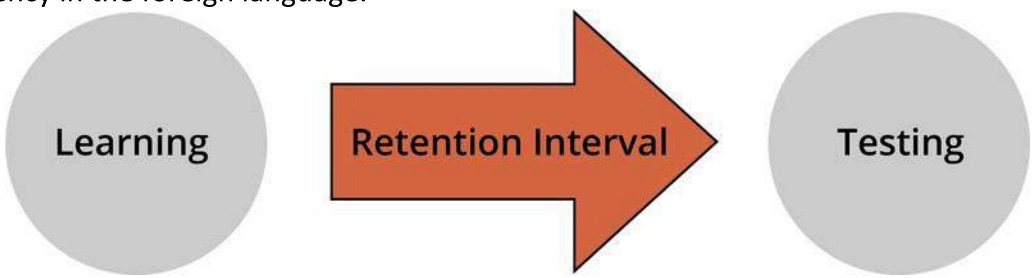


Figure 5. Retention Interval diagram

Retroactive interference is one of the main causes of forgetting (McGeoch, 1932). In the module *Eyewitness Testimony and Memory Biases* (http://noba.to/uy49tm37), Elizabeth Loftus describes her fascinating work on eyewitness memory, in which she shows how memory for an event can be changed via misinformation supplied during the retention interval. For example, if you witnessed a car crash but subsequently heard people describing it from their own perspective, this new information may interfere with or disrupt your own personal recollection of the crash. In fact, you may even come to remember the event happening exactly as the others described it! This **misinformation effect** in eyewitness memory represents a type of retroactive interference that can occur during the retention interval. Of course, if correct information is given during the retention interval, the witness's memory will usually be improved.
Although interference may arise between the occurrence of an event and the attempt to recall it, *the effect itself is always expressed when we retrieve memories*, the topic to which we turn next.

In some cases our existing memories influence our new learning. This may occur either in a backward way or a forward way. Retroactive interference occurs when *learning something new impairs our ability to retrieve information that was learned earlier*. For example, if you have learned to program in one computer language, and then you learn to program in another similar one, you may start to make mistakes programming the first language that you never would have made before you learned the new one. In this case the new memories work backward (retroactively) to influence retrieval from memory that is already in place.

In contrast to retroactive interference, *proactive interference* works in a forward direction. Proactive interference occurs when *earlier learning impairs our ability to encode information that we try to learn later*. For example, if we have learned French as a second

language, this knowledge may make it more difficult, at least in some respects, to learn a third language (say Spanish), which involves similar but not identical vocabulary.
Figure 8.14 Proactive and Retroactive Interference

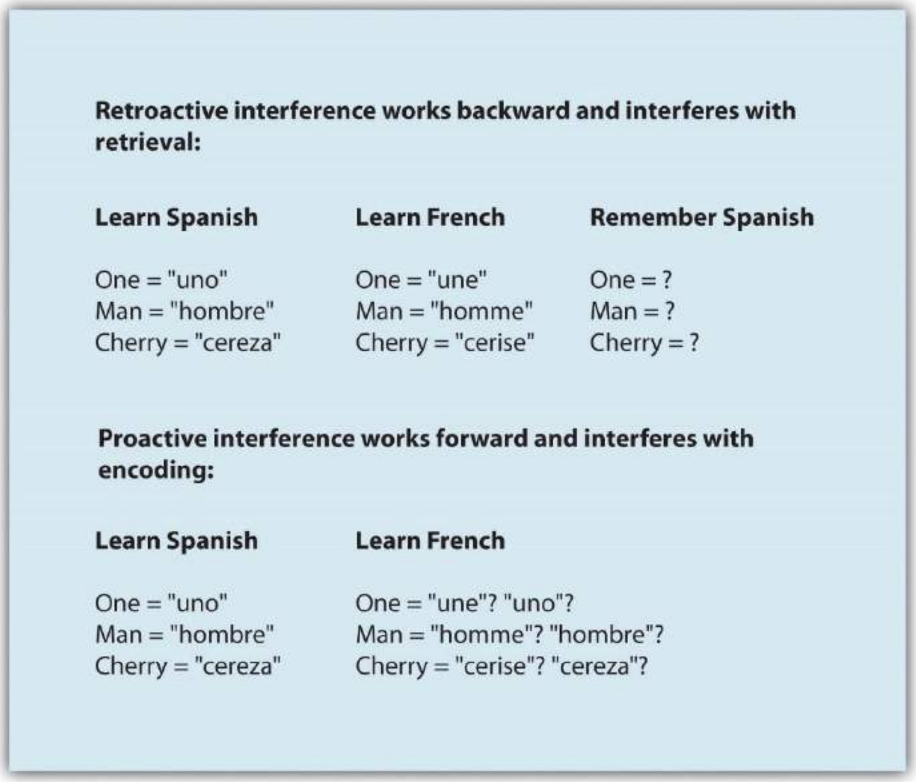


Figure 6. Retroactive and proactive interference can both influence memory.

Forgetting

Interference vs. Decay

Chances are that you have experienced memory lapses and been frustrated by them. You may have had trouble remembering the definition of a key term on an exam or found yourself unable to recall the name of an actor from one of your favorite TV shows. Maybe you forgot to call your aunt on her birthday or you routinely forget where you put your cell phone. Oftentimes, the bit of information we are searching for comes back to us, but sometimes it does not. Clearly, forgetting seems to be a natural part of life. Why do we forget? And is forgetting always a bad thing?

Figure 7. Forgetting can often be obnoxious or even embarrassing. But as we explore this module, you'll learn that forgetting is important and necessary for everyday functionality. [Image: jazbeck, https://goo.gl/nkRrJy, CC BY 2.0, https://goo.gl/BRvSA7]

Causes of Forgetting

One very common and obvious reason why you cannot remember a piece of information is because you did not learn it in the first place. If you fail to encode information into memory, you are not going to remember it later on. Usually, **encoding** failures occur because we are distracted or are not paying attention to specific details. For example, people have a lot of trouble recognizing an actual penny out of a set of drawings of very similar pennies, or lures, even though most of us have had a lifetime of experience handling pennies (Nickerson & Adams, 1979). However, few of us have studied the features of a penny in great detail, and since we have not attended to those details, we fail to recognize them later. Similarly, it has been well documented that distraction during learning impairs later memory (e.g., Craik, Govoni, Naveh-Benjamin, & Anderson, 1996). Most of the time this is not problematic, but in certain situations, such as when you are studying for an exam, failures to encode due to distraction can have serious repercussions.

Another proposed reason why we forget is that memories fade, or **decay**, over time. It has been known since the pioneering work of Hermann Ebbinghaus (1885/1913) that as time passes, memories get harder to recall. Ebbinghaus created more than 2,000 nonsense syllables, such as *dax*, *bap*, and *rif*, and studied his own memory for them, learning as many as 420 lists of 16 nonsense syllables for one experiment. He found that his memories diminished as time passed, with the most forgetting happening early on after learning. His observations and subsequent research suggested that if we do not rehearse a memory and the neural representation of that memory is not reactivated over a long period of time, the memory representation may disappear entirely or fade to the point where it can no longer be accessed. As you might imagine, it is hard to definitively prove that a memory has decayed as opposed to it being inaccessible for another reason. Critics argued that forgetting must be due to processes other than simply the passage of time, since disuse of a memory does not always guarantee forgetting (McGeoch, 1932). More recently, some memory theorists have proposed that recent memory traces may be degraded or disrupted by new experiences (Wixted, 2004). Memory traces need to be **consolidated**, or transferred from the hippocampus to more durable representations in the cortex, in order for them to last (McGaugh, 2000). When the consolidation process is interrupted by the encoding of other experiences, the memory trace for the original experience does not get fully developed and thus is forgotten.

Figure 8. At times, we will completely blank on something we're certain we've learned - people we went to school with years ago for example. However, once we get the right retrieval cue (a name perhaps), the memory (faces or experiences) rushes back to us like it was there all along. [Image: sbhsclass84, https://goo.gl/sHZyQI, CC BY-SA 2.0, https://goo.gl/rxiUsF]

Both encoding failures and decay account for more permanent forms of forgetting, in which the memory trace does not exist, but forgetting may also occur when a memory exists yet we temporarily cannot access it. This type of forgetting may occur when we lack the appropriate **retrieval** cues for bringing the memory to mind. You have probably had the frustrating experience of forgetting your password for an online site. Usually, the password has not been permanently forgotten; instead, you just need the right reminder to remember what it is. For example, if your password was "pizza0525," and you received the password hints "favorite food" and "Mom's birthday," you would easily be able to retrieve it. Retrieval hints can bring back to mind seemingly forgotten memories (Tulving & Pearlstone, 1966). One real-life illustration of the importance of retrieval cues comes from a study showing that whereas people have difficulty recalling the names of high school classmates years after graduation, they are easily able to recognize the names and match them to the appropriate faces (Bahrick, Bahrick, & Wittinger, 1975). The names are powerful enough retrieval cues that they bring back the memories of the faces that went with them. The fact that the presence of the right retrieval cues is critical for remembering adds to the difficulty in proving that a memory is permanently forgotten as opposed to temporarily unavailable.

Retrieval failures can also occur because other memories are blocking or getting in the way of recalling the desired memory. This blocking is referred to as **interference**. For example, you may fail to remember the name of a town you visited with your family on summer vacation because the names of other towns you visited on that trip or on other trips come to mind instead. Those memories then prevent the desired memory from being retrieved. Interference is also relevant to the example of forgetting a password: passwords that we have used for other websites may come to mind and interfere with our ability to retrieve the desired password. Interference can be either proactive, in which old memories block the learning of new related memories, or retroactive, in which new memories block the retrieval of old related memories. For both types of interference, competition between memories seems to be key (Mensink & Raaijmakers, 1988). Your memory for a town you visited on vacation is unlikely to interfere with your ability to remember an Internet password, but it is likely to interfere with your ability to remember a different town's name. Competition between memories can also lead to forgetting in a different way. Recalling a desired memory in the face of competition may result in the inhibition of related, competing memories (Levy & Anderson, 2002). You may have difficulty recalling the name of Kennebunkport, Maine, because other Maine towns, such as Bar Harbor, Winterport, and Camden, come to mind instead. However, if you are able to recall Kennebunkport despite strong competition from the other towns, this may actually change the competitive landscape, weakening memory for those other towns' names, leading to forgetting of them instead.

Box 1. Five Impediments to Remembering

1. Encoding failures - we don't learn the information in the first place
2. Decay - memories fade over time
3. Inadequate retrieval cues - we lack sufficient reminders
4. Interference - other memories get in the way
5. Trying not to remember - we deliberately attempt to keep things out of mind

Figure 9. The 5 Impediments to Remembering

Finally, some memories may be forgotten because *we deliberately attempt to keep them out of mind*. Over time, by actively trying not to remember an event, we can sometimes successfully keep the undesirable memory from being retrieved either by inhibiting the undesirable memory or generating diversionary thoughts (Anderson & Green, 2001). Imagine that you slipped and fell in your high school cafeteria during lunch time, and everyone at the surrounding tables laughed at you. You would likely wish to avoid thinking about that event and might try to prevent it from coming to mind. One way that you could accomplish this is by thinking of other, more positive, events that are associated with the cafeteria. Eventually, this memory may be suppressed to the point that it would only be retrieved with great difficulty (Hertel & Calcaterra, 2005)

Adaptive Forgetting

Figure 10. Could you imagine being unable to forget every path you have taken while hiking? Each new trip, you would be walking around the forest for days, incapable of distinguishing today's path from the prior ones. [Image: Dan Trew, https://goo.gl/8fJWWE, CC BY-SA 2.0, https://goo.gl/rxiUsF]

We have explored five different causes of forgetting. Together they can account for the day-to-day episodes of forgetting that each of us experience. Typically, we think of these episodes in a negative light and view forgetting as a memory failure. Is forgetting ever good? Most people would reason that forgetting that occurs in response to a deliberate attempt to keep an event out of mind is a good thing. No one wants to be constantly reminded of falling on their face in front of all of their friends. However, beyond that, it can be argued that forgetting is adaptive, allowing us to be efficient and hold onto only the most relevant memories (Bjork, 1989; Anderson & Milson, 1989). Shereshevsky, or "S," the mnemonist studied by Alexander Luria (1968), was a man who almost never forgot. His memory appeared to be virtually limitless. He could memorize a table of 50 numbers in under 3 minutes and recall the numbers in rows, columns, or diagonals with ease. He could recall lists of words and passages that he had memorized over a decade before. Yet Shereshevsky found it difficult to function in his everyday life because he was constantly distracted by a flood of details and associations that sprung to mind. His case history suggests that remembering everything is not always a good thing. You may occasionally have trouble remembering where you parked your car but imagine if every time you had to find your car, every single former parking space came to mind. The task would become impossibly difficult to sort through all of those irrelevant memories. Thus, forgetting is adaptive in that it makes us more efficient. The price of that efficiency is those moments when our memories seem to fail us (Schacter, 1999).

The Fallibility of Memory

Memories can be encoded poorly or fade with time; the storage and recovery process is not flawless.

LEARNING OBJECTIVES

- Distinguish among the factors that make some memories unrecoverable

KEY TAKEAWAYS

Key Points

- Memories are affected by how a person internalizes events through perceptions, interpretations, and emotions.
- Transience refers to the general deterioration of a specific memory over time.
- Transience is caused by proactive and retroactive interference.
- Encoding is the process of converting sensory input into a form that memory is capable of processing and storing.
- Memories that are encoded poorly or shallowly may not be recoverable.

Key Terms

- transience: The deterioration of a specific memory over time.

Memory is not perfect. Storing a memory and retrieving it later involves both biological and psychological processes, and the relationship between the two is not fully understood. Memories are affected by how a person internalizes events through perceptions, interpretations, and emotions. This can cause a divergence between what is internalized as a memory and what actually happened in reality; it can also cause events to encode incorrectly, or not at all.

Transience

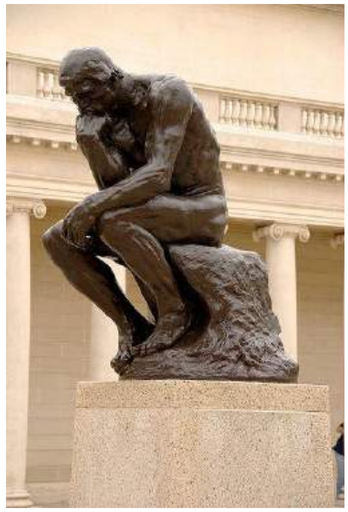


Figure 11. The Thinker by Auguste Rodin: Our memories are not infallible: over time, without use, memories decay and we lose the ability to retrieve them.

It is easier to remember recent events than those further in the past, and the more we repeat or use information, the more likely it is to enter into long-term memory. However, without use, or with the addition of new memories, old memories can decay. "Transience" refers to the general deterioration of a specific memory over time. Transience is caused by proactive and retroactive interference. Proactive interference is when old information inhibits the ability to remember new information, such as when outdated scientific facts interfere with the ability to remember updated facts. Retroactive interference is when new information inhibits the ability to remember old information, such as when hearing recent news figures, then trying to remember earlier facts and figures.

Encoding Failure

Encoding is the process of converting sensory input into a form able to be processed and stored in the memory. However, this process can be impacted by a number of factors, and how well information is encoded affects how well it is able to be recalled later. Memory is associative by nature; commonalities between points of information not only reinforce old memories, but serve to ease the establishment of new ones. The way memories are encoded is personal; it depends on what information an individual considers to be relevant and useful, and how it relates to the individual's vision of reality. All of these factors impact how memories are prioritized and how accessible they will be when they are stored in long-term memory. Information that is considered less relevant or less useful will be harder to recall than memories that are deemed valuable and important. Memories that are encoded poorly or shallowly may not be recoverable at all.

Types of Forgetting

There are many ways in which a memory might fail to be retrieved, or be forgotten.

LEARNING OBJECTIVES

- Differentiate among the different processes involved in forgetting

KEY TAKEAWAYS

Key Points

- The trace decay theory of forgetting states that all memories fade automatically as a function of time; under this theory, you need to follow a certain path, or trace, to recall a memory.
- Under interference theory, all memories interfere with the ability to recall other memories.
- Proactive interference occurs when memories from someone's past influence new memories; retroactive interference occurs when old memories are changed by new ones, sometimes so much that the original memory is forgotten.
- Cue dependent forgetting, also known as retrieval failure, is the failure to recall information in the absence of memory cues.
- The tip of the tongue phenomenon is the failure to retrieve a word from memory, combined with partial recall and the feeling that retrieval is imminent.

Key Terms

- Trace decay theory: The theory that if memories are not reviewed or recalled consistently, they will begin to decay and will ultimately be forgotten.
- Retroactive interference: When newly learned information interferes with and impedes the recall of previously learned information.
- Proactive interference: When past memories inhibit an individual's full potential to retain new memories.
- Trace: A pathway to recall a memory.

Memory is not static. How you remember an event depends on a large number of variables, including everything from how much sleep you got the night before to how happy you were during the event. Memory is not always perfectly reliable, because it is influenced not only by

the actual events it records, but also by other knowledge, experiences, expectations, interpretations, perceptions, and emotions. And memories are not necessarily permanent: they can disappear over time. This process is called forgetting. But why do we forget? The answer is currently unknown.
There are several theories that address why we forget memories and information over time, including trace decay theory, interference theory, and cue-dependent forgetting.

Trace Decay Theory

The trace decay theory of forgetting states that all memories fade automatically as a function of time. Under this theory, you need to follow a certain pathway, or trace, to recall a memory. If this pathway goes unused for some amount of time, the memory decays, which leads to difficulty recalling, or the inability to recall, the memory. Rehearsal, or mentally going over a memory, can slow this process. But disuse of a trace will lead to memory decay, which will ultimately cause retrieval failure. This process begins almost immediately if the information is not used: for example, sometimes we forget a person's name even though we have just met them.

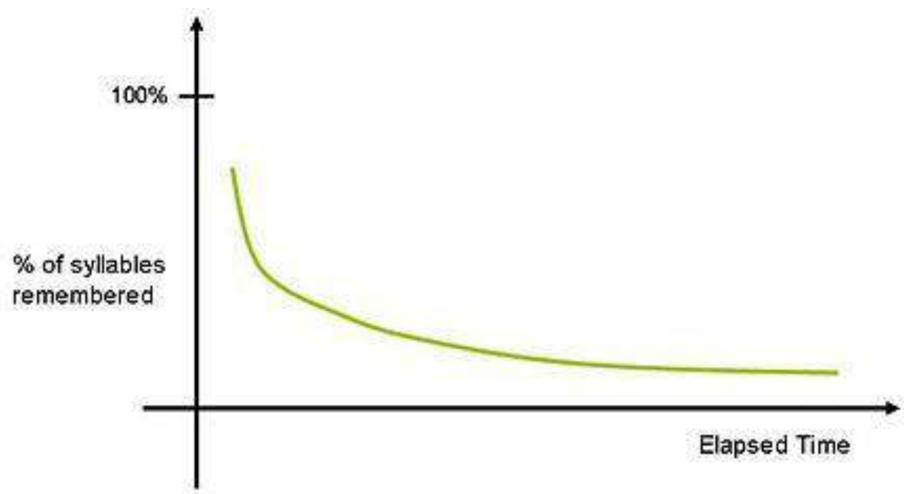


Figure 12. Memory over time: Over time, a memory becomes harder to remember. A memory is most easily recalled when it is brand new, and without rehearsal, begins to be forgotten.

Interference Theory

It is easier to remember recent events than those further in the past. " Transience " refers to the general deterioration of a specific memory over time. Under interference theory, transience occurs because all memories interfere with the ability to recall other memories. Proactive and retroactive interference can impact how well we are able to recall a memory, and sometimes cause us to forget things permanently.

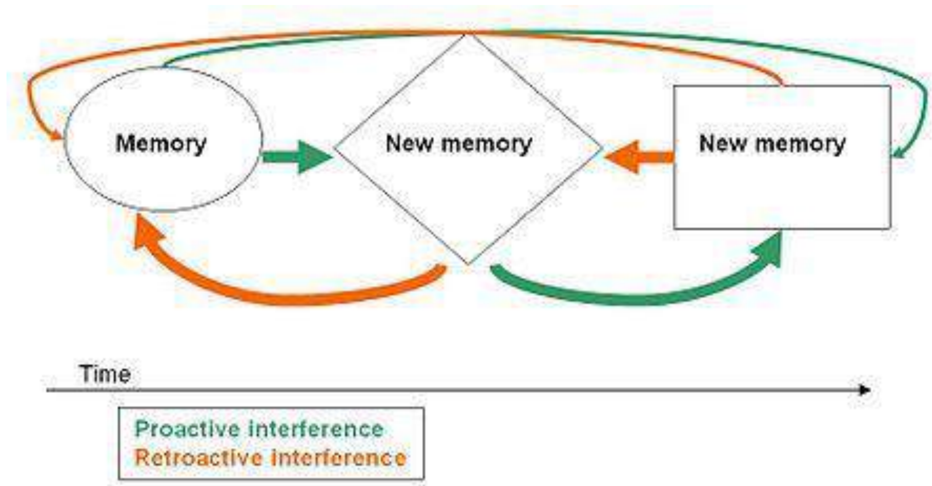


Figure 13. Memory interference: Both old and new memories can impact how well we are able to recall a memory. This is known as proactive and retroactive interference.

Proactive Interference

Proactive interference occurs when old memories hinder the ability to make new memories. In this type of interference, old information inhibits the ability to remember new information, such as when outdated scientific facts interfere with the ability to remember updated facts. This often occurs when memories are learned in similar contexts, or regarding similar things. It's when we have preconceived notions about situations and events, and apply them to current situations and events. An example would be growing up being taught that Pluto is a planet in our solar system, then being told as an adult that Pluto is no longer considered a planet. Having such a strong memory would negatively impact the recall of the new information, and when asked how many planets there are, someone who grew up thinking of Pluto as a planet might say nine instead of eight.

Retroactive Interference

Retroactive interference occurs when old memories are changed by new ones, sometimes so much that the original memory is forgotten. This is when newly learned information interferes with and impedes the recall of previously learned information. The ability to recall previously learned information is greatly reduced if that information is not utilized, and there is substantial new information being presented. This often occurs when hearing recent news figures, then trying to remember earlier facts and figures. An example of this would be learning a new way to make a paper airplane, and then being unable to remember the way you used to make them.

Cue-Dependent Forgetting

When we store a memory, we not only record all sensory data, we also store our mood and emotional state. Our current mood thus will affect the memories that are most effortlessly available to us, such that when we are in a good mood, we recollect good memories, and when we are in a bad mood, we recollect bad ones. This suggests that we are sometimes cued to remember certain things by, for example, our emotional state or our environment. Cue-dependent forgetting, also known as retrieval failure, is the failure to recall information in the absence of memory cues. There are three types of cues that can stop this type of forgetting:

- Semantic cues are used when a memory is retrieved because of its association with another memory. For example, someone forgets everything about his trip to Ohio until he is reminded that he visited a certain friend there, and that cue causes him to recollect many more events of the trip.
- State-dependent cues are governed by the state of mind at the time of encoding. The emotional or mental state of the person (such as being inebriated, drugged, upset, anxious, or happy) is key to establishing cues. Under cue-dependent forgetting theory, a memory might be forgotten until a person is in the same state.
- Context-dependent cues depend on the environment and situation. Memory retrieval can be facilitated or triggered by replication of the context in which the memory was encoded. Such conditions can include weather, company, location, the smell of a particular odor, hearing a certain song, or even tasting a specific flavor.

Other Types of Forgetting

Trace decay, interference, and lack of cues are not the only ways that memories can fail to be retrieved. Memory's complex interactions with sensation, perception, and attention sometimes render certain memories irretrievable.

Absentmindedness

If you've ever put down your keys when you entered your house and then couldn't find them later, you have experienced absentmindedness. Attention and memory are closely related, and absentmindedness involves problems at the point where attention and memory interface. Common errors of this type include misplacing objects or forgetting appointments. Absentmindedness occurs because at the time of encoding, sufficient attention was not paid to what would later need to be recalled.

Blocking

Occasionally, a person will experience a specific type of retrieval failure called blocking. Blocking is when the brain tries to retrieve or encode information, but another memory interferes with it. Blocking is a primary cause of the tip-of-the-tongue phenomenon. This is the failure to retrieve a word from memory, combined with partial recall and the feeling that retrieval is imminent. People who experience this can often recall one or more features of the target word, such as the first letter, words that sound similar, or words that have a similar meaning. Sometimes a hint can help them remember: another example of cued memory.

Amnesia

Amnesia, the inability to recall certain memories, often results from damage to any of a number of regions in the temporal lobe and hippocampus.

LEARNING OBJECTIVES

- Differentiate among the different types of amnesia and memory loss

KEY TAKEAWAYS

Key Points

- Anterograde amnesia is the inability to create new memories; long-term memories from before the event typically remain intact. However, memories that were not fully consolidated from before the event may also be lost.
- Retrograde amnesia is the inability to recall memories from before the onset of amnesia. A person may be able to encode new memories after the event, and they are more likely to remember general knowledge rather than specifics.
- Childhood amnesia is the inability to remember events from very early in childhood, due to the fact that the parts of the brain involved in long-term memory storage are still undeveloped for the first couple years of life.
- " Dementia " is a collective term for many neurocognitive disorders affecting memory that can arise in old age, including Alzheimer's disease.

Key Terms

- Retrograde amnesia: The loss of memories from the period before the amnesic episode.
- Anterograde amnesia: The inability to remember new information since the amnesic episode.

"Amnesia" is a general term for the inability to recall certain memories, or in some cases, the inability to form new memories. Some types of amnesia are due to neurological trauma; but in other cases, the term "amnesia" is just used to describe normal memory loss, such as not remembering childhood memories.

Amnesia from Brain Damage

Amnesia typically occurs when there is damage to a variety of regions of the temporal lobe or the hippocampus, causing the inability to recall memories before, or after, an (often traumatic) event. There are two main forms of amnesia: retrograde and anterograde.

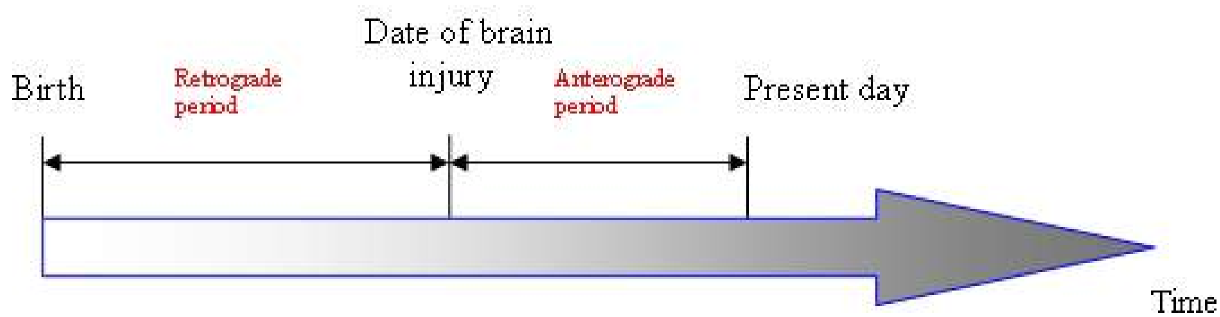


Figure 14. Amnesia: There are two main forms of amnesia: retrograde and anterograde. Retrograde prevents recall of information encoded before a brain injury, and anterograde prevents recall of information encountered after a brain injury.

Retrograde Amnesia

Retrograde amnesia is the inability to recall memories made *before* the onset of amnesia. Retrograde amnesia is usually caused by head trauma or brain damage to parts of the brain other than the hippocampus (which is involved with the encoding process of new memories). Brain damage causing retrograde amnesia can be as varied as a cerebrovascular accident, stroke, tumor, hypoxia, encephalitis, or chronic alcoholism.

Retrograde amnesia is usually temporary, and can often be treated by exposing the sufferer to cues for memories of the period of time that has been forgotten.

Anterograde Amnesia

Anterograde amnesia is the inability to create new memories *after* the onset of amnesia, while memories from before the event remain intact. Brain regions related to this condition include the medial temporal lobe, medial diencephalon, and hippocampus. Anterograde amnesia can be caused by the effects of long-term alcoholism, severe malnutrition, stroke, head trauma, surgery, Wernicke-Korsakoff syndrome, cerebrovascular events, anoxia, or other trauma. Anterograde amnesia cannot be treated with pharmaceuticals because of the damage to brain tissue. However, sufferers can be treated through education to define their daily routines: typically, procedural memories (motor skills and routines like tying shoes or playing an instrument) suffer less than declarative memories (facts and events). Additionally, social and emotional support is important to improve the quality of life of those suffering from anterograde amnesia.

The man with no short term memory:

In 1985, Clive Wearing, then a well-known musicologist, contracted a herpes simplex virus that attacked his central nervous system. The virus damaged his hippocampus, the area of the brain required in the transfer of memories from short-term to long term storage. As a result, Wearing developed a profound case of total amnesia, both retrograde and anterograde. He is completely unable to form lasting new memories— his memory only lasts for between 7 and 30 seconds— and also cannot recall aspects of his past memories, frequently believing that he has only recently awoken from a coma. Click here to watch a short video explaining his condition.

Other Types of Amnesia

Some types of forgetting are not due to traumatic brain injury, but instead are the result of the changes the human brain goes through over the course of a lifetime.

Childhood Amnesia

Do you remember anything from when you were six months old? How about two years old? There's a reason that nobody does. Childhood amnesia, also called infantile amnesia, is the inability of adults to retrieve memories before the age of 2–4. This is because for the first year or two of life, brain structures such as the limbic system (which holds the hippocampus and the amygdala and is vital t0 memory storage) are not yet fully developed. Research has shown that children have the capacity to remember events that happened to them from age 1 and before while they are still relatively young, but as they get older they tend to be unable to recall memories from their youngest years.

Neurocognitive Disorders

Neurocognitive disorders are a broad category of brain diseases typical to old age that cause a long-term and often gradual decrease in the ability to think and recall memories, such that a person's daily functioning is affected. "Neurocognitive disorder" is synonymous with "dementia" and "senility," but these terms are no longer used in the DSM-5. For the diagnosis to be made there must be a change from a person's usual mental functioning and a greater decline than one would expect due to aging. These diseases also have a significant effect on a person's caregivers.

The most common type of dementia is Alzheimer's disease, which makes up 50% to 70% of cases. Its most common symptoms are short-term memory loss and word-finding difficulties. People with Alzheimer's also have trouble with visual-spatial areas (for example, they may get lost often), reasoning, judgement, and insight into whether they are experiencing memory loss at all.

Encoding Specificity Principle

What factors determine what information can be retrieved from memory? One critical factor is the type of hints, or *cues*, in the environment. You may hear a song on the radio that suddenly evokes memories of an earlier time in your life, even if you were not trying to remember it when the song came on. Nevertheless, the song is closely associated with that time, so it brings the experience to mind.

Figure 15. We can't know the entirety of what is in our memory, but only that portion we can actually retrieve. Something that cannot be retrieved now and which is seemingly gone from memory may, with different cues applied, reemerge. [Image: Ores2k, https://goo.gl/1du8Qe, CC BY-NC-SA 2.0, https://goo.gl/jSSrcO]

The general principle that underlies the effectiveness of retrieval cues is the **encoding specificity principle** (Tulving & Thomson, 1973): when people encode information, they do so in specific ways. For example, take the song on the radio: perhaps you heard it while you were at a terrific party, having a great, philosophical conversation with a friend. Thus, the song became part of that whole complex experience. Years later, even though you haven't thought about that party in ages, when you hear the song on the radio, the whole experience rushes back to you. In general, the encoding specificity principle states that, to the extent a retrieval cue (the song) matches or overlaps the memory trace of an experience (the party, the conversation), it will be effective in evoking the memory. A classic experiment on the encoding specificity principle had participants memorize a set of words in a unique setting. Later, the participants were tested on the word sets, either in the same location they learned the words or a different one. As a result of encoding specificity, the students who took the test in the same place they learned the words were actually able to recall more words (Godden & Baddeley, 1975) than the students who took the test in a new setting. In this instance, the physical context itself provided cues for retrieval. This is why it's good to study for midterms and finals in the same room you'll be taking them in.

One caution with this principle, though, is that, for the cue to work, it can't match too many other experiences (Nairne, 2002; Watkins, 1975). Consider a lab experiment. Suppose you study 100 items; 99 are words, and one is a picture—of a penguin, item 50 in the list. Afterwards, the cue "recall the picture" would evoke "penguin" perfectly. No one would miss it. However, if the *word* "penguin" were placed in the same spot among the other 99 words, its memorability would be exceptionally worse. This outcome shows the power of distinctiveness that we discussed in the section on encoding: one picture is perfectly recalled from among 99 words because it stands out. Now consider what would happen if the experiment were repeated, but there were 25 pictures distributed within the 100-item list. Although the picture of the penguin would still be there, the probability that the cue "recall the picture" (at item 50) would be useful for the penguin would drop correspondingly. Watkins (1975) referred to this outcome as demonstrating the **cue overload principle**. That is, to be effective, a retrieval cue cannot be overloaded with too many memories. For the cue "recall the picture" to be effective, it should only match one item in the target set (as in the one-picture, 99-word case).

We are more likely to be able to retrieve items from memory when conditions at retrieval are similar to the conditions under which we encoded them. Context-dependent learning refers to *an increase in retrieval when the external situation in which information is learned matches the situation in which it is remembered*. Godden and Baddeley (1975) conducted a study to test this idea using scuba divers. They asked the divers to learn a list of words either when they were on land or when they were underwater. Then they tested the divers on their memory, either in the same or the opposite situation. As you can see in Figure 15, the divers' memory was better when they were tested in the same context in which they had learned the words than when they were tested in the other context.

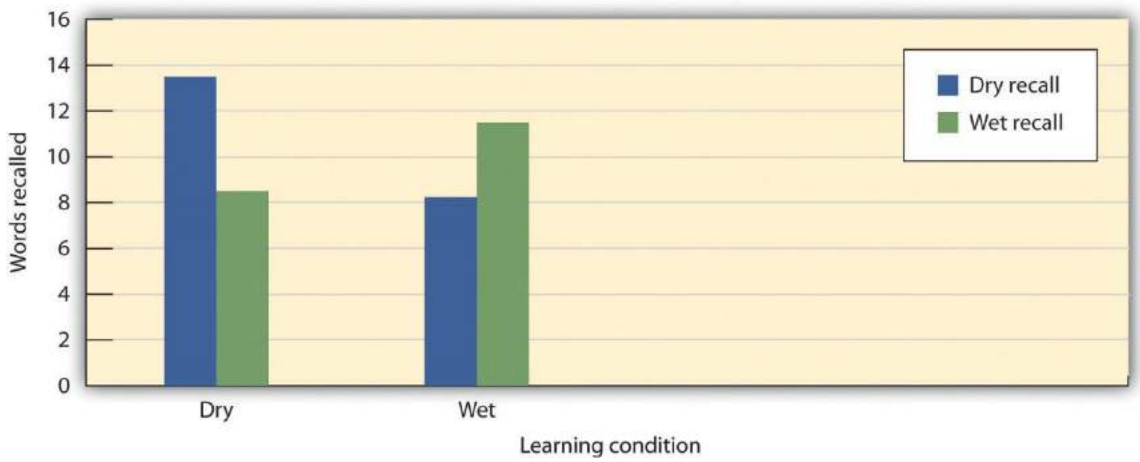


Figure 16. Godden and Baddeley (1975) tested the memory of scuba divers to learn and retrieve information in different contexts and found strong evidence for context-dependent learning. Adapted from Godden, D. R., & Baddeley, A. D. (1975). Context-dependent memory in two natural environments: On land and underwater. British Journal of Psychology, 66(3), 325–331.

You can see that context-dependent learning might also be important in improving your memory. For instance, you might want to try to study for an exam in a situation that is similar to the one in which you are going to take the exam.

Whereas context-dependent learning refers to a match in the external situation between learning and remembering, state-dependent learning refers to *superior retrieval of memories when the individual is in the same physiological or psychological state as during encoding*. Research has found, for instance, that animals that learn a maze while under the influence of one drug tend to remember their learning better when they are tested under the influence of the same drug than when they are tested without the drug (Jackson, Koek, & Colpaert, 1992). And research with humans finds that bilinguals remember better when tested in the same language in which they learned the material (Marian & Kaushanskaya, 2007). Mood states may also produce state-dependent learning. People who learn information when they are in a bad (rather than a good) mood find it easier to recall these memories when they are tested while they are in a bad mood, and vice versa. It is easier to recall unpleasant memories than pleasant ones when we're sad, and easier to recall pleasant memories than unpleasant ones when we're happy (Bower, 1981; Eich, 2008).

Reconstruction of Memories

Memories are not stored as exact replicas of reality; rather, they are modified and reconstructed during recall.

LEARNING OBJECTIVES

- **Evaluate how mood, suggestion, and imagination can lead to memory errors or bias**

KEY TAKEAWAYS

Key Points

- Because memories are reconstructed, they are susceptible to being manipulated with false information.
- Much research has shown that the phrasing of questions can alter memories. Children are particularly suggestible to such leading questions.
- People tend to place past events into existing representations of the world (schemas) to make memories more coherent.
- Intrusion errors occur when information that is related to the theme of a certain memory, but was not actually a part of the original episode, become associated with the event.
- There are many types of bias that influence recall, including fading-affect bias, hindsight bias, illusory correlation, self-serving bias, self-reference effect, source amnesia, source confusion, mood-dependent memory retrieval, and the mood congruence effect.

Key Terms

- Consolidation: The act or process of turning short-term memories into more permanent, long term memories.
- Schema: A worldview or representation.
- Leading question: A query that suggests the answer or contains the information the examiner is looking for.

Memory Errors

Memories are fallible. They are reconstructions of reality filtered through people's minds, not perfect snapshots of events. Because memories are reconstructed, they are susceptible to being manipulated with false information. Memory errors occur when memories are recalled incorrectly; a memory gap is the complete loss of a memory.

Schemas

In a 1932 study, Frederic Bartlett demonstrated how telling and retelling a story distorted information recall. He told participants a complicated Native American story and had them repeat it over a series of intervals. With each repetition, the stories were altered. Even when participants recalled accurate information, they filled in gaps with false information. Bartlett attributed this tendency to the use of *schemas*. A schema is a generalization formed in the mind based on experience. People tend to place past events into existing representations of the world to make memories more coherent. Instead of remembering precise details about commonplace occurrences, people use schemas to create frameworks for typical experiences, which shape their expectations and memories. The common use of schemas suggests that memories are not identical reproductions of experience, but a combination of actual events and already-existing schemas. Likewise, the brain has the tendency to fill in blanks and inconsistencies in a memory by making use of the imagination and similarities with other memories.

Leading Questions

Much research has shown that the phrasing of questions can also alter memories. A leading question is a question that suggests the answer or contains the information the examiner is looking for. For instance, one study showed that simply changing one word in a question could alter participants' answers: After viewing video footage of a car accident, participants who were asked how "slow" the car was going gave lower speed estimations than those who were asked how "fast" it was going. Children are particularly suggestible to such leading questions.

Intrusion Errors

Intrusion errors occur when information that is related to the theme of a certain memory, but was not actually a part of the original episode, become associated with the event. This makes it difficult to distinguish which elements are in fact part of the original memory. Intrusion errors are frequently studied through word-list recall tests.

Intrusion errors can be divided into two categories. The first are known as extra-list errors, which occur when incorrect and non-related items are recalled, and were not part of the word study list. These types of intrusion errors often follow what are known as the DRM Paradigm effects, in which the incorrectly recalled items are often thematically related to the study list one is attempting to recall from. Another pattern for extra-list intrusions would be an acoustic similarity pattern, which states that targets that have a similar sound to non-targets may be replaced with those non-targets in recall. The second type of intrusion errors are known as intra-list errors, which consist of irrelevant recall for items that were on the word study list. Although these two categories of intrusion errors are based on word-list studies in laboratories, the concepts can be extrapolated to real-life situations. Also, the same three factors that play a critical role in correct recall (i.e., recency, temporal association, and semantic relatedness) play a role in intrusions as well.

Types of Memory Bias

A person's motivations, intentions, mood, and biases can impact what they remember about an event. There are many identified types of bias that influence people's memories.

Fading-Affect Bias

In this type of bias, the emotion associated with unpleasant memories "fades" (i.e., is recalled less easily or is even forgotten) more quickly than emotion associated with positive memories.

Hindsight Bias

Hindsight bias is the "I knew it all along!" effect. In this type of bias, remembered events will seem predictable, even if at the time of encoding they were a complete surprise.

Illusory Correlation

When you experience illusory correlation, you inaccurately assume a relationship between two events related purely by coincidence. This type of bias comes from the human tendency to see cause-and-effect relationships when there are none; remember, correlation does *not* imply causation.

Mood Congruence Effect

The mood congruence effect is the tendency of individuals to retrieve information more easily when it has the same emotional content as their current emotional state. For instance, being in a depressed mood increases the tendency to remember negative events.

Mood-State Dependent Retrieval

Another documented phenomenon is mood-state dependent retrieval, which is a type of context-dependent memory. The retrieval of information is more effective when the emotional state at the time of retrieval is similar to the emotional state at the time of encoding. Thus, the probability of remembering an event can be enhanced by evoking the emotional state experienced during its initial processing.

Salience Effect

This effect, also known as the Von Restorff effect, is when an item that sticks out more (i.e., is noticeably different from its surroundings) is more likely to be remembered than other items.

Self-Reference Effect

In the self-reference effect, memories that are encoded with relation to the self are better recalled than similar memories encoded otherwise.

Self-Serving Bias

When remembering an event, individuals will often perceive themselves as being responsible for desirable outcomes, but not responsible for undesirable ones. This is known as the self-serving bias.

Source Amnesia

Source amnesia is the inability to remember where, when, or how previously learned information was acquired, while retaining the factual knowledge. Source amnesia is part of ordinary forgetting, but can also be a memory disorder. People suffering from source amnesia can also get confused about the exact content of what is remembered.

Source Confusion

Source confusion, in contrast, is not remembering the source of a memory correctly, such as personally witnessing an event versus actually only having been told about it. An example of this would be remembering the details of having been through an event, while in reality, you had seen the event depicted on television.

Considerations for Eyewitness Testimony

Increasing evidence shows that memories and individual perceptions are unreliable, biased, and manipulable.

LEARNING OBJECTIVES

- Analyze ways that the fallibility of memory can influence eyewitness testimonies

KEY TAKEAWAYS

Key Points

- The other-race effect is a studied effect in which eyewitnesses are not as good at facially identifying individuals from races different from their own.
- The weapon-focus effect is the tendency of an individual to hyper-focus on a weapon during a violent or potentially violent crime; this leads to encoding issues with other aspects of the event.
- The time between the perception and recollection of an event can also affect recollection. The accuracy of eyewitness memory degrades rapidly after initial encoding; the longer the delay between encoding and recall, the worse the recall will be.
- Research has consistently shown that even very subtle changes in the wording of a question can influence memory. Questions whose wording might bias the responder toward one answer over another are referred to as leading questions.
- Age has been shown to impact the accuracy of memory; younger witnesses are more suggestible and are more easily swayed by leading questions and misinformation.
- Other factors, such as personal biases, poor visibility, and the emotional tone of the event can influence eyewitness testimony.

Key Terms

- Leading question: A question that suggests the answer or contains the information the examiner is looking for.
- Eyewitness: Someone who sees an event and can report or testify about it.

Eyewitness testimony has been considered a credible source in the past, but its reliability has recently come into question. Research and evidence have shown that memories and individual perceptions are unreliable, often biased, and can be manipulated.

Encoding Issues

Nobody plans to witness a crime; it is not a controlled situation. There are many types of biases and attentional limitations that make it difficult to encode memories during a stressful event.

Time

When witnessing an incident, information about the event is entered into memory. However, the accuracy of this initial information acquisition can be influenced by a number of factors. One factor is the duration of the event being witnessed. In an experiment conducted by Clifford and Richards (1977), participants were instructed to approach police officers and engage in conversation for either 15 or 30 seconds. The experimenter then asked the police officer to recall details of the person to whom they had been speaking (e.g., height, hair color, facial hair, etc.). The results of the study showed that police had significantly more accurate recall of the 30-second conversation group than they did of the 15-second group. This suggests that recall is better for longer events.

Other-Race Effect

The other-race effect (a.k.a., the own-race bias, cross-race effect, other-ethnicity effect, same-race advantage) is one factor thought to affect the accuracy of facial recognition. Studies investigating this effect have shown that a person is better able to recognize faces that match their own race but are less reliable at identifying other races, thus inhibiting encoding. Perception may affect the immediate encoding of these unreliable notions due to prejudices, which can influence the speed of processing and classification of racially ambiguous targets. The ambiguity in eyewitness memory of facial recognition can be attributed to the divergent strategies that are used when under the influence of racial bias.

Weapon-Focus Effect

The weapon-focus effect suggests that the presence of a weapon narrows a person's attention, thus affecting eyewitness memory. A person focuses on a central detail (e.g., a knife) and loses focus on the peripheral details (e.g. the perpetrator's characteristics). While the weapon is remembered clearly, the memories of the other details of the scene suffer. This effect occurs because remembering additional items would require visual attention, which is occupied by the weapon. Therefore, these additional stimuli are frequently not processed.

Retrieval Issues

Trials may take many weeks and require an eyewitness to recall and describe an event many times. These conditions are not ideal for perfect recall; memories can be affected by a number of variables.

More Time Issues

The accuracy of eyewitness memory degrades swiftly after initial encoding. The "forgetting curve" of eyewitness memory shows that memory begins to drop off sharply within 20 minutes following initial encoding, and begins to level off around the second day at a dramatically reduced level of accuracy. Unsurprisingly, research has consistently found that the longer the gap between witnessing and recalling the incident, the less accurately that memory will be recalled. There have been numerous experiments that support this claim. Malpass and Devine (1981) compared the accuracy of witness identifications after 3 days (short retention period) and 5 months (long retention period). The study found no false identifications after the 3-day period, but after 5 months, 35% of identifications were false.

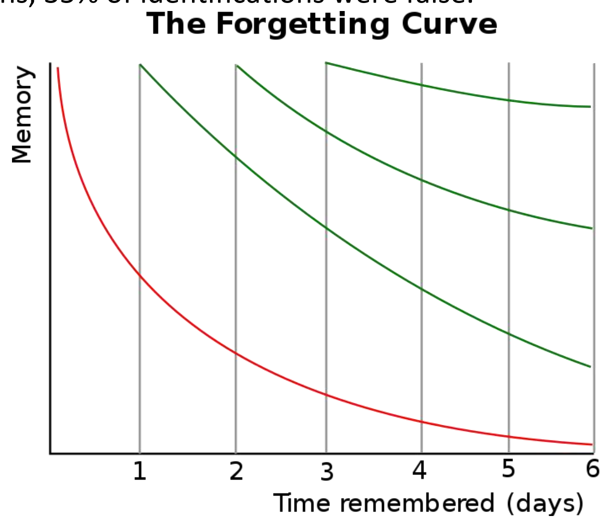


Figure 17. The forgetting curve of memory: The red line shows that eyewitness memory declines rapidly following initial encoding and flattens out after around 2 days at a dramatically reduced level of accuracy.

Leading Questions

In a legal context, the retrieval of information is usually elicited through different types of questioning. A great deal of research has investigated the impact of types of questioning on eyewitness memory, and studies have consistently shown that even very subtle changes in the wording of a question can have an influence. One classic study was conducted in 1974 by Elizabeth Loftus, a notable researcher on the accuracy of memory. In this experiment, participants watched a film of a car accident and were asked to estimate the speed the cars were going when they "contacted" or "smashed" each other. Results showed that just changing this one word influenced the speeds participants estimated: The group that was asked the speed when the cars "contacted" each other gave an average estimate of 31.8 miles per hour, whereas the average speed in the "smashed" condition was 40.8 miles per hour. Age has been shown to impact the accuracy of memory as well. Younger witnesses, especially children, are more susceptible to leading questions and misinformation.

Bias

There are also a number of biases that can alter the accuracy of memory. For instance, racial and gender biases may play into what and how people remember. Likewise, factors that interfere with a witness's ability to get a clear view of the event—like time of day, weather, and poor eyesight—can all lead to false recollections. Finally, the emotional tone of the event can have an impact: for instance, if the event was traumatic, exciting, or just physiologically activating, it will increase adrenaline and other neurochemicals that can damage the accuracy of memory recall.

Memory Conformity

“Memory conformity,” also known as social contagion of memory, refers to a situation in which one person’s report of a memory influences another person’s report of that same experience. This interference often occurs when individuals discuss what they saw or experienced, and can result in the memories of those involved being influenced by the report of another person. Some factors that contribute to memory conformity are age (the elderly and children are more likely to have memory distortions due to memory conformity) and confidence (individuals are more likely to conform their memories to others if they are not certain about what they remember).

Repressed Memories

Some research indicates that traumatic memories can be forgotten and later spontaneously recovered.

LEARNING OBJECTIVES

- Discuss the issues surrounding theories about repressed memories

KEY TAKEAWAYS

Key Points

- Some theorize that survivors of childhood sexual abuse may use repression to cope with the traumatic experience.
- Detractors of the theory of repressed memories claim that for most people, the difficulty with traumatic memories is their intrusiveness—that people are unable to forget them despite often wanting to.
- Given how unreliable memory is, some argue that attempting to recover a repressed memory runs the risk of implanting ” pseudomemories.”
- At this point it is impossible, without other corroborative evidence, to distinguish a true memory from a false one.

Key Terms

- **Pseudomemory**: A false or otherwise inaccurate memory that has usually been implanted by some form of suggestion. This term is generally used by people who do not believe that memories can be repressed and later recalled.
- **Encode**: To convert sensory input into a form able to be processed and deposited in the memory.
- **Repressed memory**: A hypothetical concept used to describe a significant memory, usually of a traumatic nature, that has become unavailable for recall.

The issue of whether memories can be repressed is controversial, to say the least. Some research indicates that memories of traumatic events, most commonly childhood sexual abuse, may be forgotten and later spontaneously recovered. However, whether these memories are actively repressed or forgotten due to natural processes is unclear.

Support for the Existence of Repressed Memories

In one study where victims of documented child abuse were re-interviewed many years later as adults, a high proportion of the women denied any memory of the abuse. Some speculate that survivors of childhood sexual abuse may repress the memories to cope with the traumatic experience. In cases where the perpetrator of the abuse is the child's caretaker, the child may push the memories out of awareness so that he or she can maintain an attachment to the person on whom they are dependent for survival.

Traumatic memories are encoded differently than memories of ordinary experiences. In traumatic memories, there is a narrowed attentional focus on certain aspects of the memory, usually those that involved the most heightened emotional arousal. For instance, when remembering a traumatic event, individuals are most likely to remember how scared they felt, the image of having a gun held to their head, or other details that are highly emotionally charged. The limbic system is the part of the brain that is in charge of giving emotional significance to sensory inputs; however, the limbic system (particularly one of its components, the hippocampus) is also important to the storage and retrieval of long-term memories. Supporters of the existence of repressed memories hypothesize that because the hippocampus is sensitive to stress hormones and because the limbic system is heavily occupied with the emotions of the event, the memory-encoding functionality may be limited during traumatic events. The end result is that the memory is encoded as an affective (i.e., relating to or influenced by the emotions) and sensory imprint, rather than a memory that includes a full account of what happened. In this way, traumatic experiences appear to be qualitatively different from those of non-traumatic events, and, as a result, they are more difficult to remember accurately.

Psychological disorders exist that could cause the repression of memories. Psychogenic amnesia, or dissociative amnesia, is a memory disorder characterized by sudden autobiographical memory loss, said to occur for a period of time ranging from hours to years. More recently, dissociative amnesia has been defined as a dissociative disorder characterized by gaps in memory of personal information, especially of traumatic events. These gaps involve an inability to recall personal information, usually of a traumatic or stressful nature. In a change from the DSM-IV to the DSM-5, dissociative fugue is now classified as a type of dissociative amnesia. Psychogenic amnesia is distinguished from organic amnesia in that it is supposed to result from a nonorganic cause; no structural brain damage or brain lesion should be evident, but some form of psychological stress should precipitate the amnesia. However, psychogenic amnesia as a memory disorder is controversial.

Opposition to the Existence of Repressed Memories

Memories of events are always a mix of factual traces of sensory information overlaid with emotions, mingled with interpretation and filled in with imaginings. Thus, there is always skepticism about the factual validity of memories.

There is considerable evidence that, rather than being pushed out of consciousness, traumatic memories are, for many people, intrusive and unforgettable. Given research showing how unreliable memory is, it is possible that any attempt to "recover" a repressed memory runs the risk of implanting false memories. Researchers who are skeptical of the idea of recovered memories note how susceptible memory is to various manipulations that can be used to implant false memories (sometimes called "pseudomemories").

A classic study in memory research conducted by Elizabeth Loftus became widely known as the "lost in the mall" experiment. In this study, subjects were given a booklet containing three accounts of real childhood events written by family members and a fourth account of a fictitious event of being lost in a shopping mall. A quarter of the subjects reported remembering the fictitious event, and elaborated on it with extensive circumstantial details.

Figure 18. "Lost in the mall" experiment: Some of the early research in memory conformity involved the "lost in the mall" technique.

While this experiment does show that false memories can be implanted in some subjects, it cannot be generalized to say that all recovered memories are false memories. Nevertheless, these studies prompted public and professional concern about recovered-memory therapy for sexual abuse. According to the American Psychiatric Association, "most leaders in the field agree that although it is a rare occurrence, a memory of early childhood abuse that has been forgotten can be remembered later. However, these leaders also agree that it is possible to construct convincing pseudomemories for events that never occurred. The mechanism(s) by which both of these phenomena happen are not well understood and, at this point it is impossible, without other corroborative evidence, to distinguish a true memory from a false one."

Autobiographical Memories

Sir Frederick Bartlett's studies

The English psychologist Sir Frederic Bartlett (1886–1969), played a major role in the psychological study of memory; particularly the cognitive and social processes of remembering. Bartlett created short stories that were in some ways logical but also contained some very unusual and unexpected events. Bartlett discovered that people found it very difficult to recall the stories exactly, even after being allowed to study them repeatedly, and he hypothesized that the stories were difficult to remember because they did not fit the participants' expectations about how stories should go.

Bartlett (1995 [1932]) is perhaps most famous for his method of repeated reproduction. He used many different written texts with this method but in "Remembering" he confined himself to an analysis of participants' reproductions of the native American folk tale *War of the Ghosts (see below),* while keeping in mind throughout corroborative detail from the use of other material. The story is particularly apt to the task because it involves numerous narrative disjuncture's, seeming lack of logic, strange and vivid imagery, among other puzzling elements. French anthropologist LÉVY-BRUHL would have interpreted the story as a good example of "primitive mentality" (WAGONER, 2012). For Bartlett, the striking difference to British ways of thinking provided a powerful illustration of the process of conventionalization. He says, "I wished particularly to see how educated and rather sophisticated subjects would deal with this lack of obvious rational order" (1995 [1932], p.64). [37]

The War of the Ghosts

The War of the Ghosts was a story used by Sir Frederic Bartlett to test the influence of prior expectations on memory. Bartlett found that even when his British research participants were allowed to read the story many times they still could not remember it well, and he believed this was because it did not fit with their prior knowledge.

One night two young men from Egulac went down to the river to hunt seals and while they were there it became foggy and calm. Then they heard war-cries, and they thought: "Maybe this is a war-party." They escaped to the shore, and hid behind a log. Now canoes came up, and they heard the noise of paddles, and saw one canoe coming up to them. There were five men in the canoe, and they said:

"What do you think? We wish to take you along. We are going up the river to make war on the people."

One of the young men said, "I have no arrows."

"Arrows are in the canoe," they said.

"I will not go along. I might be killed. My relatives do not know where I have gone. But you," he said, turning to the other, "may go with them."
So one of the young men went, but the other returned home.
And the warriors went on up the river to a town on the other side of Kalama. The people came down to the water and they began to fight, and many were killed. But presently the young man heard one of the warriors say, "Quick, let us go home: that Indian has been hit." Now he thought: "Oh, they are ghosts." He did not feel sick, but they said he had been shot.
So the canoes went back to Egulac and the young man went ashore to his house and made a fire. And he told everybody and said: "Behold I accompanied the ghosts, and we went to fight. Many of our fellows were killed, and many of those who attacked us were killed. They said I was hit, and I did not feel sick."
He told it all, and then he became quiet. When the sun rose he fell down. Something black came out of his mouth. His face became contorted. The people jumped up and cried.
He was dead. (Bartlett, 1932)Bartlett, F. C. (1932). *Remembering*. Cambridge: Cambridge University Press.

Bartlett had Cambridge students, colleagues and other residents of Cambridge read the story twice at regular reading speed.[17)] After a period of approximately 15 minutes, participants wrote out the story down by hand on a sheet of paper as best they could remember it. This was repeated several times at increasing time intervals—in one case ten years later. The reproductions produced by each participant were analyzed as a series or chain, exploring what was added, deleted, and transformed from the original to first reproduction and from one reproduction to the next. In his analysis, Bartlett provides readers with a full series of reproductions for particularly illustrative cases and a detailed analysis of the changes introduced, and then elaborates on the general trends found across his sample. As mentioned above, his analysis incorporates participants' introspective reports in order to understand the interpretive and affective processes that lead to the transformations introduced into their reproductions. One participant provided the following detailed account (abbreviated here) at the first reproduction:

> "When I read the story ... I thought the main point was the reference to the ghosts who were went off to fight the people further on ... I wrote out the story mainly by following my own images. I had a vague feeling of the style. There was a sort of rhythm about it I tried to imitate. I can't understand the contradiction about somebody being killed, and the man's being wounded, but feeling nothing. At first I thought there was something supernatural about the story. Then I saw that Ghosts must be a class, or clan name. That made the whole thing more comprehensible" (p.68). [39]

Bartlett notes that strict accuracy of reproduction is the exception rather than the rule. The most significant changes to the story were made on the first reproduction, which set the form, scheme, order, and arrangement of material for subsequent reproductions.[18)] However, as more time went by there was a progressive omission of details, simplification of events and transformation of items into the familiar. Some of the most common and persistent changes were "hunting seals" into "fishing," "canoes" into "boats," the omission of the excuse that "we have no arrows," transformations of the proper names (i.e., Egulac and Kalama) before they disappeared completely, and the precise meaning of the "ghosts." Whenever something seemed strange or incomprehensible it was either omitted completely or rationalized. For example, the "something black" that comes out of the Indian's mouth was frequently understood as the materialization of his breath and in at least one case as "his soul" leaving his body. The second meaning given to an item often appeared only in participants' introspective reports on the first reproduction but in subsequent reproductions it took the place of the original. In other cases, rationalization happened without the person's awareness, as when "hunting seals" became "fishing." [41]

Amnesia

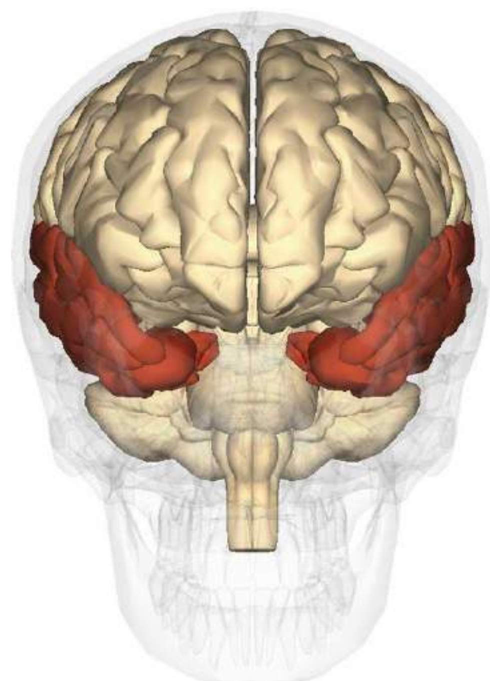


Figure 19. Patients with damage to the temporal lobes may experience anterograde amnesia and/or retrograde amnesia. [Image: en:Anatomography, https://goo.gl/ALPAu6, CC BY-SA 2.1 JP, https://goo.gl/BDF2Z4]

Clearly, remembering everything would be maladaptive, but what would it be like to remember nothing? We will now consider a profound form of forgetting called amnesia that is distinct from more ordinary forms of forgetting. Most of us have had exposure to the concept of amnesia through popular movies and television. Typically, in these fictionalized portrayals of amnesia, a character suffers some type of blow to the head and suddenly has no idea who they are and can no longer recognize their family or remember any events from their past. After some period of time (or another blow to the head), their memories come flooding back to them. Unfortunately, this portrayal of amnesia is not very accurate. What does amnesia typically look like?

The most widely studied amnesic patient was known by his initials H. M. (Scoville & Milner, 1957). As a teenager, H. M. suffered from severe epilepsy, and in 1953, he underwent surgery to have both of his medial temporal lobes removed to relieve his epileptic seizures. The **medial temporal lobes** encompass the hippocampus and surrounding cortical tissue. Although the surgery was successful in reducing H. M.'s seizures and his general intelligence was preserved, the surgery left H. M. with a profound and permanent memory deficit. From the time of his surgery until his death in 2008, H. M. was unable to learn new information, a memory impairment called **anterograde amnesia**. H. M. could not remember any event that occurred since his surgery, including highly significant ones, such as the death of his father. He could not remember a conversation he had a few minutes prior or recognize the face of someone who had visited him that same day. He could keep information in his short-term, or working, memory, but when his attention turned to something else, that information was lost for good. It is important to note that H. M.'s memory impairment was restricted to **declarative memory**, or conscious memory for facts and events. H. M. could learn new motor skills and showed improvement on motor tasks even in the absence of any memory for having performed the task before (Corkin, 2002).

In addition to anterograde amnesia, H. M. also suffered from **temporally graded retrograde amnesia**. **Retrograde amnesia** refers to an inability to retrieve old memories that occurred before the onset of amnesia. Extensive retrograde amnesia in the absence of anterograde amnesia is very rare (Kopelman, 2000). More commonly, retrograde amnesia co-occurs with anterograde amnesia and shows a temporal gradient, in which memories closest in time to the onset of amnesia are lost, but more remote memories are retained (Hodges, 1994). In the case of H. M., he could remember events from his childhood, but he could not remember events that occurred a few years before the surgery.

Amnesiac patients with damage to the hippocampus and surrounding medial temporal lobes typically manifest a similar clinical profile as H. M. The degree of anterograde amnesia and retrograde amnesia depend on the extent of the medial temporal lobe damage, with greater damage associated with a more extensive impairment (Reed & Squire, 1998). Anterograde amnesia provides evidence for the role of the hippocampus in the formation of long-lasting declarative memories, as damage to the hippocampus results in an inability to create this type of new memory. Similarly, temporally graded retrograde amnesia can be seen as providing further evidence for the importance of memory consolidation (Squire & Alvarez, 1995). A memory depends on the hippocampus until it is consolidated and transferred into a more durable form that is stored in the cortex. According to this theory, an amnesiac patient like H. M. could remember events from his remote past because those memories were fully consolidated and no longer depended on the hippocampus.

The classic amnesiac syndrome we have considered here is sometimes referred to as organic amnesia, and it is distinct from functional, or dissociative, amnesia. Functional amnesia involves a loss of memory that cannot be attributed to brain injury or any obvious brain disease and is

typically classified as a mental disorder rather than a neurological disorder (Kihlstrom, 2005). The clinical profile of dissociative amnesia is very different from that of patients who suffer from amnesia due to brain damage or deterioration. Individuals who experience **dissociative amnesia** often have a history of trauma. Their amnesia is retrograde, encompassing autobiographical memories from a portion of their past. In an extreme version of this disorder, people enter a dissociative fugue state, in which they lose most or all of their autobiographical memories and their sense of personal identity. They may be found wandering in a new location, unaware of who they are and how they got there. Dissociative amnesia is controversial, as both the causes and existence of it have been called into question. The memory loss associated with dissociative amnesia is much less likely to be permanent than it is in organic amnesia.
Just as the case study of the mnemonist Shereshevsky illustrates what a life with a near perfect memory would be like, amnesiac patients show us what a life without memory would be like. Each of the mechanisms we discussed that explain everyday forgetting—encoding failures, decay, insufficient retrieval cues, interference, and intentional attempts to forget—help to keep us highly efficient, retaining the important information and for the most part, forgetting the unimportant. Amnesiac patients allow us a glimpse into what life would be like if we suffered from profound forgetting and perhaps show us that our everyday lapses in memory are not so bad after all.

We now understand that **Amnesia** is the loss of long-term memory that occurs as the result of disease, physical trauma, or psychological trauma. Psychologist Tulving (2002) and his colleagues at the University of Toronto studied K.C. for years. K.C. suffered a traumatic head injury in a motorcycle accident and then had severe amnesia. Tulving writes,
the outstanding fact about K.C.'s mental make-up is his utter inability to remember any events, circumstances, or situations from his own life. His episodic amnesia covers his whole life, from birth to the present. The only exception is the experiences that, at any time, he has had in the last minute or two. (Tulving, 2002, p. 14)

Anterograde Amnesia

There are two common types of amnesia: anterograde amnesia and retrograde amnesia (Figure 1). Anterograde amnesia is commonly caused by brain trauma, such as a blow to the head. With **anterograde amnesia**, you cannot remember new information, although you can remember information and events that happened prior to your injury. The hippocampus is usually affected (McLeod, 2011). This suggests that damage to the brain has resulted in the inability to transfer information from short-term to long-term memory; that is, the inability to consolidate memories.

Many people with this form of amnesia are unable to form new episodic or semantic memories, but are still able to form new procedural memories (Bayley & Squire, 2002). This was true of H. M., which was discussed earlier. The brain damage caused by his surgery resulted in anterograde amnesia. H. M. would read the same magazine over and over, having no memory of ever reading it—it was always new to him. He also could not remember people he had met after his surgery. If you were introduced to H. M. and then you left the room for a few minutes, he would not know you upon your return and would introduce himself to you again. However, when presented the same puzzle several days in a row, although he did not remember having seen the puzzle before, his speed at solving it became faster each day (because of relearning) (Corkin, 1965, 1968).

Figure 19. This diagram illustrates the timeline of retrograde and anterograde amnesia. Memory problems that extend back in time before the injury and prevent retrieval of information previously stored in long-term memory are known as retrograde amnesia.

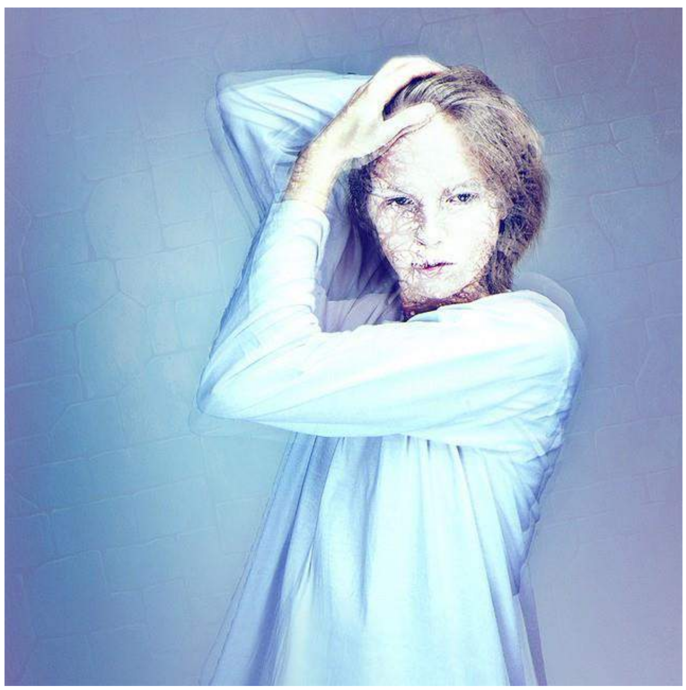


Figure 20. To help remember which amnesia is which (retrograde vs. anterograde), just think of the word "retro" (e.g., that lamp from the 70's is so retro) to help remind you that this amnesia deals with forgetting old memories. [Image: Richard Davis]

Retrograde Amnesia

Retrograde amnesia is loss of memory for events that occurred prior to the trauma. People with retrograde amnesia cannot remember some or even all of their past. They have difficulty remembering episodic memories. What if you woke up in the hospital one day and there were people surrounding your bed claiming to be your spouse, your children, and your parents? The trouble is you don't recognize any of them. You were in a car accident, suffered a head injury, and now have retrograde amnesia. You don't remember anything about your life prior to waking up in the hospital. This may sound like the stuff of Hollywood movies, and Hollywood has been fascinated with the amnesia plot for nearly a century, going all the way back to the film *Garden of Lies* from 1915 to more recent movies such as the Jason Bourne trilogy starring Matt Damon. However, for real-life sufferers of retrograde amnesia, like former NFL football player Scott Bolzan, the story is not a Hollywood movie. Bolzan fell, hit his head, and deleted 46 years of his life in an instant. He is now living with one of the most extreme cases of retrograde amnesia on record.

LINK TO LEARNING

View the **video story** profiling Scott Bolzan's amnesia and his attempts to get his life back.

GLOSSARY

- **Amnesia:** loss of long-term memory that occurs as the result of disease, physical trauma, or psychological trauma
- **Anterograde amnesia:** loss of memory for events that occur after the brain trauma
- **Retrograde amnesia:** loss of memory for events that occurred prior to brain trauma

Eyewitness Memory

Eyewitnesses can provide very compelling legal testimony, but rather than recording experiences flawlessly, their memories are susceptible to a variety of errors and biases. They (like the rest of us) can make errors in remembering specific details and can even remember whole events that did not actually happen. In this module, we discuss several of the common types of errors, and what they can tell us about human memory and its interactions with the legal system.

Learning Objectives

- Describe the kinds of mistakes that eyewitnesses commonly make and some of the ways that this can impede justice.
- Explain some of the errors that are common in human memory.
- Describe some of the important research that has demonstrated human memory errors and their consequences.

What Is Eyewitness Testimony?

Eyewitness testimony is what happens when a person witnesses a crime (or accident, or other legally important event) and later gets up on the stand and recalls for the court all the details of the witnessed event. It involves a more complicated process than might initially be presumed. It includes what happens during the actual crime to facilitate or hamper witnessing, as well as everything that happens from the time the event is over to the later courtroom appearance. The eyewitness may be interviewed by the police and numerous lawyers, describe the perpetrator to several different people, and make an identification of the perpetrator, among other things.

Figure 21. What can happen to our memory from the time we witness an event to the retelling of that event later? What can influence how we remember, or misremember, highly significant events like a crime or accident? [Image: Robert Couse-Baker, https://goo.gl/OiPUmz, CC BY 2.0, https://goo.gl/BRvSA7]

Why Is Eyewitness Testimony an Important Area of Psychological Research?

When an eyewitness stands up in front of the court and describes what happened from her own perspective, this testimony can be extremely compelling—it is hard for those hearing this testimony to take it "with a grain of salt," or otherwise adjust its power. But to what extent is this necessary?

There is now a wealth of evidence, from research conducted over several decades, suggesting that eyewitness testimony is probably the most persuasive form of evidence presented in court, but in many cases, its accuracy is dubious. There is also evidence that mistaken eyewitness evidence can lead to wrongful conviction—sending people to prison for years or decades, even to death row, for crimes they did not commit. Faulty eyewitness testimony has been implicated in at least 75% of DNA exoneration cases—more than any other cause (Garrett, 2011). In a particularly famous case, a man named Ronald Cotton was identified by a rape victim, Jennifer Thompson, as her rapist, and was found guilty and sentenced to life in prison. After more than 10 years, he was exonerated (and the real rapist identified) based on DNA evidence. For details on this case and other (relatively) lucky individuals whose false convictions were subsequently overturned with DNA evidence, see the Innocence Project website

There is also hope, though, that many of the errors may be avoidable if proper precautions are taken during the investigative and judicial processes. Psychological science has taught us what some of those precautions might involve, and we discuss some of that science now.

Misinformation

Figure 22. Misinformation can be introduced into the memory of a witness between the time of seeing an event and reporting it later. Something as straightforward as which sort of traffic sign was in place at an intersection can be confused if subjects are exposed to erroneous information after the initial incident.

In an early study of eyewitness memory, undergraduate subjects first watched a slideshow depicting a small red car driving and then hitting a pedestrian (Loftus, Miller, & Burns, 1978). Some subjects were then asked leading questions about what had happened in the slides. For example, subjects were asked, "How fast was the car traveling when it passed the yield sign?" But this question was actually designed to be misleading, because the original slide included a stop sign rather than a yield sign.

Later, subjects were shown pairs of slides. One of the pair was the original slide containing the stop sign; the other was a replacement slide containing a yield sign. Subjects were asked which of the pair they had previously seen. Subjects who had been asked about the yield sign were likely to pick the slide showing the yield sign, even though they had originally seen the slide with the stop sign. In other words, the misinformation in the leading question led to inaccurate memory.

This phenomenon is called the **misinformation effect**, because the misinformation that subjects were exposed to after the event (here in the form of a misleading question) apparently contaminates subjects' memories of what they witnessed. Hundreds of subsequent studies have demonstrated that memory can be contaminated by erroneous information that people are exposed to after they witness an event (see Frenda, Nichols, & Loftus, 2011; Loftus, 2005). The misinformation in these studies has led people to incorrectly remember everything from small but crucial details of a perpetrator's appearance to objects as large as a barn that wasn't there at all.

These studies have demonstrated that young adults (the typical research subjects in psychology) are often susceptible to misinformation, but that children and older adults can be even more susceptible (Bartlett & Memon, 2007; Ceci & Bruck, 1995). In addition, misinformation effects can occur easily, and without any intention to deceive (Allan & Gabbert, 2008). Even slight differences in the wording of a question can lead to misinformation effects. Subjects in one study were more likely to say yes when asked "Did you see the broken headlight?" than when asked "Did you see a broken headlight?" (Loftus, 1975).

Other studies have shown that misinformation can corrupt memory even more easily when it is encountered in social situations (Gabbert, Memon, Allan, & Wright, 2004). This is a problem particularly in cases where more than one person witnesses a crime. In these cases, witnesses tend to talk to one another in the immediate aftermath of the crime, including as they wait for police to arrive. But because different witnesses are different people with different perspectives, they are likely to see or notice different things, and thus remember different things, even when they witness the same event. So when they communicate about the crime later, they not only reinforce common memories for the event, they also contaminate each other's memories for the event (Gabbert, Memon, & Allan, 2003; Paterson & Kemp, 2006; Takarangi, Parker, & Garry, 2006).

The misinformation effect has been modeled in the laboratory. Researchers had subjects watch a video in pairs. Both subjects sat in front of the same screen, but because they wore differently polarized glasses, they saw two different versions of a video, projected onto a screen. So, although they were both watching the same screen, and believed (quite reasonably) that they were watching the same video, they were actually watching two different versions of the video (Garry, French, Kinzett, & Mori, 2008).

In the video, Eric the electrician is seen wandering through an unoccupied house and helping himself to the contents thereof. A total of eight details were different between the two videos. After watching the videos, the "co-witnesses" worked together on 12 memory test questions. Four of these questions dealt with details that were different in the two versions of the video, so subjects had the chance to influence one another. Then subjects worked individually on 20 additional memory test questions. Eight of these were for details that were different in the two videos. Subjects' accuracy was highly dependent on whether they had discussed the details previously. Their accuracy for items they had *not* previously discussed with their co-witness was 79%. But for items that they *had* discussed, their accuracy dropped markedly, to 34%. That is, subjects allowed their co-witnesses to corrupt their memories for what they had seen.

Identifying Perpetrators

In addition to correctly remembering many details of the crimes they witness, eyewitnesses often need to remember the faces and other identifying features of the perpetrators of those crimes. Eyewitnesses are often asked to describe that perpetrator to law enforcement and later to make identifications from books of mug shots or lineups. Here, too, there is a substantial body of research demonstrating that eyewitnesses can make serious, but often understandable and even predictable, errors (Caputo & Dunning, 2007; Cutler & Penrod, 1995).

In most jurisdictions in the United States, lineups are typically conducted with pictures, called **photo spreads**, rather than with actual people standing behind one-way glass (Wells, Memon, & Penrod, 2006). The eyewitness is given a set of small pictures of perhaps six or eight individuals who are dressed similarly and photographed in similar circumstances. One of these individuals is the police suspect, and the remainder are "**foils**" or "fillers" (people known to be innocent of the particular crime under investigation). If the eyewitness identifies the suspect, then the investigation of that suspect is likely to progress. If a witness identifies a foil or no one, then the police may choose to move their investigation in another direction.

Figure 23. Mistakes in identifying perpetrators can be influenced by a number of factors including poor viewing conditions, too little time to view the perpetrator, or too much delay from time of witnessing to identification.

This process is modeled in laboratory studies of eyewitness identifications. In these studies, research subjects witness a mock crime (often as a short video) and then are asked to make an identification from a photo or a live lineup. Sometimes the lineups are target present, meaning that the perpetrator from the mock crime is actually in the lineup, and sometimes they are target absent, meaning that the lineup is made up entirely of foils. The subjects, or **mock witnesses**, are given some instructions and asked to pick the perpetrator out of the lineup. The particular details of the witnessing experience, the instructions, and the lineup members can all influence the extent to which the mock witness is likely to pick the perpetrator out of the lineup, or indeed to make any selection at all. Mock witnesses (and indeed real witnesses) can make errors in two different ways. They can fail to pick the perpetrator out of a target present lineup (by picking a foil or by neglecting to make a selection), or they can pick a foil in a target absent lineup (wherein the only correct choice is to not make a selection).

Some factors have been shown to make eyewitness identification errors particularly likely. These include poor vision or viewing conditions during the crime, particularly stressful witnessing experiences, too little time to view the perpetrator or perpetrators, too much delay between witnessing and identifying, and being asked to identify a perpetrator from a race other than one's own (Bornstein, Deffenbacher, Penrod, & McGorty, 2012; Brigham, Bennett, Meissner, & Mitchell, 2007; Burton, Wilson, Cowan, & Bruce, 1999; Deffenbacher, Bornstein,

Penrod, & McGorty, 2004).
It is hard for the legal system to do much about most of these problems. But there are some things that the justice system can do to help lineup identifications "go right." For example, investigators can put together high-quality, fair lineups. A fair lineup is one in which the suspect and each of the foils is equally likely to be chosen by someone who has read an eyewitness description of the perpetrator but who did not actually witness the crime (Brigham, Ready, & Spier, 1990). This means that no one in the lineup should "stick out," and that everyone should match the description given by the eyewitness. Other important recommendations that have come out of this research include better ways to conduct lineups, "double blind" lineups, unbiased instructions for witnesses, and conducting lineups in a sequential fashion (see Technical Working Group for Eyewitness Evidence, 1999; Wells et al., 1998; Wells & Olson, 2003).

Kinds of Memory Biases

Memory is also susceptible to a wide variety of other biases and errors. People can forget events that happened to them and people they once knew. They can mix up details across time and place. They can even remember whole complex events that never happened at all. Importantly, these errors, once made, can be very hard to unmake. A memory is no less "memorable" just because it is wrong.

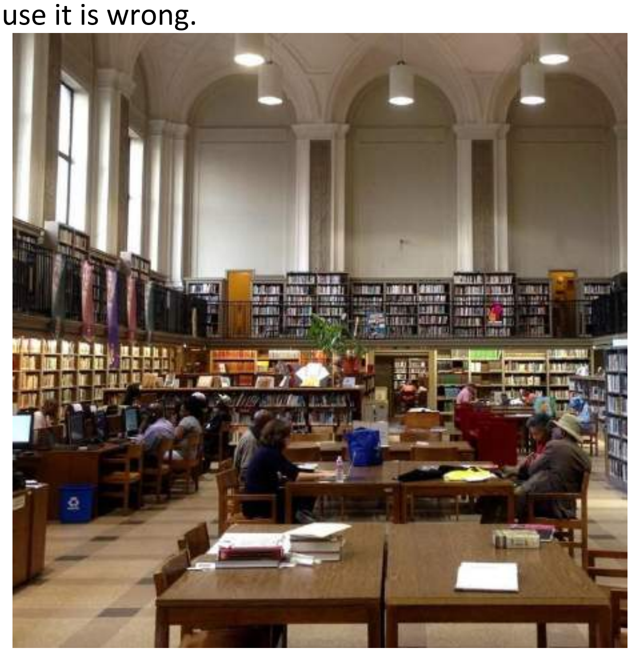


Figure 24 For most of our experiences schematas are a benefit and help with information overload. However, they may make it difficult or impossible to recall certain details of a situation later. Do you recall the library as it actually was or the library as approximated by your library schemata? [Dan Kleinman, https://goo.gl/07xyDD, CC BY 2.0, https://goo.gl/BRvSA7]

Some small memory errors are commonplace, and you have no doubt experienced many of them. You set down your keys without paying attention, and then cannot find them later when you go to look for them. You try to come up with a person's name but cannot find it, even though you have the sense that it is right at the tip of your tongue (psychologists actually call

this the tip-of-the-tongue effect, or TOT) (Brown, 1991).
Other sorts of memory biases are more complicated and longer lasting. For example, it turns out that our expectations and beliefs about how the world works can have huge influences on our memories. Because many aspects of our everyday lives are full of redundancies, our memory systems take advantage of the recurring patterns by forming and using **schemata**, or memory templates (Alba & Hasher, 1983; Brewer & Treyens, 1981). Thus, we know to expect that a library will have shelves and tables and librarians, and so we don't have to spend energy noticing these at the time. The result of this lack of attention, however, is that one is likely to remember schema-consistent information (such as tables), and to remember them in a rather generic way, whether or not they were actually present.

False Memory

Some memory errors are so "large" that they almost belong in a class of their own: **false memories**. Back in the early 1990s a pattern emerged whereby people would go into therapy for depression and other everyday problems, but over the course of the therapy develop memories for violent and horrible victimhood (Loftus & Ketcham, 1994). These patients' therapists claimed that the patients were recovering genuine memories of real childhood abuse, buried deep in their minds for years or even decades. But some experimental psychologists believed that the memories were instead likely to be false—created in therapy. These researchers then set out to see whether it would indeed be possible for wholly false memories to be created by procedures similar to those used in these patients' therapy.

In early false memory studies, undergraduate subjects' family members were recruited to provide events from the students' lives. The student subjects were told that the researchers had talked to their family members and learned about four different events from their childhoods. The researchers asked if the now undergraduate students remembered each of these four events—introduced via short hints. The subjects were asked to write about each of the four events in a booklet and then were interviewed two separate times. The trick was that one of the events came from the researchers rather than the family (and the family had actually assured the researchers that this event had *not* happened to the subject). In the first such study, this researcher-introduced event was a story about being lost in a shopping mall and rescued by an older adult. In this study, after just being asked whether they remembered these events occurring on three separate occasions, a quarter of subjects came to believe that they had indeed been lost in the mall (Loftus & Pickrell, 1995). In subsequent studies, similar procedures were used to get subjects to believe that they nearly drowned and had been rescued by a lifeguard, or that they had spilled punch on the bride's parents at a family wedding, or that they had been attacked by a vicious animal as a child, among other events (Heaps & Nash, 1999; Hyman, Husband, & Billings, 1995; Porter, Yuille, & Lehman, 1999).

More recent false memory studies have used a variety of different manipulations to produce false memories in substantial minorities and even occasional majorities of manipulated subjects (Braun, Ellis, & Loftus, 2002; Lindsay, Hagen, Read, Wade, & Garry, 2004; Mazzoni, Loftus, Seitz,

& Lynn, 1999; Seamon, Philbin, & Harrison, 2006; Wade, Garry, Read, & Lindsay, 2002). For example, one group of researchers used a mock-advertising study, wherein subjects were asked to review (fake) advertisements for Disney vacations, to convince subjects that they had once met the character Bugs Bunny at Disneyland—an impossible false memory because Bugs is a Warner Brothers character (Braun et al., 2002). Another group of researcher's photo shopped childhood photographs of their subjects into a hot air balloon picture and then asked the subjects to try to remember and describe their hot air balloon experience (Wade et al., 2002). Other researchers gave subjects unmanipulated class photographs from their childhoods along with a fake story about a class prank, and thus enhanced the likelihood that subjects would falsely remember the prank (Lindsay et al., 2004).

Using a false feedback manipulation, we have been able to persuade subjects to falsely remember having a variety of childhood experiences. In these studies, subjects are told (falsely) that a powerful computer system has analyzed questionnaires that they completed previously and has concluded that they had a particular experience years earlier. Subjects apparently believe what the computer says about them and adjust their memories to match this new information. A variety of different false memories have been implanted in this way. In some studies, subjects are told they once got sick on a particular food (Bernstein, Laney, Morris, & Loftus, 2005). These memories can then spill out into other aspects of subjects' lives, such that they often become less interested in eating that food in the future (Bernstein & Loftus, 2009b). Other false memories implanted with this methodology include having an unpleasant experience with the character Pluto at Disneyland and witnessing physical violence between one's parents (Berkowitz, Laney, Morris, Garry, & Loftus, 2008; Laney & Loftus, 2008). Importantly, once these false memories are implanted—whether through complex methods or simple ones—it is extremely difficult to tell them apart from true memories (Bernstein & Loftus, 2009a; Laney & Loftus, 2008).

Conclusion

To conclude, eyewitness testimony is very powerful and convincing to jurors, even though it is not particularly reliable. Identification errors occur, and these errors can lead to people being falsely accused and even convicted. Likewise, eyewitness memory can be corrupted by leading questions, misinterpretations of events, conversations with co-witnesses, and their own expectations for what should have happened. People can even come to remember whole events that never occurred.

The problems with memory in the legal system are real. But what can we do to start to fix them? A number of specific recommendations have already been made, and many of these are in the process of being implemented (e.g., Steblay & Loftus, 2012; Technical Working Group for Eyewitness Evidence, 1999; Wells et al., 1998). Some of these recommendations are aimed at specific legal procedures, including when and how witnesses should be interviewed, and how lineups should be constructed and conducted. Other recommendations call for appropriate education (often in the form of expert witness testimony) to be provided to jury members and others tasked with assessing eyewitness memory. Eyewitness testimony can be of great value to the legal system, but decades of research now argues that this testimony is often given far more weight than its accuracy justifies.

Outside Resources

Video 1: Eureka Foong's - The Misinformation Effect. This is a student-made video illustrating this phenomenon of altered memory. It was one of the winning entries in the 2014 Noba Student Video Award.

Video 2: Ang Rui Xia & Ong Jun Hao's - The Misinformation Effect. Another student-made video exploring the misinformation effect. Also an award winner from 2014.

Attention Blindness

In a groundbreaking series of studies in the 1970s and early 1980s, psychologist Neisser and his colleagues devised a visual analogue of the dichotic listening task (Neisser & Becklen, 1975). Their subjects viewed a video of two distinct, but partially transparent and overlapping, events. For example, one event might involve two people playing a hand-clapping game and the other might show people passing a ball. Because the two events were partially transparent and overlapping, both produced sensory signals on the retina regardless of which event received the participant's attention. When participants were asked to monitor one of the events by counting the number of times the actors performed an action (e.g., hand clapping or completed passes), they often failed to notice unexpected events in the ignored video stream (e.g., the hand-clapping players stopping their game and shaking hands). As for dichotic listening, the participants were unaware of events happening outside the focus of their attention, even when looking right at them. They could tell that other "stuff" was happening on the screen, but many were unaware of the meaning or substance of that stuff.

Figure 25. Have you ever been paying attention to something so closely you missed another event in the background? Or have you ever been so used to seeing something a certain way that when it changed, you didn't even notice it had? [Image: Tilde Ann Thurium, https://goo.gl/pb8I6Q, CC BY-NC-SA 2.0, https://goo.gl/Toc0ZF]

To test the power of selective attention to induce failures of awareness, Neisser and colleagues (Neisser, 1979) designed a variant of this task in which participants watched a video of two teams of players, one wearing white shirts and one wearing black shirts. Subjects were asked to press a key whenever the players in white successfully passed a ball, but to ignore the players in black. As for the other videos, the teams were filmed separately and then superimposed so that they literally occupied the same space (they were partially transparent). Partway through the video, a person wearing a raincoat and carrying an umbrella strolled through the scene. People were so intently focused on spotting passes that they often missed the "umbrella woman." (Pro tip: If you look closely at the video, you'll see that Ulric Neisser plays on both the black and white teams.)

These surprising findings were well known in the field, but for decades, researchers dismissed their implications because the displays had such an odd, ghostly appearance. Of course, we would notice if the displays were fully opaque and vivid rather than partly transparent and grainy. Surprisingly, no studies were built on Neisser's method for nearly 20 years. Inspired by these counterintuitive findings and after discussing them with Neisser himself, Christopher Chabris and I revisited them in the late 1990s (Simons & Chabris, 1999). We replicated Neisser's work, again finding that many people missed the umbrella woman when all of the actors in the video were partially transparent and occupying the same space. But, we added another wrinkle: a version of the video in which all of the actions of both teams of players were choreographed and filmed with a single camera. The players moved in and around each other and were fully visible. In the most dramatic version, we had a woman in a gorilla suit walk into the scene, stop to face the camera, thump her chest, and then walk off the other side after nine seconds on screen. Fully half the observers missed the gorilla when counting passes by the team in white.

This phenomenon is now known as **inattentional blindness**, the surprising failure to notice an unexpected object or event when attention is focused on something else (Mack & Rock, 1998). The past 15 years has seen a surge of interest in such failures of awareness, and we now have a better handle on the factors that cause people to miss unexpected events as well as the range of situations in which inattentional blindness occurs. People are much more likely to notice unexpected objects that share features with the attended items in a display (Most et al., 2001). For example, if you count passes by the players wearing black, you are more likely to notice the gorilla than if you count passes by the players wearing white because the color of the gorilla more closely matches that of the black-shirted players (Simons & Chabris, 1999). However, even unique items can go unnoticed. In one task, people monitored black shapes and ignored white shapes that moved around a computer window (Most et al., 2001). Approximately 30 percent of them failed to detect the bright red-cross traversing the display, even though it was the only colored item and was visible for five seconds.

Figure 26. The more effort a cognitive task requires the more likely it becomes that you'll miss noticing something significant. [Image: CC0 Public Domain, https://goo.gl/m25gce]

Another crucial influence on noticing is the effort you put into the attention-demanding task. If you have to keep separate counts of bounce passes and aerial passes, you are less likely to notice the gorilla (Simons & Chabris, 1999), and if you are tracking faster moving objects, you are less likely to notice (Simons & Jensen, 2009). You can even miss unexpected visual objects when you devote your limited cognitive resources to a memory task (Fougnie & Marois, 2007), so the limits are not purely visual. Instead, they appear to reflect limits on the capacity of attention. Without attention to the unexpected event, you are unlikely to become aware of it (Mack & Rock, 1998; Most, Scholl, Clifford, & Simons, 2005).

Inattentional blindness is not just a laboratory curiosity—it also occurs in the real world and under more natural conditions. In a recent study (Chabris, Weinberger, Fontaine, & Simons, 2011), Chabris and colleagues simulated a famous police misconduct case in which a Boston police officer was convicted of lying because he claimed not to have seen a brutal beating (Lehr, 2009). At the time, he had been chasing a murder suspect and ran right past the scene of a brutal assault. In Chabris' simulation, subjects jogged behind an experimenter who ran right past a simulated fight scene. At night, 65 percent missed the fight scene. Even during broad daylight, 44 percent of observers jogged right passed it without noticing, lending some plausibility to the Boston cop's story that he was telling the truth and never saw the beating.

Perhaps more importantly, auditory distractions can induce real-world failures to see. Although people believe they can multitask, few can. And, talking on a phone while driving or walking decreases situation awareness and increases the chances that people will miss something important (Strayer & Johnston, 2001). In a dramatic illustration of cell phone–induced inattentional blindness, Ira Hymen observed that people talking on a cell phone as they walked across a college campus were less likely than other pedestrians to notice a unicycling clown who rode across their path (Hyman, Boss, Wise, McKenzie, & Caggiano, 2011).

Recently, the study of this sort of awareness failure has returned to its roots in studies of listening, with studies documenting **inattentional deafness**: When listening to a set of spatially localized conversations over headphones, people often fail to notice the voice of a person walking through the scene repeatedly stating "I am a gorilla" (Dalton & Fraenkel, 2012). Under conditions of focused attention, we see and hear far less of the unattended information than we might expect (Macdonald & Lavie, 2011; Wayand, Levin, & Varakin, 2005).

Figure 27. Now you see me, now you don't! Although the research on attention has only developed over the last few decades, magicians have been taking advantages of our susceptibility to misguided focus for centuries. [Image: ShahanB, https://goo.gl/p5DYXH, CC BY-SA 3.0, https://goo.gl/eLCn2O]

We now have a good understanding of the ways in which focused attention affects the detection of unexpected objects falling outside that focus. The greater the demands on attention, the less likely people are to notice objects falling outside their attention (Macdonald & Lavie, 2011; Simons & Chabris, 1999; Simons & Jensen, 2009). The more like the ignored elements of a scene, the less likely people are to notice. And, the more distracted we are, the less likely we are to be aware of our surroundings. Under conditions of distraction, we effectively develop tunnel vision.

Despite this growing understanding of the limits of attention and the factors that lead to more or less noticing, we have relatively less understanding of individual differences in noticing (Simons & Jensen, 2009). Do some people consistently notice the unexpected while others are obliviously unaware of their surroundings? Or, are we all subject to inattentional blindness due to structural limits on the nature of attention? The question remains controversial. A few studies suggest that those people who have a greater working memory capacity are more likely to notice unexpected objects (Hannon & Richards, 2010; Richards, Hannon, & Derakshan, 2010). In effect, those who have more resources available when focusing attention are more likely to spot other aspects of their world. However, other studies find no such relationship: Those with greater working memory capacity are not any more likely to spot an unexpected object or event (Seegmiller, Watson, & Strayer, 2011; Bredemeier & Simons, 2012). There are theoretical reasons to predict each pattern. With more resources available, people should be more likely to notice (see Macdonald & Lavie, 2011). However, people with greater working memory capacity also tend to be better able to maintain their focus on their prescribed task, meaning that they should be less likely to notice. At least one study suggests that the ability to perform a task does not predict the likelihood of noticing (Simons & Jensen, 2009; for a replication, see Bredemeier & Simons, 2012). In a study I conducted with Melinda Jensen, we measured how well people could track moving objects around a display, gradually increasing the speed until people reached a level of 75% accuracy. Tracking ability varied greatly: Some people could track objects at more than twice the speed others could. Yet, the ability to track objects more easily was unrelated to the odds of noticing an unexpected event. Apparently, as long as people try to perform the tracking task, they are relatively unlikely to notice unexpected events.

What makes these findings interesting and important is that they run counter to our intuitions. Most people are confident they would notice the chest-thumping gorilla. In fact, nearly 90%believe they would spot the gorilla (Levin & Angelone, 2008), and in a national survey, 78% agreed with the statement, "People generally notice when something unexpected enters their field of view, even when they're paying attention to something else" (Simons & Chabris, 2010). Similarly, people are convinced that they would spot errors in movies or changes to a conversation partner (Levin & Angelone, 2008). We think we see and remember far more of our surroundings than we actually do. But why do we have such mistaken intuitions?

One explanation for this mistaken intuition is that our experiences themselves mislead us (Simons & Chabris, 2010). We rarely experience a study situation such as the gorilla experiment in which we are forced to confront something obvious that we just missed. That partly explains why demonstrations such as that one are so powerful: We expect that we would notice the gorilla, and we cannot readily explain away our failure to notice it. Most of the time, we are happily unaware of what we have missed, but we are fully aware of those elements of a scene that we have noticed. Consequently, if we assume our experiences are representative of the state of the world, we will conclude that we notice unexpected events. We don't easily think about what we're missing.

Given the limits on attention coupled with our mistaken impression that important events will capture our attention, how has our species survived? Why weren't our ancestors eaten by unexpected predators? One reason is that our ability to focus attention intently might have been more evolutionarily useful than the ability to notice unexpected events. After all, for an event to be unexpected, it must occur relatively infrequently. Moreover, most events don't require our immediate attention, so if inattentional blindness delays our ability to notice the events, the consequences could well be minimal. In a social context, others might notice that event and call attention to it. Although inattentional blindness might have had minimal consequences over the course of our evolutionary history, it does have consequences now.

At pedestrian speeds and with minimal distraction, inattentional blindness might not matter for survival. But in modern society, we face greater distractions and move at greater speeds, and even a minor delay in noticing something unexpected can mean the difference between a fender-bender and a lethal collision. If talking on a phone increases your odds of missing a unicycling clown, it likely also increases your odds of missing the child who runs into the street or the car that runs a red light. Why, then, do people continue to talk on the phone when driving? The reason might well be the same mistaken intuition that makes inattentional blindness surprising: Drivers simply do not notice how distracted they are when they are talking on a phone, so they believe they can drive just as well when talking on a phone even though they can't (Strayer & Johnston, 2001).

So, what can you do about inattentional blindness? The short answer appears to be, "not much." There is no magical elixir that will overcome the limits on attention, allowing you to notice everything (and that would not be a good outcome anyway). But, there is something you can do to mitigate the consequences of such limits. Now that you know about inattentional blindness, you can take steps to limit its impact by recognizing how your intuitions will lead you astray.

Figure 28. Even though you may think you can drive, text, listen to music, and drink a smoothie at the same time, really, your focus should be only on the road. Everything else is a potential distraction from what's most important: driving safely! [Image: FMHS The Buzz TV, https://goo.gl/TSk2RP, CC BY-NC-SA 2.0, https://goo.gl/Toc0ZF]

First, maximize the attention you do have available by avoiding distractions, especially under conditions for which an unexpected event might be catastrophic. The ring of a new call or the ding of a new text are hard to resist, so make it impossible to succumb to the temptation by turning your phone off or putting it somewhere out of reach when you are driving. If you know that you will be tempted and you know that using your phone will increase inattentional blindness, you must be proactive. Second, pay attention to what others might not notice. If you are a bicyclist, don't assume that the driver sees you, even if they appear to make eye contact. Looking is not the same as seeing. Only by understanding the limits of attention and by recognizing our mistaken beliefs about what we "know" to be true can we avoid the modern-day consequences of those limits.

Outside Resources

- Article: Scholarpedia article on inattentional blindness http://www.scholarpedia.org/article/Inattentional_blindness
- Video: The original gorilla video
- Video: The sequel to the gorilla video
- Web: Website for Chabris & Simons book, The Invisible Gorilla. Includes links to videos and descriptions of the research on inattentional blindness http://www.theinvisiblegorilla.com

Discussion Questions

1. Many people, upon learning about inattentional blindness, try to think of ways to eliminate it, allowing themselves complete situation awareness. Why might we be far worse off if we were not subject to inattentional blindness?
2. If inattentional blindness cannot be eliminated, what steps might you take to avoid its consequences?
3. Can you think of situations in which inattentional blindness is highly likely to be a problem? Can you think of cases in which inattentional blindness would not have much of an impact?

Vocabulary

- **Dichotic listening:** A task in which different audio streams are presented to each ear. Typically, people are asked to monitor one stream while ignoring the other.
- **Inattentional blindness:** The failure to notice a fully visible, but unexpected, object or event when attention is devoted to something else.
- **Inattentional deafness:** The auditory analog of inattentional blindness. People fail to notice an unexpected sound or voice when attention is devoted to other aspects of a scene.
- **Selective listening:** A method for studying selective attention in which people focus attention on one auditory stream of information while deliberately ignoring other auditory information.

(http://nobaproject.com/modules/failures-of-awareness-the-case-of-inattentional-blindness)

Weapon Focus

Weapon focus refers to a factor that affects the reliability of eyewitness testimony. Where a weapon is used during a crime, the weapon is likely to divert the witness's attention to the weapon that the perpetrator is holding and this affects the ability of the witness to concentrate on the details of the crime. The visual attention given by a witness to a weapon can impair his or her ability to make a reliable identification and describe what the culprit looks like if the crime is of short duration.

The focused attention that an eyewitness pays to the weapon that the perpetrator holds during the commission of the alleged crime forms the basis of this concept. The proponents of this view believe that all the visual attention of the eyewitness gets drawn to the weapon, thereby affecting the ability of the eyewitness to observe other details. Chief Justice Rabner acknowledged the results of a meta-analysis undertaken by Nancy Steblay on this topic. In this meta-analysis, data from various studies on this subject was collected and analyzed to determine if the presence of a weapon may actually be a factor affecting the memory or perception of an eyewitness to a real crime. Of the 19 weapon-focus studies that involved more than 2,000 identifications, Steblay found an average decrease in accuracy of about 10 per cent when a weapon was present. In a separate study, half of the witnesses observed a person holding a syringe in a way that was personally threatening to the witness; the other half saw the same person holding a pen. Sixty-four per cent of the witnesses from the first group misidentified a filler from a target-absent lineup, compared to thirty-three from the second group. Weapon focus can also affect a witness's ability to describe a perpetrator. A meta-analysis of ten studies showed that "weapon-absent condition[s] generated significantly more accurate descriptions of the perpetrator than did the weapon-present condition". Thus, especially when the interaction is brief, the presence of a visible weapon can affect the reliability of an identification and the accuracy of a witness's description of the perpetrator.

Cross –Race effect

There are numerous times in our criminal justice system that eyewitness testimony can make the difference between conviction and acquittal. When trials contain eyewitness testimony, jurors rely on it heavily, despite holding some erroneous beliefs about the factors that make eyewitnesses more or less accurate. Because jurors rely on those beliefs in evaluating eyewitness credibility and making trial judgments, false convictions in eyewitness cases are not uncommon. Indeed, eyewitness misidentifications lead to more wrongful convictions than all other causes combined.

The third and final class of explanations deals with retrieval-based processes. Research evidence indicates that the CRE reflects different processes and decision strategies occurring at the time of retrieval. More specifically, people rely more on recollection processes, as opposed to familiarity judgments, when deciding whether they have previously seen an own-race (versus an other-race) face. Witnesses also have a lower (i.e., more lenient) response criterion for other-race faces, meaning that they are more willing to make a positive identification for other-race faces than they are for own-race faces. As a result, they make more false alarms for other-race than own-race faces.

In summary, there are a number of different theories hypothesized to explain the CRE, none of which has yet to receive overwhelming support, nor has resulted in the development of appropriate remedies. There is an important practical advantage of retrieval-based explanations of the CRE, namely, that decision processes at retrieval are amenable to system variables like instructions during the lineup procedure. In contrast, cross-race contact and encoding processes are estimator variables that might predict differential performance with targets of different races, but they are much less susceptible to intervention by the criminal justice system. From an applied perspective, procedures that influence cross-race identifications at the retrieval stage could be readily implemented by lineup administrators (e.g., by providing those in a cross-race situation with specialized instructions before the identification).

Source Monitoring

One potential error in memory involves mistakes in differentiating the sources of information. Source monitoring refers to *the ability to accurately identify the source of a memory*. Perhaps you've had the experience of wondering whether you really experienced an event or only dreamed or imagined it. If so, you wouldn't be alone. Rassin, Merkelbach, and Spaan (2001) reported that up to 25% of college students reported being confused about real versus dreamed events. Studies suggest that people who are fantasy-prone are more likely to experience source monitoring errors (Winograd, Peluso, & Glover, 1998), and such errors also occur more often for both children and the elderly than for adolescents and younger adults (Jacoby & Rhodes, 2006).

In other cases we may be sure that we remembered the information from real life but be uncertain about exactly where we heard it. Imagine that you read a news story in a tabloid magazine such as the *National Enquirer*. Probably you would have discounted the information because you know that its source is unreliable. But what if later you were to remember the story but forget the source of the information? If this happens, you might become convinced that the news story is true because you forget to discount it. The sleeper effect refers to *attitude change that occurs over time when we forget the source of information* (Pratkanis, Greenwald, Leippe, & Baumgardner, 1988).

In still other cases we may forget where we learned information and mistakenly assume that we created the memory ourselves. Kaavya Viswanathan, the author of the book *How Opal Mehta Got Kissed, Got Wild, and Got a Life*, was accused of plagiarism when it was revealed that many parts of her book were very similar to passages from other material. Viswanathan argued that she had simply forgotten that she had read the other works, mistakenly assuming she had made up the material herself. And the musician George Harrison claimed that he was unaware that the melody of his song "My Sweet Lord" was almost identical to an earlier song by another composer. The judge in the copyright suit that followed ruled that Harrison didn't intentionally commit the plagiarism. (Please use this knowledge to become extra vigilant about source attributions in your written work, not to try to excuse yourself if you are accused of plagiarism.)

Memory Techniques

LEARNING OBJECTIVES

- Recognize and apply memory-enhancing strategies, including mnemonics, rehearsal, chunking, and peg-words

Most of us suffer from memory failures of one kind or another, and most of us would like to improve our memories so that we don't forget where we put the car keys or, more importantly, the material we need to know for an exam. In this section, we'll look at some ways to help you remember better, and at some strategies for more effective studying.

Memory-Enhancing Strategies

What are some everyday ways we can improve our memory, including recall? To help make sure information goes from short-term memory to long-term memory, you can use **memory-enhancing strategies**. One strategy is **rehearsal**, or the conscious repetition of information to be remembered (Craik & Watkins, 1973). Think about how you learned your multiplication tables as a child. You may recall that 6 x 6 = 36, 6 x 7 = 42, and 6 x 8 = 48. Memorizing these facts is rehearsal.

Another strategy is **chunking**: you organize information into manageable bits or chunks (Bodie, Powers, & Fitch-Hauser, 2006). Chunking is useful when trying to remember information like dates and phone numbers. Instead of trying to remember 5205550467, you remember the number as 520-555-0467. So, if you met an interesting person at a party and you wanted to remember his phone number, you would naturally chunk it, and you could repeat the number over and over, which is the rehearsal strategy.

LINK TO LEARNING

Try this **fun activity** that employs a memory-enhancing strategy.

You could also enhance memory by using **elaborative rehearsal**: a technique in which you think about the meaning of the new information and its relation to knowledge already stored in your memory (Tigner, 1999). For example, in this case, you could remember that 520 is an area code for Arizona and the person you met is from Arizona. This would help you better remember the 520 prefix. If the information is retained, it goes into long-term memory.

Mnemonic devices are memory aids that help us organize information for encoding. They are especially useful when we want to recall larger bits of information such as steps, stages, phases, and parts of a system (Bellezza, 1981). Brian needs to learn the order of the planets in the solar system, but he's having a hard time remembering the correct order. His friend Kelly suggests a mnemonic device that can help him remember. Kelly tells Brian to simply remember the name Mr. VEM J. SUN, and he can easily recall the correct order of the planets: **M**ercury, **V**enus, **E**arth, **M**ars, **J**upiter, **S**aturn, **U**ranus, and **N**eptune. You might use a mnemonic device to help you remember someone's name, a mathematical formula, or the seven levels of Bloom's taxonomy.

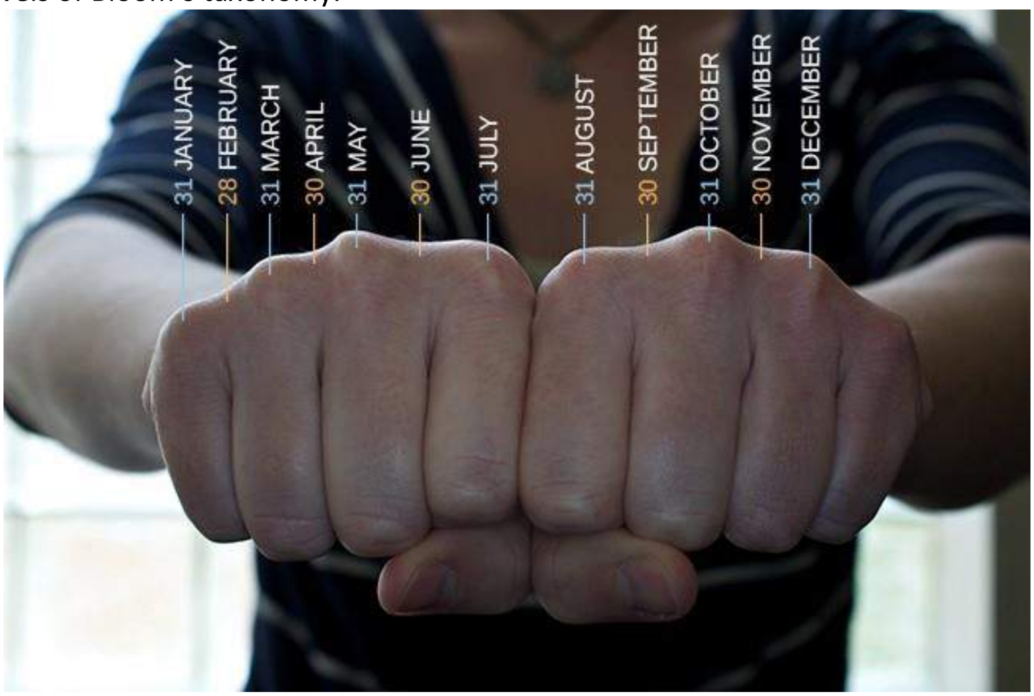


Figure 29. Figure 1. This is a knuckle mnemonic to help you remember the number of days in each month. Months with 31 days are represented by the protruding knuckles and shorter months fall in the spots between knuckles. (credit: modification of work by Cory Zanker)

If you have ever watched the television show *Modern Family*, you might have seen Phil Dunphy explain how he remembers names:

> "The other day I met this guy named Carl. Now, I might forget that name, but he was wearing a Grateful Dead t-shirt. What's a band like the Grateful Dead? Phish. Where do fish live? The ocean. What else lives in the ocean? Coral. Hello, Co-arl." (Wrubel & Spiller, 2010)

It seems the more vivid or unusual the mnemonic, the easier it is to remember. The key to using any mnemonic successfully is to find a strategy that works for you.

LINK TO LEARNING

Watch this fascinating TED Talk titled "Feats of Memory Anyone Can Do." The lecture is given by Joshua Foer, a science writer who "accidentally" won the U. S. Memory Championships. He explains a mnemonic device called the memory palace.

Some other strategies that are used to improve memory include expressive writing and saying words aloud. Expressive writing helps boost your short-term memory, particularly if you write about a traumatic experience in your life. Masao Yogo and Shuji Fujihara (2008) had participants write for 20-minute intervals several times per month. The participants were instructed to write about a traumatic experience, their best possible future selves, or a trivial topic. The researchers found that this simple writing task increased short-term memory capacity after five weeks, but only for the participants who wrote about traumatic experiences. Psychologists can't explain why this writing task works, but it does.

What if you want to remember items you need to pick up at the store? Simply say them out loud to yourself. A series of studies (MacLeod, Gopie, Hourihan, Neary, & Ozubko, 2010) found that saying a word out loud improves your memory for the word because it increases the word's distinctiveness. Feel silly, saying random grocery items aloud? This technique works equally well if you just mouth the words. Using these techniques increased participants' memory for the words by more than 10%. These techniques can also be used to help you study.

Using Peg-Words

Consider the case of Simon Reinhard. In 2013, he sat in front of 60 people in a room at Washington University, where he memorized an increasingly long series of digits. On the first round, a computer generated 10 random digits—6 1 9 4 8 5 6 3 7 1—on a screen for 10 seconds. After the series disappeared, Simon typed them into his computer. His recollection was perfect. In the next phase, 20 digits appeared on the screen for 20 seconds. Again, Simon got them all correct. No one in the audience (mostly professors, graduate students, and undergraduate students) could recall the 20 digits perfectly. Then came 30 digits, studied for 30 seconds; once again, Simon didn't misplace even a single digit. For a final trial, 50 digits appeared on the screen for 50 seconds, and again, Simon got them all right. In fact, Simon would have been happy to keep going. His record in this task—called "forward digit span"—is 240 digits!

Simon Reinhard's ability to memorize huge numbers of digits. Although it was not obvious, Simon Reinhard used deliberate mnemonic devices to improve his memory. In a typical case, the person learns a set of cues and then applies these cues to learn and remember information. Consider the set of 20 items below that are easy to learn and remember (Bower & Reitman, 1972).

1. is a gun. 11 is penny-one, hot dog bun.
2. is a shoe. 12 is penny-two, airplane glue.
3. is a tree. 13 is penny-three, bumble bee.
4. is a door. 14 is penny-four, grocery store.
5. is knives. 15 is penny-five, big beehive.
6. is sticks. 16 is penny-six, magic tricks.
7. is oven. 17 is penny-seven, go to heaven.
8. is plate. 18 is penny-eight, golden gate.
9. is wine. 19 is penny-nine, ball of twine.
10. is hen. 20 is penny-ten, ballpoint pen.

It would probably take you less than 10 minutes to learn this list and practice recalling it several times (remember to use retrieval practice!). If you were to do so, you would have a set of peg words on which you could "hang" memories. In fact, this mnemonic device is called the *peg word technique*. If you then needed to remember some discrete items—say a grocery list, or points you wanted to make in a speech—this method would let you do so in a very precise yet flexible way. Suppose you had to remember bread, peanut butter, bananas, lettuce, and so on. The way to use the method is to form a vivid image of what you want to remember and imagine it interacting with your peg words (as many as you need). For example, for these items, you might imagine a large gun (the first peg word) shooting a loaf of bread, then a jar of peanut butter inside a shoe, then large bunches of bananas hanging from a tree, then a door slamming on a head of lettuce with leaves flying everywhere. The idea is to provide good, distinctive cues (the weirder the better!) for the information you need to remember while you are learning it. If you do this, then retrieving it later is relatively easy. You know your cues perfectly (one is gun, etc.), so you simply go through your cue word list and "look" in your mind's eye at the image stored there (bread, in this case).

This peg word method may sound strange at first, but it works quite well, even with little training (Roediger, 1980). One word of warning, though, is that the items to be remembered need to be presented relatively slowly at first, until you have practice associating each with its cue word. People get faster with time. Another interesting aspect of this technique is that it's just as easy to recall the items in backwards order as forwards. This is because the peg words provide direct access to the memorized items, regardless of order.

How did Simon Reinhard remember those digits? Essentially he has a much more complex system based on these same principles. In his case, he uses "memory palaces" (elaborate scenes with discrete places) combined with huge sets of images for digits. For example, imagine mentally walking through the home where you grew up and identifying as many distinct areas and objects as possible. Simon has hundreds of such memory palaces that he uses. Next, for remembering digits, he has memorized a set of 10,000 images. Every four-digit number for him immediately brings forth a mental image. So, for example, 6187 might recall Michael Jackson. When Simon hears all the numbers coming at him, he places an image for every four digits into locations in his memory palace. He can do this at an incredibly rapid rate, faster than 4 digits per 4 seconds when they are flashed visually, as in the demonstration at the beginning of the module. As noted, his record is 240 digits, recalled in exact order. Simon also holds the world record in an event called "speed cards," which involves memorizing the precise order of a shuffled deck of cards. Simon was able to do this in 21.19 seconds! Again, he uses his memory palaces, and he encodes groups of cards as single images.

How to Study Effectively

Based on the information presented in this chapter, here are some strategies and suggestions to help you hone your study techniques (Figure 2). The key with any of these strategies is to figure out what works best for you.

Figure 30. Figure 2. Memory techniques can be useful when studying for class. (credit: Barry Pousman)

- **Use elaborative rehearsal**: In a famous article, Craik and Lockhart (1972) discussed their belief that information we process more deeply goes into long-term memory. Their theory is called **levels of processing**. If we want to remember a piece of information, we should think about it more deeply and link it to other information and memories to make it more meaningful. For example, if we are trying to remember that the hippocampus is involved with memory processing, we might envision a hippopotamus with excellent memory and then we could better remember the hippocampus.
- **Apply the self-reference effect**: As you go through the process of elaborative rehearsal, it would be even more beneficial to make the material you are trying to memorize personally meaningful to you. In other words, make use of the self-reference effect. Write notes in your own words. Write definitions from the text, and then rewrite them in your own words. Relate the material to something you have already learned for

another class, or think how you can apply the concepts to your own life. When you do this, you are building a web of retrieval cues that will help you access the material when you want to remember it.

- **Don't forget the forgetting curve**: As you know, the information you learn drops off rapidly with time. Even if you think you know the material, study it again right before test time to increase the likelihood the information will remain in your memory. Overlearning can help prevent storage decay.
- **Rehearse, rehearse, rehearse**: Review the material over time, in spaced and organized study sessions. Organize and study your notes, and take practice quizzes/exams. Link the new information to other information you already know well.
- **Be aware of interference**: To reduce the likelihood of interference, study during a quiet time without interruptions or distractions (like television or music).
- **Keep moving**: Of course you already know that exercise is good for your body, but did you also know it's also good for your mind? Research suggests that regular aerobic exercise (anything that gets your heart rate elevated) is beneficial for memory (van Praag, 2008). Aerobic exercise promotes neurogenesis: the growth of new brain cells in the hippocampus, an area of the brain known to play a role in memory and learning.
- **Get enough sleep**: While you are sleeping, your brain is still at work. During sleep the brain organizes and consolidates information to be stored in long-term memory (Abel & Bäuml, 2013).
- **Make use of mnemonic devices**: As you learned earlier in this chapter, mnemonic devices often help us to remember and recall information. There are different types of mnemonic devices, such as the acronym. An acronym is a word formed by the first letter of each of the words you want to remember. For example, even if you live near one, you might have difficulty recalling the names of all five Great Lakes. What if I told you to think of the word Homes? HOMES is an acronym that represents Huron, Ontario, Michigan, Erie, and Superior: the five Great Lakes. Another type of mnemonic device is an acrostic: you make a phrase of all the first letters of the words. For example, if you are taking a math test and you are having difficulty remembering *the order of operations*, recalling the following sentence will help you: "Please Excuse My Dear Aunt Sally," because the order of mathematical operations is Parentheses, Exponents, Multiplication, Division, Addition, Subtraction. There also are jingles, which are rhyming tunes that contain key words related to the concept, such as *i before e, except after c*.

MEMORY TESTS

Apply some of the memory techniques you learned about by completing the memory exercises below:

Go to **http://garyfisk.com/anim/lecture_stm.swf**. Do the demonstration.

- How many digits were you able to remember without messing up at all?
- How many digits did you remember out of the last sequence?

Go to the Faces Memory Challenge found here: **http://experiments.wustl.edu/**

- How did you do?

- Is it easier for you to remember faces or numbers? Why?

Go to **https://www.exploratorium.edu/memory/dont_forget/index.html**. Play the memory solitaire game. Then play game #2: Tell Yourself a Story.

- Did your memory improve the second time? Why or why not?

THINK IT OVER

- Create a mnemonic device to help you remember a term or concept from this module.
- What is an effective study technique that you have used? How is it similar to/different from the strategies suggested in this module?

GLOSSARY

- **Chunking:** organizing information into manageable bits or chunks
- **Elaborative rehearsal:** thinking about the meaning of the new information and its relation to knowledge already stored in your memory
- **Levels of processing:** information that is thought of more deeply becomes more meaningful and thus better committed to memory
- **Memory-enhancing strategy:** technique to help make sure information goes from short-term memory to long-term memory
- **Mnemonic device:** memory aids that help organize information for encoding

Chapter 6 – Problem Solving

People face problems every day—usually, multiple problems throughout the day. Sometimes these problems are straightforward: To double a recipe for pizza dough, for example, all that is required is that each ingredient in the recipe be doubled. Sometimes, however, the problems we encounter are more complex. For example, say you have a work deadline, and you must mail a printed copy of a report to your supervisor by the end of the business day. The report is time-sensitive and must be sent overnight. You finished the report last night, but your printer will not work today. What should you do? First, you need to identify the problem and then apply a strategy for solving the problem.

Types of Problems

Ill- Defined and Well-Defined Problems

Well-defined Problems For many abstract problems it is possible to find an algorithmic [4] solution. We call all those problems well-defined that can be properly formalised, which comes along with the following properties:

- The problem has a clearly defined given state. This might be the line-up of a chess game, a given formula you have to solve, or the set-up of the towers of Hanoi game (which we will discuss later).
- There is a finite set of operators, that is, of rules you may apply to the given state. For the chess game, e.g., these would be the rules that tell you which piece you may move to which position.
- Finally, the problem has a clear goal state: The equations is resolved to x, all discs are moved to the right stack, or the other player is in checkmate.

Not surprisingly, a problem that fulfils these requirements can be implemented algorithmically (also see convergent thinking). Therefore many well-defined problems can be very effectively solved by computers, like playing chess.

Ill-defined Problems Though many problems can be properly formalised (sometimes only if we accept an enormous complexity) there are still others where this is not the case. Good examples for this are all kinds of tasks that involve creativity [5], and, generally speaking, all problems for which it is not possible to clearly define a given state and a goal state: Formalising a problem of the kind “Please paint a beautiful picture” may be impossible. Still this is a problem most people would be able to access in one way or the other, even if the result may be totally different from person to person. And while Knut might judge that picture X is gorgeous, you might completely disagree.

Nevertheless ill-defined problems often involve sub-problems that can be totally well-defined. On the other hand, many every-day problems that seem to be completely well-defined involve- when examined in detail- a big deal of creativity and ambiguities. If we think of Knut's fairly ill-defined task of writing an essay, he will not be able to complete this task without first understanding the text he has to write about. This step is the first subgoal Knut has to solve. Interestingly, ill-defined problems often involve subproblems that are well-defined.

Problem Solving Strategies

When you are presented with a problem—whether it is a complex mathematical problem or a broken printer, how do you solve it? Before finding a solution to the problem, the problem must first be clearly identified. After that, one of many problem solving strategies can be applied, hopefully resulting in a solution.

A problem-solving strategy is a plan of action used to find a solution. Different strategies have different action plans associated with them (**Table 3**). For example, a well-known strategy is trial and error. The old adage, "If at first you don't succeed, try, try again" describes trial and error. In terms of your broken printer, you could try checking the ink levels, and if that doesn't work, you could check to make sure the paper tray isn't jammed. Or maybe the printer isn't actually connected to your laptop. When using trial and error, you would continue to try different solutions until you solved your problem. Although trial and error is not typically one of the most time-efficient strategies, it is a commonly used one

Method	Description	Example
Trial and error	Continue trying different solutions until problem is solved	Restarting phone, turning off WiFi, turning off bluetooth in order to determine why your phone is malfunctioning
Algorithm	Step-by-step problem-solving formula	Instruction manual for installing new software on your computer
Heuristic	General problem-solving framework	Working backwards; breaking a task into steps

Table 1. Problem Solving Strategies

Another type of strategy is an algorithm. An algorithm is a problem-solving formula that provides you with step-by-step instructions used to achieve a desired outcome (Kahneman, 2011). You can think of an algorithm as a recipe with highly detailed instructions that produce the same result every time they are performed. Algorithms are used frequently in our everyday lives, especially in computer science. When you run a search on the Internet, search engines like Google use algorithms to decide which entries will appear first in your list of results. Facebook also uses algorithms to decide which posts to display on your newsfeed. Can you identify other situations in which algorithms are used?

A heuristic is another type of problem solving strategy. While an algorithm must be followed exactly to produce a correct result, a heuristic is a general problem-solving framework (Tversky

& Kahneman, 1974). You can think of these as mental shortcuts that are used to solve problems. A "rule of thumb" is an example of a heuristic. Such a rule saves the person time and energy when making a decision, but despite its time-saving characteristics, it is not always the best method for making a rational decision. Different types of heuristics are used in different types of situations, but the impulse to use a heuristic occurs when one of five conditions is met (Pratkanis, 1989):

- When one is faced with too much information
- When the time to make a decision is limited
- When the decision to be made is unimportant
- When there is access to very little information to use in making the decision
- When an appropriate heuristic happens to come to mind in the same moment

Working backwards is a useful heuristic in which you begin solving the problem by focusing on the end result. Consider this example: You live in Washington, D.C. and have been invited to a wedding at 4 PM on Saturday in Philadelphia. Knowing that Interstate 95 tends to back up any day of the week, you need to plan your route and time your departure accordingly. If you want to be at the wedding service by 3:30 PM, and it takes 2.5 hours to get to Philadelphia without traffic, what time should you leave your house? You use the working backwards heuristic to plan the events of your day on a regular basis, probably without even thinking about it.

LINK TO LEARNING

What problem-solving method could you use to solve Einstein's famous riddle?

Another useful heuristic is the practice of accomplishing a large goal or task by breaking it into a series of smaller steps. Students often use this common method to complete a large research project or long essay for school. For example, students typically brainstorm, develop a thesis or main topic, research the chosen topic, organize their information into an outline, write a rough draft, revise and edit the rough draft, develop a final draft, organize the references list, and proofread their work before turning in the project. The large task becomes less overwhelming when it is broken down into a series of small steps.

Everyday Connections: Solving Puzzles

Problem-solving abilities can improve with practice. Many people challenge themselves every day with puzzles and other mental exercises to sharpen their problem-solving skills. Sudoku puzzles appear daily in most newspapers. Typically, a sudoku puzzle is a 9×9 grid. The simple sudoku below is a 4×4 grid. To solve the puzzle, fill in the empty boxes with a single digit: 1, 2, 3, or 4. Here are the rules: The numbers must total 10 in each bolded box, each row, and each column; however, each digit can only appear once in a bolded box, row, and column. Time yourself as you solve this puzzle and compare your time with a classmate.

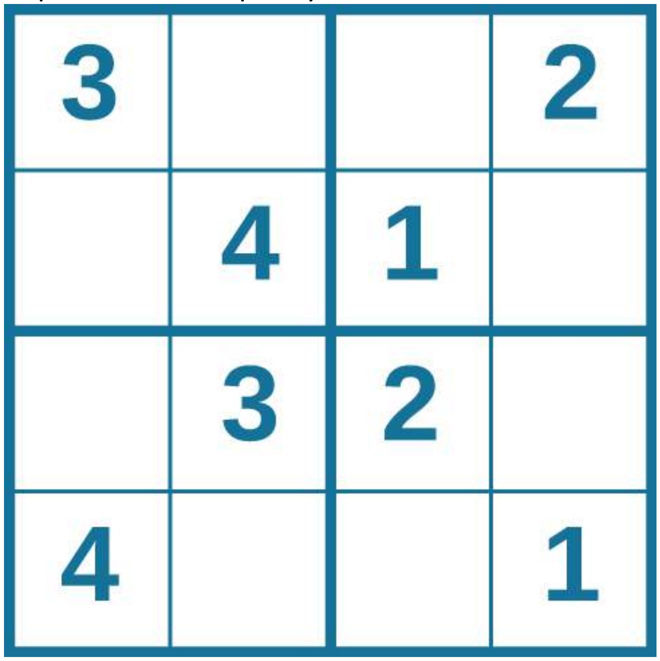


Figure 1. How long did it take you to solve this sudoku puzzle? (You can see the answer at the end of this section.)

Here is another popular type of puzzle that challenges your spatial reasoning skills. Connect all nine dots with four connecting straight lines without lifting your pencil from the paper:

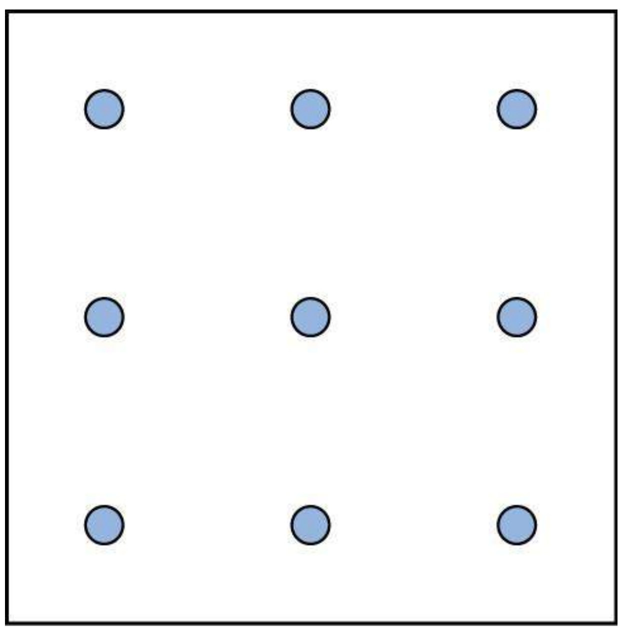


Figure 2. Did you figure it out? (The answer is at the end of this section.) Once you understand how to crack this puzzle, you won't forget.

Take a look at the "Puzzling Scales" logic puzzle below. Sam Loyd, a well-known puzzle master, created and refined countless puzzles throughout his lifetime (Cyclopedia of Puzzles, n.d.).

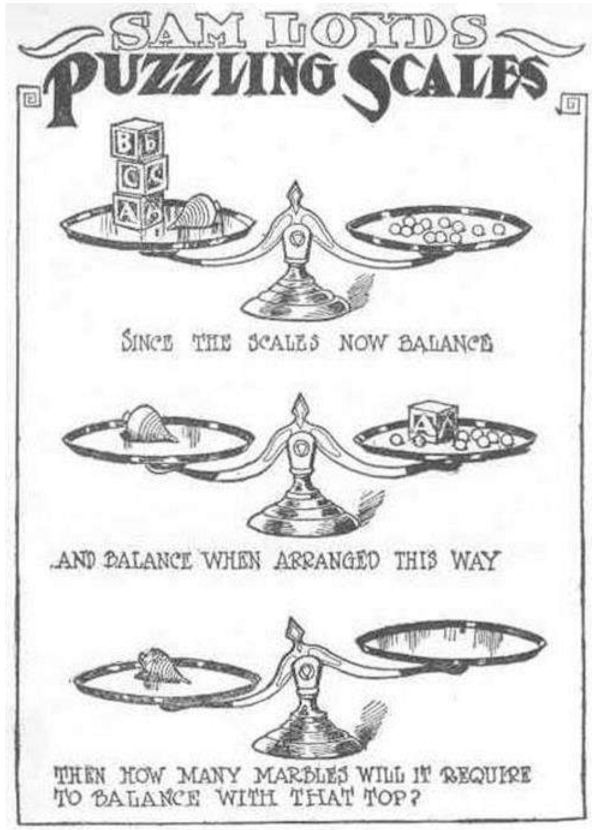


Figure 3. Puzzling Scales by Sam Loyds

Were you able to determine how many marbles are needed to balance the scales in **Figure 3**? You need **nine**. Were you able to solve the problems in **Figure 1** and **Figure 2**? Here are the answers.

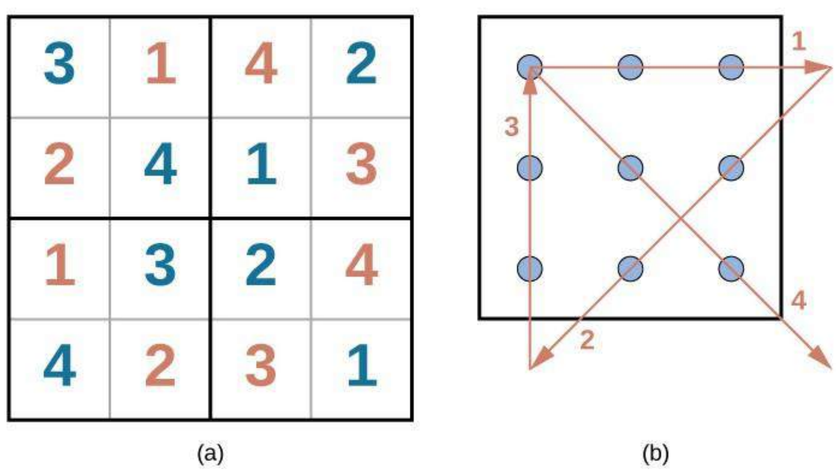


Figure 4.

Means –Ends Analysis

In Means-End Analysis you try to reduce the difference between initial state and goal state by creating sub goals until a sub goal can be reached directly (probably you know several examples

of recursion which works on the basis of this).
An example for a problem that can be solved by Means-End Analysis are the „Towers of Hanoi“

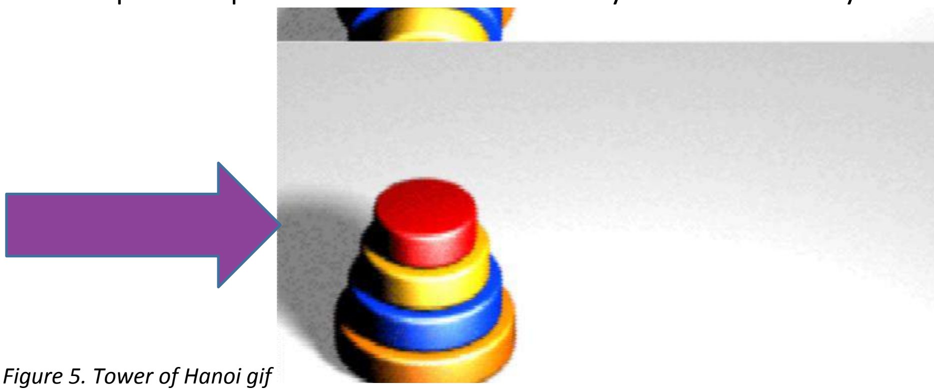


Figure 5. Tower of Hanoi gif

The initial state of this problem is described by the different sized discs being stacked in order of size on the first of three pegs (the “start-peg“). The goal state is described by these discs being stacked on the third pegs (the “end-peg“) in exactly the same order.

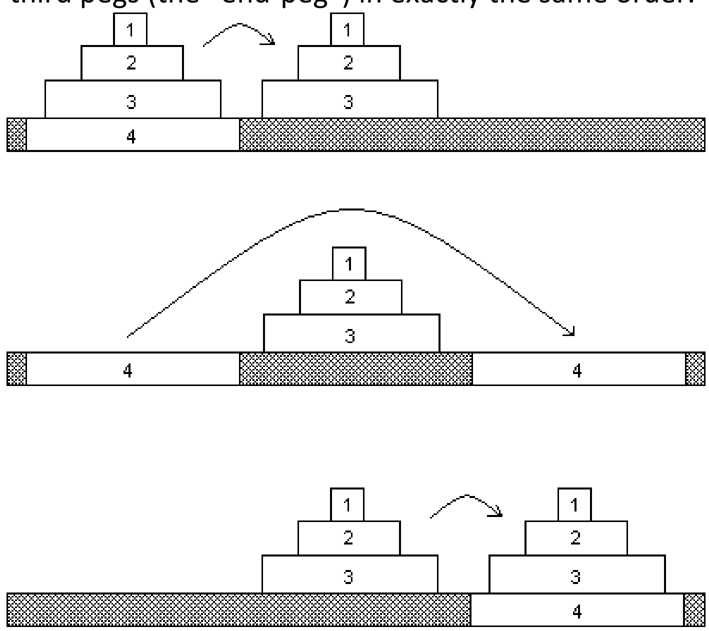


Figure 6. ToH

There are three operators:

- You are allowed to move one single disc from one peg to another one
- You are only able to move a disc if it is on top of one stack
- A disc cannot be put onto a smaller one.

In order to use Means-End Analysis we have to create subgoals. One possible way of doing this is described in the picture:

1. Moving the discs lying on the biggest one onto the second peg.
2. Shifting the biggest disc to the third peg.

3. Moving the other ones onto the third peg, too.

You can apply this strategy again and again in order to reduce the problem to the case where you only have to move a single disc – which is then something you are allowed to do.

Strategies of this kind can easily be formulated for a computer; the respective algorithm for the Towers of Hanoi would look like this:

1. move n-1 discs from A to B
2. move disc #n from A to C
3. move n-1 discs from B to C

Where n is the total number of discs, A is the first peg, B the second, C the third one. Now the problem is reduced by one with each recursive loop.

Means-end analysis is important to solve everyday-problems - like getting the right train connection: You have to figure out where you catch the first train and where you want to arrive, first of all. Then you have to look for possible changes just in case you do not get a direct connection. Third, you have to figure out what are the best times of departure and arrival, on which platforms you leave and arrive and make it all fit together.

Reasoning by Analogy

Analogies describe similar structures and interconnect them to clarify and explain certain relations. In a recent study, for example, a song that got stuck in your head is compared to an itching of the brain that can only be scratched by repeating the song over and over again.

Restructuring by Using Analogies

One special kind of restructuring, the way already mentioned during the discussion of the Gestalt approach, is analogical problem solving. Here, to find a solution to one problem - the so called target problem, an analogous solution to another problem - the source problem, is presented. An example for this kind of strategy is the radiation problem posed by K. Duncker in 1945:

> "As a doctor you have to treat a patient with a malignant, inoperable tumour, buried deep inside the body. There exists a special kind of ray, which is perfectly harmless at a low intensity, but at the sufficient high intensity is able to destroy the tumour - as well as the healthy tissue on his way to it. What can be done to avoid the latter?"

When this question was asked to participants in an experiment, most of them couldn't come up with the appropriate answer to the problem. Then they were told a story that went something like this:

> A General wanted to capture his enemy's fortress. He gathered a large army to launch a

> full-scale direct attack, but then learned, that all the roads leading directly towards the fortress were blocked by mines. These roadblocks were designed in such a way, that it was possible for small groups of the fortress-owner's men to pass them safely, but every large group of men would initially set them off. Now the General figured out the following plan: He divided his troops into several smaller groups and made each of them march down a different road, timed in such a way, that the entire army would reunite exactly when reaching the fortress and could hit with full strength.

Here, the story about the General is the source problem, and the radiation problem is the target problem. The fortress is analogous to the tumour and the big army corresponds to the highly intensive ray. Consequently a small group of soldiers represents a ray at low intensity. The solution to the problem is to split the ray up, as the general did with his army, and send the now harmless rays towards the tumour from different angles in such a way that they all meet when reaching it. No healthy tissue is damaged but the tumour itself gets destroyed by the ray at its full intensity. M. Gick and K. Holyoak presented Duncker's radiation problem to a group of participants in 1980 and 1983. Only 10 percent of them were able to solve the problem right away, 30 percent could solve it when they read the story of the general before. After given an additional hint - to use the story as help - 75 percent of them solved the problem.
With this results, Gick and Holyoak concluded, that analogical problem solving depends on three steps:

1. **Noticing** that an analogical connection exists between the source and the target problem.
2. **Mapping** corresponding parts of the two problems onto each other (fortress → tumour, army → ray, etc.)
3. **Applying** the mapping to generate a parallel solution to the target problem (using little groups of soldiers approaching from different directions →sending several weaker rays from different directions)

Next, Gick and Holyoak started looking for factors that could be helpful for the noticing and the mapping parts, for example: Discovering the basic linking concept behind the source and the target problem.

Schema

The concept that links the target problem with the analogy (the “source problem“) is called problem schema. Gick and Holyoak obtained the activation of a schema on their participants by giving them two stories and asking them to compare and summarise them. This activation of problem schemata is called “schema induction“.

The two presented texts were picked out of six stories which describe analogical problems and their solution. One of these stories was "The General" (remember example in Chapter 4.1).

After solving the task the participants were asked to solve the radiation problem (see chapter 4.2). The experiment showed that in order to solve the target problem reading of two stories with analogical problems is more helpful than reading only one story: After reading two stories 52% of the participants were able to solve the radiation problem (As told in chapter 4.2 only 30% were able to solve it after reading only one story, namely: "The General"). Gick and Holyoak found out that the quality of the schema a participant developed differs. They classified them into three groups:

1. Good schemata: In good schemata it was recognised that the same concept was used in order to solve the problem (21% of the participants created a good schema and 91% of them were able to solve the radiation problem).
2. Intermediate schemata: The creator of an intermediate schema has figured out that the root of the matter equals (here: many small forces solved the problem). (20% created one, 40% of them had the right solution).
3. Poor schemata: The poor schemata were hardly related to the target problem. In many poor schemata the participant only detected that the hero of the story was rewarded for his efforts (59% created one, 30% of them had the right solution).

The process of using a schema or analogy, i.e. applying it to a novel situation is called transduction. One can use a common strategy to solve problems of a new kind. To create a good schema and finally get to a solution is a problem-solving skill that requires practice and some background knowledge.

Transformation Problems:

What are transformation problems? In Cognitive psychology transformation problems refer to a major modification or shift in an individual's thought and/or behavior patterns. Cognitive psychologists have determined that an individual must carry out a certain sequence of transformations to achieve specific desired goals. A good example of this phenomena is the Wallas Stage Model of the creative process.

The Wallas Stage Model of the Creative Process

In the Wallas Stage Model , creative insights or illuminations occur in the following stages of work:

1. Preparation (conscious work on a creative problem)
2. Internalisation (internalisation of the problem context and goals into the subconscious) and Incubation (internal processing of the problem unconsciously), and
3. Illumination (the emergence – perhaps dramatically – of the creative insight to consciousness as an 'aha!' experience)
4. Verification and Elaboration (checking that the insight is valid and then developing it to a point where it can be used or shared).

As the creative individual (for example a scientist or engineer) works on a problem, if it is a difficult problem they may spend quite some effort, try several different avenues, and clarify or redefine the problem situation. All this activity works to begin to internalize the problem into the subconscious, at which point the ideas about the problem can churn around in the subconscious without necessarily any further conscious input – they are "incubating." As the problems are incubated, they may begin to coalesce into a solution to the problem, which then dramatically emerges to consciousness as an 'aha!' illumination experience. But this experience may or may not be a real solution to the problem – it needs to be verified and tested. It may then need further elaboration and development before it is put to use or shared with other people.

Historically, Wallas's Stage Model was based on the insights of two of the leading scientific minds of the late 19th century. On his 70th birthday celebration, Hermann Ludwig Ferdinand von Helmholtz offered his thoughts on his creative process, consistent with the Wallas Stage Model. These were published in 1896. In 1908, Henri Poincare's (the leading mathematician and scientist of his time) published his 1908 classic essay *Mathematical Creation*, in which he put forward his views on and understanding of the creative processes in mathematical work – again broadly consistent with the Wallas model, although Poincare offered his own thoughts on possible psychological mechanisms underlying the broad features of the Wallas model.

Poincare speculated that what happened was that once ideas were internalised, they bounced around in the subconscious somewhat like billiard balls, colliding with each other – but occasionally interlocking to form new stable combinations. When this happened and there was a significant fit, Poincare speculated that the mechanism which identified that a solution to the problem had been found was a sort of aesthetic sense, a "sensibility." Poincare wrote that in creative illumination experiences:
. . . the privileged unconscious phenomena, those susceptible of becoming conscious, are those which, directly or indirectly, affect most profoundly our emotional sensibility. It may be surprising to see emotional sensibility evoked a propos of mathematical demonstrations which, it would seem, can only be of interest to the intellect. This would be to forget the feeling of mathematical beauty, of the harmony of numbers and forms, of geometric elegance. This is a true aesthetic feeling that all real mathematicians know, and surely it belongs to emotional sensibility.
Poincare argued that in the subconscious, "the useful combinations are precisely the most beautiful, I mean those best able to charm this special sensibility that all mathematicians know." Such combinations are "capable of touching this special sensibility of the geometer of which I have just spoken, and . . . once aroused, will call our attention to them, and thus give them occasion to become conscious."

Generalizing from Poincare's discussion, the conscious mind receives a vast range of information inputs daily. The conscious and subconscious mental faculties sort and internalize this information by making patterns and associations between them and developing a "sense" of how new pieces of information "fit" with patterns, rules, associations and so forth that have already been internalized and may or may not even be consciously understood or brought into awareness.
Which brings us back to a discussion of intuition.

Incubation

Incubation is the concept of "sleeping on a problem," or disengaging from actively and consciously trying to solve a problem, in order to allow, as the theory goes, the unconscious processes to work on the problem. Incubation can take a variety of forms, such as taking a break, sleeping, or working on another kind of problem either more difficult or less challenging. Findings suggest that incubation can, indeed, have a positive impact on problem-solving outcomes. Interestingly, lower-level cognitive tasks (e.g., simple math or language tasks, vacuuming, putting items away) resulted in higher problem-solving outcomes than more challenging tasks (e.g., crossword puzzles, math problems). Educators have also found that taking active breaks increases children's creativity and problem-solving abilities in classroom settings.

Problem Solving Experts

With the term expert we describe someone who devotes large amounts of his or her time and energy to one specific field of interest in which he, subsequently, reaches a certain level of mastery. It should not be of surprise that experts tend to be better in solving problems in their field than novices (people who are beginners or not as well trained in a field as experts) are. They are faster in coming up with solutions and have a higher success rate of right solutions. But what is the difference between the way experts and non-experts solve problems? Research on the nature of expertise has come up with the following conclusions:

1. Experts know more about their field,
2. their knowledge is organized differently,
3. and they spend more time analyzing the problem.

When it comes to problems that are situated outside the experts' field, their performance often does not differ from that of novices.

Knowledge:

An experiment by Chase and Simon (1973a, b) dealt with the question how well experts and novices are able to reproduce positions of chess pieces on chessboards when these are presented to them only briefly. The results showed that experts were far better in reproducing actual game positions, but that their performance was comparable with that of novices when the chess pieces were arranged randomly on the board. Chase and Simon concluded that the superior performance on actual game positions was due to the ability to recognize familiar patterns: A chess expert has up to 50,000 patterns stored in his memory. In comparison, a good player might know about 1,000 patterns by heart and a novice only few to none at all. This very detailed knowledge is of crucial help when an expert is confronted with a new problem in his field. Still, it is not pure size of knowledge that makes an expert more successful. Experts also organize their knowledge quite differently from novices.

Organization:

In 1982 M. Chi and her co-workers took a set of 24 physic problems and presented them to a group of physics professors as well as to a group of students with only one semester of physics. The task was to group the problems based on their similarities. As it turned out the students tended to group the problems based on their surface structure (similarities of objects used in the problem, e.g. on sketches illustrating the problem), whereas the professors used their deep structure (the general physical principles that underlay the problems) as criteria. By recognizing the actual structure of a problem experts are able to connect the given task to the relevant knowledge they already have (e.g. another problem they solved earlier which required the same strategy).

Analysis:

Experts often spend more time analyzing a problem before actually trying to solve it. This way of approaching a problem may often result in what appears to be a slow start, but in the long run this strategy is much more effective. A novice, on the other hand, might start working on the problem right away, but often has to realize that he reaches dead ends as he chose a wrong path in the very beginning.

Blocks to Problem Solving

Fixation

Sometimes, previous experience or familiarity can even make problem solving more difficult. This is the case whenever habitual directions get in the way of finding new directions – an effect called fixation.

Functional Fixedness

Functional fixedness concerns the solution of object-use problems. The basic idea is that when the usual way of using an object is emphasised, it will be far more difficult for a person to use that object in a novel manner. An example for this effect is the **candle problem**: Imagine you are given a box of matches, some candles and tacks. On the wall of the room there is a cork-board. Your task is to fix the candle to the cork-board in such a way that no wax will drop on the floor when the candle is lit. – Got an idea?

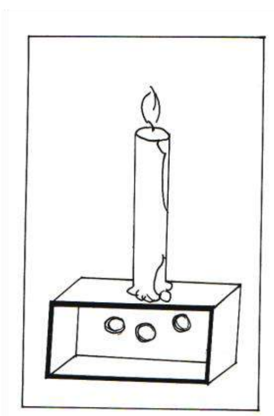


Figure 7. The Candle Problem

Explanation: The clue is just the following: when people are confronted with a problem and given certain objects to solve it, it is difficult for them to figure out that they could use them in a different (not so familiar or obvious) way. In this example the box has to be recognized as a support rather than as a container.

A further example is the two-string problem: Knut is left in a room with a chair and a pair of pliers given the task to bind two strings together that are hanging from the ceiling. The problem he faces is that he can never reach both strings at a time because they are just too far away from each other. What can Knut do?

Figure 8. The Pendulum Problem

Solution: Knut has to recognize he can use the pliers in a novel function – as weight for a pendulum. He can bind them to one of the :strings, push it away, hold the other string and just wait for the first one moving towards him. If necessary, Knut can even climb :on the chair, but he is not that small, we suppose…

Mental Fixedness

Functional fixedness as involved in the examples above illustrates a mental set - a person's tendency to respond to a given task in a manner based on past experience. Because Knut maps an object to a particular function he has difficulties to vary the way of use (pliers as pendulum's weight). One approach to studying fixation was to study wrong-answer verbal insight problems. It was shown that people tend to give rather an incorrect answer when failing to solve a problem than to give no answer at all.

A typical example: People are told that on a lake the area covered by water lilies doubles every 24 hours and that it takes 60 days to cover the whole lake. Then they are asked how many days it takes to cover half the lake. The typical response is '30 days' (whereas 59 days is correct).

These wrong solutions are due to an inaccurate interpretation, hence representation, of the problem. This can happen because of sloppiness (a quick shallow reading of the problem and/or weak monitoring of their efforts made to come to a solution). In this case error feedback should help people to reconsider the problem features, note the inadequacy of their first answer, and find the correct solution. If, however, people are truly fixated on their incorrect representation, being told the answer is wrong does not help. In a study made by P.I. Dallop and R.L. Dominowski in 1992 these two possibilities were contrasted. In approximately one third of the cases error feedback led to right answers, so only approximately one third of the wrong answers were due to inadequate monitoring. [6] Another approach is the study of examples with and without a preceding analogous task. In cases such like the water-jug task analogous thinking indeed leads to a correct solution, but to take a different way might make the case much simpler:

> Imagine Knut again, this time he is given three jugs with different capacities and is asked to measure the required amount of water. :Of course he is not allowed to use anything despite the jugs and as much water as he likes. In the first case the sizes are 127 : litres, 21 litres and 3 litres while 100 litres are desired. In the second case Knut is asked to measure 18 litres from jugs of 39, 15 and three litres size.

In fact participants faced with the 100 litre task first choose a complicate way in order to solve the second one. Others on the contrary who did not know about that complex task solved the 18 litre case by just adding three litres to 15.

Pitfalls to Problem Solving

Not all problems are successfully solved, however. What challenges stop us from successfully solving a problem? Albert Einstein once said, “Insanity is doing the same thing over and over again and expecting a different result.” Imagine a person in a room that has four doorways. One doorway that has always been open in the past is now locked. The person, accustomed to exiting the room by that particular doorway, keeps trying to get out through the same doorway even though the other three doorways are open. The person is stuck—but she just needs to go to another doorway, instead of trying to get out through the locked doorway. A **mental set** is where you persist in approaching a problem in a way that has worked in the past but is clearly not working now. **Functional fixedness** is a type of mental set where you cannot perceive an object being used for something other than what it was designed for. During the *Apollo 13*mission to the moon, NASA engineers at Mission Control had to overcome functional fixedness to save the lives of the astronauts aboard the spacecraft. An explosion in a module of the spacecraft damaged multiple systems. The astronauts were in danger of being poisoned by rising levels of carbon dioxide because of problems with the carbon dioxide filters. The engineers found a way for the astronauts to use spare plastic bags, tape, and air hoses to create a makeshift air filter, which saved the lives of the astronauts.

LINK TO LEARNING

Check out this ***Apollo 13* scene** where the group of NASA engineers are given the task of overcoming functional fixedness.

Researchers have investigated whether functional fixedness is affected by culture. In one experiment, individuals from the Shuar group in Ecuador were asked to use an object for a purpose other than that for which the object was originally intended. For example, the participants were told a story about a bear and a rabbit that were separated by a river and asked to select among various objects, including a spoon, a cup, erasers, and so on, to help the animals. The spoon was the only object long enough to span the imaginary river, but if the spoon was presented in a way that reflected its normal usage, it took participants longer to choose the spoon to solve the problem. (German & Barrett, 2005). The researchers wanted to know if exposure to highly specialized tools, as occurs with individuals in industrialized nations, affects their ability to transcend functional fixedness. It was determined that functional fixedness is experienced in both industrialized and non-industrialized cultures (German & Barrett, 2005).

Common obstacles to solving problems

The example also illustrates two common problems that sometimes happen during problem solving. One of these is **functional fixedness**: a tendency to regard the *functions* of objects and ideas as *fixed* (German & Barrett, 2005). Over time, we get so used to one particular purpose for an object that we overlook other uses. We may think of a dictionary, for example, as necessarily something to verify spellings and definitions, but it also can function as a gift, a doorstop, or a footstool. For students working on the nine-dot matrix described in the last section, the notion of "drawing" a line was also initially fixed; they assumed it to be connecting dots but not extending lines beyond the dots. Functional fixedness sometimes is also called **response set**, the tendency for a person to frame or think about each problem in a series in the same way as the previous problem, even when doing so is not appropriate to later problems. In the example of the nine-dot matrix described above, students often tried one solution after another, but each solution was constrained by a set response *not* to extend any line beyond the matrix.

Functional fixedness and the response set are obstacles in **problem representation**, the way that a person understands and organizes information provided in a problem. If information is misunderstood or used inappropriately, then mistakes are likely—if indeed the problem can be solved at all. With the nine-dot matrix problem, for example, construing the instruction to draw four lines as meaning "draw four lines entirely within the matrix" means that the problem simply could not be solved. For another, consider this problem: "The number of water lilies on a lake doubles each day. Each water lily covers exactly one square foot. If it takes 100 days for the lilies to cover the lake exactly, how many days does it take for the lilies to cover exactly half of the lake?” If you think that the size of the lilies affects the solution to this problem, you have not represented the problem correctly. Information about lily size is *not* relevant to the solution, and only serves to distract from the truly crucial information, the fact that the lilies *double* their coverage each day. (The answer, incidentally, is that the lake is half covered in 99 days; can you think why?)

Chapter 7 – Creativity

What do the following have in common: the drug penicillin, the Eiffel Tower, the film *Lord of the Rings*, the General Theory of Relativity, the hymn *Amazing Grace*, the iPhone, the novel *Don Quixote*, the painting *The Mona Lisa*, a recipe for chocolate fudge, the soft drink Coca-Cola, the video game *Wii Sports*, the West Coast offense in football, and the zipper? You guessed right! All of the named items were products of the creative mind. Not one of them existed until somebody came up with the idea. Creativity is not something that you just pick like apples from a tree. Because creative ideas are so special, creators who come up with the best ideas are often highly rewarded with fame, fortune, or both. Nobel Prizes, Oscars, Pulitzers, and other honors bring fame, and big sales and box office bring fortune. Yet what is creativity in the first place?

Figure 1. People often have difficulty describing where their creative ideas came from. When you think of something creative, how do you typically come up with it?

Creativity: What Is It?

Creativity happens when someone comes up with a creative idea. An example would be a creative solution to a difficult problem. But what makes an idea or solution creative? Creativity is the ability to generate, create, or discover new ideas, solutions, and possibilities. Very creative people often have intense knowledge about something, work on it for years, look at novel solutions, seek out the advice and help of other experts, and take risks. Although creativity is often associated with the arts, it is actually a vital form of intelligence that drives people in many disciplines to discover something new. Creativity can be found in every area of life, from the way you decorate your residence to a new way of understanding how a cell works.

Although psychologists have offered several definitions of creativity (Plucker, Beghetto, & Dow, 2004; Runco & Jaeger, 2012), probably the best definition is the one recently adapted from the three criteria that the U.S. Patent Office uses to decide whether an invention can receive patent protection (Simonton, 2012).

The first criterion is *originality*. The idea must have a low probability. Indeed, it often should be unique. Albert Einstein's special theory of relativity certainly satisfied this criterion. No other scientist came up with the idea.

The second criterion is *usefulness*. The idea should be valuable or work. For example, a solution must, in fact, solve the problem. An original recipe that produces a dish that tastes too terrible to eat cannot be creative. In the case of Einstein's theory, his relativity principle provided explanations for what otherwise would be inexplicable empirical results.

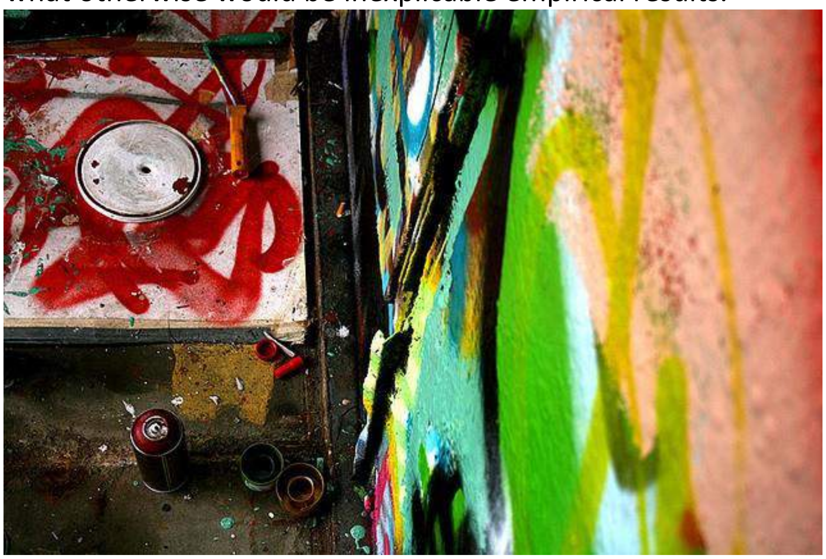


Figure 2. Even with the three criteria for creativity (originality, usefulness, and surprise), determining whether art is "creative" can prove difficult. Especially with all the examples of artists whose work wasn't deemed creative until after their deaths. [Image: Linus Bohman]

The third and last criterion is *surprise*. The idea should be surprising, or at least nonobvious (to use the term used by the Patent Office). For instance, a solution that is a straightforward derivation from acquired expertise cannot be considered surprising even if it were original. Einstein's relativity theory was not a step-by-step deduction from classical physics but rather the theory was built upon a new foundation that challenged the very basis of traditional physics. When applying these three criteria, it is critical to recognize that originality, usefulness, and surprise are all quantitative rather than qualitative attributes of an idea. Specifically, we really have to speak of degree to which an idea satisfies each of the three criteria. In addition, the three attributes should have a zero point, that is, it should be possible to speak of an idea lacking any originality, usefulness, or surprise whatsoever. Finally, we have to assume that if an idea scores zero on any one criterion then it must have zero creativity as well. For example, someone who reinvents the wheel is definitely producing a useful idea, but the idea has zero originality and hence no creativity whatsoever. Similarly, someone who invented a parachute made entirely out of steel reinforced concrete would get lots of credit for originality—and surprise!—but none for usefulness.

Definitions of Creativity

We already introduced a lot of ways to solve a problem, mainly strategies that can be used to find the “correct” answer. But there are also problems which do not require a “right answer” to be given - It is time for creative productiveness! Imagine you are given three objects – your task is to invent a completely new object that is related to nothing you know. Then try to describe its function and how it could additionally be used. Difficult? Well, you are free to think creatively and will not be at risk to give an incorrect answer. For example think of what can be constructed from a half-sphere, wire and a handle. The result is amazing: a lawn lounger, global earrings, a sled, a water weigher, a portable agitator, ... [10]

Divergent Thinking

The term divergent thinking describes a way of thinking that does not lead to one goal, but is open-ended. Problems that are solved this way can have a large number of potential 'solutions' of which none is exactly 'right' or 'wrong', though some might be more suitable than others. Solving a problem like this involves indirect and productive thinking and is mostly very helpful when somebody faces an ill-defined problem, i.e. when either initial state or goal state cannot be stated clearly and operators or either insufficient or not given at all.

The process of divergent thinking is often associated with creativity, and it undoubtedly leads to many creative ideas. Nevertheless, researches have shown that there is only modest correlation between performance on divergent thinking tasks and other measures of creativity. Additionally it was found that in processes resulting in original and practical inventions things like searching for solutions, being aware of structures and looking for analogies are heavily involved, too. Thus, divergent thinking alone is not an appropriate tool for making an invention. You also need to analyze the problem in order to make the suggested, i.e. invention, solution appropriate.

Convergent Thinking

Divergent can be contrasted by convergent thinking - thinking that seeks to find the correct answer to a specific problem. This is an adequate strategy for solving most of the well-defined problems (problems with given initial state, operators and goal state) we presented so far. To solve the given tasks it was necessary to think directly or reproductively.

It is always helpful to use a strategy to think of a way to come closer to the solution, perhaps using knowledge from previous tasks or sudden insight.

Remote Associates Test & Unusual Uses Task:

Cognitive scientists have long been interested in the thinking processes that lead to creative ideas. Indeed, many so-called “creativity tests” are actually measures of the thought processes believed to underlie the creative act. The following two measures are among the best known. The first is the Remote Associates Test, or RAT, that was introduced by Mednick. Mednick believed that the creative process requires the ability to associate ideas that are considered very far apart conceptually. The RAT consists of items that require the respondent to identify a word that can be associated to three rather distinct stimulus words. For example, what word can be associated with the words "widow, bite, monkey"? The answer is spider (black widow spider, spider bite, spider monkey). This question is relatively easy, others are much more difficult, but it gives you the basic idea.

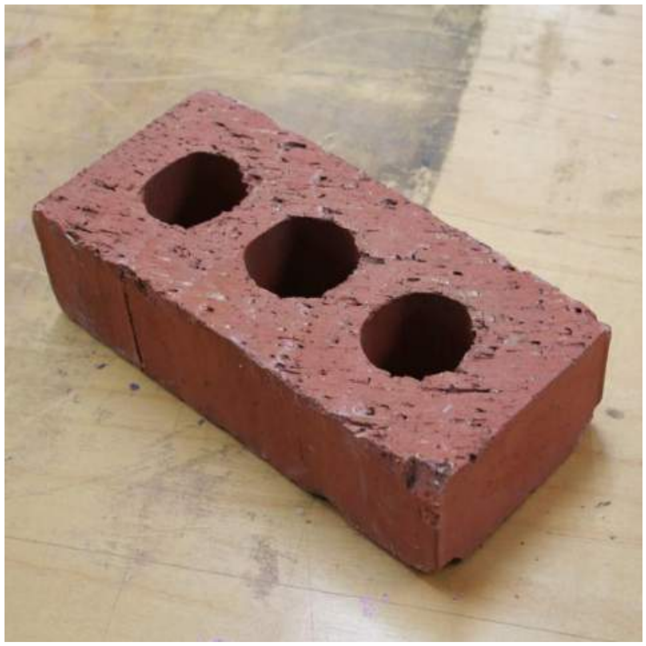


Figure 31. What do you see? An ordinary piece of building material? Those who score higher on the Unusual Uses Task are able to imagine many possibilities for the humble brick. [Image: CC0 Public Domain, https://goo.gl/m25gce]

The second measure is the Unusual Uses Task. Here, the participant is asked to generate alternative uses for a common object, such as a brick. The responses can be scored on four dimensions: (a) *fluency*, the total number of appropriate uses generated; (b) *originality*, the statistical rarity of the uses given; (c) *flexibility*, the number of distinct conceptual categories implied by the various uses; and (d) *elaboration*, the amount of detail given for the generated uses. For example, using a brick as a paperweight represents a different conceptual category that using its volume to conserve water in a toilet tank.

The capacity to produce **unusual uses** is but one example of the general cognitive ability to engage in **divergent thinking** (Guilford, 1967). Unlike **convergent thinking**, which converges on the single best answer or solution, divergent thinking comes up with multiple possibilities that might vary greatly in usefulness. Unfortunately, many different cognitive processes have been linked to creativity (Simonton & Damian, 2013). That is why we cannot use the singular; there is no such thing as *the* “creative process.” Nonetheless, the various processes do share one feature: All enable the person to “think outside the box” imposed by routine thinking—to venture into territory that would otherwise be ignored (Simonton, 2011). Creativity requires that you go where you don’t know where you’re going.

Insight

There are two very different ways of approaching a goal-oriented situation. In one case an organism readily reproduces the response to the given problem from past experience. This is called **reproductive thinking**. The second way requires something new and different to achieve the goal, prior learning is of little help here. Such **productive thinking** is (sometimes) argued to involve **insight**. Gestalt psychologists even state that insight problems are a separate category of problems in their own right.

Tasks that might involve insight usually have certain features - they require something new and non-obvious to be done and in most cases they are difficult enough to predict that the initial solution attempt will be unsuccessful. When you solve a problem of this kind you often have a so called "**AHA-experience**" - the solution pops up all of a sudden. At one time you do not have any ideas of the answer to the problem, you do not even feel to make any progress trying out different ideas, but in the next second the problem is solved. For all those readers who would like to experience such an effect, here is an example for an Insight Problem: Knut is given four pieces of a chain; each made up of three links. The task is to link it all up to a closed loop and he has only 15 cents. To open a link costs 2, to close a link costs 3 cents. What should Knut do?

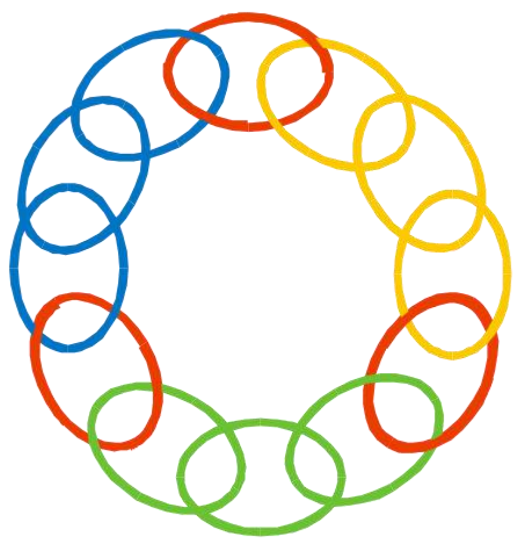


Figure 3. A link Chain [https://en.wikibooks.org/w/index.php?title=File:Chain_solved.svg]

To show that solving insight problems involves restructuring, psychologists created a number of problems that were more difficult to solve for participants provided with previous experiences, since it was harder for them to change the representation of the given situation (see Fixation).

Sometimes given hints may lead to the insight required to solve the problem. And this is also true for involuntarily given ones. For instance it might help you to solve a memory game if someone accidentally drops a card on the floor and you look at the other side. Although such help is not obviously a hint, the effect does not differ from that of intended help. For *non-insight* problems the opposite is the case. Solving arithmetical problems, for instance, requires schemas, through which one can get to the solution step by step.

Chapter 8- Reasoning

Formal Reasoning

No matter which public topic you discuss or which personal aspect you worry about – you need reasons for your opinion and argumentation. Moreover, the ability of reasoning is responsible for your cognitive features of decision making and choosing among alternatives. Every one of us uses these two abilities in everyday life to the utmost. Let us, therefore, consider the following scene of Knut's life: "It is again a rainy afternoon in Osnabrück (Germany) and as Knut and his wife are tired of observing the black crows in their garden they decide to escape from the shabby weather and spend their holidays in Spain. Knut has never been to Spain before and is pretty excited. They will leave the next day, thus he is packing his bag. The crucial things first: some underwear, some socks, a pair of pajamas and his wash bag with a toothbrush, shampoo, soap, sun milk and insect spray. But, Knut cannot find the insect spray until his wife tells him that she lost it and will buy some new. He advises her to take an umbrella for the way to the chemist as it is raining outside, before he turns back to his packing task. But what did he already pack into his bag? Immediately, he remembers and continues, packing his clothing into the bag, considering that each piece fits another one and finally his Ipod as he exclusively listens to music with this device. Since the two of them are going on summer holidays, Knut packs especially shorts and T-Shirts into his bag. After approximately half an hour, he is finally convinced that he has done everything necessary for having some fine holidays." With regard to this sketch of Knut's holiday preparation, we will explain the basic principles of reasoning and decision making. In the following, it will be shown how much cognitive work is necessary for this fragment of everyday life. After presenting an insight into the topic, we will illustrate what kind of brain lesions lead to what kind of impairments of these two cognitive features.

Reasoning

In a process of reasoning available information is taken into account in form of premises. Through a process of inferencing a conclusion is reached on the base of these premises. The conclusion's content of information goes beyond the one of the premises. To make this clear consider the following consideration Knut makes before planning his holiday:

1. Premise: In all countries in southern Europe it is pretty warm during summer.
2. Premise: Spain is in southern Europe.

   Conclusion: Therefore, in Spain it is pretty warm during summer.

The conclusion in this example follows directly from the premises but it entails information which is not explicitly stated in the premises. This is a rather typical feature of a process of reasoning. In the following it is decided between the two major kinds of reasoning, namely inductive and deductive which are often seen as the complement of one another.

Deductive Reasoning

Deductive reasoning is concerned with syllogisms in which the conclusion follows logically from the premises. The following example about Knut makes this process clear:

1. Premise: Knut knows: If it is warm, one needs shorts and T-Shirts.
2. Premise: He also knows that it is warm in Spain during summer.

Conclusion: Therefore, Knut reasons that he needs shorts and T-Shirts in Spain.

In the given example it is obvious that the premises are about rather general information and the resulting conclusion is about a more special case which can be inferred from the two premises. Hereafter it is differentiated between the two major kinds of syllogisms, namely categorical and conditional ones.

Categorical Syllogisms

In categorical syllogisms the statements of the premises begin typically with “all”, “none” or “some” and the conclusion starts with “therefore” or “hence”. These kinds of syllogisms fulfill the task of describing a relationship between two categories. In the example given above in the introduction of deductive reasoning these categories are Spain and the need for shorts and T-Shirts. Two different approaches serve the study of categorical syllogisms which are the **normative approach** and the **descriptive approach.**

The normative approach

The normative approach is based on logic and deals with the problem of categorizing conclusions as either valid or invalid. “Valid” means that the conclusion follows logically from the premises whereas “invalid” means the contrary. Two basic principles and a method called **Euler Circles** (Figure 1) have been developed to help judging about the validity. The first principle was created by Aristotle and says “If the two premises are true, the conclusion of a valid syllogism must be true” (cp. Goldstein, 2005). The second principle describes that “The validity of a syllogism is determined only by its form, not its content.” These two principles explain why the following syllogism is (surprisingly) valid:

All flowers are animals. All animals can jump. Therefore, all flowers can jump.

Even though it is quite obvious that the first premise is not true and further that the conclusion is not true, the whole syllogism is still valid. Applying formal logic to the syllogism in the example, the conclusion is valid.

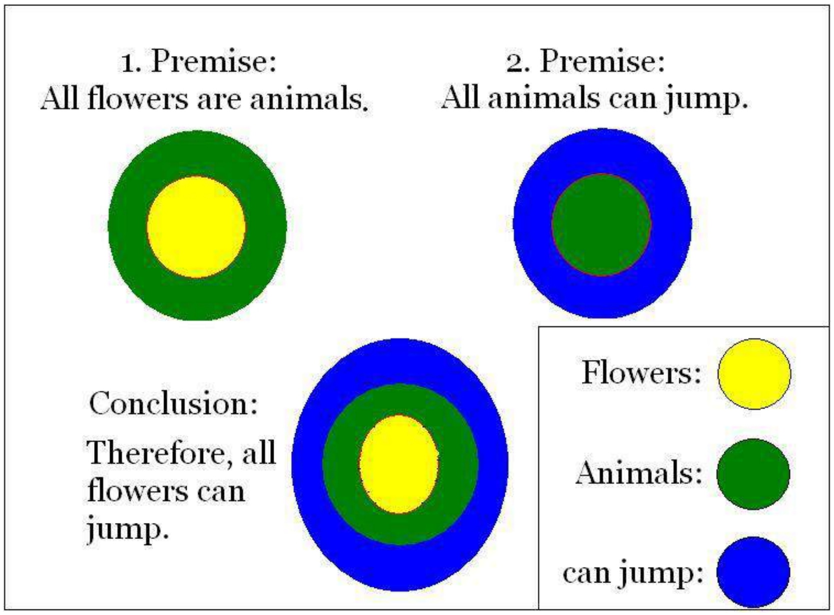


Figure 1. Euler Circles

Due to this precondition it is possible to display a syllogism formally with symbols or letters and explain its relationship graphically with the help of diagrams. There are various ways to demonstrate a premise graphically. Starting with a circle to represent the first premise and adding one or more circles for the second one (Figure 1), the crucial move is to compare the constructed diagrams with the conclusion. It should be clearly laid out whether the diagrams are contradictory or not. Agreeing with one another, the syllogism is valid. The displayed syllogism (Figure 1) is obviously valid. The conclusion shows that everything that can jump contains animals which again contains flowers. This agrees with the two premises which point out that flowers are animals and that these are able to jump. The method of Euler Circles is a good device to make syllogisms better conceivable.

The descriptive approach

The descriptive approach is concerned with estimating people´s ability of judging validity and explaining judging errors. This psychological approach uses two methods in order to determine people`s performance:

Method of evaluation: People are given two premises, a conclusion and the task to judge whether the syllogism is valid or not. (preferred one)
Method of production: Participants are supplied with two premises and asked to develop a logically valid conclusion. (if possible)

While using the **method of evaluation** researchers found typical misjudgments about syllogisms. Premises starting with “All”, “Some” or “No” imply a special atmosphere and influence a person in the process of decision making. One mistake often occurring is judging a syllogism incorrectly as valid, in which the two premises as well as the conclusion starts with “All”. The influence of the provided atmosphere leads to the right decision at most times, but is definitely not reliable and guides the person to a rash decision. This phenomenon is called the **atmosphere effect**.

In addition to the form of a syllogism, the content is likely to influence a person's decision as well and causes the person to neglect his logical thinking. The belief bias states that people tend to judge syllogisms with believable conclusions as valid, while they tend to judge syllogisms with unbelievable conclusions as invalid. Given a conclusion as like "Some bananas are pink", hardly any participants would judge the syllogism as valid, even though it might be valid according to its premises (e.g. Some bananas are fruits. All fruits are pink.)

Mental models of deductive reasoning

It is still not possible to consider what mental processes might occur when people are trying to determine whether a syllogism is valid. After researchers observed that Euler Circles can be used to determine the validity of a syllogism, Phillip Johnson–Laird (1999) wondered whether people would use such circles naturally without any instruction how to use them. At the same time he found out that they do not work for some more complex syllogisms and that a problem can be solved by applying logical rules, but most people solve them by imagining the situation. This is the basic idea of people using mental models – a specific situation that is represented in a person's mind that can be used to help determine the validity of syllogisms – to solve deductive reasoning problems. The basic principle behind the Mental Model Theory is: A conclusion is valid only if it cannot be refuted by any mode of the premises. This theory is rather popular because it makes predictions that can be tested and because it can be applied without any knowledge about rules of logic. But there are still problems facing researchers when trying to determine how people reason about syllogisms. These problems include the fact that a variety of different strategies are used by people in reasoning and that some people are better in solving syllogisms than others.

Effects of culture on deductive reasoning

People can be influenced by the content of syllogisms rather than by focusing on logic when judging their validity. Psychologists have wondered whether people are influenced by their cultures when judging. Therefore, they have done cross–cultural experiments in which reasoning problems were presented to people of different cultures. They observed that people from different cultures judge differently to these problems. People use evidence from their own experience (empirical evidence) and ignore evidence presented in the syllogism (theoretical evidence).

Conditional syllogisms

Another type of syllogisms is called "conditional syllogism". Just like the categorical one, it also has two premises and a conclusion. In difference the first premise has the form "If … then". Syllogisms like this one are common in everyday life. Consider the following example from the story about Knut:

1. Premise: If it is raining, Knut`s wife gets wet.
2. Premise: It is raining.

Conclusion: Therefore, Knut`s wife gets wet.

Conditional syllogisms are typically given in the abstract form: “If p then q”, where “p” is called the **antecedent** and “q” the **consequent**.

Forms of conditional syllogisms

There are four major forms of conditional syllogisms, namely Modus Ponens, Modus Tollens, Denying The Antecedent and Affirming The Consequent. Obviously, the validity of the syllogisms with valid conclusions is easier to judge in a correct manner than the validity of the ones with invalid conclusions. The conclusion in the instance of the modus ponens is apparently valid. In the example it is very clear that Knut`s wife gets wet, if it is raining.
The validity of the modus tollens is more difficult to recognize. Referring to the example, in the case that Knut`s wife does not get wet it can`t be raining. Because the first premise says that if it is raining, she gets wet. So the reason for Knut`s wife not getting wet is that it is not raining. Consequently, the conclusion is valid. The validity of the remaining two kinds of conditional syllogisms is judged correctly only by 40% of people. If the method of denying the antecedent is applied, the second premise says that it is not raining. But from this fact it follows not logically that Knut`s wife does not get wet – obviously rain is not the only reason for her to get wet. It could also be the case that the sun is shining and Knut tests his new water pistol and makes her wet. So, this kind of conditional syllogism does not lead to a valid conclusion. Affirming the consequent in the case of the given example means that the second premise says that Knut`s wife gets wet. But again the reason for this can be circumstances apart from rain. So, it follows not logically that it is raining. In consequence, the conclusion of this syllogism is invalid. The four kinds of syllogisms have shown that it is not always easy to make correct judgments concerning the validity of the conclusions. The following passages will deal with other errors people make during the process of conditional reasoning.

The Wason Selection Task

The Wason Selection Task [1] is a famous experiment which shows that people make more errors in the process of reasoning, if it is concerned with abstract items than if it involves real-world items (Wason, 1966). In the abstract version of the Wason Selection Task four cards are shown to the participants with each a letter on one side and a number on the other (Figure 3, yellow cards). The task is to indicate the minimum number of cards that have to be turned over to test whether the following rule is observed: “If there is a vowel on one side then there is an even number on the other side”. 53% of participants selected the ‘E’ card which is correct, because turning this card over is necessary for testing the truth of the rule. However still another card needs to be turned over. 64 % indicated that the ‘4’ card has to be turned over which is not right. Only 4% of participants answered correctly that the ‘7’ card needs to be turned over in addition to the ‘E’. The correctness of turning over these two cards becomes more obvious if the same task is stated in terms of real-world items instead of vowels and numbers. One of the experiments for determining this was the beer/drinking-age problem used by Richard Griggs and James Cox (1982). This experiment is identical to the Wason Selection

Task except that instead of numbers and letters on the cards everyday terms (beer, soda and ages) were used (Figure 3, green cards). Griggs and Cox gave the following rule to the participants: “If a person is drinking beer then he or she must be older than 19 years.” In this case 73% of participants answered in a correct way, namely that the cards with “Beer” and “14 years” on it have to be turned over to test whether the rule is kept.

Why is the performance better in the case of real–world items?

There are two different approaches which explain why participants’ performance is significantly better in the case of the beer/drinking-age problem than in the abstract version of the Wason Selection Task, namely one approach concerning permission schemas and an evolutionary approach.

The regulation: “If one is 19 years or older then he/she is allowed to drink alcohol”, is known by everyone as an experience from everyday life (also called **permission schema**). As this permission schema is already learned by the participants it can be applied to the Wason Selection Task for real–world items to improve participants` performance. On the contrary such a permission schema from everyday life does not exist for the abstract version of the Wason Selection Task.

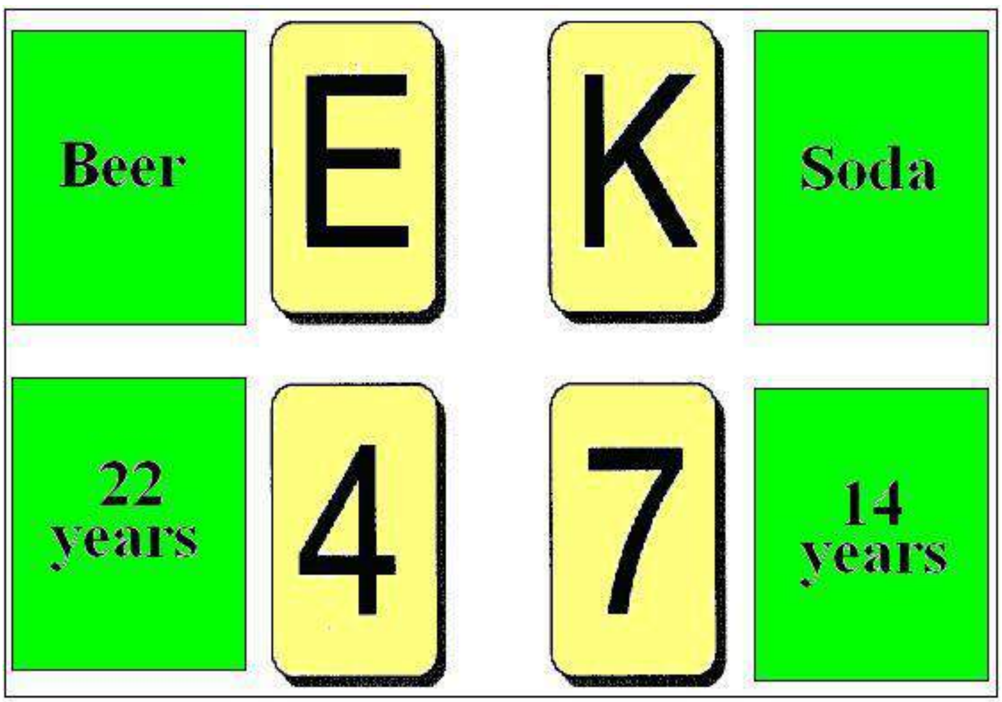


Figure 2. The Wason Selection Task

The evolutionary approach concerns the important human ability of **cheater-detection**. This approach states that an important aspect of human behavior especially in the past was/is the ability for two persons to cooperate in a way that is beneficial for both of them. As long as each person receives a benefit for whatever he/she does in favor of the other one, everything works well in their social exchange. But if someone cheats and receives benefit from others without giving it back, some problem arises (see also chapter 3. Evolutionary Perspective on Social

Cognitions [2]). It is assumed that the property to detect cheaters has become a part of human`s cognitive makeup during evolution. This cognitive ability improves the performance in the beer/drinking-age version of the Wason Selection Task as it allows people to detect a cheating person who does not behave according to the rule. Cheater-detection does not work in the case of the abstract version of the Wason Selection Task as vowels and numbers do not behave or even cheat at all as opposed to human beings.

Inductive reasoning

In the previous sections deductive reasoning was discussed, reaching conclusions based on logical rules applied to a set of premises. However, many problems cannot be represented in a way that would make it possible to use these rules to get a conclusion. This subchapter is about a way to be able to decide in terms of these problems as well: inductive reasoning. Figure 4, Deductive and inductive reasoning Inductive reasoning is the process of making simple observations of a certain kind and applying these observations via generalization to a different problem to make a decision. Hence one infers from a special case to the general principle which is just the opposite of the procedure of deductive reasoning (Figure 3).

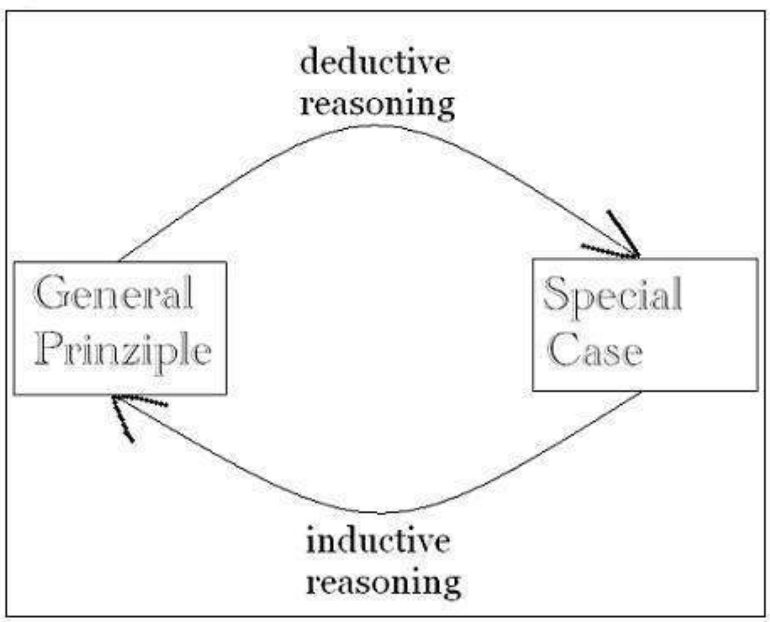


Figure 3.Deductive and Inductive reasoning

A good example for inductive reasoning is the following:

Premise: All crows Knut and his wife have ever seen are black.
Conclusion: Therefore, they reason that all crows on earth are black.

In this example it is obvious that Knut and his wife infer from the simple observation about the crows they have seen to the general principle about all crows. Considering figure 4 this means that they infer from the subset (yellow circle) to the whole (blue circle). As in this example it is typical in a process of inductive reasoning that the premises are believed to support the conclusion, but do not ensure it.

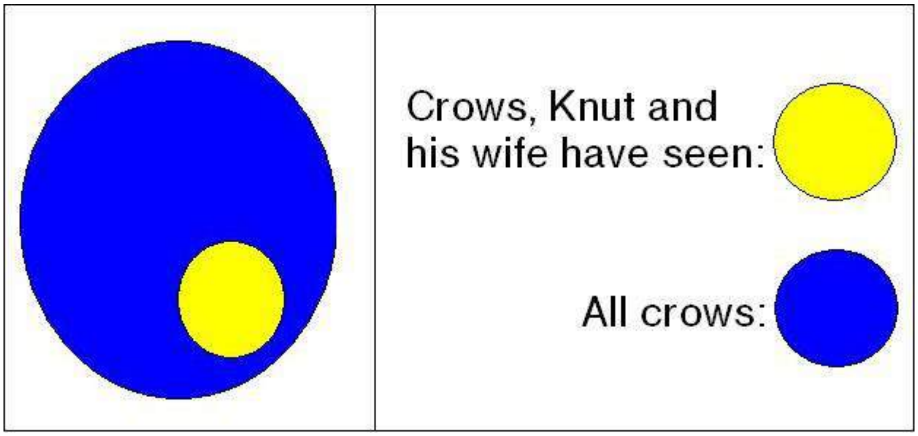


Figure 4. Crow Diagram

Forms of inductive reasoning

The two different forms of inductive reasoning are "strong" and "weak" induction. The former describes that the truth of the conclusion is very likely, if the assumed premises are true. An example for this form of reasoning is the one given in the previous section. In this case it is obvious that the premise ("All crows Knut and his wife have ever seen are black") gives good evidence for the conclusion ("All crows on earth are black") to be true. But nevertheless it is still possible, although very unlikely, that not all crows are black.

On the contrary, conclusions reached by "weak induction" are supported by the premises in a rather weak manner. In this approach the truth of the premises makes the truth of the conclusion possible, but not likely.

An example for this kind of reasoning is the following:

> Premise: Knut always hears music with his IPod.
> Conclusion: Therefore, he reasons that all music is only heard with IPods.

In this instance the conclusion is obviously false. The information the premise contains is not very representative and although it is true, it does not give decisive evidence for the truth of the conclusion. To sum it up, strong inductive reasoning gets to conclusions which are very probable whereas the conclusions reached through weak inductive reasoning on the base of the premises are unlikely to be true.

Reliability of conclusions

If the strength of the conclusion of an inductive argument has to be determined, three factors concerning the premises play a decisive role. The following example which refers to Knut and his wife and the observations they made about the crows (see previous sections) displays these factors: When Knut and his wife observe in addition to the black crows in Germany also the crows in Spain, the **number of observations** they make concerning the crows obviously increases. Furthermore, the **representativeness of these observations** is supported, if Knut and his wife observe the crows at all different day- and night times and see that they are black every time. Theoretically it may be that the crows change their color at night what would make the conclusion that all crows are black wrong. The **quality of the evidence** for all crows to be black increases, if Knut and his wife add scientific measurements which support the conclusion. For example they could find out that the crows' genes determine that the only color they can have is black. Conclusions reached through a process of inductive reasoning are never definitely true as no one has seen all crows on earth and as it is possible, although very unlikely, that there is a green or brown exemplar. The three mentioned factors contribute decisively to the strength of an inductive argument. So, the stronger these factors are, the more reliable are the conclusions reached through induction.

Processes and constraints

In a process of inductive reasoning people often make use of certain heuristics which lead in many cases quickly to adequate conclusions but sometimes may cause errors. In the following, two of these heuristics (**availability heuristic** and **representativeness heuristic**) are explained. Subsequently, the **confirmation bias** is introduced which sometimes influences peoples' reasons according to their own opinion without them realising it.

The availability heuristic

Things that are more easily remembered are judged to be more prevalent. An example for this is an experiment done by Lichtenstein et al. (1978). The participants were asked to choose from two different lists the causes of death which occur more often. Because of the availability heuristic people judged more "spectacular" causes like homicide or tornado to cause more deaths than others, like asthma. The reason for the subjects answering in such a way is that for example films and news in television are very often about spectacular and interesting causes of death. This is why these information are much more available to the subjects in the experiment. Another effect of the usage of the availability heuristic is called **illusory correlations**. People tend to judge according to stereotypes. It seems to them that there are correlations between certain events which in reality do not exist. This is what is known by the term "prejudice". It means that a much oversimplified generalization about a group of people is made. Usually a correlation seems to exist between negative features and a certain class of people (often fringe groups). If, for example, one's neighbour is jobless and very lazy one tends to correlate these two attributes and to create the prejudice that all jobless people are lazy. This illusory correlation occurs because one takes into account information which is available and judges this to be prevalent in many cases.

The representativeness heuristic

If people have to judge the probability of an event they try to find a comparable event and assume that the two events have a similar probability. Amos Tversky and Daniel Kahneman (1974) presented the following task to their participants in an experiment: "We randomly chose a man from the population of the U.S., Robert, who wears glasses, speaks quietly and reads a

lot. Is it more likely that he is a librarian or a farmer?" More of the participants answered that Robert is a librarian which is an effect of the representativeness heuristic. The comparable event which the participants chose was the one of a typical librarian as Robert with his attributes of speaking quietly and wearing glasses resembles this event more than the event of a typical farmer. So, the event of a typical librarian is better comparable with Robert than the event of a typical farmer. Of course this effect may lead to errors as Robert is randomly chosen from the population and as it is perfectly possible that he is a farmer although he speaks quietly and wears glasses.
The representativeness heuristic also leads to errors in reasoning in cases where the **conjunction rule** is violated. This rule states that the conjunction of two events is never more likely to be the case than the single events alone. An example for this is the case of the feminist bank teller (Tversky & Kahneman, 1983). If we are introduced to a woman of whom we know that she is very interested in women's rights and has participated in many political activities in college and we are to decide whether it is more likely that she is a bank teller or a feminist bank teller, we are drawn to conclude the latter as the facts we have learnt about her resemble the event of a feminist bank teller more than the event of only being a bank teller.

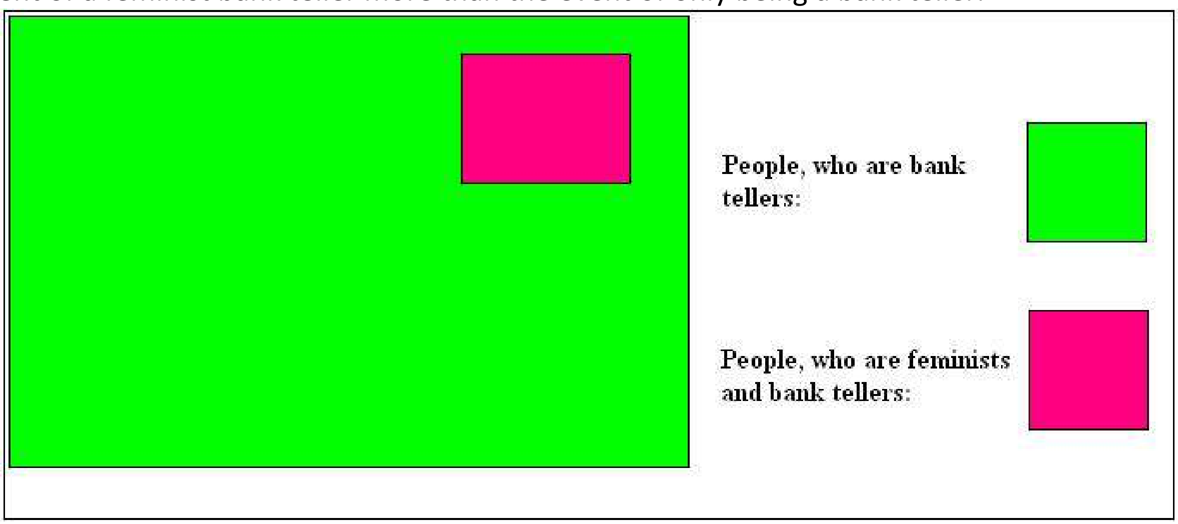


Figure 5. Feminist Bank Tellers

But it is in fact much more likely that somebody is just a bank teller than it is that someone is a feminist in addition to being a bank teller. This effect is illustrated in figure 6 where the green square, which stands for just being a bank teller, is much larger and thus more probable than the smaller violet square, which displays the conjunction of bank tellers and feminists, which is a subset of bank tellers.

The confirmation bias

This phenomenon describes the fact that people tend to decide in terms of what they themselves believe to be true or good. If, for example, someone believes that one has bad luck on Friday the thirteenth, he will especially look for every negative happening at this particular date but will be inattentive to negative happenings on other days. This behaviour strengthens the belief that there exists a relationship between Friday the thirteenth and having bad luck.

This example shows that the actual information is not taken into account to come to a conclusion but only the information which supports one's own belief. This effect leads to errors as people tend to reason in a subjective manner, if personal interests and beliefs are involved. All the mentioned factors influence the subjective probability of an event so that it differs from the actual probability (**probability heuristic**). Of course all of these factors do not always appear alone, but they influence one another and can occur in combination during the process of reasoning.

Why inductive reasoning at all?

All the described constraints show how prone to errors inductive reasoning is and so the question arises, why we use it at all? But inductive reasons are important nevertheless because they act as shortcuts for our reasoning. It is much easier and faster to apply the availability heuristic or the representativeness heuristic to a problem than to take into account all information concerning the current topic and draw a conclusion by using logical rules. In the following excerpt of very usual actions there is a lot of inductive reasoning involved although one does not realize it on the first view. It points out the importance of this cognitive ability:
The sunrise every morning and the sunset in the evening, the change of seasons, the TV program, the fact that a chair does not collapse when we sit on it or the light bulb that flashes after we have pushed a button.

All of these cases are conclusions derived from processes of inductive reasoning. Accordingly, one assumes that the chair one is sitting on does not collapse as the chairs on which one sat before did not collapse. This does not ensure that the chair does not break into pieces but nevertheless it is a rather helpful conclusion to assume that the chair remains stable as this is very probable. To sum it up, inductive reasoning is rather advantageous in situations where deductive reasoning is just not applicable because only evidence but no proved facts are available. As these situations occur rather often in everyday life, living without the use of inductive reasoning is inconceivable.

Induction vs. deduction

The table below (Figure 6) summarizes the most prevalent properties and differences between deductive and inductive reasoning which are important to keep in mind.

	Deductive Reasoning	Inductive Reasoning
Premises	Stated as facts or general principles ("It is warm in the summer in Spain.").	Based on observations of specific cases ("All crows Knut and his wife have seen are black.").
Conclusion	Conclusion is more special than the information the premises provide. It is reached directly by applying logical rules to the premises.	Conclusion is more general than the information the premises provide. It is reached by generalizing the premises` information.
Validity	If the premises are true, the conclusion must be true.	If the premises are true, the conclusion is probably true.
Usage	More difficult to use (mainly in logical problems). One needs facts which are definitely true.	Used often in everyday life (fast and easy). Evidence is used instead of proved facts.

Figure 6. Induction vs. Deduction

Decision making

According to the different levels of consequences, each process of making a decision requires appropriate effort and various aspects to be considered. The following excerpt from the story about Knut makes this obvious: "After considering facts like the warm weather in Spain and shirts and shorts being much more comfortable in this case (information gathering and likelihood estimation) Knut reasons that he needs them for his vacation. In consequence, he finally makes the decision to pack mainly shirts and shorts in his bag (final act of choosing)." Now it seems like there cannot be any decision making without previous reasoning, but that is not true. Of course there are situations in which someone decides to do something spontaneously, with no time to reason about it. We will not go into detail here but you might think about questions like *"Why do we choose one or another option in that case?"*

Choosing among alternatives

The psychological process of decision making constantly goes along with situations in daily life. Thinking about Knut again we can imagine him to decide between packing more blue or more green shirts for his vacation (which would only have minor consequences) but also about applying a specific job or having children with his wife (which would have relevant influence on important circumstances of his future life). The mentioned examples are both characterized by personal decisions, whereas professional decisions, dealing for example with economic or political issues, are just as important.

The utility approach

There are three different ways to analyze decision making. The normative approach assumes a rational decision-maker with well-defined preferences. While the rational choice theory is based on a priori considerations, the descriptive approach is based on empirical observations and on experimental studies of choice behavior. The prescriptive enterprise develops methods in order to improve decision making. According to Manktelow and Reber´s definition, "utility refers to outcomes that are desirable because they are in the person's best interest" (Reber, A. S., 1995; Manktelow, K., 1999). This normative/descriptive approach characterizes optimal decision making by the maximum expected utility in terms of monetary value. This approach can be helpful in gambling theories, but simultaneously includes several disadvantages. People do not necessarily focus on the monetary payoff, since they find value in things other than money, such as fun, free time, family, health and others. But that is not a big problem, because it is possible to apply the graph (Figure 7), which shows the relation between (monetary) gains/losses and their subjective value / utility, which is equal to all the valuable things mentioned above. Therefore, not choosing the maximal monetary value does not automatically describe an irrational decision process.

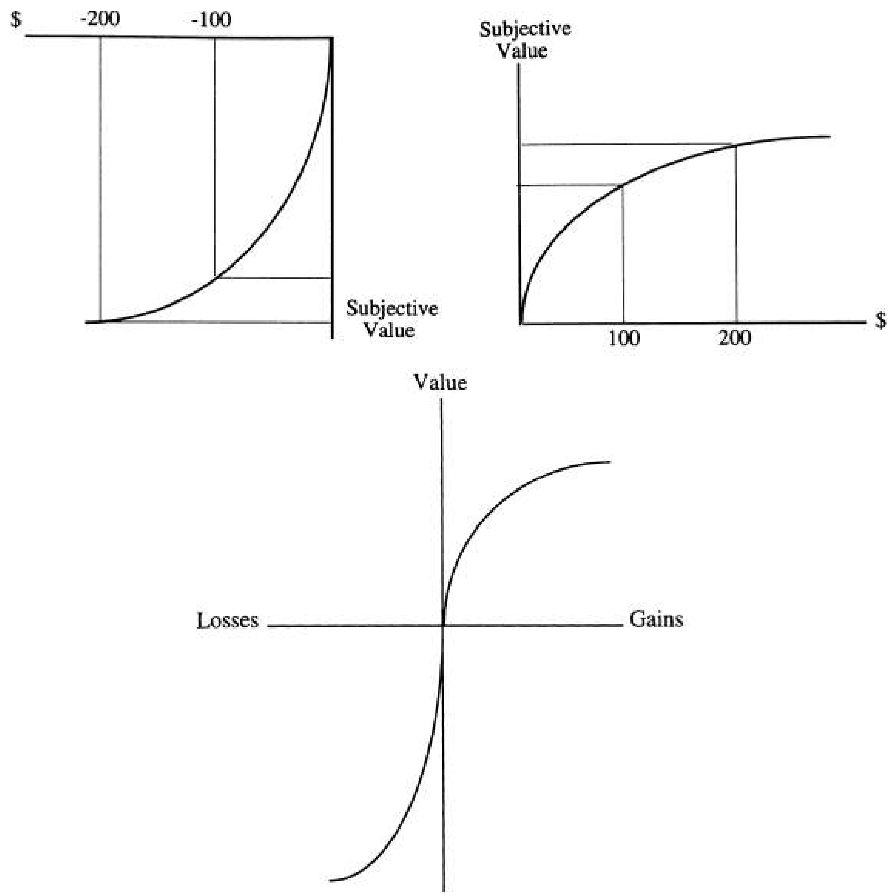


Figure 7. Relation between (monetary)

Misleading effects

But even respecting the considerations above there might still be problems to make the "right" decision because of different misleading effects, which mainly arise because of the constraints of inductive reasoning. In general this means that our model of a situation/problem might not be ideal to solve it in an optimal way. The following three points are typical examples for such effects.

Subjective models

This effect is rather equal to the illusory correlations mentioned before in the part about the constraints of inductive reasoning. It is about the problem that models which people create might be misleading, since they rely on subjective speculations. An example could be deciding where to move by considering typical prejudices of the countries (e.g. always good pizza, nice weather and a relaxed life-style in Italy in contrast to some kind of boring food and steady rain in Great Britain). The predicted events are not equal to the events occurring indeed. (Kahneman & Tversky, 1982; Dunning & Parpal, 1989)

Focusing illusion

Another misleading effect is the so-called **focusing illusion**. By considering only the most obvious aspects in order to make a certain decision (e.g. the weather) people often neglect various really important outcomes (e.g. circumstances at work). This effect occurs more often, if people judge about others compared with judgments about their own living.

Framing effect

A problem can be described in different ways and therefore evoke different decision strategies. If a problem is specified in terms of gains, people tend to use a risk-aversion strategy, while a problem description in terms of losses leads to apply a risk-taking strategy. An example of the same problem and predictably different choices is the following experiment: A group of people is asked to imagine themselves $300 richer than they are, is confronted with the choice of a sure gain of $100 or an equal chance to gain $200 or nothing. Most people avoid the risk and take the sure gain, which means they take the risk-aversion strategy. Alternatively if people are asked to assume themselves to be $500 richer than in reality, given the options of a sure loss of $100 or an equal chance to lose $200 or nothing, the majority opts for the risk of losing $200 by taking the risk seeking or risk-taking strategy. This phenomenon is known as **framing effect** and can also be illustrated by figure 8 above, which is a concave function for gains and a convex one for losses. (Foundations of Cognitive Psychology, Levitin, D. J., 2002)

Justification in decision making

Decision making often includes the need to assign a reason for the decision and therefore justify it. This factor is illustrated by an experiment by A. Tversky and E. Shafir (1992): A very attractive vacation package has been offered to a group of students who have just passed an exam and to another group of students who have just failed the exam and have the chance to rewrite it after the holidays coming up. All students have the options to buy the ticket straight away, to stay at home, or to pay $5 for keeping the option open to buy it later. At this point, there is no difference between the two groups, since the number of students who passed the exam and decided to book the flight (with the justification of a deserving a reward), is the same as the number of students who failed and booked the flight (justified as consolation and having time for reoccupation). A third group of students who were informed to receive their results in two more days was confronted with the same problem. The majority decided to pay $5 and keep the option open until they would get their results. The conclusion now is that even though the actual exam result does not influence the decision, it is required in order to provide a rationale.

Executive functions

Subsequently, the question arises how this cognitive ability of making decisions is realized in the human brain. As we already know that there are a couple of different tasks involved in the whole process, there has to be something that coordinates and controls those brain activities – namely the executive functions. They are the brain's conductor, instructing other brain regions to perform, or be silenced, and generally coordinating their synchronized activity (Goldberg, 2001). Thus, they are responsible for optimizing the performance of all "multi-threaded" cognitive tasks.

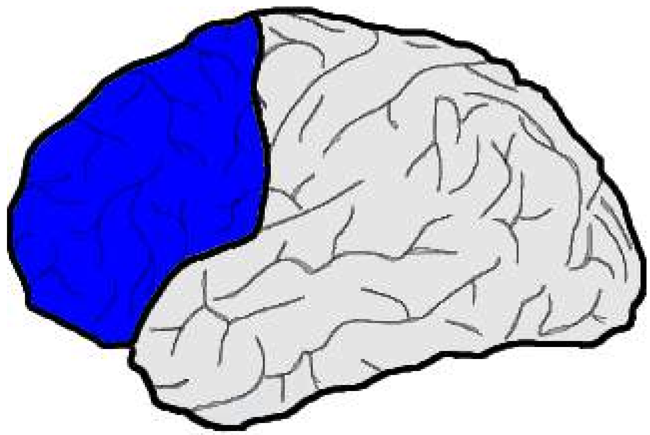


Figure 8. Left frontal lobe

Locating those executive functions is rather difficult, as they cannot be appointed to a single brain region. Traditionally, they have been equated with the frontal lobes, or rather the prefrontal regions of the frontal lobes; but it is still an open question whether all of their aspects can be associated with these regions.
Nevertheless, we will concentrate on the prefrontal regions of the frontal lobes, to get an impression of the important role of the executive functions within cognition. Moreover, it is possible to subdivide these regions into functional parts. But it is to be noted that not all researchers regard the prefrontal cortex as containing functionally different regions.

Executive functions in practice

According to Norman and Shallice, there are five types of situations in which executive functions may be needed in order to optimize performance, as the automatic activation of behavior would be insufficient. These are situations involving...

1. planning or decision making.
2. error correction or trouble shooting.
3. responses containing novel sequences of actions.
4. technical difficulties or dangerous circumstances.
5. the control of action or the overcoming of strong habitual responses.

The following parts will have a closer look to each of these points, mainly referring to brain-damaged individuals. Surprisingly, intelligence in general is not affected in cases of frontal lobe injuries (Warrington, James & Maciejewski, 1986). However, dividing intelligence into crystallised intelligence (based on previously acquired knowledge) and fluid intelligence (meant to rely on the current ability of solving problems), emphasizes the executive power of the frontal lobes, as patients with lesions in these regions performed significantly worse in tests of fluid intelligence (Duncan, Burgess & Emslie, 1995).

1. Planning or decision making: Impairments in abstract and conceptual thinking

To solve many tasks it is important that one is able to use given information. In many cases, this means that material has to be processed in an abstract rather than in a concrete manner. Patients with executive dysfunction have abstraction difficulties. This is proven by a card sorting experiment (Delis et al., 1992): The cards show names of animals and black or white triangles placed above or below the word. Again, the cards can be sorted with attention to different attributes of the animals (living on land or in water, domestic or dangerous, large or small) or the triangles (black or white, above or below word). People with frontal lobe damage fail to solve the task because they cannot even conceptualize the properties of the animals or the triangles, thus are not able to deduce a sorting-rule for the cards (in contrast, there are some individuals only perseverating; they find a sorting-criterion but are unable to switch to a new one). These problems might be due to a general difficulty in strategy formation.

Goal directed behavior

Let us again take Knut into account to get an insight into the field of goal directed behavior – in principle, this is nothing but problem solving since it is about organizing behavior towards a goal. Thus, when Knut is packing his bag for his holiday, he obviously has a goal in mind (in other words: He wants to solve a problem) – namely get ready before the plane starts. There are several steps necessary during the process of reaching a certain goal:

Goal must be kept in mind:

Knut should never forget that he has to pack his bag in time.

Dividing into subtasks and sequencing:

Knut packs his bag in a structured way. He starts packing the crucial things and then goes on with rest.

Completed portions must be kept in mind:

If Knut already packed enough underwear into his bag, he would not need to search for more.

Flexibility and adaptability:

Imagine that Knut wants to pack his favourite T-Shirt, but he realizes that it is dirty. In this case, Knut has to adapt to this situation and has to pick another T-Shirt that was not in his plan originally.

Evaluation of actions:

Along the way of reaching his ultimate goal Knut constantly has to evaluate his performance in terms of ‘How am I doing considering that I have the goal of packing my bag?’.

Executive dysfunction and goal directed behavior

The breakdown of executive functions impairs goal directed behavior to a large extend. In which way cannot be stated in general, it depends on the specific brain regions that are damaged. So it is quite possible that an individual with a particular lesion has problems with two or three of the five points described above and performs within average regions when the other abilities are tested. However, if only one link is missing from the chain, the whole plan might get very hard or even impossible to master. Furthermore, the particular hemisphere affected plays a role as well.

Another interesting result was the fact that lesions in the frontal lobes of left and right hemisphere impaired different abilities. While a lesion in the right hemisphere caused trouble in making regency judgements, a lesion in the left hemisphere impaired the patient's performance only when the presented material was verbal or in a variation of the experiment that required self-ordered sequencing. Because of that we know that the ability to sequence behavior is not only located in the frontal lobe but in the left hemisphere particularly when it comes to motor action.

Problems in sequencing

In an experiment by Milner (1982), people were shown a sequence of cards with pictures. The experiment included two different tasks: recognition trials and recency trials. In the former the patients were shown two different pictures, one of them has appeared in the sequence before, and the participants had to decide which one it was. In the latter they were shown two different pictures, both of them have appeared before, they had to name the picture that was shown more recently than the other one.

The results of this experiment showed that people with lesions in temporal regions have more trouble with the recognition trial and patients with frontal lesions have difficulties with the recency trial since anterior regions are important for sequencing. This is due to the fact that the recognition trial demanded a properly functioning recognition memory [3], the recency trial a properly functioning memory for item order [3]. These two are dissociable and seem to be processed in different areas of the brain. The frontal lobe is not only important for sequencing but also thought to play a major role for working memory [3] . This idea is supported by the fact that lesions in the lateral regions of the frontal lobe are much more likely to impair the ability of 'keeping things in mind' than damage to other areas of the frontal cortex do. But this is not the only thing there is to sequencing. For reaching a goal in the best possible way it is important that a person is able to figure out which sequence of actions, which strategy, best suits the purpose, in addition to just being able to develop a correct sequence.

This is proven by an experiment called 'Tower of London' (Shallice, 1982) which is similar to the famous 'Tower of Hanoi' [4] task with the difference that this task required three balls to be put onto three poles of different length so that one pole could hold three balls, the second one two and the third one only one ball, in a way that a changeable goal position is attained out of a fixed initial position in as few moves as possible. Especially patients with damage to the left frontal lobe proved to work inefficiently and ineffectively on this task. They needed many moves and engaged in actions that did not lead toward the goal.

Problems with the interpretation of available information
Quite often, if we want to reach a goal, we get hints on how to do it best. This means we have to be able to interpret the available information in terms of what the appropriate strategy would be. For many patients of executive dysfunction this is not an easy thing to do either. They have trouble to use this information and engage in inefficient actions. Thus, it will take them much longer to solve a task than healthy people who use the extra information and develop an effective strategy.

Problems with self-criticism and -monitoring
The last problem for people with frontal lobe damage we want to present here is the last point in the above list of properties important for proper goal directed behavior. It is the ability to evaluate one's actions, an ability that is missing in most patients. These people are therefore very likely to 'wander off task' and engage in behavior that does not help them to attain their goal. In addition to that, they are also not able to determine whether their task is already completed at all. Reasons for this are thought to be a lack of motivation or lack of concern about one's performance (frontal lobe damage is usually accompanied by changes in emotional processing) but these are probably not the only explanations for these problems. Another important brain region in this context – the medial portion of the frontal lobe – is responsible for detecting behavioral errors made while working towards a goal. This has been shown by ERP experiments [5] where there was an error-related negativity 100ms after an error has been made. If this area is damaged, this mechanism cannot work properly anymore and the patient loses the ability to detect errors and thus monitor his own behavior. However, in the end we must add that although executive dysfunction causes an enormous number of problems in behaving correctly towards a goal, most patients when assigned with a task are indeed anxious to solve it but are just unable to do so.

2. Error correction and trouble shooting
The most famous experiment to investigate error correction and trouble shooting is the Wisconsin Card Sorting Test (WCST). A participant is presented with cards that show certain objects. These cards are defined by shape, color and number of the objects on the cards. These cards now have to be sorted according to a rule based on one of these three criteria. The participant does not know which rule is the right one but has to reach the conclusion after positive or negative feedback of the experimenter. Then at some point, after the participant has found the correct rule to sort the cards, the experimenter changes the rule and the previous correct sorting will lead to negative feedback. The participant has to realize the change and adapt to it by sorting the cards according to the new rule.

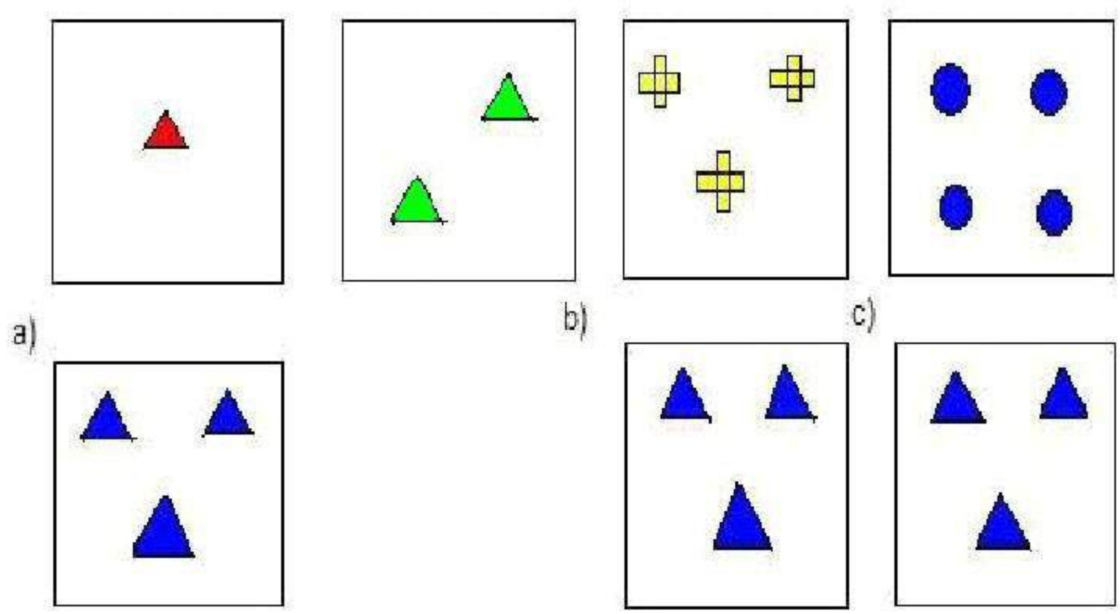


Figure 9. Example for the WCST: Cards sorted according to shape (a), number (b) or color (c) of the objects

Patients with executive dysfunction have problems identifying the rule in the first place. It takes them noticeably longer because they have trouble using already given information to make a conclusion. But once they got to sorting correctly and the rule changes, they keep sorting the cards according to the old rule although many of them notice the negative feedback. They are just not able to switch to another sorting-principle, or at least they need many tries to learn the new one. They **perseverate**.

Problems in shifting and modifying strategies

Intact neuronal tissue in the frontal lobe is also crucial for another executive function connected with goal directed behavior that we described above: Flexibility and adaptability. This means that persons with frontal lobe damage will have difficulties in shifting their way of thinking – meaning creating a new plan after recognizing that the original one cannot becarried out for some reason. Thus, they are not able to modify their strategy according to this new problem. Even when it is clear that one hypothesis cannot be the right one to solve a task, patients will stick to it nevertheless and are unable to abandon it (called 'tunnel vision'). Moreover, such persons do not use as many appropriate hypotheses for creating a strategy as people with damage to other brain regions do. In what particular way this can be observed in patients can again not be stated in general but depends on the nature of the shift that has to be made.

These earlier described problems of 'redirecting' of one's strategies stand in contrast to the atcual 'act of switching' between tasks. This is yet another problem for patients with frontal lobe damage. Since the control system that leads task switching as such is independent from the parts that actually perform these tasks, the task switching is particularly impaired in patients with lesions to the dorsolateral prefrontal cortex while at the same time they have no trouble with performing the single tasks alone. This of course, causes a lot of problems in goal directed behavior because as it was said before: Most tasks consist of smaller subtasks that have to be completed.

3. Responses containing novel sequences of actions

Many clinical tests have been done, requiring patients to develop strategies for dealing with novel situations. In the Cognitive Estimation Task (Shallice & Evans, 1978) patients are presented with questions whose answers are unlikely to be known. People with damage to the prefrontal cortex have major difficulties to produce estimates for questions like: "How many camels are in Holland?". In the FAS Test (Miller, 1984) subjects have to generate sequences of words (not proper names) beginning with a certain letter ("F" , "A" or "S") in a one-minute period. This test involves developing new strategies, selecting between alternatives and avoiding repeating previous given answers. Patients with left lateral prefrontal lesions are often impaired (Stuss et al., 1998).

4. Technical difficulties or dangerous circumstances

One single mistake in a dangerous situation may easily lead to serious injuries while a mistake in a technical difficult situation (e.g. building a house of cards) would obviously lead to failure. Thus, in such situations, automatic activation of responses clearly would be insufficient and executive functions seem to be the only solution for such problems. Wilkins, Shallice and McCarthy (1987) were able to prove a connection between dangerous or difficult situations and the prefrontal cortex, as patients with lesions to this area were impaired during experiments concerning dangerous or difficult situations. The ventromedial and orbitofrontal cortex may be particularly important for these aspects of executive functions.

5. Control of action or the overcoming of strong habitual responses

Deficits in initiation, cessation and control of action

We start by describing the effects of the loss of the ability to start something, to initiate an action. A person with executive dysfunction is likely to have trouble beginning to work on a task without strong help from the outside, while people with left frontal lobe damage often show impaired spontaneous speech and people with right frontal lobe damage rather show poor nonverbal fluency. Of course, one reason is the fact that this person will not have any intention, desire or concern on his or her own of solving the task since this is yet another characteristic of executive dysfunction. But it is also due to a psychological effect often connected with the loss of properly executive functioning: Psychological inertia. Like in physics, inertia in this case means that an action is very hard to initiate, but once started, it is again very hard to shift or stop. This phenomenon is characterized by engagement in repetitive behavior, is called perseveration (cp. WCST [6]).

Another problem caused by executive dysfunction can be observed in patients suffering from the so called **environmental dependency syndrome**. Their actions are impelled or obligated by their physical or social environment. This manifests itself in many different ways and depends to a large extent on the individual's personal history. Examples are patients who begin to type

when they see a computer key board, who start washing the dishes upon seeing a dirty kitchen or who hang up pictures on the walls when finding hammer, nails and pictures on the floor. This makes these people appear as if they were acting impulsively or as if they have lost their 'free will'. It shows a lack of control for their actions. This is due to the fact that an impairment in their executive functions causes a disconnection between thought and action. These patients know that their actions are inappropriate but like in the WCST, they cannot control what they are doing. Even if they are told by which attribute to sort the cards, they will still keep sorting them sticking to the old rule due to major difficulties in the translation of these directions into action.
What is needed to avoid problems like these are the abilities to start, stop or change an action but very likely also the ability to use information to direct behavior.

Deficits in cognitive estimation
Next to the difficulties to produce estimates to questions whose answers are unlikely known, patients with lesions to the frontal lobes have problems with cognitive estimation in general. Cognitive estimation is the ability to use known information to make reasonable judgments or deductions about the world. Now the inability for cognitive estimation is the third type of deficits often observed in individuals with executive dysfunction. It is already known that people with executive dysfunction have a relatively unaffected knowledge base. This means they cannot retain knowledge about information or at least they are unable to make inferences based on it. There are various effects which are shown on such individuals. Now for example patients with frontal lobe damage have difficulty estimating the length of the spine of an average woman.

Making such realistic estimations requires inferencing based on other knowledge which is in this case, knowing that the height of the average woman is about 5ft 6 in (168cm) and considering that the spine runs about one third to one half the length of the body and so on. Patients with such a dysfunction do not only have difficulties in their estimates of cognitive information but also in their estimates of their own capacities (such as their ability to direct activity in goal – oriented manner or in controlling their emotions). Prigatuno, Altman and O'Brien (1990) reported that when patients with anterior lesions associated with diffuse axonal injury to other brain areas are asked how capable they are of performing tasks such as scheduling their daily activities or preventing their emotions from affecting daily activities, they grossly overestimate their abilities. From several experiments Smith and Miler (1988) found out that individuals with frontal lobe damages have no difficulties in determining whether an item was in a specific inspection series they find it difficult to estimate how frequently an item did occur. This may not only reflect difficulties in cognitive estimation but also in memory task that place a premium on remembering temporal information. Thus both difficulties (in cognitive estimation and in temporal sequencing) may contribute to a reduced ability to estimate frequency of occurrence.

Despite these impairments in some domains the abilities of estimation are preserved in patients with frontal lobe damage. Such patients also do have problems in estimating how well they can prevent their emotions for affecting their daily activities. They are also as good at judging how many dues they will need to solve a puzzle as patients with temporal lobe damage or neurologically intact people.

Theories of frontal lobe function in executive control

In order to explain that patients with frontal lobe damage have difficulties in performing executive functions, four major approaches have developed. Each of them leads to an improved understanding of the role of frontal regions in executive functions, but none of these theories covers all the deficits occurred.

Role of working memory

The most anatomically specific approach assumes the dorsolateral prefrontal area of the frontal lobe to be critical for working memory. The working memory which has to be clearly distinguished from the long term memory keeps information on-line for use in performing a task. Not being generated for accounting for the broad array of dysfunctions it focuses on the three following deficits:

1. Sequencing information and directing behavior toward a goal
2. Understanding of temporal relations between items and events
3. Some aspects of environmental dependency and perseveration

Research on monkeys has been helpful to develop this approach (the delayed-response paradigm, Goldman-Rakic, 1987, serves as a classical example).

Role of Controlled Versus Automatic Processes

There are two theories based on the underlying assumption that the frontal lobes are especially important for controlling behavior in non-experienced situations and for overriding stimulus-response associations, but contribute little to automatic and effortless behavior (Banich, 1997). Stuss and Benson (1986) consider control over behavior to occur in a hierarchical manner. They distinguish between three different levels, of which each is associated with a particular brain region. In the first level sensory information is processed automatically by posterior regions, in the next level (associated with the executive functions of the frontal lobe) conscious control is needed to direct behavior toward a goal and at the highest level controlled self-reflection takes place in the prefrontal cortex. This model is appropriate for explaining deficits in goal-oriented behavior, in dealing with novelty, the lack of cognitive flexibility and the environmental dependency syndrome. Furthermore it can explain the inability to control action consciously and to criticise oneself. The second model developed by Shalice (1982) proposes a system consisting of two parts that influence the choice of behavior. The first part, a cognitive system called contention scheduling, is in charge of more automatic processing. Various links and processing schemes cause a single stimulus to result in an automatic string of actions. Once an action is initiated, it remains active until inhibited. The second cognitive system is the supervisory attentional system which directs attention and guides action through decision processes and is only active "when no processing schemes are available, when the task is technically difficult, when problem solving is required and when certain response tendencies must be overcome” (Banich , 1997). This theory supports the observations of few deficits in routine situations, but relevant problems in dealing with novel tasks (e.g. the Tower of London task, Shallice, 1982), since no schemes in contention scheduling exist for dealing with it. Impulsive action is another characteristic of patients with frontal lobe damages which can be explained by this theory. Even if asked not to do certain things, such patients stick to their routines and cannot control their automatic behavior.

Use of Scripts

The approach based on scripts, which are sets of events, actions and ideas that are linked to form a unit of knowledge was developed by Schank (1982) amongst others. Containing information about the setting in which an event occurs, the set of events needed to achieve the goal and the end event terminating the action. Such managerial knowledge units (MKUs) are supposed to be stored in the prefrontal cortex. They are organized in a hierarchical manner being abstract at the top and getting more specific at the bottom. Damage of the scripts leads to the inability to behave goal-directed, finding it easier to cope with usual situations (due to the difficulty of retrieving a MKU of a novel event) and deficits in the initiation and cessation of action (because of MKUs specifying the beginning and ending of an action.)

Role of a goal list

The perspective of artificial intelligence and machine learning introduced an approach which assumes that each person has a goal list, which contains the tasks requirements or goals. This list is fundamental to guiding behavior and since frontal lobe damages disrupt the ability to form a goal list, the theory helps to explain difficulties in abstract thinking, perceptual analysis, verbal output and staying on task. It can also account for the strong environmental influence on patients with frontal lobe damages, due to the lack of internal goals and the difficulty of organizing actions toward a goal.

Brain Region	Possible Function (left hemisphere)	Possible Function (right hemisphere)	Brodman's Areas which are involved
ventrolateral prefrontal cortex (VLPFC)	Retrieval and maintenance of semantic and/or linguistic information	Retrieval and maintenance of visuospatial information	*44, 45, 47 (44 & 45 = Broca's Area)*
dorsolateral prefrontal cortex)DLPRF)	Selecting a range of responses and suppressing inappropriate ones; manipulating the contents of working memory	Monitoring and checking of information held in mind, particularly in conditions of uncertainty; vigilance and sustained attention	*9, 46*
anterior prefrontal cortex; frontal pole; rostral prefrontal cortex	Multitasking; maintaining future intentions & goals while currently performing other tasks or subgoals	Same	*10*

Table 3

Summary

It is important to keep in mind that reasoning and decision making are closely connected to each other: Decision making in many cases happens with a previous process of reasoning. People's everyday life is decisively coined by the synchronized appearance of these two human cognitive features. This synchronization, in turn, is realized by the executive functions which seem to be mainly located in the frontal lobes of the brain.

Deductive Reasoning + Inductive Reasoning

There is more than one way to start with information and arrive at an inference; thus, there is more than one way to reason. Each has its own strengths, weaknesses, and applicability to the real world.

Deduction

In this form of reasoning a person starts with a known claim or general belief, and from there determines what follows. Essentially, deduction starts with a hypothesis and examines the possibilities within that hypothesis to reach a conclusion. Deductive reasoning has the advantage that, if your original premises are true in all situations and your reasoning is correct, your conclusion is guaranteed to be true. However, deductive reasoning has limited applicability in the real world because there are very few premises which are guaranteed to be true all of the time.

A syllogism is a form of deductive reasoning in which two statements reach a logical conclusion. An example of a syllogism is, “All dogs are mammals; Kirra is a dog; therefore, Kirra is a mammal.”

Induction

Inductive reasoning makes broad inferences from specific cases or observations. In this process of reasoning, general assertions are made based on specific pieces of evidence. Scientists use inductive reasoning to create theories and hypotheses. An example of inductive reasoning is, "The sun has risen every morning so far; therefore, the sun rises every morning." Inductive reasoning is more practical to the real world because it does not rely on a known claim; however, for this same reason, inductive reasoning can lead to faulty conclusions. A faulty example of inductive reasoning is, "I saw two brown cats; therefore, the cats in this neighborhood are brown."

Sherlock Holmes, master of reasoning: In this video, we see the famous literary character Sherlock Holmes use both inductive and deductive reasoning to form inferences about his friends. As you can see, inductive reasoning can lead to erroneous conclusions. Can you distinguish between his deductive (general to specific) and inductive (specific to general) reasoning?

Propositional Reasoning:

Cindy Sifonis is a professor of psychology at Oakland University, listen to her 4:44 min podcast on Propositional Reasoning **to better understand the role it plays in cognitive psychology.**

Venn Diagrams

To visualize the interaction of sets, John Venn in 1880 thought to use overlapping circles, building on a similar idea used by Leonhard Euler in the 18th century. These illustrations now called **Venn Diagrams**.

A Venn diagram represents each set by a circle, usually drawn inside of a containing box representing the universal set. Overlapping areas indicate elements common to both sets.
Basic Venn diagrams can illustrate the interaction of two or three sets.

Example 1

Create Venn diagrams to illustrate $A \cup B$, $A \cap B$, and $Ac \cap B$
$A \cup B$ contains all elements in *either* set.

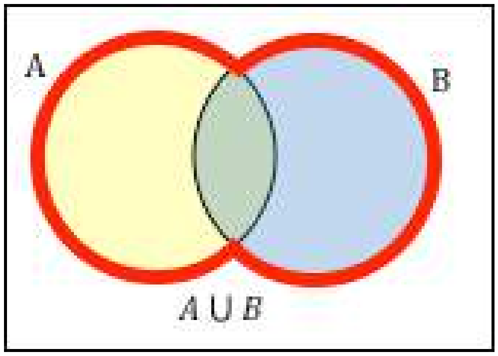


Figure 10. Circles A & B

$A \cap B$ contains only those elements in both sets – in the overlap of the circles.

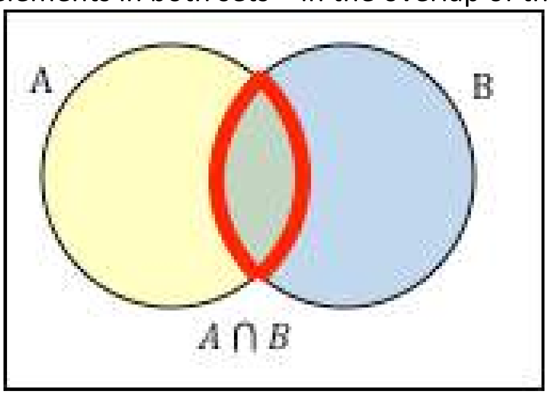


Figure 11. Circles A & B

Ac will contain all elements *not* in the set A. $A^c \cap B$ will contain the elements in set *B* that are not in set *A*.

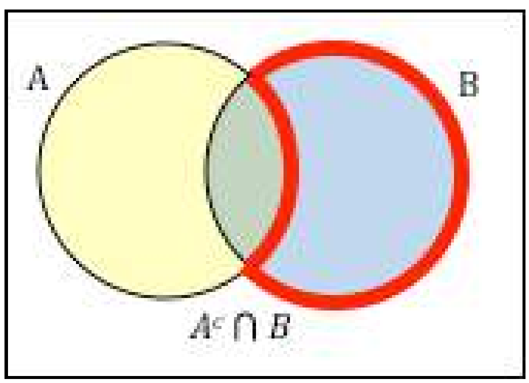


Figure 12. Circles A & B

Example 2

Use a Venn diagram to illustrate $(H \cap F)c \cap W$

We'll start by identifying everything in the set $H \cap F$

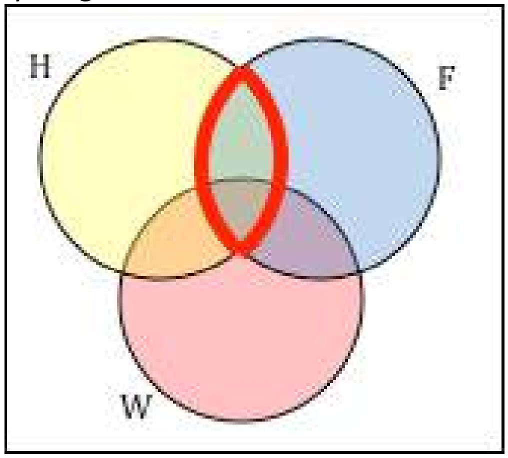


Figure 13. Circles H, F, & W

Now, $(H \cap F)c \cap W$ will contain everything *not* in the set identified above that is also in set *W*.

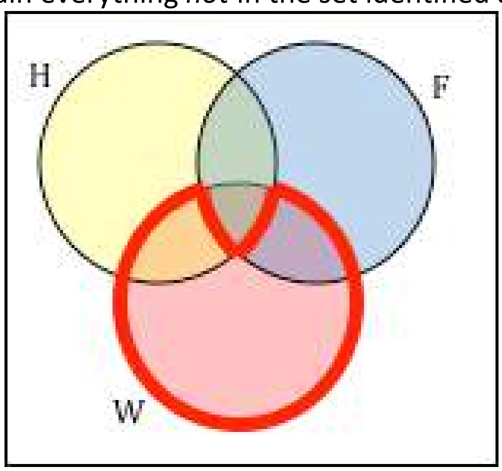


Figure 14. Circles H, F, & W

Example 3

Create an expression to represent the outlined part of the Venn diagram shown.

The elements in the outlined set *are* in sets *H* and *F*, but are not in set *W*. So we could represent this set as $H \cap F \cap W^c$

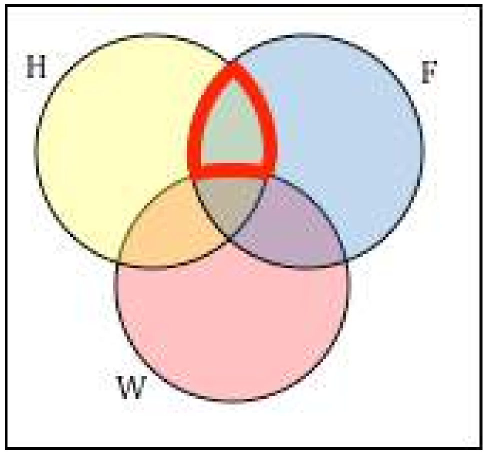


Figure 15. Circles H, F, & W

Try it Now

Create an expression to represent the outlined portion of the Venn diagram shown

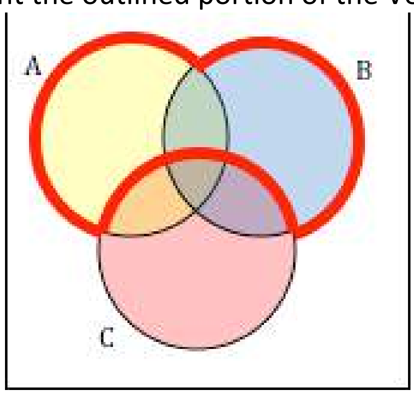


Figure 16. Circles A, B, & C

Syllogisms

Syllogisms are an example of Deductive reasoning. Deductive reasoning derives specifics from what is already known. It was the preferred form of reasoning used by ancient rhetoricians like Aristotle to make logical arguments. A **syllogism** is an example of deductive reasoning that is commonly used when teaching logic. A syllogism is an example of deductive reasoning in which a conclusion is supported by major and minor premises. The conclusion of a valid argument can be deduced from the major and minor premises. A commonly used example of a syllogism is "All humans are mortal. Socrates is a human. Socrates is mortal." In this case, the conclusion, "Socrates is mortal," is derived from the major premise, "All humans are mortal," and the minor premise, "Socrates is a human." In some cases, the major and minor premises of a syllogism may be taken for granted as true. In the previous example, the major premise is presumed true because we have no knowledge of an immortal person to disprove the statement. The minor premise is presumed true because Socrates looks and acts like other individuals we know to be human. Detectives or scientists using such logic would want to test their conclusion. We could test our conclusion by stabbing Socrates to see if he dies, but since the logic of the syllogism is sound, it may be better to cut Socrates a break and deem the argument valid. Since most arguments are more sophisticated than the previous example, speakers need to support their premises with research and evidence to establish their validity before deducing their conclusion.

A syllogism can lead to incorrect conclusions if one of the premises isn't true, as in the following example:

- All presidents have lived in the White House. (Major premise)
- George Washington was president. (Minor premise)
- George Washington lived in the White House. (Conclusion)

In the previous example, the major premise was untrue, since John Adams, our second president, was the first president to live in the White House. This causes the conclusion to be false. A syllogism can also exhibit faulty logic even if the premises are both true but are unrelated, as in the following example:

- Penguins are black and white. (Major premise)
- Some old television shows are black and white. (Minor premise)
- Some penguins are old television shows. (Conclusion)

Figure 17. Like in the game of Clue, real-life detectives use deductive reasoning to draw a conclusion about who committed a crime based on the known evidence. Sleepmyf – Lego detective – CC BY-NC-ND 2.0.

Chapter 9 - Decision Making

Representativeness

Humans pay particular attention to stimuli that are salient—things that are unique, negative, colorful, bright, and moving. In many cases, we base our judgments on information that seems to represent, or match, what we expect will happen. When we do so, we are using the representativeness heuristic.

Cognitive accessibility refers to the extent to which knowledge is activated in memory and thus likely to be used to guide our reactions to others. The tendency to overuse accessible social constructs can lead to errors in judgment, such as the availability heuristic and the false consensus bias. Counterfactual thinking about what might have happened and the tendency to anchor on an initial construct and not adjust sufficiently from it are also influenced by cognitive accessibility.

You can use your understanding of social cognition to better understand how you think accurately—but also sometimes inaccurately—about yourself and others.

Availability

Although which characteristics we use to think about objects or people is determined in part by the salience of their characteristics (our perceptions are influenced by our social situation), individual differences in the person who is doing the judging are also important (our perceptions are influenced by person variables). People vary in the schemas that they find important to use when judging others and when thinking about themselves. One way to consider this importance is in terms of the *cognitive accessibility* of the schema. Cognitive accessibility refers to *the extent to which a schema is activated in memory and thus likely to be used in information processing*.

You probably know people who are golf nuts (or maybe tennis or some other sport nuts). All they can talk about is golf. For them, we would say that golf is a highly accessible construct. Because they love golf, it is important to their self-concept; they set many of their goals in terms of the sport, and they tend to think about things and people in terms of it ("if he plays golf, he must be a good person!"). Other people have highly accessible schemas about eating healthy food, exercising, environmental issues, or really good coffee, for instance. In short, when a schema is accessible, we are likely to use it to make judgments of ourselves and others.

Although accessibility can be considered a person variable (a given idea is more highly accessible for some people than for others), accessibility can also be influenced by situational factors. When we have recently or frequently thought about a given topic, that topic becomes more accessible and is likely to influence our judgments. This is in fact the explanation for the results of the priming study you read about earlier—people walked slower because the concept of elderly had been primed and thus was currently highly accessible for them.

Because we rely so heavily on our schemas and attitudes—and particularly on those that are salient and accessible—we can sometimes be overly influenced by them. Imagine, for instance, that I asked you to close your eyes and determine whether there are more words in the English language that begin with the letter *R* or that have the letter *R* as the third letter. You would probably try to solve this problem by thinking of words that have each of the characteristics. It turns out that most people think there are more words that begin with *R*, even though there are in fact more words that have *R* as the third letter.

You can see that this error can occur as a result of cognitive accessibility. To answer the question, we naturally try to think of all the words that we know that begin with *R* and that have *R* in the third position. The problem is that when we do that, it is much easier to retrieve the former than the latter, because we store words by their first, not by their third, letter. We may also think that our friends are nice people because we see them primarily when they are around us (their friends). And the traffic might seem worse in our own neighborhood than we think it is in other places, in part because nearby traffic jams are more accessible for us than are traffic jams that occur somewhere else. And do you think it is more likely that you will be killed in a plane crash or in a car crash? Many people fear the former, even though the latter is much more likely: Your chances of being involved in an aircraft accident are about 1 in 11 million, whereas your chances of being killed in an automobile accident are 1 in 5,000—over 50,000 people are killed on U.S. highways every year.

In this case, the problem is that plane crashes, which are highly salient, are more easily retrieved from our memory than are car crashes, which are less extreme.

The tendency to make judgments of the frequency of an event, or the likelihood that an event will occur, on the basis of the ease with which the event can be retrieved from memory is known as the availability heuristic (Schwarz & Vaughn, 2002; Tversky & Kahneman, 1973).

The idea is that things that are highly accessible (in this case, the term *availability* is used) come to mind easily and thus may overly influence our judgments. Thus, despite the clear facts, it may be easier to think of plane crashes than of car crashes because the former are so highly salient. If so, the availability heuristic can lead to errors in judgments.

Still another way that the cognitive accessibility of constructs can influence information processing is through their effects on *processing fluency*. Processing fluency refers to *the ease with which we can process information in our environments*. When stimuli are highly accessible, they can be quickly attended to and processed, and they therefore have a large influence on our perceptions. This influence is due, in part, to the fact that our body reacts positively to information that we can process quickly, and we use this positive response as a basis of judgment (Reber, Winkielman, & Schwarz, 1998; Winkielman & Cacioppo, 2001).

In one study demonstrating this effect, Norbert Schwarz and his colleagues (Schwarz et al., 1991) asked one set of college students to list 6 occasions when they had acted either *assertively*or *unassertively* and asked another set of college students to list 12 such examples. Schwarz determined that for most students, it was pretty easy to list 6 examples but pretty hard to list 12.

The researchers then asked the participants to indicate how assertive or unassertive they actually were. You can see from Figure 1 "Processing Fluency" that the ease of processing influenced judgments. The participants who had an easy time listing examples of their behavior (because they only had to list 6 instances) judged that they did in fact have the characteristics they were asked about (either assertive or unassertive), in comparison with the participants who had a harder time doing the task (because they had to list 12 instances). Other research has found similar effects—people rate that they ride their bicycles more often after they have been asked to recall only a few rather than many instances of doing so (Aarts & Dijksterhuis, 1999), and they hold an attitude with more confidence after being asked to generate few rather than many arguments that support it (Haddock, Rothman, Reber, & Schwarz, 1999).

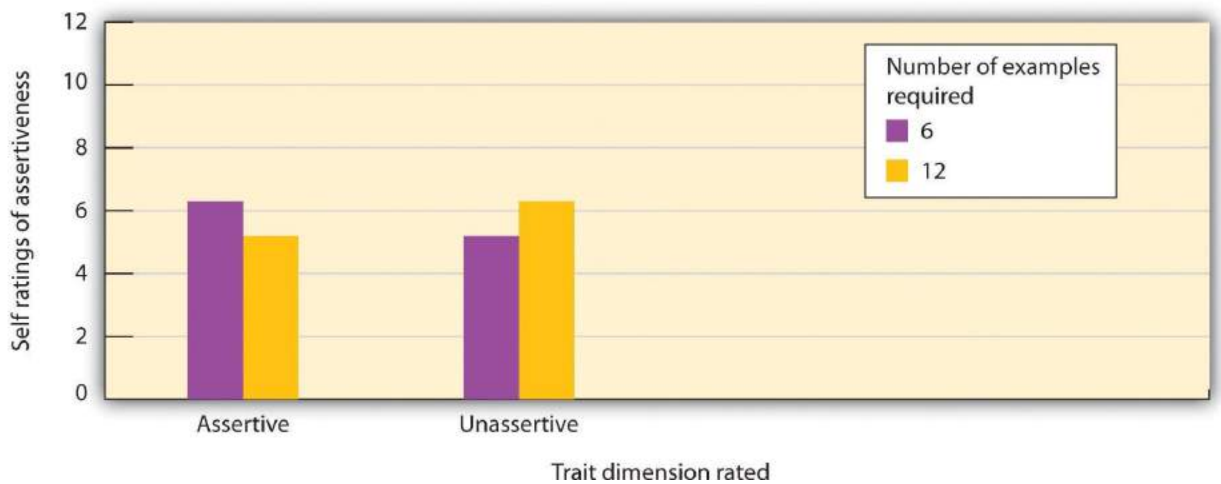


Figure 1. Processing Fluency

When it was relatively easy to complete the questionnaire (only 6 examples were required), the student participants rated that they had more of the trait than when the task was more difficult (12 answers were required). Data are from Schwarz et al. (1991).
We are likely to use this type of quick and "intuitive" processing, based on our feelings about how easy it is to complete a task, when we don't have much time or energy for more in-depth processing, such as when we are under time pressure, tired, or unwilling to process the stimulus in sufficient detail. Of course, it is very adaptive to respond to stimuli quickly (Sloman, 2002; Stanovich & West, 2002; Winkielman, Schwarz, & Nowak, 2002), and it is not impossible that in at least some cases, we are better off making decisions based on our initial responses than on a more thoughtful cognitive analysis (Loewenstein, weber, Hsee, & Welch, 2001). For instance, Dijksterhuis, Bos, Nordgren, and van Baaren (2006) found that when participants were given tasks requiring decisions that were very difficult to make on the basis of a cognitive analysis of the problem, they made better decisions when they didn't try to analyze the details carefully but simply relied on their unconscious intuition.

In sum, people are influenced not only by the information they get but by how they get it. We are more highly influenced by things that are salient and accessible and thus easily attended to, remembered, and processed. On the other hand, information that is harder to access from memory, is less likely to be attended to, or takes more effort to consider is less likely to be used in our judgments, even if this information is statistically equally informative or even more informative.

Anchoring

How tall do you think Mt. Everest is? (Don't Google it—that kind of defeats the purpose) You probably don't know the exact number, but do you think it's taller or shorter than 150 feet? Assuming you said "taller"[1], make a guess. How tall do you think it is?

Figure 2. Mt. Everest

Mt. Everesrt is roughly 29,000 ft. in height.

How'd you do? If I were to guess, based on the psychology I'm about to share with you, you probably undershot it. Even if *you* didn't, *most people* would.[3] The reason is what's called the **anchoring heuristic**.

Back in the 1970s, Amos Tversky and Daniel Kahneman identified a few reliable **mental shortcuts** people use when they have to make judgments. Oh, you thought people were completely rational every time they make a decision? It's nice to think, but it's not always what happens. We're busy! We have lives! I can't sit around and do the math anytime I want to know how far away a stop sign is, so I make estimates based on pretty reliable rules of thumb. The tricks we use to do that are called *heuristics*.

The Basics of the Anchoring Heuristic

The basic idea of anchoring is that **when we're making a numerical estimate, we're often biased by the number we start at**. In the case of the *Mt. Everest* estimate, I gave you the starting point of 150 feet. You though "Well, it's taller than *that*," so you likely adjusted the estimate from 150 feet to something taller than that. The tricky thing, though, is that **we don't often adjust far enough away from the anchor**.

Let's jump into an alternate timeline and think about how things could have gone differently. Instead of starting you at 150 feet, this time I ask you whether Mt. Everest is taller or shorter than 300,000 feet. This time you'd probably end up at a final estimate that's *bigger* than the correct answer. The reason is you'd start at 300,000 and start adjusting down, but you'd probably stop before you got all the way down to the right answer.

Coming Up With Your Own Anchors

In general, this is a strategy that tends to work for people. After all, when we don't know an exact number, how are we *supposed* to figure it out? It seems pretty reasonable to start with a concrete anchor and go from there.

In fact, some research has shown that this is how people make these estimates when left to their own devices. Rather than work from an anchor that's *given* to them (like in the Mt. Everest example), people will make their own anchor—a "*self-generated anchor*."

For example, if you ask someone how many days it takes Mercury to orbit the sun, she'll likely to start at 365 (the number of days it takes Earth to do so) and then adjust downward. But of course, people usually don't adjust far enough.

Biased By Completely Arbitrary Starting Points

Figure 3. A game of Roulette

This paints an interesting picture of how we strive to be reasonable by adopting a pretty decent strategy for coming up with numerical estimates. When you think about, even though we're biased by the starting point, it sounds like a decent strategy. After all, you've got to start somewhere!

But what if the starting point is totally arbitrary? Sure, the "150 feet" anchor from before probably seems pretty arbitrary, but at the time you might have thought "Why would he have started me at 150 feet? It must be a meaningful starting point."

The truth is that **these anchors bias judgments even when everyone realizes how arbitrary they are**. To test this idea, one study asked people to guess the percentage of African countries

in the United Nations. To generate a starting point, though, the researchers spun a "Wheel-of-Fortune" type of wheel with numbers between 0 – 100.
For whichever number the wheel landed on, people said whether they thought the real answer was more or less than that number. Even these random anchors ended up biasing people's estimates. If the wheel had landed on 10, people tended to say about 25% of countries in the UN are African, but if the wheel had landed on 65, they tended to say about 45% of countries in the UN are African. That's a pretty big difference in estimates, and it comes from a random change in a completely arbitrary value.
People's judgments can even be biased by anchors based on their own social security numbers.

Biased By Numbers in the Air

Through all of these examples, the anchor has been a key part of the judgment process. That is, someone says "Is it higher or lower than this anchor?" and then you make a judgment. But what if the starting point is in the periphery?
Even when some irrelevant number is just hanging out in the environment somewhere, *it can still bias your judgments!* These have been termed "incidental anchors."

Figure 4. Restaurant seating

For example, participants in one study were given a description of a restaurant and asked to report how much money they would be willing to spend there. Two groups of people made this judgment, and the only difference between them is that for one group, the restaurant's name was "***Studio 17***" and for the other group, the restaurant's name was "***Studio 97***." When the restaurant was "*Studio 97*," people said they'd spend more money (an average of about $32) than when the restaurant was "*Studio 17*" (where they reported a willingness to spend about $24).

Other research has shown that people were willing to pay more money for a CD when a totally separate vendor was selling $80 sweatshirts, compared to when that other vendor was selling $10 sweatshirts.

In both of these examples, the anchor was completely *irrelevant* to the number judgments, and people weren't even necessarily *focused* on the anchor. Even still, just having a number in the environment could bias people's final judgments.

Raising the Anchor and Saying "Ahoy"

Across all of these studies, a consistent pattern emerges: even arbitrary starting points end up biasing numerical judgments. Whether we're judging prices, heights, ages, or percentages, the number we start at keeps us from reaching the most accurate final answer.

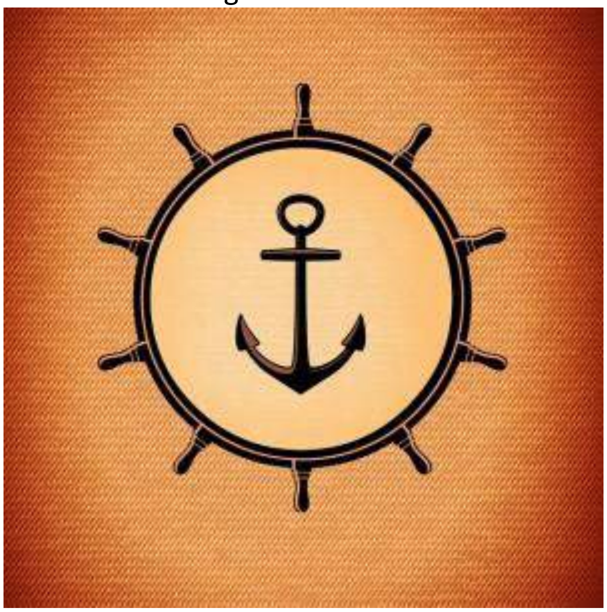


Figure 5. Lifting our mental anchors

This has turned out to be a well-studied phenomenon as psychologists have explored the limits of its effects. Some results have shown that anchoring effects depend on your personality, and others have shown that they depend on your mood.

In fact, there's still some debate over *how* anchoring works. Whereas some evidence argues for the original conception that people *adjust* their estimates from a starting point, others argue for a "selective accessibility" model in which people entertain a variety of specific hypotheses before settling on an answer. Still others have provided evidence suggesting that anchoring works similarly to persuasion.

Overall, however, the anchoring effect appears robust, and when you're in the throes of numerical estimates, think about whether your answer could have been biased by other numbers floating around.

Problem 2 (adapted from Joyce & Biddle, 1981):

We know that executive fraud occurs and that it has been associated with many recent financial scandals. And, we know that many cases of management fraud go undetected even when annual audits are performed. Do you think that the incidence of significant executive-level management fraud is more than 10 in 1,000 firms (that is, 1 percent) audited by Big Four accounting firms?

a. Yes, more than 10 in 1,000 Big Four clients have significant executive-level management fraud.
b. No, fewer than 10 in 1,000 Big Four clients have significant executive-level management fraud.

What is your estimate of the number of Big Four clients per 1,000 that have significant executive-level management fraud? (Fill in the blank below with the appropriate number.)
________ in 1,000 Big Four clients have significant executive-level management fraud.

Regarding the second problem, people vary a great deal in their final assessment of the level of executive-level management fraud, but most think that 10 out of 1,000 is too low. When I run this exercise in class, half of the students respond to the question that I asked you to answer. The other half receive a similar problem, but instead are asked whether the correct answer is higher or lower than 200 rather than 10. Most people think that 200 is high. But, again, most people claim that this "**anchor**" does not affect their final estimate. Yet, on average, people who are presented with the question that focuses on the number 10 (out of 1,000) give answers that are about one-half the size of the estimates of those facing questions that use an anchor of 200. When we are making decisions, any initial anchor that we face is likely to influence our judgments, even if the anchor is arbitrary. That is, we insufficiently adjust our judgments away from the anchor.

Framing

Problem 3 (adapted from Tversky & Kahneman, 1981):

Imagine that the United States is preparing for the outbreak of an unusual avian disease that is expected to kill 600 people. Two alternative programs to combat the disease have been proposed. Assume that the exact scientific estimates of the consequences of the programs are as follows.

1. Program A: If Program A is adopted, 200 people will be saved.
2. Program B: If Program B is adopted, there is a one-third probability that 600 people will be saved and a two-thirds probability that no people will be saved.

Which of the two programs would you favor?

Turning to Problem 3, most people choose Program A, which saves 200 lives for sure, over Program B. But, again, if I was in front of a classroom, only half of my students would receive this problem. The other half would have received the same set-up, but with the following two options:

1. Program C: If Program C is adopted, 400 people will die.
2. Program D: If Program D is adopted, there is a one-third probability that no one will die and a two-thirds probability that 600 people will die.

Which of the two programs would you favor?

Careful review of the two versions of this problem clarifies that they are objectively the same. Saving 200 people (Program A) means losing 400 people (Program C), and Programs B and D are also objectively identical. Yet, in one of the most famous problems in judgment and decision making, most individuals choose Program A in the first set and Program D in the second set (Tversky & Kahneman, 1981). People respond very differently to saving versus losing lives—even when the difference is based just on the "**framing**" of the choices.

The problem that I asked you to respond to was framed in terms of saving lives, and the implied reference point was the worst outcome of 600 deaths. Most of us, when we make decisions that concern gains, are risk averse; as a consequence, we lock in the possibility of saving 200 lives for sure. In the alternative version, the problem is framed in terms of losses. Now the implicit reference point is the best outcome of no deaths due to the avian disease. And in this case, most people are risk seeking when making decisions regarding losses.

These are just three of the many biases that affect even the smartest among us. Other research shows that we are biased in favor of information that is easy for our minds to retrieve, are insensitive to the importance of base rates and sample sizes when we are making inferences, assume that random events will always look random, search for information that confirms our expectations even when disconfirming information would be more informative, claim a priori knowledge that didn't exist due to the hindsight bias, and are subject to a host of other effects that continue to be developed in the literature (Bazerman & Moore, 2013).

Sunk Cost Effect

Sunk cost is a term used in economics referring to non-recoverable investments of time or money. The trap occurs when a person's aversion to loss impels them to throw good money after bad, because they don't want to waste their earlier investment. This is vulnerable to manipulation. The more time and energy a cult recruit can be persuaded to spend with the group, the more "invested" they will feel, and, consequently, the more of a loss it will feel to leave that group. Consider the advice of billionaire investor Warren Buffet: "When you find yourself in a hole, the best thing you can do is stop digging" (Levine, 2003).

Hindsight Bias

Hindsight bias is the opposite of overconfidence bias, as it occurs when looking backward in time where mistakes made seem obvious after they have already occurred. In other words, after a surprising event occurred, many individuals are likely to think that they already knew this was going to happen. This may be because they are selectively reconstructing the events. Hindsight bias becomes a problem especially when judging someone else's decisions. For example, let's say a company driver hears the engine making unusual sounds before starting her morning routine. Being familiar with this car in particular, the driver may conclude that the probability of a serious problem is small and continue to drive the car. During the day, the car malfunctions, stranding her away from the office. It would be easy to criticize her decision to continue to drive the car because, in hindsight, the noises heard in the morning would make us believe that she should have known something was wrong and she should have taken the car in for service. However, the driver may have heard similar sounds before with no consequences, so based on the information available to her at the time, she may have made a reasonable choice. Therefore, it is important for decision makers to remember this bias before passing judgments on other people's actions.

Illusory Correlations

The temptation to make erroneous cause-and-effect statements based on correlational research is not the only way we tend to misinterpret data. We also tend to make the mistake of illusory correlations, especially with unsystematic observations. **Illusory correlations**, or false correlations, occur when people believe that relationships exist between two things when no such relationship exists. One well-known illusory correlation is the supposed effect that the moon's phases have on human behavior. Many people passionately assert that human behavior is affected by the phase of the moon, and specifically, that people act strangely when the moon is full (Figure 3).

Figure 6. Many people believe that a full moon makes people behave oddly. (credit: Cory Zanker)

There is no denying that the moon exerts a powerful influence on our planet. The ebb and flow of the ocean's tides are tightly tied to the gravitational forces of the moon. Many people believe, therefore, that it is logical that we are affected by the moon as well. After all, our bodies are largely made up of water. A meta-analysis of nearly 40 studies consistently demonstrated, however, that the relationship between the moon and our behavior does not exist (Rotton & Kelly, 1985). While we may pay more attention to odd behavior during the full phase of the moon, the rates of odd behavior remain constant throughout the lunar cycle.

Why are we so apt to believe in illusory correlations like this? Often we read or hear about them and simply accept the information as valid. Or, we have a hunch about how something works and then look for evidence to support that hunch, ignoring evidence that would tell us our hunch is false; this is known as **confirmation bias**. Other times, we find illusory correlations based on the information that comes most easily to mind, even if that information is severely limited. And while we may feel confident that we can use these relationships to better understand and predict the world around us, illusory correlations can have significant drawbacks. For example, research suggests that illusory correlations—in which certain behaviors are inaccurately attributed to certain groups—are involved in the formation of prejudicial attitudes that can ultimately lead to discriminatory behavior.

Confirmation Bias

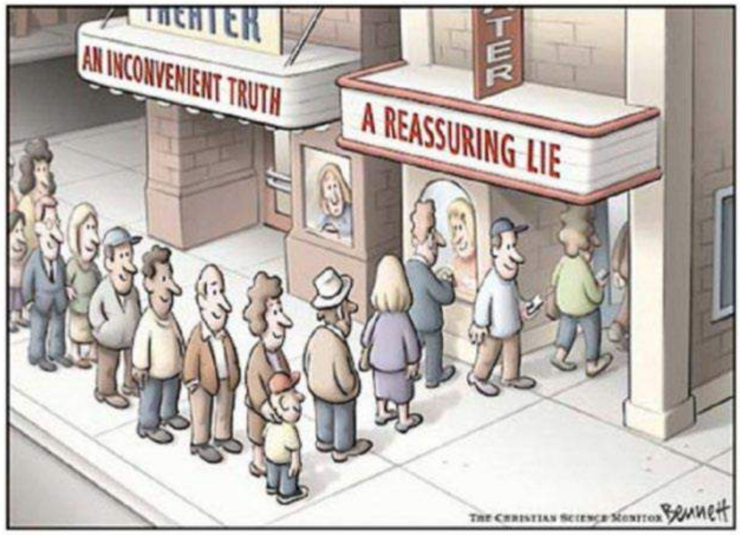


Figure 7. Most people use conformation bias unwittingly because it is usually easier to cling to a reassuring lie than an inconvenient truth.

Confirmation bias is a person's tendency to seek, interpret and use evidence in a way that conforms to their existing beliefs. This can lead a person to make certain mistakes such as: poor judgments that limits their ability to learn, induces changing in beliefs to justify past actions, and act in a hostile manner towards people who disagree with them. Confirmation bias lead a person to perpetuate stereotypes or cause a doctor to inaccurately diagnose a condition.

What is noteworthy about confirmation bias is that it supports the The Argumentative Theory. Although confirmation bias is almost universally deplored as a regrettable failing of reason in others, the argumentative theory of reason explains that this bias is Adaptive Behavior because it aids in forming persuasive arguments by preventing us from being distracted by useless evidence and unhelpful stories.

Interestingly, Charles Darwin made a practice of recording evidence against his theory in a special notebook, because he found that this *contradictory evidence was particularly difficult to remember.*

Belief Perseverance Bias

Belief Perseverance bias occurs when a person has clear evidence against, they still hold on to their previous belief. Many people in the skeptic community are often frustrated when, after they have laid out so many sound arguments based on clear reasoning, they still can't seem to change what someone believes. Once you believe something, it is so easy to see the reasons for why you hold that belief but for others it seems impossible. Try as you might to share your beliefs with others, you still fail at winning them to your side.

"The human understanding when it has once adopted an opinion draws all things else to support and agree with it. And though there be a greater number and weight of instances to be found on the other side, yet these it either neglects and despises, or else by some distinction sets aside and rejects."
– Francis Bacon

What we are talking about here is, at the least, confirmation bias, the tendency to seek only information that supports one's previous belief and reject information that refutes it. But there is also the issue of belief perseverance. In other words, Much of this stems from people's preference for certainty and continuity. We like our knowledge to be consistent, linear, and absolute. "I already came to a conclusion and am absolutely certain that what I believe is true. I no longer want to think about it. If I exert all of the work required to admit that I am wrong and was wrong, there will be a lot of additional work to learn and integrate that new information. In the meantime, I will have a very difficult time functioning. My life will be much easier if I simply accept that my previous belief was true." Or as Daniel Kahneman says:

"Sustaining doubt is harder work than sliding into certainty."
– Daniel Kahneman

Overconfidence

Problem 1 (adapted from Alpert & Raiffa, 1969):

Listed below are 10 uncertain quantities. Do not look up any information on these items. For each, write down your best estimate of the quantity. Next, put a lower and upper bound around your estimate, such that you are 98 percent confident that your range surrounds the actual quantity. Respond to each of these items even if you admit to knowing very little about these quantities.

1. The first year the Nobel Peace Prize was awarded
2. The date the French celebrate "Bastille Day"
3. The distance from the Earth to the Moon
4. The height of the Leaning Tower of Pisa
5. Number of students attending Oxford University (as of 2014)
6. Number of people who have traveled to space (as of 2013)
7. 2012-2013 annual budget for the University of Pennsylvania
8. Average life expectancy in Bangladesh (as of 2012)
9. World record for pull-ups in a 24-hour period
10. Number of colleges and universities in the Boston metropolitan area

On the first problem, if you set your ranges so that you were justifiably 98 percent confident, you should expect that approximately 9.8, or nine to 10, of your ranges would include the actual value. So, let's look at the correct answers:

Figure 7. Overconfidence is a natural part of most people's decision-making process and this can get us into trouble. Is it possible to overcome our faulty thinking? Perhaps. See the "Fixing Our Decisions" section below. [Image: Barn Images, https://goo.gl/BRvSA7]

1. 1901
2. 14th of July
3. 384,403 km (238,857 mi)
4. 56.67 m (183 ft)
5. 22,384 (as of 2014)
6. 536 people (as of 2013)
7. $6.007 billion
8. 70.3 years (as of 2012)
9. 4,321
10. 52

Count the number of your 98% ranges that actually surrounded the true quantities. If you surrounded nine to 10, you were appropriately confident in your judgments. But most readers surround only between three (30%) and seven (70%) of the correct answers, despite claiming 98% confidence that each range would surround the true value. As this problem shows, humans tend to be **overconfident** in their judgments.

In 1984, Jennifer Thompson was raped. During the attack, she studied the attacker's face, determined to identify him if she survived the attack. When presented with a photo lineup, she identified Cotton as her attacker. Twice, she testified against him, even after seeing Bobby Poole, the man who boasted to fellow inmates that he had committed the crimes for which Cotton was convicted. After Cotton's serving 10.5 years of his sentence, DNA testing conclusively proved that Poole was indeed the rapist.

Thompson has since become a critic of the reliability of eyewitness testimony. She was remorseful after learning that Cotton was an innocent man who was sent to prison. Upon release, Cotton was awarded $110,000 compensation from the state of North Carolina. Cotton and Thompson have reconciled to become close friends, and tour in support of eyewitness testimony reform.

One of the most remarkable aspects of Jennifer Thompson's mistaken identity of Ronald Cotton was her certainty. But research reveals a pervasive cognitive bias toward overconfidence, which is *the tendency for people to be too certain about their ability to accurately remember events and to make judgments*. David Dunning and his colleagues (Dunning, Griffin, Milojkovic, & Ross, 1990) asked college students to predict how another student would react in various situations. Some participants made predictions about a fellow student whom they had just met and interviewed, and others made predictions about their roommates whom they knew very well. In both cases, participants reported their confidence in each prediction, and accuracy was determined by the responses of the people themselves. The results were clear: Regardless of whether they judged a stranger or a roommate, the participants consistently overestimated the accuracy of their own predictions.

Eyewitnesses to crimes are also frequently overconfident in their memories, and there is only a small correlation between how accurate and how confident an eyewitness is. The witness who claims to be absolutely certain about his or her identification (e.g., Jennifer Thompson) is not much more likely to be accurate than one who appears much less sure, making it almost impossible to determine whether a particular witness is accurate or not (Wells & Olson, 2003).

I am sure that you have a clear memory of when you first heard about the 9/11 attacks in 2001, and perhaps also when you heard that Princess Diana was killed in 1997 or when the verdict of the O. J. Simpson trial was announced in 1995. This type of memory, which we experience along with a great deal of emotion, is known as a flashbulb memory—*a vivid and emotional memory of an unusual event that people believe they remember very well.* (Brown & Kulik, 1977).

People are very certain of their memories of these important events, and frequently overconfident. Talarico and Rubin (2003) tested the accuracy of flashbulb memories by asking students to write down their memory of how they had heard the news about either the September 11, 2001, terrorist attacks or about an everyday event that had occurred to them during the same time frame. These recordings were made on September 12, 2001. Then the participants were asked again, either 1, 6, or 32 weeks later, to recall their memories. The participants became less accurate in their recollections of both the emotional event and the everyday events over time. But the participants' confidence in the accuracy of their memory of learning about the attacks did not decline over time. After 32 weeks the participants were overconfident; they were much more certain about the accuracy of their flashbulb memories than they should have been. Schmolck, Buffalo, and Squire (2000) found similar distortions in memories of news about the verdict in the O. J. Simpson trial.

Chapter 10 – Perception

Sensation vs. Perception

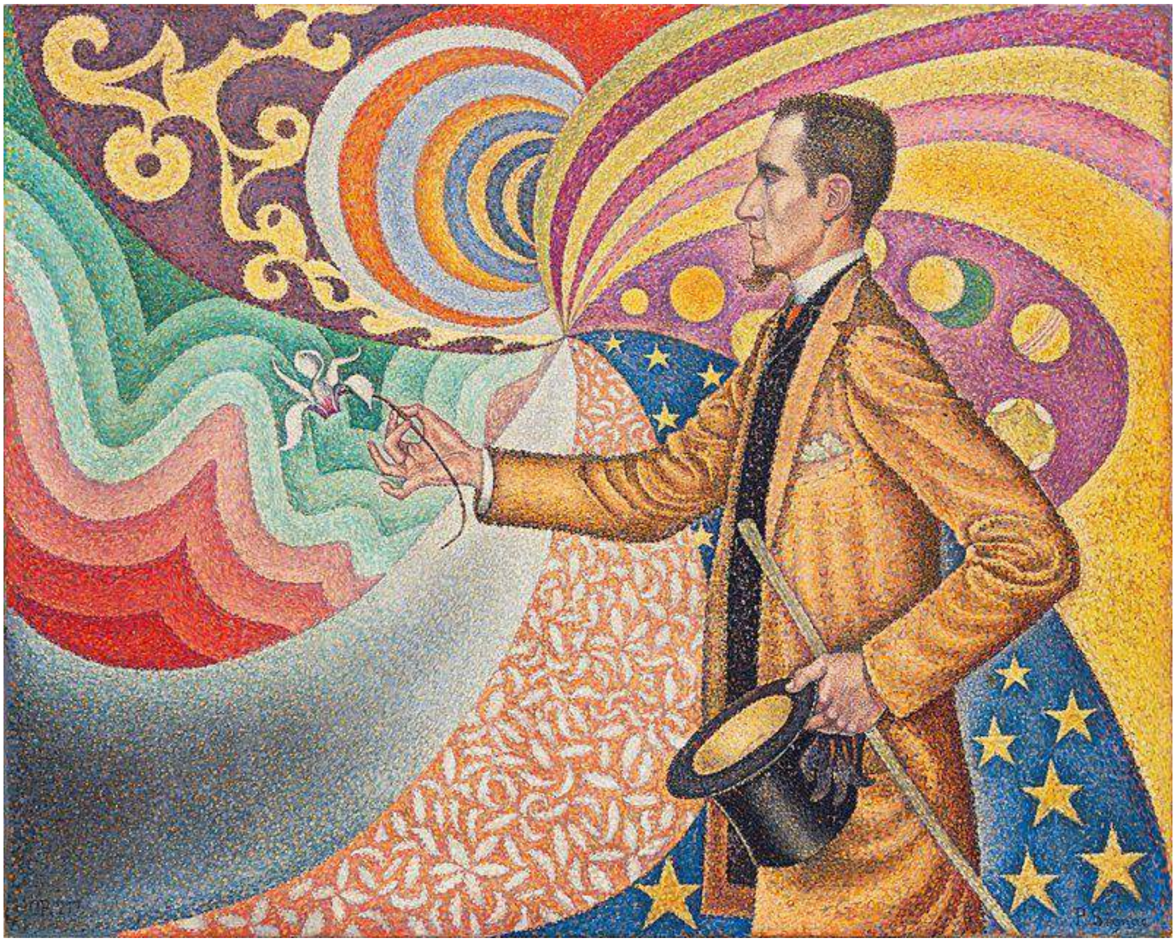


Figure 1. Portrait de Félix Fénéon de Paul Signac - Ciné-club de Caen

Sensation and perception are two separate processes that are very closely related. Sensation is input about the physical world obtained by our sensory receptors, and perception is the process by which the brain selects, organizes, and interprets these sensations. In other words, senses are the physiological basis of perception. Perception of the same senses may vary from one person to another because each person's brain interprets stimuli differently based on that individual's learning, memory, emotions, and expectations.

Figure 2. If you were standing in the midst of this street scene, you would be absorbing and processing numerous pieces of sensory input. (credit: modification of work by Cory Zanker)

Imagine standing on a city street corner. You might be struck by movement everywhere as cars and people go about their business, by the sound of a street musician's melody or a horn honking in the distance, by the smell of exhaust fumes or of food being sold by a nearby vendor, and by the sensation of hard pavement under your feet.

We rely on our sensory systems to provide important information about our surroundings. We use this information to successfully navigate and interact with our environment so that we can find nourishment, seek shelter, maintain social relationships, and avoid potentially dangerous situations. But while sensory information is critical to our survival, there is so much information available at any given time that we would be overwhelmed if we were forced to attend to all of it. In fact, we are aware of only a fraction of the sensory information taken in by our sensory systems at any given time.

This section will provide an overview of how sensory information is received and processed by the nervous system and how that affects our conscious experience of the world. We begin by learning the distinction between sensation and perception. Then we consider the physical properties of light and sound stimuli, along with an overview of the basic structure and function of the major sensory systems. The module will close with a discussion of a historically important theory of perception called the Gestalt theory. This theory attempts to explain some underlying principles of perception.

> Seeing something is not the same thing as making sense of what you see. Why is it that our senses are so easily fooled? In this video, you will come to see how our perceptions are not infallible, and they can be influenced by bias, prejudice, and other factors. Psychologists are interested in how these false perceptions influence our thoughts and behavior.

Classic View of Perception:

Distal stimulus, proximal stimulus, percept:

To understand what perception does, you must understand the difference between the the **proximal** (~ap*proxima*te = close) **stimulus** and the **distal**(~ *dista*nt) **stimulus** or object.

- **distal stimuli** are objects and events out in the world about you.
- **proximal stimuli** are the patterns of stimuli from these objects and events that actually reach your senses (eyes, ears, etc.)

Most of the time, perception reflects the properties of the distal objects and events very accurately, much more accurately than you might expect from the apparently limited, varying, unstable pattern of proximal stimulation the brain/mind gets. The problem of perception is to understand how the mind/brain extracts accurate stable perceptions of objects and events from such apparently limited, inadequate information.

In vision, light rays from distal objects form a sharply focused array on the retina in back of the eye. But this array continually varies as the eyes move, as the observer gets different views of the same object, as amount of light varies, etc. Although this proximal stimulus array is what actually triggers the neural signals to the brain, we are quite unaware of it or pay little attention to it (most of the time). Instead we are aware of and respond to the distal objects that the proximal stimulus represents. This is completely reasonable: the distal object is what is important.

Visual Illusions

Psychologists have analyzed perceptual systems for more than a century. Vision and hearing have received the most attention by far, but other perceptual systems, like those for smell taste movement, balance, touch, and pain, have also been studied extensively. Perception scientists use a variety of approaches to study these systems—they design experiments, study neurological patients with damaged brain regions, and create perceptual illusions that toy with the brain's efforts to interpret the sensory world.

Figure 9. This 3-D street art demonstrates how artists utilize illusions to portray depth on a 2-D sidewalk.

Creation and testing of perceptual illusions has been a fruitful approach to the study of perception—particularly visual perception—since the early days of psychology. People often think that visual illusions are simply amusing tricks that provide us with entertainment. Many illusions are fun to experience, but perception scientists create illusions based on their understanding of the perceptual system. Once they have created a successful illusion, the scientist can explore what people experience, what parts of the brain are involved in interpretation of the illusion, and what variables increase or diminish the strength of the illusion. Scientists are not alone in this interest. Visual artists have discovered and used many illusion-producing principles for centuries, allowing them to create the experience of depth, movement, light and shadow, and relative size on two-dimensional canvases.

Depth Illusions

When we look at the world, we are not very good at detecting the absolute qualities of things—their exact size or color or shape. What we are very good at is judging objects in the context of other objects and conditions. Let's take a look at a few illusions to see how they are based on insights about our perception. Look at Figure 2 below. Which of the two horizontal yellow lines looks wider, the top one or the bottom one?

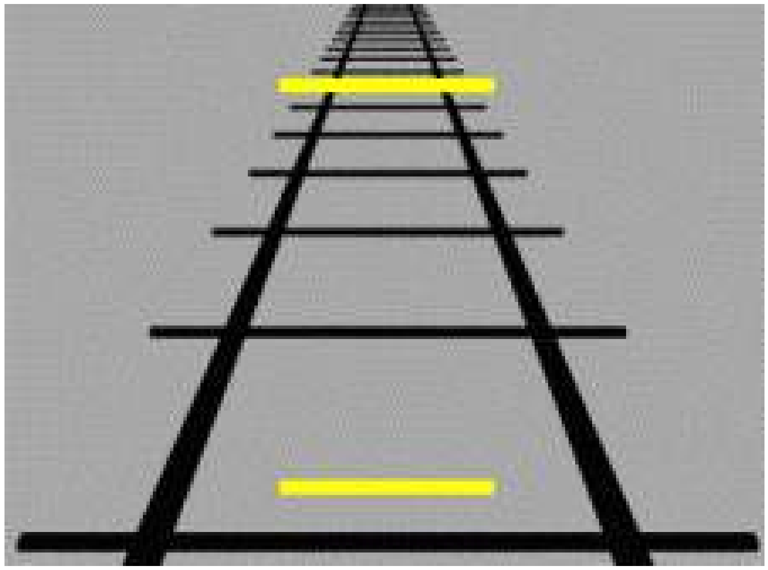


Figure 10. The Ponzo Illusion.

Most people experience the top line as wider. They are both exactly the same length. This experience is called the Ponzo illusion. Even though you know that the lines are the same length, it is difficult to see them as identical. Our perceptual system takes the context into account, here using the converging “railroad tracks” to produce an experience of depth. Then, using some impressive mental geometry, our brain adjusts the experienced length of the top line to be consistent with the size it would have if it were that far away: if two lines are the same length on my retina, but different distances from me, the more distant line must be in reality longer. You experience a world that “makes sense” rather than a world that reflects the actual objects in front of you.

There are many depth illusions. It is difficult to see the drawing on the left below as a two-dimensional figure. The converging lines and smaller square at the center seem to coax our perceptual systems into seeing depth, even though we know that the drawing is flat. This urge to see depth is probably so strong because our ability to use two-dimensional information to infer a three dimensional world is essential for allowing us to operate in the world. The picture on the right below is a driving tunnel, something you would need to process at high speed if you were in a car going through it. Your quick and detailed use of converging lines and other cues allows you to make sense of this 3-D world.

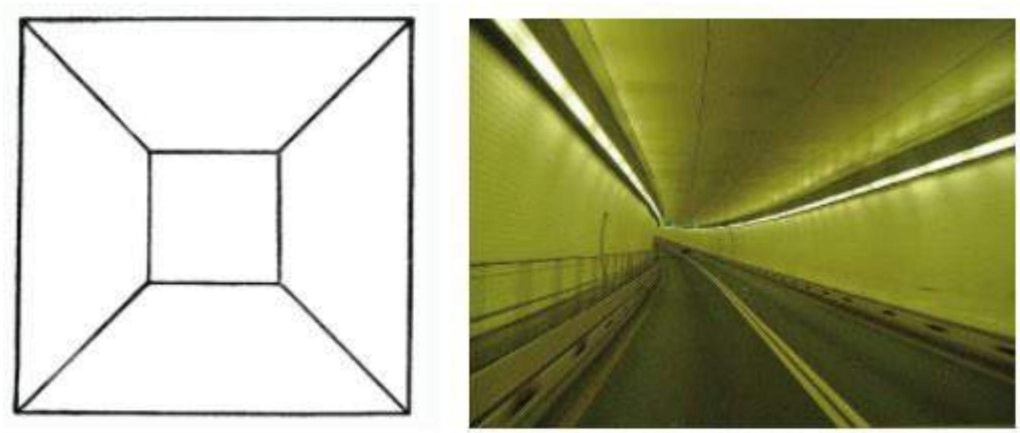


Figure 11. Understanding depth enables us to function in a 3-dimensional world.

Light and Size Illusions

Depth is not the only quality in the world that shows how we adjust what we experience to fit the surrounding world. Look at the two gray squares in the figure below. Which one looks darker?

Figure 12. Which gray square appears darker?

Most people experience the square on the right as the darker of the two gray squares. You've probably already guessed that the squares are actually identical in shade, but the surrounding area—black on the left and white on the right—influence how our perceptual systems interpret the gray area. In this case, the greater difference in shading between the white surrounding area and the gray square on the right results in the experience of a darker square.
Here is another example below. The two triangular figures are identical in shade, but the triangle on the left looks lighter against the dark background of the cross when compared to the triangle in the white area on the right.

Figure 13. Benary Cross

Our visual systems work with more than simple contrast. They also use our knowledge of how the world works to adjust our perceptual experience. Look at the checkerboard below. There are two squares with letters in them, one marked “A” and the other “B”. Which one of those two squares is darker?

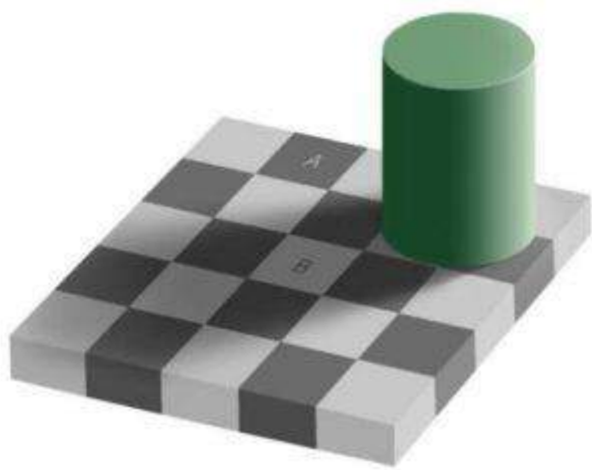


Figure 14. Which looks darker, A or B?

This seems like an easy comparison, but the truth is that squares A and B are identical in shade. Our perceptual system adjusts our experience by taking some visual information into account. First, “A” is one of the “dark squares” and “B” is a “light square” if we take the checkerboard pattern into account. Perhaps even more impressive, our visual systems notice that “B” is in a shadow. Object in a shadow appear darker, so our experience is adjusted to take account of effect of the shadow, resulting in perceiving square B as being lighter than square A, which sits in the bright light. And if you really don’t believe your eyes, take a look at a video showing the same color tiles **here**.

LINK TO LEARNING
If you want to explore more visual illusions, here is a great site with dozens of interesting illusions created by Michael Bach.

Ebbinghaus in the Real World

Imagine that you are in a golf competition in which you are putting against someone with the same experience and skill that you have. There is one problem: Your opponent gets to putt into a hole that is 10% larger than the hole you have to use. You'd probably think that the competition was unfairly biased against you.

Figure 15. Do you suspect that the perceived size of a golf hole will affect putting performance?

Now imagine a somewhat different situation. You and your opponent are about equal in ability and the holes you are using are the same size, but the hole that your opponent is using *looks* 10% larger than the one you are using. Would your opponent have an unfair advantage now?

If you read the earlier section on the Ebbinghaus effect, you have an idea how psychologists could exploit your perceptual system (and your opponent's) to test this very question.

Psychologist Jessica Witt and her colleagues Sally Linkenauger and Dennis Proffitt recruited research participants with no unusual golf experience to participate in a putting task. They competed against themselves rather than against another person.

The experimenters made the task challenging by using a hole with a 2-inch diameter, which is about half the diameter of the hole you will find on a golf course. An overhead projector mounted on the ceiling of their lab allowed them to project Ebbinghaus's circles around the putting hole. Some participants saw the putting hole surrounded by circles that were smaller than the hole in the center; the other half saw surrounding black circles that were larger.

Participants putted from about 11½ feet away. They took 10 putts in one condition, and then 10 in the other condition. Half of the participants putted with the large surrounding circles first and half saw the small surrounding circles first. This procedure is called **counterbalancing**. If there is any advantage (e.g., getting better over time with practice) or disadvantage (e.g., getting tired of putting), counterbalancing assures that both conditions are equally exposed to the positive or negative effects of which task goes first or second. Failure to take account of this type of problem means that you may have a **confounding variable**—practice or fatigue—that influences performance. A confounding variable is something that *could* influence performance, but is not part of the study. We try to *control* (that is, neutralize) potentially confounding variables so they cannot be the cause of performance differences. So, for instance, if everyone did the large surrounding circles condition first and then the small surrounding circles, then differences in performance could be due to order of conditions (leading to practice or fatigue effects) rather than the size of the surrounding circles. By counterbalancing, we don't get rid of the effects of practice or fatigue for any particular person, but—across all the participants—practice or fatigue should affect both conditions (both types of Ebbinghaus circles) equally.

The experimenters wanted to know two things. First, did they actually produce the Ebbinghaus illusion? Remember: there is no guarantee that people see or think the way your theory says they should. So just before the participant started putting in a particular condition, he or she drew a circle using a computerized drawing tool, attempting to match the exact size of the putting hole. This is better than simply asking, "do you see the illusion?" The drawing task attempts to directly measure what they perceive.

Second, the experimenters wanted to see if the perceived size of the hole influenced putting accuracy. They recorded the success or failure of each putt. Each participant could get a score of 0 to 10 successful putts in each condition.

Methods Summary

Recap the steps you've read about thus far:

1. The participant practices putting to get used to the task.
2. The participant completes the first condition (large surrounding circles for half of the participants and small surrounding circles for the other half).
    - The participant draws a circle corresponding to his or her estimation of the actual size of the putting hole. This allows the experimenters to determine if the Ebbinghaus effect actually occurred.
    - The participant putts 10 times in this condition.
3. Participant completes the second condition (whichever condition they have not yet done).
    - The participant draws a circle corresponding to his or her estimation of the actual size of the putting hole.
    - The participant putts 10 times in this condition.

This is not the only experiment that has used a sports context to study the effects of illusions. Other experiments have shown that people hit softballs better when the balls are perceived as larger. People score higher in darts when the board appears larger. Athletes kick field goals and return tennis balls more successfully when the goal posts or tennis balls appear larger. In all of these studies, the balls or boards or goal posts were not actually larger, but they were perceived as larger because the experimenters created illusions. Skilled athletes often report that targets appear larger or time slows down when they are "in the zone", as if practice and skill create their own perceptual illusions that increase confidence and make difficult challenges feel easier.

LINK TO LEARNING
Watch this interview with Psychologist Jessica Witt to see her talk about how her research utilizing the Ebbinghaus illusion impacts a golfer's perception and performance. You can also read about more about similar variations of her research here.

A Final Note: Science Doesn't Always Produce Simple Results

Professor Witt's study had interesting results; however, they weren't quite as simple as we have made them seem. The researchers actually had two different hole sizes: 2 inches and 4 inches. The Ebbinghaus circles were adjusted to be relatively larger or smaller than the putting hole.

The Ebbinghaus illusion worked for the smaller (2 inch) putting holes, but not for the larger (4 inch) putting holes. In other words, when people drew the circles as they perceived them (the "manipulation check" dependent variable), they drew different sized circles for the 2 inch holes (the Ebbinghaus illusion), but the same size circles for the 4 inch holes (no Ebbinghaus illusion).

For the larger (4 inch) putting holes, putting accuracy was the same for the two different conditions. This didn't bother the experimenters, because—as we have already noted—the participants did not experience the Ebbinghaus illusion with the larger holes. If the holes were perceived as the same, then self-confidence should not have been affected and, in turn, putting should not have been better in one condition than the other.
In the research paper, the experimenters suggest a few technical reasons that the larger hole might not have produced the Ebbinghaus illusion, but they admit that they have no definitive explanation. That's okay. Science often yields messy results—and these can be the basis for new experiments and sometimes for really interesting discoveries. The world is not as simple as our theories try to make it seem. Happily, in science, as in many aspects of life, you learn more from your failures than your successes, so good scientists don't try to hide from results they don't expect.

Top-Down vs. Bottom-Up (Conceptually-driven vs. Data-driven processing)

While our sensory receptors are constantly collecting information from the environment, it is ultimately how we interpret that information that affects how we interact with the world. **Perception** refers to the way sensory information is organized, interpreted, and consciously experienced. Perception involves both bottom-up and top-down processing. **Bottom-up processing** refers to the fact that perceptions are built from sensory input. On the other hand, how we interpret those sensations is influenced by our available knowledge, our experiences, and our thoughts. This is called **top-down processing**.

Look at the shape in Figure 16 below. Seen alone, your brain engages in bottom-up processing. There are two thick vertical lines and three thin horizontal lines. There is no context to give it a specific meaning, so there is no top-down processing involved.

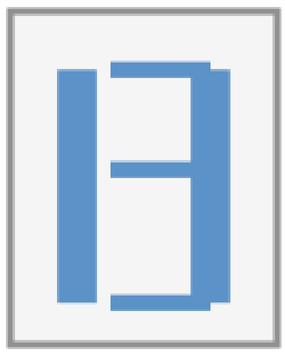


Figure 16.

Now, look at the same shape in two different contexts. Surrounded by sequential letters, your brain expects the shape to be a letter and to complete the sequence. In that context, you perceive the lines to form the shape of the letter "B."

Figure 17.

Surrounded by numbers, the same shape now looks like the number "13."

Figure 18.

When given a context, your perception is driven by your cognitive expectations. Now you are processing the shape in a top-down fashion.
One way to think of this concept is that sensation is a physical process, whereas perception is psychological. For example, upon walking into a kitchen and smelling the scent of baking cinnamon rolls, the *sensation* is the scent receptors detecting the odor of cinnamon, but the *perception* may be "Mmm, this smells like the bread Grandma used to bake when the family gathered for holidays."

Although our perceptions are built from sensations, not all sensations result in perception. In fact, we often don't perceive stimuli that remain relatively constant over prolonged periods of time. This is known as **sensory adaptation**. Imagine entering a classroom with an old analog clock. Upon first entering the room, you can hear the ticking of the clock; as you begin to engage in conversation with classmates or listen to your professor greet the class, you are no longer aware of the ticking. The clock is still ticking, and that information is still affecting sensory receptors of the auditory system. The fact that you no longer perceive the sound demonstrates sensory adaptation and shows that while closely associated, sensation and perception are different.

Multisensory Perception

Figure 19. The way we receive the information from the world is called sensation while our interpretation of that information is called perception. [Image: Laurens van Lieshou]

Although it has been traditional to study the various senses independently, most of the time, perception operates in the context of information supplied by multiple **sensory modalities** at the same time. For example, imagine if you witnessed a car collision. You could describe the stimulus generated by this event by considering each of the senses independently; that is, as a set of **unimodal** stimuli. Your eyes would be stimulated with patterns of light energy bouncing off the cars involved. Your ears would be stimulated with patterns of acoustic energy emanating from the collision. Your nose might even be stimulated by the smell of burning rubber or gasoline. However, all of this information would be relevant to the same thing: your perception of the car collision. Indeed, unless someone was to explicitly ask you to describe your perception in unimodal terms, you would most likely experience the event as a unified bundle of sensations from multiple senses. In other words, your perception would be **multimodal**. The question is whether the various sources of information involved in this multimodal stimulus are processed separately by the perceptual system or not.

For the last few decades, perceptual research has pointed to the importance of **multimodal perception**: the effects on the perception of events and objects in the world that are observed when there is information from more than one sensory modality. Most of this research indicates that, at some point in perceptual processing, information from the various sensory modalities is **integrated**. In other words, the information is combined and treated as a unitary representation of the world.

Behavioral Effects of Multimodal Perception

Although neuroscientists tend to study very simple interactions between neurons, the fact that they've found so many crossmodal areas of the cortex seems to hint that the way we experience the world is fundamentally multimodal. Our intuitions about perception are consistent with this; it does not seem as though our perception of events is constrained to the perception of each sensory modality independently. Rather, we perceive a unified world, regardless of the sensory modality through which we perceive it.

It will probably require many more years of research before neuroscientists uncover all the details of the neural machinery involved in this unified experience. In the meantime, experimental psychologists have contributed to our understanding of multimodal perception through investigations of the behavioral effects associated with it. These effects fall into two broad classes. The first class—**multimodal phenomena**—concerns the binding of inputs from multiple sensory modalities and the effects of this binding on perception. The second class—**crossmodal phenomena**—concerns the influence of one sensory modality on the perception of another (Spence, Senkowski, & Roder, 2009).

Multimodal Phenomena

Audiovisual Speech

Multimodal phenomena concern stimuli that generate simultaneous (or nearly simultaneous) information in more than one sensory modality. As discussed above, speech is a classic example of this kind of stimulus. When an individual speaks, she generates sound waves that carry meaningful information. If the perceiver is also looking at the speaker, then that perceiver also has access to *visual*patterns that carry meaningful information. Of course, as anyone who has ever tried to lipread knows, there are limits on how informative visual speech information is. Even so, the visual speech pattern alone is sufficient for very robust speech perception. Most people assume that deaf individuals are much better at lipreading than individuals with normal hearing. It may come as a surprise to learn, however, that some individuals with normal hearing are also remarkably good at lipreading (sometimes called "speechreading"). In fact, there is a wide range of speechreading ability in both normal hearing and deaf populations (Andersson, Lyxell, Rönnberg, & Spens, 2001). However, the reasons for this wide range of performance are not well understood (Auer & Bernstein, 2007; Bernstein, 2006; Bernstein, Auer, & Tucker, 2001; Mohammed et al., 2005).

How does visual information about speech interact with auditory information about speech? One of the earliest investigations of this question examined the accuracy of recognizing spoken words presented in a noisy context, much like in the example above about talking at a crowded party. To study this phenomenon experimentally, some irrelevant noise ("white noise"—which sounds like a radio tuned between stations) was presented to participants. Embedded in the white noise were spoken words, and the participants' task was to identify the words. There were two conditions: one in which only the auditory component of the words was presented (the "auditory-alone" condition), and one in both the auditory and visual components were presented (the "audiovisual" condition). The noise levels were also varied, so that on some trials, the noise was very loud relative to the loudness of the words, and on other trials, the noise was very soft relative to the words. Sumby and Pollack (1954) found that the accuracy of identifying the spoken words was much higher for the audiovisual condition than it was in the auditory-alone condition. In addition, the pattern of results was consistent with the Principle of Inverse Effectiveness: The advantage gained by audiovisual presentation was highest when the auditory-alone condition performance was lowest (i.e., when the noise was loudest). At these noise levels, the audiovisual advantage was considerable: It was estimated that allowing the participant to see the speaker was equivalent to turning the volume of the noise down by over half. Clearly, the audiovisual advantage can have dramatic effects on behavior.

Another phenomenon using audiovisual speech is a very famous illusion called the "McGurk effect" (named after one of its discoverers). In the classic formulation of the illusion, a movie is recorded of a speaker saying the syllables "gaga." Another movie is made of the same speaker saying the syllables "baba." Then, the auditory portion of the "baba" movie is dubbed onto the visual portion of the "gaga" movie. This combined stimulus is presented to participants, who are asked to report what the speaker in the movie said. McGurk and MacDonald (1976) reported that 98 percent of their participants reported hearing the syllable "dada"—which was in neither the visual nor the auditory components of the stimulus. These results indicate that when visual and auditory information about speech is integrated, it can have profound effects on perception.

Watch this video to see an example of the McGurk effect.

Subliminal Perception

The idea of subliminal perception - that stimuli presented below the threshold for awareness can influence thoughts, feelings, or actions – is a fascinating and kind of creepy one. Can messages you are unaware of, embedded in movies or ads or the music playing in the grocery store, really influence what you buy? Many such claims of the power of subliminal perception have been made. One of the most famous came from a market researcher who claimed that the message “Eat Popcorn” briefly flashed throughout a movie increased popcorn sales by more than 50% although he later admitted that the study was made up (Merikle, 2000). Psychologists have worked hard to investigate whether this is a valid phenomenon. Studying subliminal perception is more difficult than it might seem, because of the difficulty establishing what the threshold for consciousness is or of even determining what type of thresholds important; for example, Cheesman and Merikle (1984, 1986) make an important distinction between objective and subjective thresholds. The bottom line is that there is some evidence that individuals can be influenced by stimuli they are not aware of, but how complex stimuli can be or the extent to which unconscious material can affect behavior is not settled.

Table 1. Subliminal Perception

Synesthesia:

Synesthesia is a condition in which a sensory stimulus presented in one area evokes a sensation in a different area. In the 19th century Francis Galton observed that a certain proportion of the general population who were otherwise normal had a hereditary condition he dubbed "synesthesia"; a sensory stimulus presented through one modality spontaneously evoked a sensation experienced in an unrelated modality. For example, an individual may experience a specific color for every given note (“C sharp is red”) or printed number or letter- is tinged with a specific hue (e.g. 5 is indigo and 7 is green). The specificity of the colors remains stable over time within any given individual but the same note or letter doesn’t necessarily evoke the same color in different people. Although long regarded as a curiosity there has been a tremendous resurgence of interest in synesthesia in the last decade. Synesthesia used to be regarded as a rare condition but recent estimates suggest that it affects 4% of the population. The most common of which appears to be letter sounds associated with color. Most individuals report having had the experience as far back in childhood as they can remember. As Galton himself noted, the condition tends to run in families and recent work suggests a genetic basis. Synesthesia was previously believed 6 times more common in women than in men according to responses from newspaper ads. However, Simner and colleagues showed no difference between the sexes testing a large population for synesthesia. Sometimes, sensory deficiency can lead to one sensory input evoking sensations in a different modality. For example, after early visual deprivation due to a disease that attacked eye retinas, touch stimuli can produce “visual light” or after a thalamic lesion leading to a loss of tactile sensation, sounds can elicit touch sensations. This probably occurs because the tactile or auditory sensory input now begins to cross-activate the deprived cortical areas. This could be regarded as a form of acquired synesthesia.

McGurk Effect-Bimodal Speech Perception:

Watch this video to understand the impact of the McGurk effect on perception.

Chapter 11 – Attention

Figure 1. What do you think he's looking at?

We use the term "attention" all the time, but what processes or abilities does that concept really refer to? This module will focus on how attention allows us to select certain parts of our environment and ignore other parts, and what happens to the ignored information. A key concept is the idea that we are limited in how much we can do at any one time. So we will also consider what happens when someone tries to do several things at once, such as driving while using electronic devices.

WHAT IS ATTENTION?

Before we begin exploring attention in its various forms, take a moment to consider how you think about the concept. How would you define attention, or how do you use the term? We certainly use the word very frequently in our everyday language: "ATTENTION! USE ONLY AS DIRECTED!" warns the label on the medicine bottle, meaning be alert to possible danger. "Pay attention!" pleads the weary seventh-grade teacher, not warning about danger (with possible exceptions, depending on the teacher) but urging the students to focus on the task at hand. We may refer to a child who is easily distracted as having an attention disorder, although we also are told that Americans have an attention span of about 8 seconds, down from 12 seconds in 2000, suggesting that we *all* have trouble sustaining concentration for any amount of time (from www.Statisticbrain.com). How that number was determined is not clear from the Web site, nor is it clear how attention span in the goldfish—9 seconds!—was measured, but the fact that our average span reportedly is less than that of a goldfish is intriguing, to say the least.

William James wrote extensively about attention in the late 1800s. An often quoted passage (James, 1890/1983) beautifully captures how intuitively obvious the concept of attention is, while it remains very difficult to define in measurable, concrete terms:

Everyone knows what attention is. It is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalization, concentration of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others. (pp. 381–382)

Figure 2. Are you reading these words right here right now? If so, it's only because you directed your attention toward them. [Image: geralt]

Notice that this description touches on the conscious nature of attention, as well as the notion that what is in consciousness is often controlled voluntarily but can also be determined by events that capture our attention. Implied in this description is the idea that we seem to have a limited capacityfor information processing, and that we can only attend to or be consciously aware of a small amount of information at any given time.

Many aspects of attention have been studied in the field of psychology. In some respects, we define different types of attention by the nature of the task used to study it. For example, a crucial issue in World War II was how long an individual could remain highly alert and accurate while watching a radar screen for enemy planes, and this problem led psychologists to study how attention works under such conditions. When watching for a rare event, it is easy to allow concentration to lag. (This a continues to be a challenge today for TSA agents, charged with looking at images of the contents of your carry-on items in search of knives, guns, or shampoo bottles larger than 3 oz.) Attention in the context of this type of search task refers to the level of *sustained attention* or *vigilance* one can maintain. In contrast, divided attention tasks allow us to determine how well individuals can attend to many sources of information at once. *Spatial attention* refers specifically to how we focus on one part of our environment and how we move attention to other locations in the environment. These are all examples of different aspects of attention, but an implied element of most of these ideas is the concept of selective attention; some information is attended to while other information is intentionally blocked out. This module will focus on important issues in selective and divided attention, addressing these questions:

- Can we pay attention to several sources of information at once, or do we have a limited capacity for information?

- How do we select what to pay attention to?
- What happens to information that we try to ignore?
- Can we learn to divide attention between multiple tasks?

History of Attention

There has been a large increase in research activity in the area of attention since the 1950s. This research has focused not only on attention, but also how attention is related to memory and executive functioning. Human learning and behaviour are dependent on our ability to pay attention to our environment, retain and retrieve information, and use cognitive strategies. An understanding of the development of attention is also critical when we consider that deficits in attention often lead to difficulties in school and in the work force. Thus, attention is an important topic in the study of psychology, specifically in the areas of development (see Part II of this book), learning (Part III), and psychological disorders (see the section on ADHD in Part IV). There is no doubt that an understanding of attention and related concepts is critical to our understanding of human cognition and learning.

Introduction to the History of Research on Attention

The study of attention is a major part of contemporary cognitive psychology and cognitive neuroscience. Attention plays a critical role in essentially all aspects of perception, cognition, and action, influencing the choices we make. The study of attention has been of interest to the field of psychology since its earliest days. However, many ideas about attention can be traced to philosophers in the 18th and 19th centuries, preceding the foundation of the field of psychology. The topic of attention was originally discussed by philosophers. Among the issues considered were the role of attention on conscious awareness and thought, and whether attention was directed voluntarily or involuntarily toward objects or events. The characterization of attention provided by each philosopher reflected that individual's larger metaphysical views of the nature of things and how we come to know the world. For instance, Joan Luis Vives (1492-1540) recognized the role of attention in forming memories. Gottfried Leibniz (1646-1716) introduced the concept of apperception, which refers to an act that is necessary for an individual to become conscious of a perceptual event. He noted that without apperception, information does not enter conscious awareness. Leibniz said, "Attention is a determination of the soul to know something in preference to other things". In summary, many philosophers gave attention a central role in perception and thinking. They introduced several important issues, such as the extent to which attention is directed automatically or intentionally. These topics continue to be examined and evaluated in contemporary research. Although they conducted little experimental research themselves, their conceptual analysis of attention laid the foundation for the scientific study of attention in ensuing years. The philosophical analyses of attention led to some predictions that could be tested experimentally. In addition, in the mid-1800s psychophysical methods were being developed that allowed the relation between physical stimulus properties and their corresponding psychological perceptions to be measured. Wilhelm Wundt, who established the first laboratory devoted to psychological research in 1879, was responsible for introducing the study of attention to the field. In addition, the relation between attention and perception was one of the first topics to be studied in experimental psychology. Wundt held that attention was an inner activity that caused ideas to be present to differing degrees in consciousness. He distinguished between perception, which was the entry into the field of attention, and apperception, which was responsible for entry into the inner focus. He assumed that the focus of attention could narrow or widen. This view that has also enjoyed popularity in recent years. At the end of the 19th century, Hermann von Helmholtz (1821-1894) argued that attention is essential for visual perception. Using himself as a subject and pages of briefly visible printed letters as stimuli, he found that attention could be directed in advance of the stimulus presentation to a particular region of the page, even though the eyes were kept fixed at a central point. He also found that attention was limited: The letters in by far the largest part of the visual field, even in the vicinity of the fixation point, were not automatically perceived.

William James's [1] (1890/1950) views on attention are probably the most well known of the early psychologists. In his famous Principles of Psychology (1980), James asserted that "the faculty of voluntarily bringing back a wandering attention, over and over again, is the very root of judgment, character, and will." His definition of attention is also widely quoted. According to James (1890), "It is taking possession by the mind, in clear and vivid form, of one of what seem several simultaneously possible objects or trains of thought. Focalization, concentration, of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others, and is a condition which has a real opposite in the confused, dazed, scatterbrained state." Moreover, according to James, the immediate effects of attention are to make us perceive, conceive, distinguish and remember, better than we otherwise could –both more successive things and each thing more clearly. It also shortens "reaction time". James's definition also mentions clearness, which Titchener (1908/1973) viewed as the central aspect of attention. Pillsbury (1908/1973) agreed with Titchener, indicating, "the essence of attention as a conscious process is an increase in the clearness on one idea or a group of ideas at the expense of others". Researchers at the beginning of the 20th century debated how this increased clearness is obtained. In summary, around 1860, the philosophical approach dominated the study of psychology in general and attention especially. During the period from 1980 to 1909, the study of attention was transformed, as was the field of psychology as a whole, to one of scientific inquiry with emphasis on experimental investigations. However, given that behaviourism came to dominate psychology in the next period, at least in the United States, the study of attentional mechanisms was largely delayed until the middle of the 20th century.

Although one often reads that research on attention essentially ceased during the period of 1910-1949, attention research never disappeared completely. However, there was an increase in interest in the topic with the advent of contemporary cognitive psychology. Lovie (1983) compiled tables showing the numbers of papers on attention listed in Psychological Abstracts and its predecessor, Psychological Index, in five-year intervals from 1910 to 1960, showing that studies on the topic were conducted during these time periods. Among the important works on attention was that of Jersild (1927) who published a classic monograph, "Mental Set and Shift".

Another significant contribution during this era was the discovery of the psychological refractory period effect by Telford (1931). He noted that numerous studies showed that stimulation of neurons was followed by a refractory phase during which the neurons were less sensitive to stimulation. Stroop (1935/1992) also published what is certainly one of the most widely cited studies in the field of psychology, in which he demonstrated that stimulus information that is irrelevant to the task can have a major impact on performance (see below for John Ridley Stroop and the impact of the Stroop Color-Word Task on research on attention). Paschal (1941), Gibson (1940) and Mowrer, Rayman and Bliss (1940) also conducted research on attention such as that on preparatory set or mental set. In sum, although the proportion of psychological research devoted to the topic of attention was much less during this time period than during preceding decades, many important discoveries were made, which have influenced contemporary research on the topic.

The period from 1950 to 1974 saw a revival of interest in the characterization of human information processing. Research on attention during this period was characterized by an interplay between technical applications and theory. Mackworth (1950) reported experiments on the maintenance of vigilance that exemplified this interaction and set the stage for extensive research on the topic over the remainder of the 20th century. This research originated from concerns about the performance of radar operators in World War II detecting infrequently occurring signals. Cherry (1953) conducted one of the seminal works in attention during this period, studying the problem of selective attention, or, as he called it, "the cocktail party phenomenon". He used a procedure called dichotic listening in which he presented different messages to each ear through headphones. Broadbent (1958) developed the first complete model of attention, called Filter Theory (see below). Treisman (1960) reformulated Broadbent's Filter Theory into what is now called the Filter-Attenuation Theory (see below). In the early 1970s, there was a shift from studying attention mainly with auditory tasks to studying it mainly with visual tasks. A view that regards attention as a limited-capacity resource that can be directed toward various processes became popular. Kahneman's (1973) model is the most well known of these unitary capacity or resource theories.

According to this model, attention is a single resource that can be divided among different tasks in different amounts. The basic idea behind these models is that multiple tasks should produce interference when they compete for the limited capacity resources. Also, in this time period, the first controlled experiments that used psychophysiological techniques to study attention were conducted on humans. These experiments used methods that allow brain activity relating to the processing of a stimulus, called event related potentials, to be measured using electrodes placed on the scalp. In sum, the research during this period yielded considerable information about the mechanisms of attention. The most important development was the introduction of detailed information processing models of attention. Research on attention blossomed during the last quarter of the 20th century. Multiple resources models have emerged from many studies showing that it is easier to perform two tasks together when the tasks use different stimulus or response modalities than when they use the same modalities. Treisman and Gelade (1980) also developed a highly influential variant of the Spotlight Theory called the Feature

Integration Theory to explain the results from visual search studies, in which subjects are to detect whether a target is present among distracters. Priming studies have also been popular during the most recent period of attention research. In such studies, a prime stimulus precedes the imperative stimulus to which the subject is to respond; the prime can be the same as or different from some aspect of the imperative stimulus. In addition, a major focus has been on gathering neuropsychological evidence pertaining to the brain mechanisms that underlie attention. Cognitive neuroscience, of which studies of attention are a major part, has made great strides due to the continued development of neuroimaging technologies. The converging evidence provided by neuropsychological and behavioral data promises to advance the study of attention significantly in the first half of the 21st century.

Finally, significant advances have also been made toward expanding the theories and methods of attention to address a range of applied problems. Two major areas can be identified. The first one concerns ergonomics in its broadest sense, ranging from human-machine interactions to improvement of work environments such as mental workload and situation awareness. The second major area of application is clinical neuropsychology, which has benefited substantially from adopting cognitive models and experimental methods to describe and investigate cognitive deficits in neurological patients. There is also work being done on the clinical application of attentional strategies (e.g., mindfulness training) in the treatment of a wide range of psychological disorders (see section on mindfulness).

John Ridley Stroop and The Stroop Effect

For over half a century, the Stroop effect has been one of the most well known standard demonstrations in undergraduate psychology courses and laboratories. In this cognitive task, participants asked to name the color of the ink in which an incompatible color word is printed (e.g., to say “red” aloud in response to the stimulus word GREEN printed in red ink) take longer than when asked to name the color in a control condition (e.g., to say "red" to the stimulus XXXXX printed in red ink). This effect, now known as the Stroop effect, was first reported in the classic article “Studies of Interference in Serial Verbal Reactions” published in the Journal of Experimental Psychology in 1935. Since then, this phenomena has become one of the most well known in the history of psychology.

Stroop’s article has become one of the most cited articles in the history of experimental psychology. It has more than 700 studies seeking to explain some nuance of the Stroop effect along with thousands of others directly or indirectly influenced by this article (MacLeod, 1992). However, at the time of its publication, it had relatively little impact because it was published at the height of Behaviourism in America (MacLeod, 1991). For the next thirty years after its publication, almost no experimental investigations of the Stroop effect occurred. For instance, between 1935 and 1964, only 16 articles are cited that directly examined the Stroop effect. In 1960s, with the advent of information processing as the dominant perspective in cognitive psychology, Stroop's work was rediscovered. Since then, the annual number of studies rose quickly, until by 1969 the number of articles settled in at just over 20 annually, where it appears to have remained (MacLeod, 1992).

Donald Broadbent and Dichotic Listening

Donald E. Broadbent has been praised for his outstanding contributions to the field of psychology since the 1950s, most notably in the area of attention. In fact, despite the undeniable role that attention plays in almost all psychological processes, research in this area was neglected by psychologists for the first half of the twentieth century (Massaro, 1996). During that time, behaviourists ignored the role of attention in human behaviour. Behaviourism was characterized by a stimulus-response approach, emphasizing the association between a stimulus and a response, but without identifying the cognitive operations that lead to that response (Reed, 2000). Subsequently, in the mid-1950s, a growing number of psychologists became interested in the information-processing approach as opposed to the stimulus-response approach. It was Broadbent's elaboration of the idea of the human organism as an information-processing system that lead to a systematic study of attention, and more generally, to the interrelation of scientific theory and practical application in the study of psychology.

Dichotic Listening Experiments

In 1952, Broadbent published his first report in a series of experiments that involved a dichotic listening paradigm. In that report, he was concerned with a person's ability to answer one of two messages that were delivered at the same time, but one of which was irrelevant.

The participants were required to answer a series of Yes-No questions about a visual display over a radio-telephone. For example, the participant would be asked "S-1 from G.D.O. Is there a heart on Position 1?" Over," to which the participant should answer "G.D.O. from S-1. Yes, over." Participants in groups I, II, III, and IV heard two successive series of messages, in which two voices (G.D.O and Turret) spoke simultaneously during some of the messages. Only one of the voices was addressing S-1, and the other addressed S-2, S-3, S-4, S-5, or S-6. Participants were assigned to the following five groups:

- **Group I**: instructed to answer the message for S-1 and ignore the other on both runs
- **Group II**: instructed on one run to only answer the message from G.D.O. and on the second run was provided with a visual cue before the pairs of messages began for the name of the voice to be answered
- **Group III**: were given the same directions as Group I on one run, and on the other run had the experimenter indicate the correct voice verbally after the two messages had reached the "over" stage
- **Group IV**: had the correct voice indicated in all cases, but in one run it was before the messages began (like in Group II) and in the other run it was after the messages had finished (like in Group III)
- **Group V**: under the same conditions as Group I, heard the same recordings as Groups I, II, III and IV, but then also heard a two new recordings. One recording had a voice that addressed S-1 and a voice that addressed T-2, T-3, T-4, T-5, or T-6 (thus the simultaneous messages were more distinct than for the other

groups). The other recording had this same differentiation of messages, but also had both voices repeat the call-sign portion of the message (i.e., "S-1 from G.D.O., S-1 from G.D.O.)

For groups I and II, it is important to note that the overall proportion of failures to answer the correct message correctly was 52%. Results from Groups III and IV indicated that delaying knowledge of the correct voice until the message is completed makes that knowledge almost useless. More specifically, Broadbent (1952) stated:

> "The present case is an instance of selection in perception (attention). Since the visual cue to the correct voice is useless when it arrives towards the ends of the message, it is clear that process of discarding part of the information contained in the mixed voices has already taken place…It seems possible that one of the two voices is selected for response without reference to its correctness, and that the other is ignored…If one of the two voices is selected (attended to) in the resulting mixture there is no guarantee that it will be the correct one, and both call signs cannot be perceived at once any more than both messages can be received and stored till a visual cue indicates the one to be answered". (p. 55)

In 1954, Broadbent used the same procedure as discussed above with slight modifications. In that case, he found information that indicated the positive impact that spatial separation of the messages has on paying attention to and understanding the correct message. The dichotic listening paradigm has been utilized in numerous other publications, both by Broadbent and by other psychologists working in the field of cognition. For example, Cherry (1953) investigated how we can recognize what one person is saying when others are speaking at the same time, which be described as the "cocktail party problem" (p. 976). In his experiment, subjects listened to simultaneous messages and were instructed to repeat one of the messages word by word or phrase by phrase.

Information-Processing and the Filter Model of Attention

Cognitive psychology is often called human information processing, which reflects the approach taken by many cognitive psychologists in studying cognition. The stage approach, with the acquisition, storage, retrieval, and use of information in a number of separate stages, was influenced by the computer metaphor and the way people enter, store, and retrieve data from a computer (Reed, 2000). The stages in an information-processing model are:

- **Sensory Store**: brief storage for information in its original sensory form
- **Filter:** part of attention in which some perceptual information is blocked out and not recognized, while other information is attended to and recognized
- **Pattern Recognition**: stage in which a stimulus is recognized
- **Selection:** stage that determines what information a person will try to remember
- **Short-Term Memory**: memory with limited capacity, that lasts for about 20-30

seconds without attending to its content

- **Long-Term Memory**: memory that has no capacity limit and lasts from minutes to a lifetime

Using an information-processing approach, Broadbent collected data on attention (Reed, 2000). He used a dichotic listening paradigm (see above section), asking participants to listen simultaneously to messages played in each ear, and based on the difficulty that participants had in listening to the simultaneous messages, proposed that a listener can attend to only one message at a time (Broadbent, 1952; Broadbent, 1954). More specifically, he asked enlisted men in England's Royal Army to listen to three pairs of digits. One digit from each pair was presented to one ear at the same time that the other digit from the pair was presented to the other ear. The subjects were asked to recall the digits in whatever order they chose, and almost all of the correct reports involved recalling all of the digits presented to one ear, followed by all the digits presented to the other ear. A second group of participants were asked to recall the digits in the order they were presented (i.e., as pairs). Performance was worse than when they were able to recall all digits from one ear and then the other.

To account for these findings, Broadbent hypothesized that the mechanism of attention was controlled by two components: a selective device or filter located early in the nervous system, and a temporary buffer store that precedes the filter (Broadbent, 1958). He proposed that the filter was tuned to one channel or the other, in an all-or-nothing manner. Broadbent's filter model, described in his book Perception and Communication (1958), was one of the first information-processing models to be examined by psychologists.

Shortly after, it was discovered that if the unattended message became highly meaningful (for example, hearing one's name as in Cherry's Cocktail Party Effect, as mentioned above), then attention would switch automatically to the new message. This result led to the paradox that the content of the message is understood before it is selected, indicating that Broadbent needed to revise his theory (Craik & Baddeley, 1995). Broadbent did not shy away from this task. In fact, he saw all scientific theories as temporary statements, a method of integrating current evidence in a coherent manner. According to Craik and Baddeley, (1995), although Broadbent always presented his current theories firmly and persuasively, he never took the position of obstinately defending an outmoded theory. When he published his second book on the topic, Decision and Stress (1971), he used his filter model as the starting point, to which he applied modifications and added concepts "to accommodate new findings that the model itself had stimulated" (Massaro, 1996, pp. 141). Despite its inconsistencies with emerging findings, the filter model remains the first and most influential information-processing model of human cognition.

Anne Treisman and Feature Integration Theory

Anne Treisman is one of the most influential cognitive psychologists in the world today. For over four decades, she has been has using innovative research methods to define fundamental issues in the area of attention and perception. Best known for her Feature Integration Theory (1980, 1986), Treisman's hypotheses about the mechanisms involved in information processing have formed a starting point for many theorists in this area of research.

In 1967, while Treisman worked as a visiting scientist in the psychology department at Bell Telephone Laboratories, she published an influential paper in Psychological Review that was central to the development of selective attention as a scientific field of study. This paper articulated many of the fundamental issues that continue to guide studies of attention to this day. While at Bell, Treisman's research interests began to expand (Anon, 1991). Although she remained intrigued by the role of attention on auditory perception, she was now also fascinated by the way this construct modulates perception in the visual modality.

In the following years, Treisman returned to Oxford, where she accepted a position as University lecturer in the Psychology Department and was appointed a Fellow of St. Anne's College (Treisman, 2006). Here, she began to explore the notion that attention is involved in integrating separate features to form visual perceptual representations of objects. Using a stopwatch and her children as research participants, she found that the search for a red 'X' among red 'Os' and blue 'Xs' was slow and laborious compared to the search for either shape or colour alone (Gazzaniga et al., 2002). These findings were corroborated by results from testing adult participants in the laboratory and provided the basis of a new research program, where Treisman conducted experiments exploring the relationships between feature integration, attention and object perception (Triesman & Gelade, 1980).

In 1976, Treisman's marriage to Michel Treisman ended. She remarried in 1978, to Daniel Kahneman, a fellow psychologist who would go on to win the Nobel Prize for Economics in 2002. Shortly thereafter, Treisman and Kahneman accepted positions at the University of British Columbia, Canada. In 1980, Treisman and Gelade published a seminal paper proposing her enormously influential Feature Integration Theory (FIT). Treisman's research demonstrated that during the early stages of object perception, early vision encodes features such as color, form, and orientation as separate entities (in "feature maps") (Treisman, 1986). Focused attention to these features recombines the separate features resulting in correct object perception. In the absence of focused attention, these features can bind randomly to form illusory conjunctions (Treisman & Schmidt, 1982; Treisman, 1986). Feature integration theory has had an overarching impact both within and outside the area of psychology.

Feature Integration Theory Experiments

According to Treisman's Feature Integration Theory perception of objects is divided into two stages:

1. **Pre-Attentive Stage:** The first stage in perception is so named because it happens automatically, without effort or attention by the perceiver. In this stage, an object is analyzed into its features (i.e., color, texture, shapes etc.). Treisman suggests that the reason we are unaware of the breakdown of an object into its elementary features is

that this analysis occurs early in the perceptual processes, before we have become conscious of the object. Evidence: Treisman created a display of four objects flanked by two black numbers. This display was flashed on a screen for one-fifth of a second and followed by a random dot masking field in order to eliminate residual perception of the stimuli. Participants were asked to report the numbers first, followed by what they saw at each of the four locations where the shapes had been. In 18 percent of trials, participants reported seeing objects that consisted of a combination of features from two different stimuli (i.e., color and shape). The combinations of features from different stimuli are called illusory conjunctions (Treisman and Schmidt, 1982). The experiment also showed that these illusory conjunctions could occur even if the stimuli differ greatly in shape and size. According to Treisman, **illusory conjunctions** occur because early in the perceptual process, features may exist independently of one another, and can therefore be incorrectly combined in laboratory settings when briefly flashed stimuli are followed by a masking field (Treisman, 1986).

2. **Focused Attention Stage:** During this second stage of perception features are recombined to form whole objects. Evidence: Treisman repeated the illusory conjunction experiment, but this time, participants were instructed to ignore the flanking numbers, and to focus their attention on the four target objects. Results demonstrated that this focused attention eliminated illusory conjunctions, so that all shapes were paired with their correct colours (Treisman and Schmidt, 1982). The experiment demonstrates the role of attention in the correct perception of objects.

Selective Attention and Models of Attention

THE COCKTAIL PARTY

Figure 3. Beyond just hearing your name from the clamor at a party, other words or concepts, particularly unusual or significant ones to you, can also snag your attention. [Image: Catholic Church (England and Wales), https://goo.gl/c3O8B3, CC BY-NC-SA

2.0, https://goo.gl/iF4hmM]

Selective attention is *the ability to select certain stimuli in the environment to process, while ignoring distracting information*. One way to get an intuitive sense of how attention works is to consider situations in which attention is used. A party provides an excellent example for our purposes. Many people may be milling around, there is a dazzling variety of colors and sounds and smells, the buzz of many conversations is striking. There are so many conversations going on; how is it possible to select just one and follow it? You don't have to be looking at the person talking; you may be listening with great interest to some gossip while pretending not to hear. However, once you are engaged in conversation with someone, you quickly become aware that you cannot also listen to other conversations at the same time. You also are probably *not* aware of how tight your shoes feel or of the smell of a nearby flower arrangement. On the other hand, if someone behind you mentions your name, you typically notice it immediately and may start attending to that (much more interesting) conversation. This situation highlights an interesting set of observations. We have an amazing ability to select and track one voice, visual object, etc., even when a million things are competing for our attention, but at the same time, we seem to be limited in how much we can attend to at one time, which in turn suggests that attention is crucial in selecting what is important. How does it all work?

DICHOTIC LISTENING STUDIES

This cocktail party scenario is the quintessential example of selective attention, and it is essentially what some early researchers tried to replicate under controlled laboratory conditions as a starting point for understanding the role of attention in perception (e.g., Cherry, 1953; Moray, 1959). In particular, they used **dichotic listening** and **shadowing tasks** to evaluate the selection process. Dichotic listening simply refers to the situation when two messages are presented simultaneously to an individual, with one message in each ear. In order to control which message the person attends to, the individual is asked to repeat back or "shadow" one of the messages as he hears it. For example, let's say that a story about a camping trip is presented to John's left ear, and a story about Abe Lincoln is presented to his right ear. The typical dichotic listening task would have John repeat the story presented to one ear as he hears it. Can he do that without being distracted by the information in the other ear?
People can become pretty good at the shadowing task, and they can easily report the content of the message that they attend to. But what happens to the ignored message? Typically, people can tell you if the ignored message was a man's or a woman's voice, or other physical characteristics of the speech, but they cannot tell you what the message was about. In fact, many studies have shown that people in a shadowing task were not aware of a change in the language of the message (e.g., from English to German; Cherry, 1953), and they didn't even notice when the same word was repeated in the unattended ear more than 35 times (Moray, 1959)! Only the basic physical characteristics, such as the pitch of the unattended message, could be reported.

On the basis of these types of experiments, it seems that we can answer the first question about how much information we can attend to very easily: not very much. We clearly have a limited capacity for processing information for meaning, making the selection process all the more important. The question becomes: How does this selection process work?

MODELS OF SELECTIVE ATTENTION

Broadbent's Filter Model. Many researchers have investigated how selection occurs and what happens to ignored information. Donald Broadbent was one of the first to try to characterize the selection process. His Filter Model was based on the dichotic listening tasks described above as well as other types of experiments (Broadbent, 1958). He found that people select information on the basis of *physical features*: the sensory channel (or ear) that a message was coming in, the pitch of the voice, the color or font of a visual message. People seemed vaguely aware of the physical features of the unattended information, but had no knowledge of the meaning. As a result, Broadbent argued that selection occurs *very early*, with no additional processing for the unselected information. A flowchart of the model might look like this:

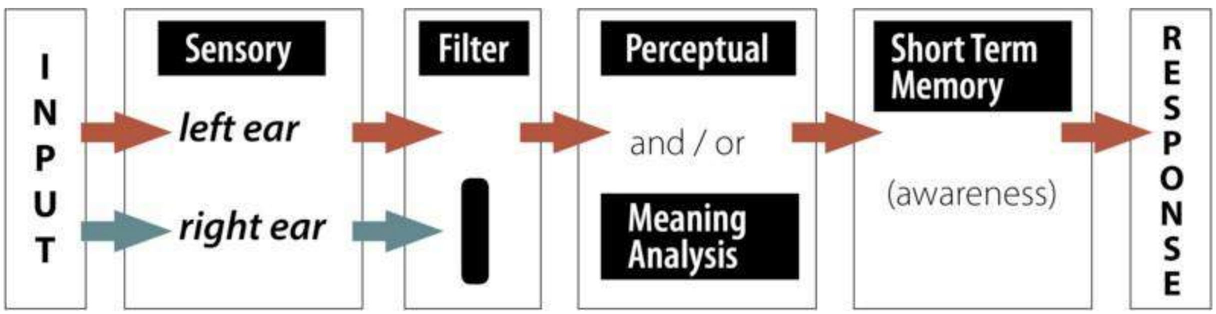


Figure 4. This figure shows information going in both the left and right ears. Some basic sensory information, such as pitch, is processed, but the filter only allows the information from one ear to be processed further. Only the information from the left ear is transferred to short-term memory (STM) and conscious awareness, and then further processed for meaning. That means that the ignored information never makes it beyond a basic physical analysis.

TREISMAN'S ATTENUATION MODEL

Broadbent's model makes sense, but if you think about it you already know that it cannot account for all aspects of the Cocktail Party Effect. What doesn't fit? The fact is that you tend to hear your own name when it is spoken by someone, even if you are deeply engaged in a conversation. We mentioned earlier that people in a shadowing experiment were unaware of a word in the unattended ear that was repeated many times—and yet many people noticed their own name in the unattended ear even it occurred only once.

Anne Treisman (1960) carried out a number of dichotic listening experiments in which she presented two different stories to the two ears. As usual, she asked people to shadow the message in one ear. As the stories progressed, however, she switched the stories to the opposite ears. Treisman found that individuals spontaneously followed the story, or the content of the message, when it shifted from the left ear to the right ear. Then they realized they were shadowing the wrong ear and switched back.

Results like this, and the fact that you tend to hear meaningful information even when you aren't paying attention to it, suggest that we *do* monitor the unattended information to some degree on the basis of its meaning. Therefore, the filter theory can't be right to suggest that unattended information is completely blocked at the sensory analysis level. Instead, Treisman suggested that selection *starts* at the physical or perceptual level, but that the unattended information is not blocked completely, it is just weakened or *attenuated*. As a result, highly meaningful or pertinent information in the unattended ear will get through the filter for further processing at the level of meaning. The figure below shows information going in both ears, and in this case there is no filter that completely blocks nonselected information. Instead, selection of the left ear information strengthens that material, while the nonselected information in the right ear is weakened. However, if the preliminary analysis shows that the nonselected information is especially pertinent or meaningful (such as your own name), then the Attenuation Control will instead strengthen the more meaningful information.

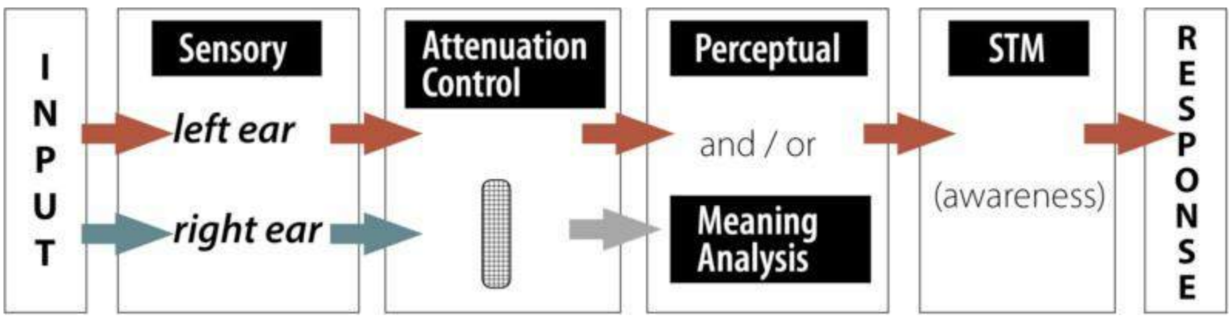


Figure 5. ATTENUATION MODEL

LATE SELECTION MODELS

Other selective attention models have been proposed as well. A *late selection* or *response selection* model proposed by Deutsch and Deutsch (1963) suggests that all information in the unattended ear is processed on the basis of meaning, not just the selected or highly pertinent information. However, only the information that is relevant for the task response gets into conscious awareness. This model is consistent with ideas of subliminal perception; in other words, that you don't have to be aware of or attending a message for it to be fully processed for meaning.

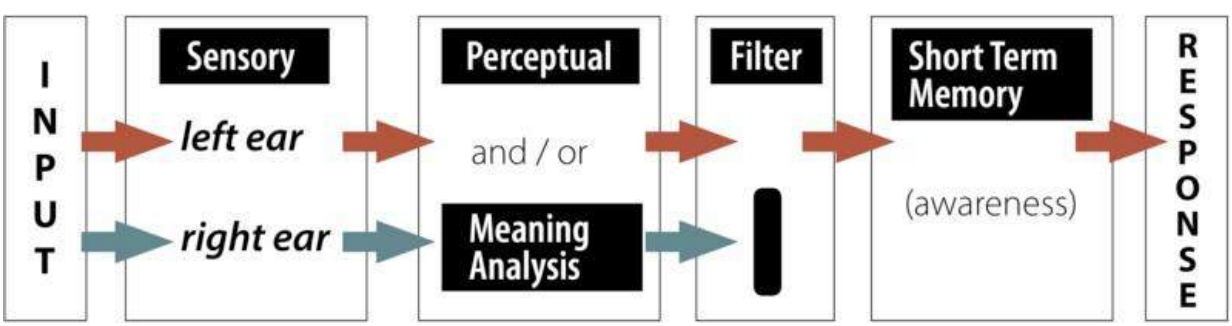


Figure 6. LATE SELECTION MODEL

You might notice that this figure looks a lot like that of the Early Selection model—only the location of the selective filter has changed, with the assumption that analysis of meaning occurs *before* selection occurs, but only the selected information becomes conscious.

MULTIMODE MODEL

Why did researchers keep coming up with different models? Because no model really seemed to account for all the data, some of which indicates that non-selected information is blocked completely, whereas other studies suggest that it can be processed for meaning. The multimode model addresses this apparent inconsistency, suggesting that the stage at which selection occurs can change depending on the task. Johnston and Heinz (1978) demonstrated that under some conditions, we can select what to attend to at a very early stage and we do not process the content of the unattended message very much at all. Analyzing physical information, such as attending to information based on whether it is a male or female voice, is relatively easy; it occurs automatically, rapidly, and doesn't take much effort. Under the right conditions, we can select what to attend to on the basis of the meaning of the messages. However, the late selection option—processing the content of all messages before selection—is more difficult and requires more effort. The benefit, though, is that we have the flexibility to change how we deploy our attention depending upon what we are trying to accomplish, which is one of the greatest strengths of our cognitive system.

This discussion of selective attention has focused on experiments using auditory material, but the same principles hold for other perceptual systems as well. Neisser (1979) investigated some of the same questions with visual materials by superimposing two semi-transparent video clips and asking viewers to attend to just one series of actions. As with the auditory materials, viewers often were unaware of what went on in the other clearly visible video. Twenty years later, Simons and Chabris (1999) explored and expanded these findings using similar techniques, and triggered a flood of new work in an area referred to as inattentional blindness. We touch on those ideas below, and you can also refer to another Noba Module, *Failures of Awareness: The Case of Inattentional Blindness* for a more complete discussion.

Divided Attention

In spite of the evidence of our limited capacity, we all like to think that we can do several things at once. Some people claim to be able to multitask without any problem: reading a textbook while watching television and talking with friends; talking on the phone while playing computer games; texting while driving. The fact is that we sometimes can *seem* to juggle several things at once, but the question remains whether dividing attention in this way impairs performance.

Is it possible to overcome the limited capacity that we experience when engaging in cognitive tasks? We know that with extensive practice, we can acquire skills that do not appear to require conscious attention. As we walk down the street, we don't need to think consciously about what muscle to contract in order to take the next step. Indeed, paying attention to automated skills can lead to a breakdown in performance, or "choking" (e.g., Beilock & Carr, 2001). But what about higher level, more mentally demanding tasks: Is it possible to learn to perform two complex tasks at the same time?

DIVIDED ATTENTION TASKS

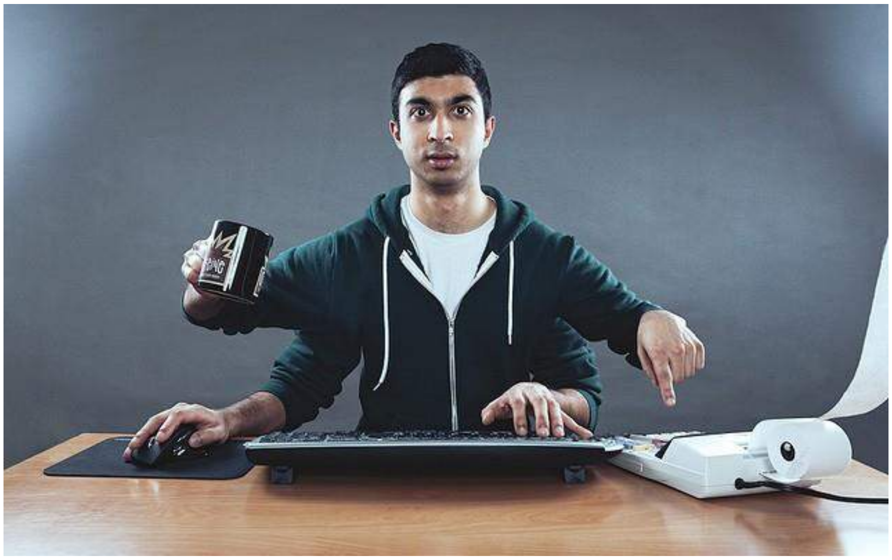


Figure 7. Unless a task is fully automated, some researchers suggest that "multi-tasking" doesn't really exist; you are just rapidly switching your attention back and forth between tasks. [Image: Ryan Ritchie]

In a classic study that examined this type of divided attention task, two participants were trained to take dictation for spoken words while reading unrelated material for comprehension (Spelke, Hirst, & Neisser, 1976). In divided attention tasks such as these, each task is evaluated separately, in order to determine baseline performance when the individual can allocate as many cognitive resources as necessary to one task at a time. Then performance is evaluated when the two tasks are performed simultaneously. A decrease in performance for either task would suggest that even if attention can be divided or switched between the tasks, the cognitive demands are too great to avoid disruption of performance. (We should note here that divided attention tasks are designed, in principle, to see if two tasks can be carried out simultaneously. A related research area looks at *task switching* and how well we can switch back and forth among different tasks [e.g., Monsell, 2003]. It turns out that switching itself is cognitively demanding and can impair performance.)

The focus of the Spelke et al. (1976) study was whether individuals could learn to perform two relatively complex tasks concurrently, without impairing performance. The participants received plenty of practice—the study lasted 17 weeks and they had a 1-hour session each day, 5 days a week. These participants were able to learn to take dictation for lists of words and read for comprehension without affecting performance in either task, and the authors suggested that perhaps there are not fixed limits on our attentional capacity. However, changing the tasks somewhat, such as reading aloud rather than silently, impaired performance initially, so this multitasking ability may be specific to these well-learned tasks. Indeed, not everyone could learn to perform two complex tasks without performance costs (Hirst, Neisser, & Spelke, 1978), although the fact that some can is impressive.

DISTRACTED DRIVING

More relevant to our current lifestyles are questions about multitasking while texting or having cell phone conversations. Research designed to investigate, under controlled conditions, multitasking while driving has revealed some surprising results. Certainly there are many possible types of distractions that could impair driving performance, such as applying makeup using the rearview mirror, attempting (usually in vain) to stop the kids in the backseat from fighting, fiddling with the CD player, trying to negotiate a handheld cell phone, a cigarette, and a soda all at once, eating a bowl of cereal while driving (!). But we tend to have a strong sense that we CAN multitask while driving, and cars are being built with more and more technological capabilities that encourage multitasking. How good are we at dividing attention in these cases?

Figure 8.If you look at your phone for just 5 seconds while driving at 55mph, that means you have driven the length of a football field without looking at the road. [Image: Lord Jim]

Most people acknowledge the distraction caused by texting while driving and the reason seems obvious: Your eyes are off the road and your hands and at least one hand (often both) are engaged while texting. However, the problem is not simply one of occupied hands or eyes, but rather that the *cognitive* demands on our limited capacity systems can seriously impair driving performance (Strayer, Watson, & Drews, 2011). The effect of a cell phone conversation on performance (such as not noticing someone's brake lights or responding more slowly to them) is just as significant when the individual is having a conversation with a hands-free device as with a handheld phone; the same impairments do not occur when listening to the radio or a book on tape (Strayer & Johnston, 2001). Moreover, studies using eye-tracking devices have shown that drivers are less likely to later recognize objects that they *did* look at when using a cell phone while driving (Strayer & Drews, 2007). These findings demonstrate that cognitive distractions such as cell phone conversations can produce inattentional blindness, or a lack of awareness of what is right before your eyes (see also, Simons & Chabris, 1999). Sadly, although we all like to think that we can multitask while driving, in fact the percentage of people who can truly perform cognitive tasks without impairing their driving performance is estimated to be about 2% (Watson & Strayer, 2010).

Subitizing

There are theories that apply to a small number of closely related phenomena. One of these theories is a very specific quantitative ability called subitizing. This refers to people's ability to quickly and accurately perceive the number of objects in a scene without counting them—as long as the number is four or fewer. Several theories have been proposed to explain subitizing. Among them is the idea that small numbers of objects are associated with easily recognizable patterns. For example, people know immediately that there are three objects in a scene because the three objects tend to form a "triangle" and it is this pattern that is quickly perceived.

Though fewer, narrow theories have their place in psychological research. Broad theories organize more phenomena but tend to be less formal and less precise in their predictions. Narrow theories organize fewer phenomena but tend to be more formal and more precise in their predictions.

Treisman's Attenuation Model as it relates to Divided Attention

In 1960 psychologist Anne Treisman carried out a number of dichotic listening experiments in which she presented two different stories to the two ears. As usual, she asked people to shadow the message in one ear. As the stories progressed, however, she switched the stories to the opposite ears. Treisman found that individuals spontaneously followed the story, or the content of the message, when it shifted from the left ear to the right ear. Then they realized they were shadowing the wrong ear and switched back.

Results like this, and the fact that you tend to hear meaningful information even when you aren't paying attention to it, suggest that we *do* monitor the unattended information to some degree on the basis of its meaning. Therefore, the established filter theory can't be right to suggest that unattended information is completely blocked at the sensory analysis level. Instead, Treisman suggested that selection *starts* at the physical or perceptual level, but that the unattended information is not blocked completely, it is just weakened or *attenuated*. As a result, highly meaningful or pertinent information in the unattended ear will get through the filter for further processing at the level of meaning. The figure below shows information going in both ears, and in this case there is no filter that completely blocks nonselected information. Instead, selection of the left ear information strengthens that material, while the nonselected information in the right ear is weakened. However, if the preliminary analysis shows that the nonselected information is especially pertinent or meaningful (such as your own name), then the Attenuation Control will instead strengthen the more meaningful information.

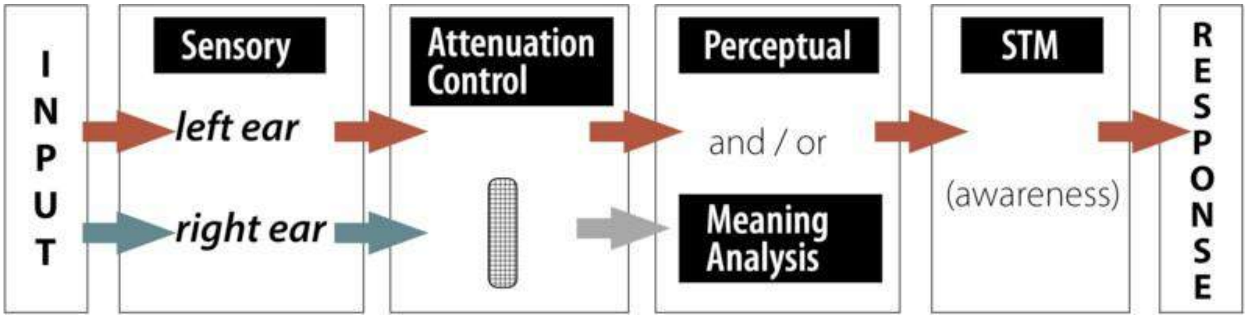


*Figure 9. **Attenuation** Input Response Model*

Auditory Attention

More than 50 years ago, experimental psychologists began documenting the many ways that our perception of the world is limited, not by our eyes and ears, but by our minds. We appear able to process only one stream of information at a time, effectively filtering other information from awareness. To a large extent, we perceive only that which receives the focus of our cognitive efforts: our attention.

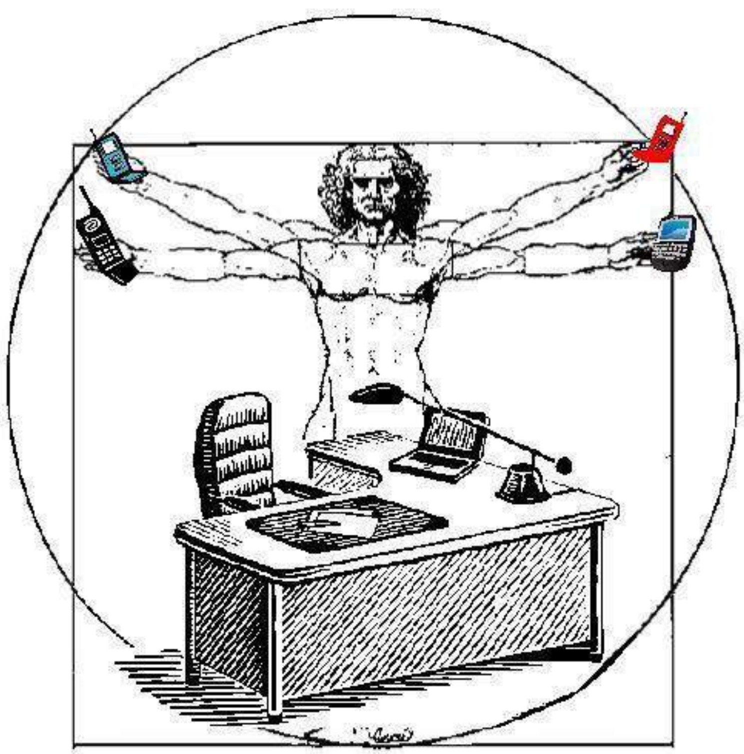


Figure 10. Some researchers contend that there really is no such thing as multi-tasking. Instead, people are just rapidly switching their attention between tasks, rather than holding those tasks in their attention at the same time. [Image: Mike Licht, https://goo.gl/z7rkve, CC BY 2.0, https://goo.gl/v4Y0Zv]

Imagine the following task, known as **dichotic listening**: You put on a set of headphones that play two completely different speech streams, one to your left ear and one to your right ear.

Your task is to repeat each syllable spoken into your left ear as quickly and accurately as possible, mimicking each sound as you hear it. When performing this attention-demanding task, you won't notice if the speaker in your right ear switches to a different language or is replaced by a different speaker with a similar voice. You won't notice if the content of their speech becomes nonsensical. In effect, you are deaf to the substance of the ignored speech. But, that is not because of the limits of your auditory senses. It is a form of cognitive deafness, due to the nature of focused, selective attention. Even if the speaker on your right headphone says your name, you will notice it only about one-third of the time (Conway, Cowan, & Bunting, 2001). And, at least by some accounts, you only notice it that often because you still devote some of your limited attention to the ignored speech stream (Holendar, 1986). In this task, you will tend to notice only large physical changes (e.g., a switch from a male to a female speaker), but not substantive ones, except in rare cases.

This **selective listening** task highlights the power of attention to filter extraneous information from awareness while letting in only those elements of our world that we want to hear. Focused attention is crucial to our powers of observation, making it possible for us to zero in on what we want to see or hear while filtering out irrelevant distractions. But, it has consequences as well: We can miss what would otherwise be obvious and important signals.

Criteria for Automaticity:

MIT has published a video lecture that explains Automaticity. The video will begin playing at 30 minutes, watch till 37:08 to understand the criteria for automaticity.

Chapter 12 - Classification and Categorization / Pattern Recognition

Approaches to Pattern Recognition

Template Matching:

One way for people to recognize objects in their environment would be for them to compare their representations of those objects with templates stored in memory. For example, if I can achieve a match between the large red object I see in the street and my stored representation of a London bus, then I recognize a London bus. However, one difficulty for this theory is illustrated in the figure to the below.

What did you read?

Table 1. THE CHT

Here, we have no problem differentiating the middle letters in each word (H and A), even though they are identical. A second problem is that we continue to recognize most objects regardless of what perspective we see them from (e.g. from the front, side, back, bottom, top, etc.). This would suggest we have a nearly infinite store of templates, which hardly seems credible.

Prototypes:

An alternative to template theory is based on prototype matching. Instead of comparing a visual array to a stored template, the array is compared to a stored prototype, the prototype being a kind of average of many other patterns. The perceived array does not need to exactly match the prototype in order for recognition to occur, so long as there is a family resemblance. For example, if I am looking down on a London bus from above its qualities of size and redness enable me to recognize it as a bus, even though the shape does not match my prototype. There is good evidence that people do form prototypes after exposure to a series of related stimuli. For instance, in one study people were shown a series of patterns that were related to a prototype, but not the prototype itself. When later shown a series of distractor patterns plus the prototype, the participants identified the prototype as a pattern they had seen previously.

Feature Analysis:

Feature-matching theories propose that we decompose visual patterns into a set of critical features, which we then try to match against features stored in memory. For example, in memory I have stored the information that the letter "Z" comprises two horizontal lines, one oblique line, and two acute angles, whereas the letter "Y" has one vertical line, two oblique lines, and one acute angle. I have similar stored knowledge about other letters of the alphabet. When I am presented with a letter of the alphabet, the process of recognition involves identifying the types of lines and angles and comparing these to stored information about all letters of the alphabet. If presented with a "Z", as long as I can identify the features then I should recognise it as a "Z", because no other letter of the alphabet shares this combination of features. The best known model of this kind is Oliver Selfridge'sPandemonium.

One source of evidence for feature matching comes from Hubel and Wiesel's research, which found that the visual cortex of cats contains neurons that only respond to specific features (e.g. one type of neuron might fire when a vertical line is presented, another type of neuron might fire if a horizontal line moving in a particular direction is shown).

Some authors have distinguished between local features and global features. In a paper titled Forest before trees David Navon suggested that "global" features are processed before "local" ones. He showed participants large letter "H"s or "S"s that were made up of smaller letters, either small Hs or small Ss. People were faster to identify the larger letter than the smaller ones, and the response time was the same regardless of whether the smaller letters (the local features) were Hs or Ss. However, when required to identify the smaller letters people responded more quickly when the large letter was of the same type as the smaller letters.

One difficulty for feature-matching theory comes from the fact that we are normally able to read slanted handwriting that does not seem to conform to the feature description given above. For example, if I write a letter "L" in a slanted fashion, I cannot match this to a stored description that states that L must have a vertical line. Another difficulty arises from trying to generalise the theory to the natural objects that we encounter in our environment.

Face Recognition Systems:

Prosopagnosia:

Faces provide information about one’s gender, age, ethnicity, emotional state, and perhaps most importantly, they identify the owner. Thus, the ability to recognize an individual just by looking at their face is crucial for human social interaction. Prosopagnosia is a cognitive condition characterized by a relatively selective impairment in face recognition. The disorder can be acquired or developmental in nature, with the latter also referred to as “congenital” or “hereditary” prosopagnosia. The condition occurs in the absence of any neurological damage, socio-emotional dysfunction or lower-level visual deficits[4], and may affect 2–2.5% of the adult population[7] and 1.2–4% of those in middle childhood.

In the last 20 years, individuals with DP have been used to make theoretical inferences about the development and functioning of the cognitive and neural architecture of the typical and impaired face recognition system. Given some individuals also report moderate-to-severe psychosocial consequences of the condition , there has been increasing interest in the accurate diagnosis of DP via objective testing. Many researchers diagnose the condition using a combination of the Cambridge Face Memory Test (CFMT[17]) and the Cambridge Face Perception Test (CFPT[18]) - regarded as the leading objective tests of face recognition - and a famous faces test. Participants are thought to meet the diagnostic criteria for DP when their scores are considered together, and in many cases, this will mean that DP is determined when individuals score atypically on at least two of these three measures.

Unlike those with acquired prosopagnosia, those with DP have no point of comparison nor experience an abrupt loss of their face recognition skills: many individuals tested in our laboratory did not become aware of their difficulties until mid or even late adulthood (see also[33,34]). This is likely to be due to a combination of reasons. For instance, many people with prosopagnosia can identify people via voice, gait and general appearance and manner[15]. Face recognition difficulties have also been reported to be highly heritable (e.g. refs[39,40]) and individuals may be comparing their abilities to family members who are equally poor at recognizing faces. Subsequently, these individuals may not become aware of their difficulties for a long period of time. Additionally, some people with DP devise their own strategies to recognize others and cope relatively well with their difficulties[33]. This may conceal the condition from other people, or even falsely indicate to oneself, that they are able to recognize others in the same manner as most others in the general population.
If an unaffected person is to recognize the traits of DP in others (as would typically be required to identify the condition in children), they must first know that the condition exists and have an understanding of its behavioral manifestation on an everyday level.

Concepts and Categories

Categories

A **category** a set of objects that can be treated as equivalent in some way. For example, consider the following categories: trucks, wireless devices, weddings, psychopaths, and trout. Although the objects in a given category are different from one another, they have many commonalities. When you know something is a truck, you know quite a bit about it. The psychology of categories concerns how people learn, remember, and use informative categories such as trucks or psychopaths. The mental representations we form of categories are called concepts. There is a category of trucks in the world, and you also have a concept of trucks in your head. We assume that people’s concepts correspond more or less closely to the actual category, but it can be useful to distinguish the two, as when someone’s concept is not really correct.

Figure 1 although you've (probably) never seen this particular truck before, you know a lot about it because of the knowledge you've accumulated in the past about the features in the category of trucks. [Image: CC0 Public Domain, https://goo.gl/m25gce]

Consider the following set of objects: some dust, papers, a computer monitor, two pens, a cup, and an orange. What do these things have in common? Only that they all happen to be on my desk as I write this. This set of things can be considered a **category**, a set of objects that can be treated as equivalent in some way. But, most of our categories seem much more informative—they share many properties. For example, consider the following categories: trucks, wireless devices, weddings, psychopaths, and trout. Although the objects in a given category are different from one another, they have many commonalities. When you know something is a truck, you know quite a bit about it. The psychology of categories concerns how people learn, remember, and use informative categories such as trucks or psychopaths.

The mental representations we form of categories are called **concepts**. There is a category of trucks in the world, and I also have a concept of trucks in my head. We assume that people's concepts correspond more or less closely to the actual category, but it can be useful to distinguish the two, as when someone's concept is not really correct.
Concepts are at the core of intelligent behavior. We expect people to be able to know what to do in new situations and when confronting new objects. If you go into a new classroom and see chairs, a blackboard, a projector, and a screen, you know what these things are and how they will be used. You'll sit on one of the chairs and expect the instructor to write on the blackboard or project something onto the screen. You do this *even if you have never seen any of these particular objects before*, because you have concepts of classrooms, chairs, projectors, and so forth, that tell you what they are and what you're supposed to do with them. Furthermore, if someone tells you a new fact about the projector—for example, that it has a halogen bulb—

you are likely to extend this fact to other projectors you encounter. In short, concepts allow you to extend what you have learned about a limited number of objects to a potentially infinite set of entities.

You know thousands of categories, most of which you have learned without careful study or instruction. Although this accomplishment may seem simple, we know that it isn't, because it is difficult to program computers to solve such intellectual tasks. If you teach a learning program that a robin, a swallow, and a duck are all birds, it may not recognize a cardinal or peacock as a bird. As we'll shortly see, the problem is that objects in categories are often surprisingly diverse.

Simpler organisms, such as animals and human infants, also have concepts (Mareschal, Quinn, & Lea, 2010). Squirrels may have a concept of predators, for example, that is specific to their own lives and experiences. However, animals likely have many fewer concepts and cannot understand complex concepts such as mortgages or musical instruments.

Nature of Categories

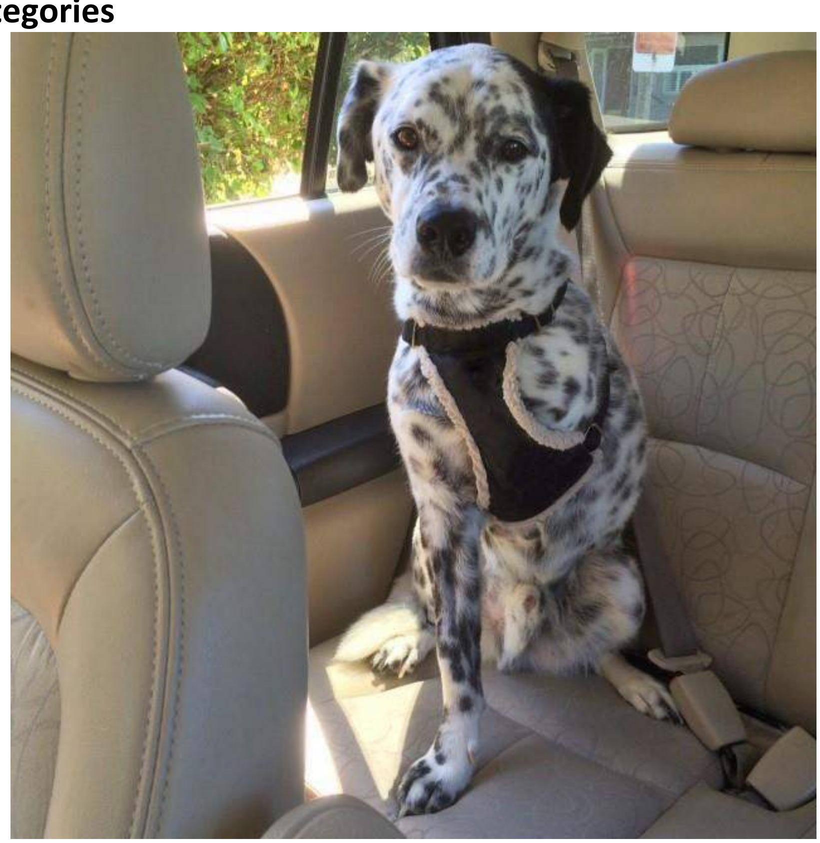


Figure 2. Here is a very good dog, but one that does not fit perfectly into a well-defined category where all dogs have four legs. [Image: State Farm, https://goo.gl/KHtu6N, CC BY 2.0, https://goo.gl/BRvSA7]

Traditionally, it has been assumed that categories are *well-defined*. This means that you can give a definition that specifies what is in and out of the category. Such a definition has two parts. First, it provides the *necessary features* for category membership: What must objects have in order to be in it? Second, those features must be *jointly sufficient*for membership: If an object has those features, then it is in the category. For example, if I defined a dog as a four-legged animal that barks, this would mean that every dog is four-legged, an animal, and barks, and also that anything that has all those properties is a dog.

Unfortunately, it has not been possible to find definitions for many familiar categories. Definitions are neat and clear-cut; the world is messy and often unclear. For example, consider our definition of dogs. In reality, not all dogs have four legs; not all dogs bark. I knew a dog that lost her bark with age (this was an improvement); no one doubted that she was still a dog. It is often possible to find some necessary features (e.g., all dogs have blood and breathe), but these features are generally not sufficient to determine category membership (you also have blood and breathe but are not a dog).

Even in domains where one might expect to find clear-cut definitions, such as science and law, there are often problems. For example, many people were upset when Pluto was downgraded from its status as a planet to a dwarf planet in 2006. Upset turned to outrage when they discovered that there was no hard-and-fast definition of planethood: "Aren't these astronomers scientists? Can't they make a simple definition?" In fact, they couldn't. After an astronomical organization tried to make a definition for planets, a number of astronomers complained that it might not include accepted planets such as Neptune and refused to use it. If everything looked like our Earth, our moon, and our sun, it would be easy to give definitions of planets, moons, and stars, but the universe has sadly not conformed to this ideal.

Fuzzy Categories

Borderline Items

Experiments also showed that the psychological assumptions of well-defined categories were not correct. Hampton (1979) asked subjects to judge whether a number of items were in different categories. He did not find that items were either clear members or clear nonmembers. Instead, he found many items that were just barely considered category members and others that were just barely not members, with much disagreement among subjects. Sinks were barely considered as members of the kitchen utensil category, and sponges were barely excluded. People just included seaweed as a vegetable and just barely excluded tomatoes and gourds. Hampton found that members and nonmembers formed a continuum, with no obvious break in people's membership judgments. If categories were well defined, such examples should be very rare. Many studies since then have found such *borderline members* that are not clearly in or clearly out of the category.

Furniture	Fruit
chair	orange
table	banana
desk	pear
bookcase	plum
lamp	strawberry
cushion	pineapple
rug	lemon
stove	honeydew
picture	date
vase	tomato

Table 2. Examples of two categories, with members ordered by typicality (from Rosch & Mervis, 1975)

McCloskey and Glucksberg (1978) found further evidence for borderline membership by asking people to judge category membership twice, separated by two weeks. They found that when people made repeated category judgments such as "Is an olive a fruit?" or "Is a sponge a kitchen utensil?" they changed their minds about borderline items—up to 22 percent of the time. So, not only do people disagree with one another about borderline items, they disagree with themselves! As a result, researchers often say that categories are *fuzzy*, that is, they have unclear boundaries that can shift over time.

Typicality

A related finding that turns out to be most important is that even among items that clearly are in a category, some seem to be "better" members than others (Rosch, 1973). Among birds, for example, robins and sparrows are very **typical**. In contrast, ostriches and penguins are very *atypical* (meaning not typical). If someone says, "There's a bird in my yard," the image you have will be of a smallish passerine bird such as a robin, not an eagle or hummingbird or turkey.

You can find out which category members are typical merely by asking people. Table 1 shows a list of category members in order of their rated typicality. Typicality is perhaps the most important variable in predicting how people interact with categories. The following text box is a partial list of what typicality influences.

We can understand the two phenomena of borderline members and typicality as two sides of the same coin. Think of the most typical category member: This is often called the category *prototype*. Items that are less and less similar to the prototype become less and less typical. At some point, these less typical items become so atypical that you start to doubt whether they are in the category at all. Is a rug really an example of furniture? It's in the home like chairs and tables, but it's also different from most furniture in its structure and use. From day to day, you might change your mind as to whether this atypical example is in or out of the category. So, changes in typicality ultimately lead to borderline members.

Influences of Typicality on Cognition
• **Typical items are judged category members more often** (Hampton, 1979).
• **Speed of categorization is faster for typical items** (Rips, Shoben, & Smith, 1973).
• **Typical members are learned before atypical ones** (Rosch & Mervis, 1975).
• **Learning a category is easier if typical examples are provided** (Mervis & Pani, 1980).
• **In language comprehension, references to typical members are understood more easily** (Garrod & Sanford, 1977).
• **In language production, people tend to say typical items before atypical ones (e.g., "apples and lemons" rather than "lemons and apples")** (Onishi, Murphy, & Bock, 2008).

Table 3. Typicality and Cognition

Source of Typicality

Intuitively, it is not surprising that robins are better examples of birds than penguins are,or that a table is a more typical kind of furniture than is a rug. But given that robins and penguins are known to be birds, why should one be more typical than the other? One possible answer is the frequency with which we encounter the object: We see a lot more robins than penguins, so they must be more typical. Frequency does have some effect, but it is actually not the most important variable (Rosch, Simpson, & Miller, 1976). For example, I see both rugs and tables every single day, but one of them is much more typical as furniture than the other.

The best account of what makes something typical comes from Rosch and Mervis's (1975) *family resemblance theory*. They proposed that items are likely to be typical if they (a) have the features that are frequent in the category and (b) do not have features frequent in other categories. Let's compare two extremes, robins and penguins. Robins are small flying birds that sing, live in nests in trees, migrate in winter, hop around on your lawn, and so on. Most of these properties are found in many other birds. In contrast, penguins do not fly, do not sing, do not live in nests or in trees, do not hop around on your lawn. Furthermore, they have properties that are common in other categories, such as swimming expertly and having wings that look and act like fins. These properties are more often found in fish than in birds.

Figure 3. When you think of "bird," how closely does the robin resemble your general figure? [Image: CC0 Public Domain, https://goo.gl/m25gce]

According to Rosch and Mervis, then, it is not because a robin is a very common bird that makes it typical. Rather, it is because the robin has the shape, size, body parts, and behaviors that are very common among birds—and not common among fish, mammals, bugs, and so forth.

In a classic experiment, Rosch and Mervis (1975) made up two new categories, with arbitrary features. Subjects viewed example after example and had to learn which example was in which category. Rosch and Mervis constructed some items that had features that were common in the category and other items that had features less common in the category. The subjects learned the first type of item before they learned the second type. Furthermore, they then rated the items with common features as more typical. In another experiment, Rosch and Mervis constructed items that differed in how many features were shared with a *different* category. The more features were shared, the longer it took subjects to learn which category the item was in. These experiments, and many later studies, support both parts of the family resemblance theory.

Category Hierarchies

Many important categories fall into *hierarchies*, in which more concrete categories are nested inside larger, abstract categories. For example, consider the categories: brown bear, bear, mammal, vertebrate, animal, entity. Clearly, all brown bears are bears; all bears are mammals; all mammals are vertebrates; and so on. Any given object typically does not fall into just one category—it could be in a dozen different categories, some of which are structured in this hierarchical manner. Examples of biological categories come to mind most easily, but within the realm of human artifacts, hierarchical structures can readily be found: desk chair, chair, furniture, artifact, object.

Brown (1958), a child language researcher, was perhaps the first to note that there seems to be a preference for which category we use to label things. If your office desk chair is in the way, you'll probably say, "Move that chair," rather than "Move that desk chair" or "piece of furniture." Brown thought that the use of a single, consistent name probably helped children to learn the name for things. And, indeed, children's first labels for categories tend to be exactly those names that adults prefer to use (Anglin, 1977).

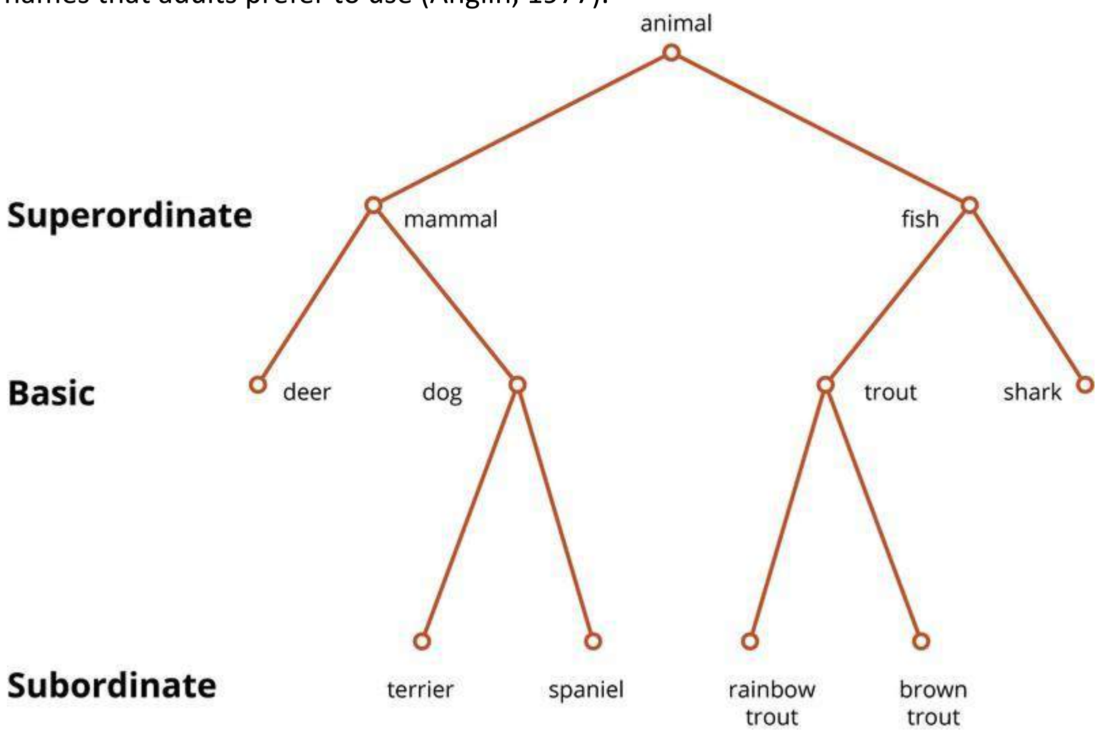


Figure 4. This is a highly simplified illustration of hierarchically organized categories, with the superordinate, basic, and subordinate levels labeled. Keep in mind that there may be even more specific subordinates (e.g., wire-haired terriers) and more general superordinates (e.g., living thing)

This preference is referred to as a preference for the **basic level of categorization**, and it was first studied in detail by Eleanor Rosch and her students (Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). The basic level represents a kind of Goldilocks effect, in which the category used for something is not too small (northern brown bear) and not too big (animal), but is just right (bear). The simplest way to identify an object's basic-level category is to discover how it would be labeled in a neutral situation. Rosch et al. (1976) showed subjects pictures and asked them to provide the first name that came to mind. They found that 1,595 names were at the basic level, with 14 more specific names (*subordinates*) used. Only once did anyone use a more general name (*superordinate*). Furthermore, in printed text, basic-level labels are much more frequent than most subordinate or superordinate labels (e.g., Wisniewski & Murphy, 1989).

The preference for the basic level is not merely a matter of labeling. Basic-level categories are usually easier to learn. As Brown noted, children use these categories first in language learning, and superordinates are especially difficult for children to fully acquire. People are faster at identifying objects as members of basic-level categories (Rosch et al., 1976).
Rosch et al. (1976) initially proposed that basic-level categories cut the world at its joints, that is, merely reflect the big differences between categories like chairs and tables or between cats and mice that exist in the world. However, it turns out that which level is basic is not universal. North Americans are likely to use names like *tree, fish*, and *bird* to label natural objects. But people in less industrialized societies seldom use these labels and instead use more specific words, equivalent to *elm, trout,* and *finch* (Berlin, 1992). Because Americans and many other people living in industrialized societies know so much less than our ancestors did about the natural world, our basic level has "moved up" to what would have been the superordinate level a century ago. Furthermore, experts in a domain often have a preferred level that is more specific than that of non-experts. Birdwatchers see sparrows rather than just birds, and carpenters see roofing hammers rather than just hammers (Tanaka & Taylor, 1991). This all suggests that the preferred level is not (only) based on how different categories are in the world, but that people's knowledge and interest in the categories has an important effect.

One explanation of the basic-level preference is that basic-level categories are more *differentiated:* The category members are similar to one another, but they are different from members of other categories (Murphy & Brownell, 1985; Rosch et al., 1976). (The alert reader will note a similarity to the explanation of typicality I gave above. However, here we're talking about the entire category and not individual members.) Chairs are pretty similar to one another, sharing a lot of features (legs, a seat, a back, similar size and shape); they also don't share that many features with other furniture. Superordinate categories are not as useful because their members are not very similar to one another. What features are common to most furniture? There are very few. Subordinate categories are not as useful, because they're very similar to other categories: Desk chairs are quite similar to dining room chairs and easy chairs. As a result, it can be difficult to decide which subordinate category an object is in (Murphy & Brownell, 1985). Experts can differ from novices in which categories are the most differentiated, because they know different things about the categories, therefore changing how similar the categories are.

This is a controversial claim, as some say that infants learn superordinates before anything else (Mandler, 2004). However, if true, then it is very puzzling that older children have great difficulty learning the correct meaning of words for superordinates, as well as in learning artificial superordinate categories (Horton & Markman, 1980; Mervis, 1987). However, it seems fair to say that the answer to this question is not yet fully known.

Conclusion: So, what is Cognitive Psychology?

Ultimatly Cognitive psychology is the scientific investigation of human cognition, that is, all our mental abilities – perceiving, learning, remembering, thinking, reasoning, and understanding. It is closely related to the highly interdisciplinary cognitive science and influenced by artificial intelligence, computer science, philosophy, anthropology, linguistics, biology, physics, and neuroscience.

The term “cognition” stems from the Latin word “cognoscere” or "to know". Fundamentally, cognitive psychology studies how people acquire and apply knowledge or information.

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