UPEI Introduction to Psychology 1

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PHILIP SMITH

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Contents

Acknowledgements

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INTRODUCTION TO PSYCHOLOGY

Figure 1.1 Psychology is the scientific study of mind and behavior. (credit "background": modification of work by Nattachai Noogure; credit "top left": modification of work by U.S. Navy; credit "top middle-left": modification of work by Peter Shanks; credit "top middle-right": modification of work by "devinf"/Flickr; credit "top right": modification of work by Alejandra Quintero Sinisterra; credit "bottom left": modification of work by Gabriel Rocha; credit "bottom middle- left": modification of work by Caleb Roenigk; credit "bottom middle-right": modification of work by Staffan Scherz; credit "bottom right": modification of work by Czech Provincial Reconstruction Team)

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What Is Psychology?

In Greek mythology, Psyche was a mortal woman whose beauty was so great that it rivaled that of the goddess Aphrodite. Aphrodite became so jealous of Psyche that she sent her son, Eros, to make Psyche fall in love with the ugliest man in the world. However, Eros accidentally pricked himself with the tip of his arrow and fell madly in love with Psyche himself. He took Psyche to his palace and showered her with gifts, yet she could never see his face. While visiting Psyche, her sisters roused suspicion in Psyche about her mysterious lover, and eventually, Psyche betrayed Eros' wishes to remain unseen to her (**Figure 1.2**). Because of this betrayal, Eros abandoned Psyche. When Psyche appealed to Aphrodite to reunite her with Eros, Aphrodite gave her a series of impossible tasks to complete. Psyche managed to complete all of these trials; ultimately, her perseverance paid off as she was reunited with Eros and was ultimately transformed into a goddess herself (Ashliman, 2001; Greek Myths & Greek Mythology, 2014).

Figure 1.2 Antonio Canova's sculpture depicts Eros and Psyche.

Psyche comes to represent the human soul's triumph over the misfortunes of life in the pursuit of true happiness (Bulfinch, 1855); in fact, the Greek word **psyche** means soul, and it is often represented as a butterfly. The word *psychology* was coined at a time when the concepts of soul and mind were not as clearly distinguished (Green, 2001). The root **ology** denotes scientific study of, and **psychology** refers to the scientific study of the mind. Since science studies only observable phenomena and the mind is not directly observable, we expand this definition to the scientific study of mind and behavior.

The scientific study of any aspect of the world uses the scientific method to acquire knowledge. To apply the scientific method, a researcher with a question about how or why something happens will propose a tentative explanation, called a hypothesis, to explain the phenomenon. A hypothesis is not just any explanation; it should fit into the context of a scientific theory. A scientific theory is a broad explanation or group of explanations for some aspect of the natural world that is consistently supported by evidence over time. A theory is the best understanding that we have of that part of the natural world. Armed with the hypothesis, the researcher then makes observations or, better still, carries out an experiment to test the validity of the hypothesis. That test and its results are then published so that others can check the results or build on them. It is necessary that any explanation in science be testable, which means that the phenomenon must be perceivable and measurable. For example, that a bird sings because it is happy is not a testable hypothesis, since we have no way to measure the happiness of a bird. We must ask a different question, perhaps about the brain state of the bird, since this can be measured. In general, science deals only with matter and energy, that is, those things that can be measured, and it cannot arrive at knowledge about values and morality. This is one reason why our scientific understanding of the mind is so limited, since thoughts, at least as we experience them, are neither matter nor energy. The scientific method is also a form of empiricism. An **empirical method** for acquiring knowledge is one based on observation, including experimentation, rather than a method based only on forms of logical argument or previous authorities.

It was not until the late 1800s that psychology became accepted as its own academic discipline. Before this time, the workings of the mind were considered under the auspices of philosophy. Given that any behavior is, at its roots, biological, some areas of psychology take on aspects of a natural science like biology. No biological organism exists in isolation, and our behavior is influenced by our interactions with others. Therefore, psychology is also a social science.

MERITS OF AN EDUCATION IN PSYCHOLOGY

Often, students take their first psychology course because they are interested in helping others and want to learn more about themselves and why they act the way they do. Sometimes, students take a psychology course because it either satisfies a general education requirement or is required for a program of study such as nursing or pre-med. Many of these students develop such an interest in the area that they go on to declare psychology as their major. As a result, psychology is one of the most popular majors on college campuses across the United States (Johnson & Lubin, 2011). A number of well-known individuals were psychology majors. Just a few famous names on this list are Facebook's creator Mark Zuckerberg, television personality and political satirist Jon Stewart, actress Natalie Portman, and filmmaker Wes Craven (Halonen, 2011). About 6 percent of all bachelor degrees granted in the United States are in the discipline of psychology (U.S. Department of Education, 2013).

An education in psychology is valuable for a number of reasons. Psychology students hone critical thinking skills and are trained in the use of the scientific method. Critical thinking is the active application of a set of skills to information for the understanding and evaluation of that information. The evaluation of information—assessing its reliability and usefulness— is an important skill in a world full of competing "facts," many of which are designed to be misleading. For example, critical thinking involves maintaining an attitude of skepticism, recognizing internal biases, making use of logical thinking, asking appropriate questions, and making observations. Psychology students also can develop better communication skills during the course of their undergraduate coursework (American Psychological Association, 2011). Together, these factors increase students' scientific literacy and prepare students to critically evaluate the various sources of information they encounter.

In addition to these broad-based skills, psychology students come to understand the complex factors that shape one's behavior. They appreciate the interaction of our biology, our environment, and our experiences in determining who we are and how we will behave. They learn about basic principles that guide how we think and behave, and they come to recognize the tremendous diversity that exists across individuals and across cultural boundaries (American Psychological Association, 2011).

LINK TO LEARNING

Watch a brief video (http://openstaxcollege.org/l/psycmajor) that describes some of the questions a student should consider before deciding to major in psychology.

History 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. This section will provide an overview of the shifts in paradigms that have influenced psychology from Wundt and James through today.

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 (**Figure 1.3**). 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).

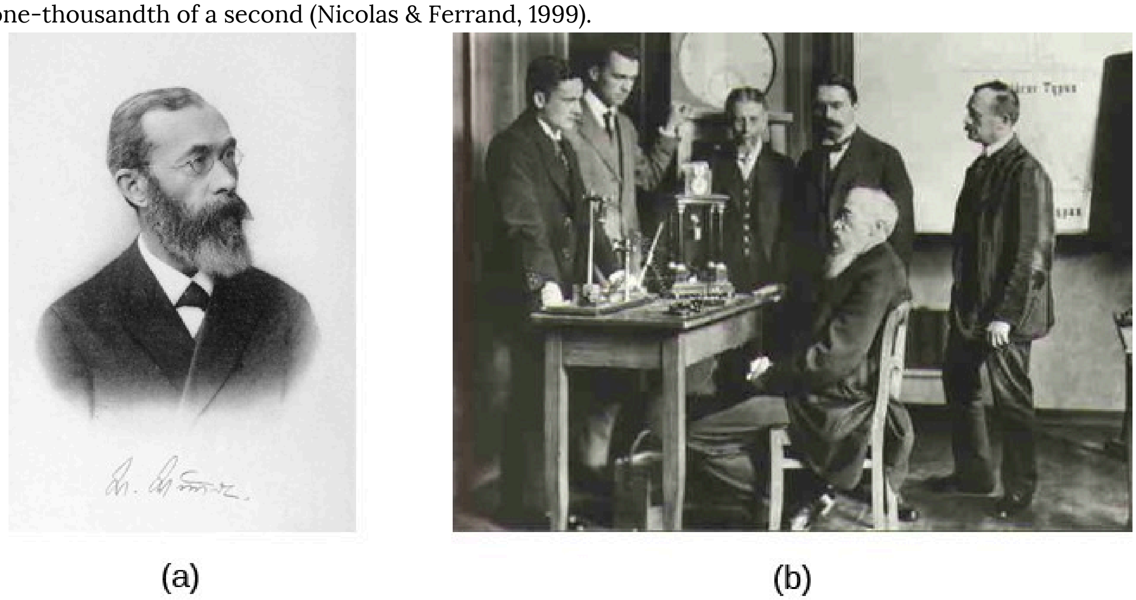


Figure 1.3 (a) Wilhelm Wundt is credited as one of the founders of psychology. He created the first laboratory for

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).

JAMES AND FUNCTIONALISM

William James (1842–1910) was the first American psychologist who espoused a different perspective on how psychology should operate (**Figure 1.4**). 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 1.4 William James, shown here in a self-portrait, was the first American psychologist.

FREUD AND PSYCHOANALYTIC THEORY

Perhaps one of the most influential and well-known figures in psychology's history was Sigmund Freud (**Figure 1.5**). Freud (1856–1939) was an Austrian neurologist who was fascinated by patients suffering from "hysteria" and neurosis. Hysteria was an ancient diagnosis for disorders, primarily of women with a wide variety of symptoms, including physical symptoms and emotional disturbances, none of which had an apparent physical cause. Freud theorized that many of his patients' problems arose from the unconscious mind. In Freud's view, the unconscious mind was a repository of feelings and urges of which we have no awareness. Gaining access to the unconscious, then, was crucial to the successful resolution of the patient's problems. According to Freud, the unconscious mind could be accessed through dream analysis, by examinations of the first words that came to people's minds, and through seemingly innocent slips of the tongue. **Psychoanalytic theory** focuses on the role of a person's unconscious, as well as early childhood experiences, and this particular perspective dominated clinical psychology for several decades (Thorne & Henley, 2005).

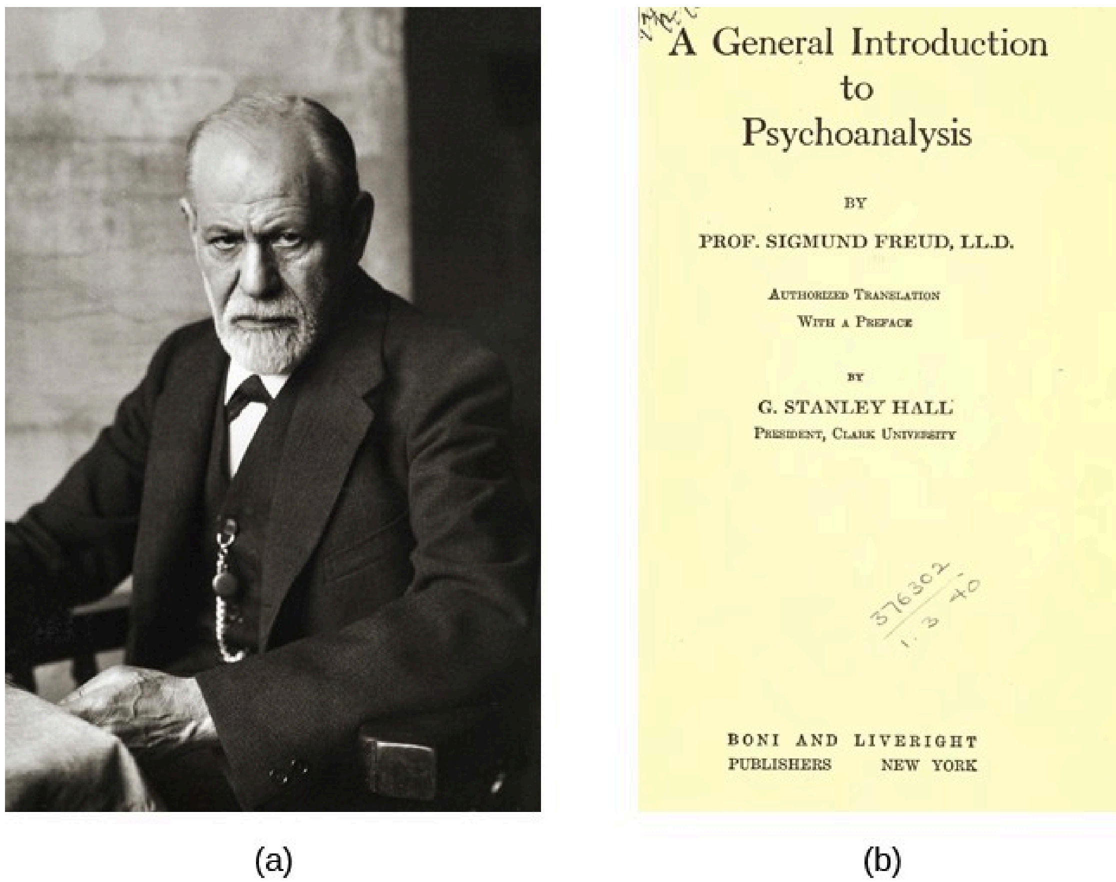


Figure 1.5 (a) Sigmund Freud was a highly influential figure in the history of psychology. (b) One of his many books, A *General Introduction to Psychoanalysis*, shared his ideas about psychoanalytical therapy; it was published in 1922.

Freud's ideas were influential, and you will learn more about them when you study lifespan development, personality, and therapy. For instance, many therapists believe strongly in the unconscious and the impact of early childhood experiences on the rest of a person's life. The method of psychoanalysis, which involves the patient talking about their experiences and selves, while not invented by Freud, was certainly popularized by him and is still used today. Many of Freud's other ideas, however, are controversial. Drew Westen (1998) argues that many of the criticisms of Freud's ideas are misplaced, in that they attack his older ideas without taking into account later writings. Westen also argues that critics fail to consider the success of the broad ideas that Freud introduced or developed, such as the importance of childhood experiences in adult motivations, the role of unconscious versus conscious motivations in driving our behavior, the fact that motivations can cause conflicts that affect behavior, the effects of mental representations of ourselves and others in guiding our interactions, and the development of personality over time. Westen identifies subsequent research support for all of these ideas.

More modern iterations of Freud's clinical approach have been empirically demonstrated to be effective (Knekt et al., 2008; Shedler, 2010). Some current practices in psychotherapy involve examining unconscious aspects of the self and relationships, often through the relationship between the therapist and the client.

Freud's historical significance and contributions to clinical practice merit his inclusion in a discussion of the historical movements within psychology.

WERTHEIMER, KOFFKA, KÖHLER, AND GESTALT PSYCHOLOGY

Max Wertheimer (1880–1943), Kurt Koffka (1886–1941), and Wolfgang Köhler (1887–1967) were three German psychologists who immigrated to the United States in the early 20th century to escape Nazi Germany. These men are credited with introducing psychologists in the United States to various Gestalt principles. The word Gestalt roughly translates to "whole;" a major emphasis of Gestalt psychology deals with the fact that although a sensory experience can be broken down into individual parts, how those parts relate to each other as a whole is often what the individual responds to in perception. For example, a song may be made up of individual notes played by different instruments, but the real nature of the song is perceived in the combinations of these notes as they form the melody, rhythm, and harmony. In many ways, this particular perspective would have directly contradicted Wundt's ideas of structuralism (Thorne & Henley, 2005).

Unfortunately, in moving to the United States, these men were forced to abandon much of their work and were unable to continue to conduct research on a large scale. These factors along with the rise of behaviorism (described next) in the United States prevented principles of Gestalt psychology from being as influential in the United States as they had been in their native Germany (Thorne & Henley, 2005). Despite these issues, several Gestalt principles are still very influential today. Considering the human individual as a whole rather than as a sum of individually measured parts became an important foundation in humanistic theory late in the century. The ideas of Gestalt have continued to influence research on sensation and perception.

Structuralism, Freud, and the Gestalt psychologists were all concerned in one way or another with describing and understanding inner experience. But other researchers had concerns that inner experience could be a legitimate subject of scientific inquiry and chose instead to exclusively study behavior, the objectively observable outcome of mental processes.

PAVLOV, WATSON, SKINNER, AND BEHAVIORISM

Early work in the field of behavior was conducted by the Russian physiologist Ivan Pavlov (1849–1936). Pavlov studied a form of learning behavior called a conditioned reflex, in which an animal or human produced a reflex (unconscious) response to a stimulus and, over time, was conditioned to produce the response to a different stimulus that the experimenter associated with the original stimulus. The reflex Pavlov worked with was salivation in response to the presence of food. The salivation reflex could be elicited using a second stimulus, such as a specific sound, that was presented in association with the initial food stimulus several times. Once the response to the second stimulus was “learned,” the food stimulus could be omitted. Pavlov’s “classical conditioning” is only one form of learning behavior studied by behaviorists.

John B. Watson (1878–1958) was an influential American psychologist whose most famous work occurred during the early 20th century at Johns Hopkins University (**Figure 1.6**). While Wundt and James were concerned with understanding conscious experience, Watson thought that the study of consciousness was flawed. Because he believed that objective analysis of the mind was impossible, Watson preferred to focus directly on observable behavior and try to bring that behavior under control. Watson was a major proponent of shifting the focus of psychology from the mind to behavior, and this approach of observing and controlling behavior came to be known as **behaviorism**. A major object of study by behaviorists was learned behavior and its interaction with inborn qualities of the organism. Behaviorism commonly used animals in experiments under the assumption that what was learned using animal models could, to some degree, be applied to human behavior. Indeed, Tolman (1938) stated, “I believe that everything important in psychology (except … such matters as involve society and words) can be investigated in essence through the continued experimental and theoretical analysis of the determiners of rat behavior at a choice-point in a maze.”

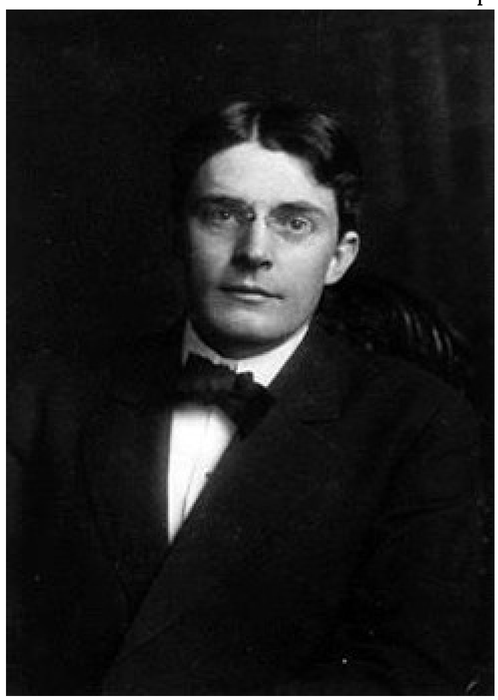


Figure 1.6 John B. Watson is known as the father of behaviorism within psychology.

Behaviorism dominated experimental psychology for several decades, and its influence can still be felt today (Thorne & Henley, 2005). Behaviorism is largely responsible for establishing psychology as a scientific discipline through its objective methods and especially experimentation. In addition, it is used in behavioral and cognitive-behavioral therapy. Behavior modification is commonly used in classroom settings. Behaviorism has also led to research on environmental influences on human behavior.

B. F. Skinner (1904–1990) was an American psychologist (**Figure 1.7**). Like Watson, Skinner was a behaviorist, and he concentrated on how behavior was affected by its consequences. Therefore, Skinner spoke of reinforcement and punishment as major factors in driving behavior. As a part of his research, Skinner developed a chamber that allowed the careful study of the principles of modifying behavior through reinforcement and punishment. This device, known as an operant conditioning chamber (or more familiarly, a Skinner box), has remained a crucial resource for researchers studying behavior (Thorne & Henley, 2005).

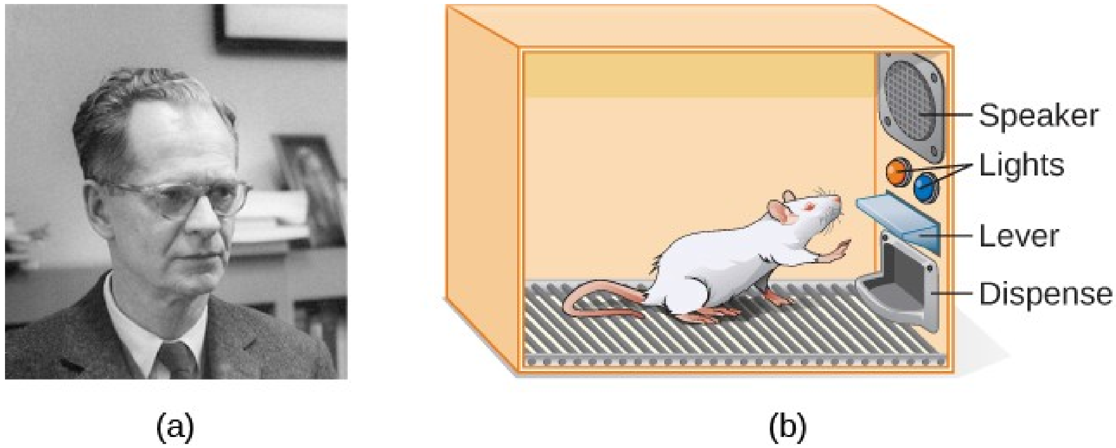


Figure 1.7 (a) B. F. Skinner is famous for his research on operant conditioning. (b) Modified versions of the operant conditioning chamber, or Skinner box, are still widely used in research settings today. (credit a: modification of work by "Silly rabbit"/Wikimedia Commons)

The Skinner box is a chamber that isolates the subject from the external environment and has a behavior indicator such as a lever or a button. When the animal pushes the button or lever, the box is able to deliver a positive reinforcement of the behavior (such as food) or a punishment (such as a noise) or a token conditioner (such as a light) that is correlated with either the positive reinforcement or punishment.

Skinner's focus on positive and negative reinforcement of learned behaviors had a lasting influence in psychology that has waned somewhat since the growth of research in cognitive psychology. Despite this, conditioned learning is still used in human behavioral modification. Skinner's two widely read and controversial popular science books about the value of operant conditioning for creating happier lives remain as thought-provoking arguments for his approach (Greengrass, 2004).

MASLOW, ROGERS, AND HUMANISM

During the early 20th century, American psychology was dominated by behaviorism and psychoanalysis. However, some psychologists were uncomfortable with what they viewed as limited perspectives being so influential to the field. They objected to the pessimism and determinism (all actions driven by the unconscious) of Freud. They also disliked the reductionism, or simplifying nature, of behaviorism. Behaviorism is also deterministic at its core, because it sees human behavior as entirely determined by a combination of genetics and environment. Some psychologists began to form their own ideas that emphasized personal control, intentionality, and a true predisposition for "good" as important for our self- concept and our behavior. Thus, humanism emerged. **Humanism** is a perspective within psychology that emphasizes the potential for good that is innate to all humans. Two of the most well-known proponents of humanistic psychology are Abraham Maslow and Carl Rogers (O'Hara, n.d.).

Abraham Maslow (1908–1970) was an American psychologist who is best known for proposing a hierarchy of human needs in motivating behavior (**Figure 1.8**). Although this concept will be discussed in more detail in a later chapter, a brief overview will be provided here. Maslow asserted that so long as basic needs necessary for survival were met (e.g., food, water, shelter), higher-level needs (e.g., social needs) would begin to motivate behavior. According to Maslow, the highest-level needs relate to self-actualization, a process by which we achieve our full potential. Obviously, the focus on the positive aspects of human nature that are characteristic of the humanistic perspective is evident (Thorne & Henley, 2005). Humanistic psychologists rejected, on principle, the research approach based on reductionist experimentation in the tradition of the physical and biological sciences, because it missed the "whole" human being.

Beginning with Maslow and Rogers, there was an insistence on a humanistic research program. This program has been largely qualitative (not measurement-based), but there exist a number of quantitative research strains within humanistic psychology, including research on happiness, self-concept, meditation, and the outcomes of humanistic psychotherapy (Friedman, 2008).

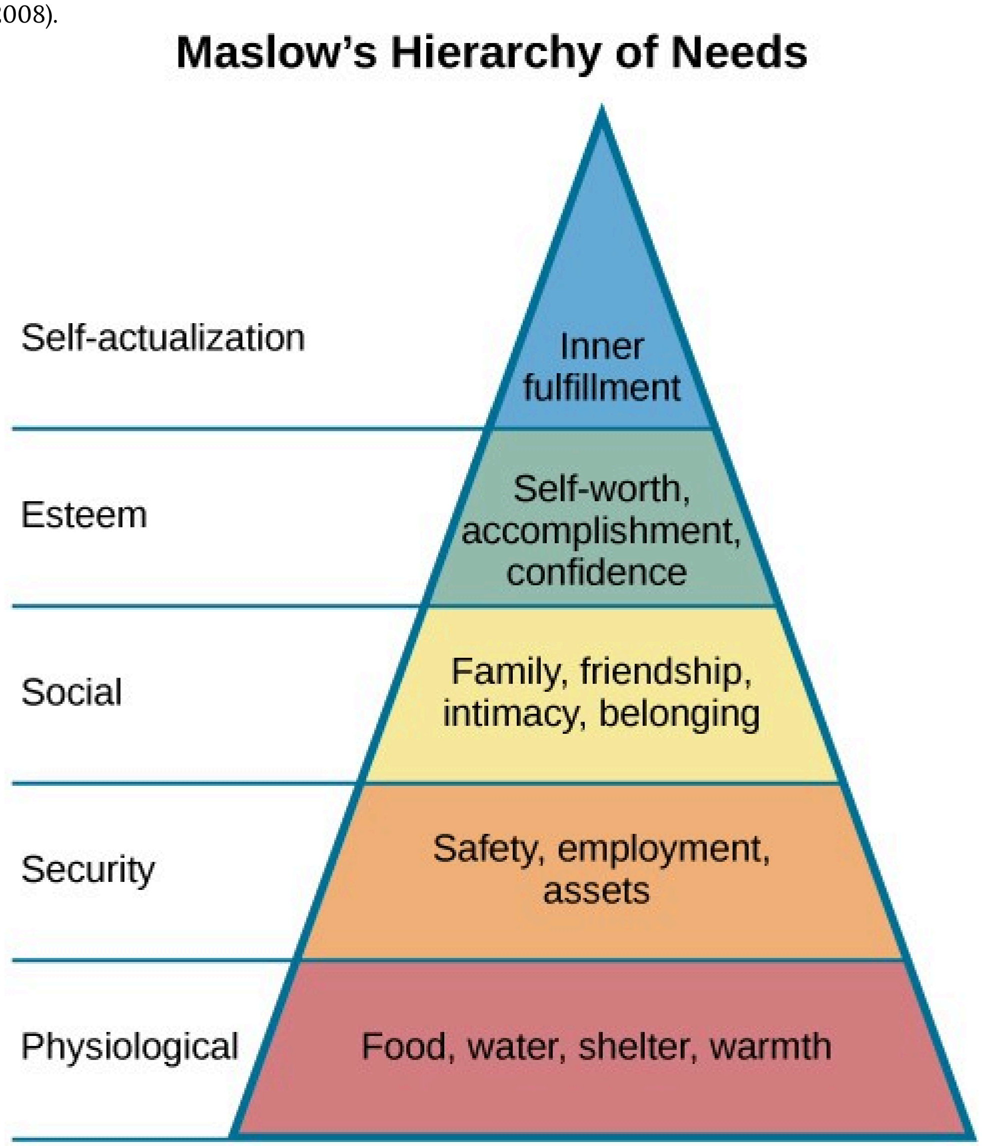


Figure 1.8 Maslow's hierarchy of needs is shown.

Carl Rogers (1902–1987) was also an American psychologist who, like Maslow, emphasized the potential for good that exists within all people (**Figure 1.9**). Rogers used a therapeutic technique known as client- centered therapy in helping his clients deal with problematic issues that resulted in their seeking psychotherapy. Unlike a psychoanalytic approach in which the therapist plays an important role in interpreting what conscious behavior reveals about the unconscious mind, client-centered therapy involves the patient taking a lead role in the therapy session. Rogers believed that a therapist needed to display three features to maximize the effectiveness of this particular approach: unconditional positive regard, genuineness, and empathy. Unconditional positive regard refers to the fact that the therapist accepts their client for who they are, no matter what he or she might say. Provided these factors, Rogers believed that people were more than capable of dealing with and working through their own issues (Thorne & Henley, 2005).

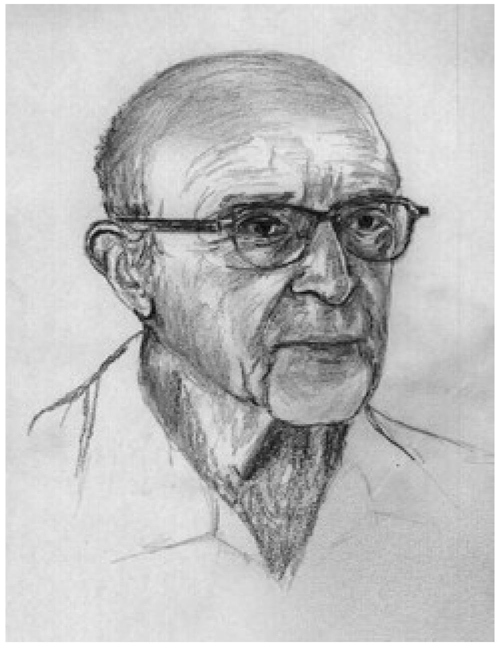


Figure 1.9 Carl Rogers, shown in this portrait, developed a client-centered therapy method that has been influential in clinical settings. (credit: "Didius"/Wikimedia Commons)

Humanism has been influential to psychology as a whole. Both Maslow and Rogers are well-known names among students of psychology (you will read more about both men later in this text), and their ideas have influenced many scholars. Furthermore, Rogers' client-centered approach to therapy is still commonly used in psychotherapeutic settings today (O'hara, n.d.)

LINK TO LEARNING View a brief video (http://openstaxcollege.org/l/crogers1) of Carl Rogersdescribing his therapeutic approach.

THE COGNITIVE REVOLUTION

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 (**Figure 1.10**). 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 1.10 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).

DIG DEEPER

Feminist Psychology

The science of psychology has had an impact on human wellbeing, both positive and negative. The dominant influence of Western, white, and male academics in the early history of psychology meant that psychology developed with the biases inherent in those individuals, which often had negative consequences for members of society that were not white or male. Women, members of ethnic minorities in both the United States and other countries, and individuals with sexual orientations other than heterosexual had difficulties entering the field of psychology and therefore influencing its development. They also suffered from the attitudes of white, male psychologists, who were not immune to the nonscientific attitudes prevalent in the society in which they developed and worked. Until the 1960s, the science of psychology was largely a "womanless" psychology (Crawford & Marecek, 1989), meaning that few women were able to practice psychology, so they had little influence on what was studied. In addition, the experimental subjects of psychology were mostly men, which resulted from underlying assumptions that gender had no influence on psychology and that women were not of sufficient interest to study.

An article by Naomi Weisstein, first published in 1968 (Weisstein, 1993), stimulated a feminist revolution in psychology by presenting a critique of psychology as a science. She also specifically criticized male psychologists for constructing the psychology of women entirely out of their own cultural biases and without careful experimental tests to verify any of their characterizations of women. Weisstein used, as examples, statements by prominent psychologists in the 1960s, such as this quote by Bruno Bettleheim: ". . . we must start with the realization that, as much as women want to be good scientists or engineers, they want first and foremost to be womanly companions of men and to be mothers." Weisstein's critique formed the foundation for the subsequent development of a feminist psychology that attempted to be free of the influence of male cultural biases on our knowledge of the psychology of women and, indeed, of both genders.

Crawford & Marecek (1989) identify several feminist approaches to psychology that can be described as feminist psychology. These include re-evaluating and discovering the contributions of women to the history of psychology, studying psychological gender differences, and questioning the male bias present across the practice of the scientific approach to knowledge.

MULTICULTURAL PSYCHOLOGY

Culture has important impacts on individuals and social psychology, yet the effects of culture on psychology are understudied. There is a risk that psychological theories and data derived from white, American settings could be assumed to apply to individuals and social groups from other cultures and this is unlikely to be true (Betancourt & López, 1993). One weakness in the field of cross-cultural psychology is that in looking for differences in psychological attributes across cultures, there remains a need to go beyond simple descriptive statistics (Betancourt & López, 1993). In this sense, it has remained a descriptive science, rather than one seeking to determine cause and effect. For example, a study of characteristics of individuals seeking treatment for a binge eating disorder in Hispanic American, African American, and Caucasian American individuals found significant differences between groups (Franko et al., 2012). The study concluded that results from studying any one of the groups could not be extended to the other groups, and yet potential causes of the differences were not measured.

This history of multicultural psychology in the United States is a long one. The role of African American psychologists in researching the cultural differences between African American individual and social psychology is but one example. In 1920, Cecil Sumner was the first African American to receive a PhD in psychology in the United States. Sumner established a psychology degree program at Howard University, leading to the education of a new generation of African American psychologists (Black, Spence, and Omari, 2004). Much of the work of early African American psychologists (and a general focus of much work in first half of the 20th century in psychology in the United States) was dedicated to testing and intelligence testing in particular (Black et al., 2004). That emphasis has continued, particularly because of the importance of testing in determining opportunities for children, but other areas of exploration in African-American psychology research include learning style, sense of community and belonging, and spiritualism (Black et al., 2004).

The American Psychological Association has several ethnically based organizations for professional psychologists that facilitate interactions among members. Since psychologists belonging to specific ethnic groups or cultures have the most interest in studying the psychology of their communities, these organizations provide an opportunity for the growth of research on the impact of culture on individual and social psychology.

LINK TO LEARNING Read a news story (http://openstaxcollege.org/l/crogers2) about the influence of an African American's psychology research on the historic Brown v. Board of Education civil rights case.

Contemporary Psychology

Learning Objectives

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

Contemporary psychology is a diverse field that is influenced by all of the historical perspectives described in the preceding section. Reflective of the discipline's diversity is the diversity seen within the **American Psychological Association (APA)**. The APA is a professional organization representing psychologists in the United States. The APA is the largest organization of psychologists in the world, and its mission is to advance and disseminate psychological knowledge for the betterment of people. There are 56 divisions within the APA, representing a wide variety of specialties that range from Societies for the Psychology of Religion and Spirituality to Exercise and Sport Psychology to Behavioral Neuroscience and Comparative Psychology. Reflecting the diversity of the field of psychology itself, members, affiliate members, and associate members span the spectrum from students to doctoral-level psychologists, and come from a variety of places including educational settings, criminal justice, hospitals, the armed forces, and industry (American Psychological Association, 2014). The Association for Psychological Science (APS) was founded in 1988 and seeks to advance the scientific orientation of psychology. Its founding resulted from disagreements between members of the scientific and clinical branches of psychology within the APA. The APS publishes five research journals and engages in education and advocacy with funding agencies. A significant proportion of its members are international, although the majority is located in the United States. Other organizations provide networking and collaboration opportunities for professionals of several ethnic or racial groups working in psychology, such as the National Latina/o Psychological Association (NLPA), the Asian American Psychological Association (AAPA), the Association of Black Psychologists (ABPsi), and the Society of Indian Psychologists (SIP). Most of these groups are also dedicated to studying psychological and social issues within their specific communities.

This section will provide an overview of the major subdivisions within psychology today in the order in which they are introduced throughout the remainder of this textbook. This is not meant to be an exhaustive listing, but it will provide insight into the major areas of research and practice of modern-day psychologists.

LINK TO LEARNING

Please visit http://openstaxcollege.org/l/biopsychology to learn about the divisions within the APA. Student resources (http://openstaxcollege.org/l/studentresource) are also provided by the APA.

BIOPSYCHOLOGY AND EVOLUTIONARY PSYCHOLOGY

As the name suggests, **biopsychology** explores how our biology influences our behavior. While biological psychology is a broad field, many biological psychologists want to understand how the structure and function of the nervous system is related to behavior (**Figure 1.11**). As such, they often combine the research strategies of both psychologists and physiologists to accomplish this goal (as discussed in Carlson, 2013).

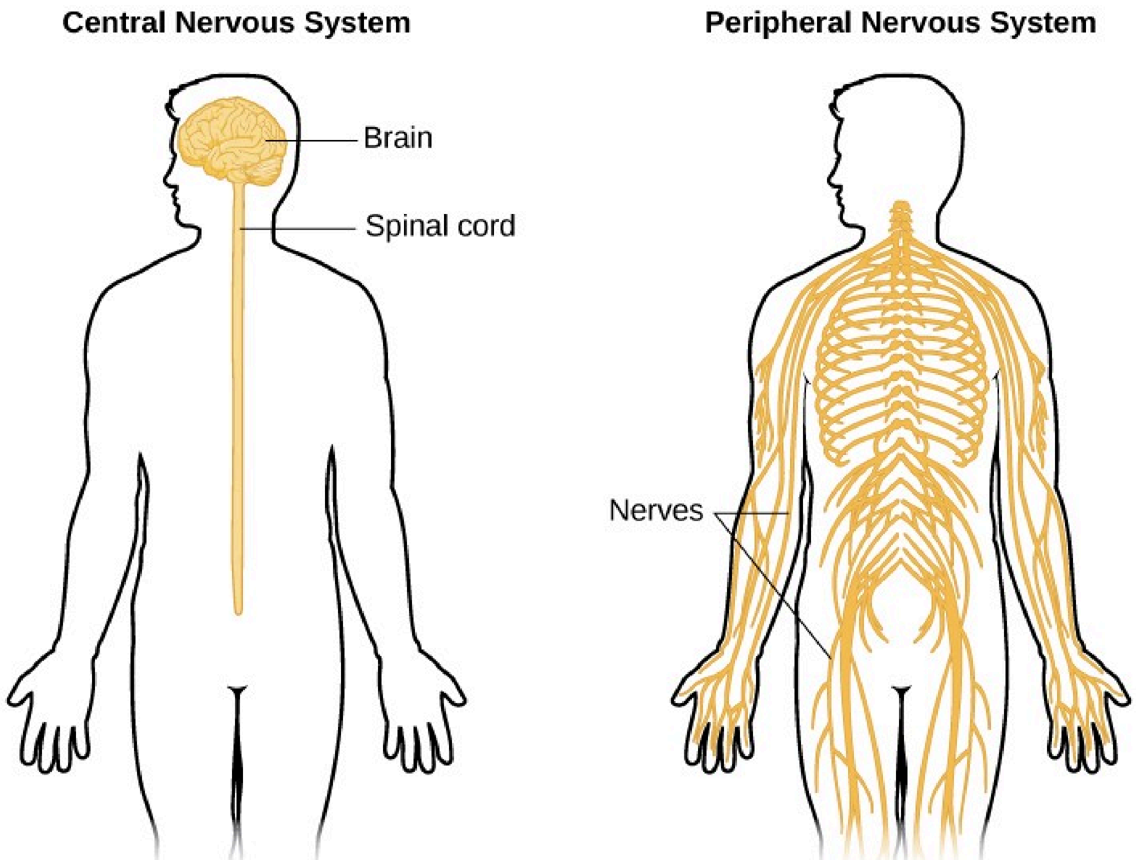


Figure 1.11 Biological psychologists study how the structure and function of the nervous system generate behavior.

The research interests of biological psychologists span a number of domains, including but not limited to, sensory and motor systems, sleep, drug use and abuse, ingestive behavior, reproductive behavior, neurodevelopment, plasticity of the nervous system, and biological correlates of psychological disorders. Given the broad areas of interest falling under the purview of biological psychology, it will probably come as no surprise that individuals from all sorts of backgrounds are involved in this research, including biologists, medical professionals, physiologists, and chemists. This interdisciplinary approach is often referred to as neuroscience, of which biological psychology is a component (Carlson, 2013).

While biopsychology typically focuses on the immediate causes of behavior based in the physiology of a human or other animal, evolutionary psychology seeks to study the ultimate biological causes of behavior. To the extent that a behavior is impacted by genetics, a behavior, like any anatomical characteristic of a human or animal, will demonstrate adaption to its surroundings. These surroundings include the physical environment and, since interactions between organisms can be important to survival and reproduction, the social environment. The study of behavior in the context of evolution has its origins with Charles Darwin, the co-discoverer of the theory of evolution by natural selection. Darwin was well aware that behaviors should be adaptive and wrote books titled, *The Descent of Man* (1871) and *The Expression of the Emotions in Man and Animals* (1872), to explore this field.

Evolutionary psychology, and specifically, the evolutionary psychology of humans, has enjoyed a resurgence in recent decades. To be subject to evolution by natural selection, a behavior must have a significant genetic cause. In general, we expect all human cultures to express a behavior if it is caused genetically, since the genetic differences among human groups are small. The approach taken by most evolutionary psychologists is to predict the outcome of a behavior in a particular situation based on evolutionary theory and then to make observations, or conduct experiments, to determine whether the results match the theory. It is important to recognize that these types of studies are not strong evidence that a behavior is adaptive, since they lack information that the behavior is in some part genetic and not entirely cultural (Endler, 1986). Demonstrating that a trait, especially in humans, is naturally selected is extraordinarily difficult; perhaps for this reason, some evolutionary psychologists are content to assume the behaviors they study have genetic determinants (Confer et al., 2010).

One other drawback of evolutionary psychology is that the traits that we possess now evolved under environmental and social conditions far back in human history, and we have a poor understanding of what these conditions were. This makes predictions about what is adaptive for a behavior difficult. Behavioral traits need not be adaptive under current conditions, only under the conditions of the past when they evolved, about which we can only hypothesize.

There are many areas of human behavior for which evolution can make predictions. Examples include memory, mate choice, relationships between kin, friendship and cooperation, parenting, social organization, and status (Confer et al., 2010).

Evolutionary psychologists have had success in finding experimental correspondence between observations and expectations. In one example, in a study of mate preference differences between men and women that spanned 37 cultures, Buss (1989) found that women valued earning potential factors greater than men, and men valued potential reproductive factors (youth and attractiveness) greater than women in their prospective mates. In general, the predictions were in line with the predictions of evolution, although there were deviations in some cultures.

SENSATION AND PERCEPTION

Scientists interested in both physiological aspects of sensory systems as well as in the psychological experience of sensory information work within the area of sensation and perception (**Figure 1.12**). As such, sensation and perception research is also quite interdisciplinary. Imagine walking between buildings as you move from one class to another. You are inundated with sights, sounds, touch sensations, and smells. You also experience the temperature of the air around you and maintain your balance as you make your way. These are all factors of interest to someone working in the domain of sensation and perception.

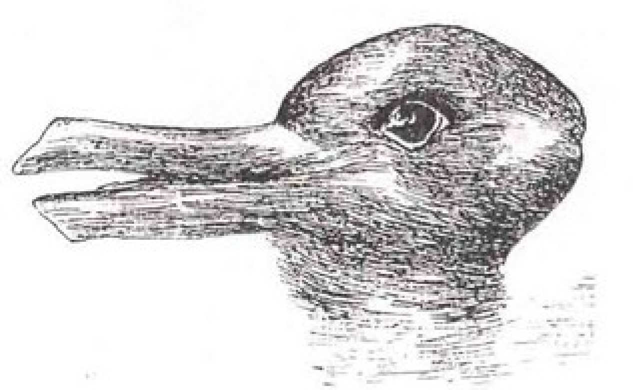


Figure 1.12 When you look at this image, you may see a duck or a rabbit. The sensory information remains the same, but your perception can vary dramatically.

As described in a later chapter that focuses on the results of studies in sensation and perception, our experience of our world is not as simple as the sum total of all of the sensory information (or sensations) together. Rather, our experience (or perception) is complex and is influenced by where we focus our attention, our previous experiences, and even our cultural backgrounds.

COGNITIVE PSYCHOLOGY

As mentioned in the previous section, the cognitive revolution created an impetus for psychologists to focus their attention on better understanding the mind and mental processes that underlie behavior. Thus, **cognitive psychology** is the area of psychology that focuses on studying cognitions, or thoughts, and their relationship to our experiences and our actions. Like biological psychology, cognitive psychology is broad in its scope and often involves collaborations among people from a diverse range of disciplinary backgrounds. This has led some to coin the term cognitive science to describe the interdisciplinary nature of this area of research (Miller, 2003).

Cognitive psychologists have research interests that span a spectrum of topics, ranging from attention to problem solving to language to memory. The approaches used in studying these topics are equally diverse.

Given such diversity, cognitive psychology is not captured in one chapter of this text per se; rather, various concepts related to cognitive psychology will be covered in relevant portions of the chapters in this text on sensation and perception, thinking and intelligence, memory, lifespan development, social psychology, and therapy.

LINK TO LEARNING View a brief video (http://openstaxcollege.org/l/cogpsys) recapping some of themajor concepts explored by cognitive psychologists.

DEVELOPMENTAL PSYCHOLOGY

Developmental psychology is the scientific study of development across a lifespan. Developmental psychologists are interested in processes related to physical maturation. However, their focus is not limited to the physical changes associated with aging, as they also focus on changes in cognitive skills, moral reasoning, social behavior, and other psychological attributes.

Early developmental psychologists focused primarily on changes that occurred through reaching adulthood, providing enormous insight into the differences in physical, cognitive, and social capacities that exist between very young children and adults. For instance, research by Jean Piaget (**Figure 1.13**) demonstrated that very young children do not demonstrate object permanence. Object permanence refers to the understanding that physical things continue to exist, even if they are hidden from us. If you were to show an adult a toy, and then hide it behind a curtain, the adult knows that the toy still exists. However, very young infants act as if a hidden object no longer exists. The age at which object permanence is achieved is somewhat controversial (Munakata, McClelland, Johnson, and Siegler, 1997).

Figure 1.13 Jean Piaget is famous for his theories regarding changes in cognitive ability that occur as we move from infancy to adulthood.

While Piaget was focused on cognitive changes during infancy and childhood as we move to adulthood, there is an increasing interest in extending research into the changes that occur much later in life. This may be reflective of changing population demographics of developed nations as a whole. As more and more people live longer lives, the number of people of advanced age will continue to increase.

Indeed, it is estimated that there were just over 40 million people aged 65 or older living in the United States in 2010. However, by 2020, this number is expected to increase to about 55 million. By the year 2050, it is estimated that nearly 90 million people in this country will be 65 or older (Department of Health and Human Services, n.d.).

PERSONALITY PSYCHOLOGY

Personality psychology focuses on patterns of thoughts and behaviors that make each individual unique. Several individuals (e.g., Freud and Maslow) that we have already discussed in our historical overview of psychology, and the American psychologist Gordon Allport, contributed to early theories of personality. These early theorists attempted to explain how an individual's personality develops from his or her given perspective. For example, Freud proposed that personality arose as conflicts between the conscious and unconscious parts of the mind were carried out over the lifespan. Specifically, Freud theorized that an individual went through various psychosexual stages of development. According to Freud, adult personality would result from the resolution of various conflicts that centered on the migration of erogenous (or sexual pleasure-producing) zones from the oral (mouth) to the anus to the phallus to the genitals. Like many of Freud's theories, this particular idea was controversial and did not lend itself to experimental tests (Person, 1980).

More recently, the study of personality has taken on a more quantitative approach. Rather than explaining how personality arises, research is focused on identifying **personality traits**, measuring these traits, and determining how these traits interact in a particular context to determine how a person will behave in any given situation. Personality traits are relatively consistent patterns of thought and behavior, and many have proposed that five trait dimensions are sufficient to capture the variations in personality seen across individuals. These five dimensions are known as the "Big Five" or the Five Factor model, and include dimensions of conscientiousness, agreeableness, neuroticism, openness, and extraversion (**Figure 1.14**). Each of these traits has been demonstrated to be relatively stable over the lifespan (e.g., Rantanen, Metsäpelto, Feldt, Pulkinnen, and Kokko, 2007; Soldz & Vaillant, 1999; McCrae & Costa, 2008) and is influenced by genetics (e.g., Jang, Livesly, and Vernon, 1996).

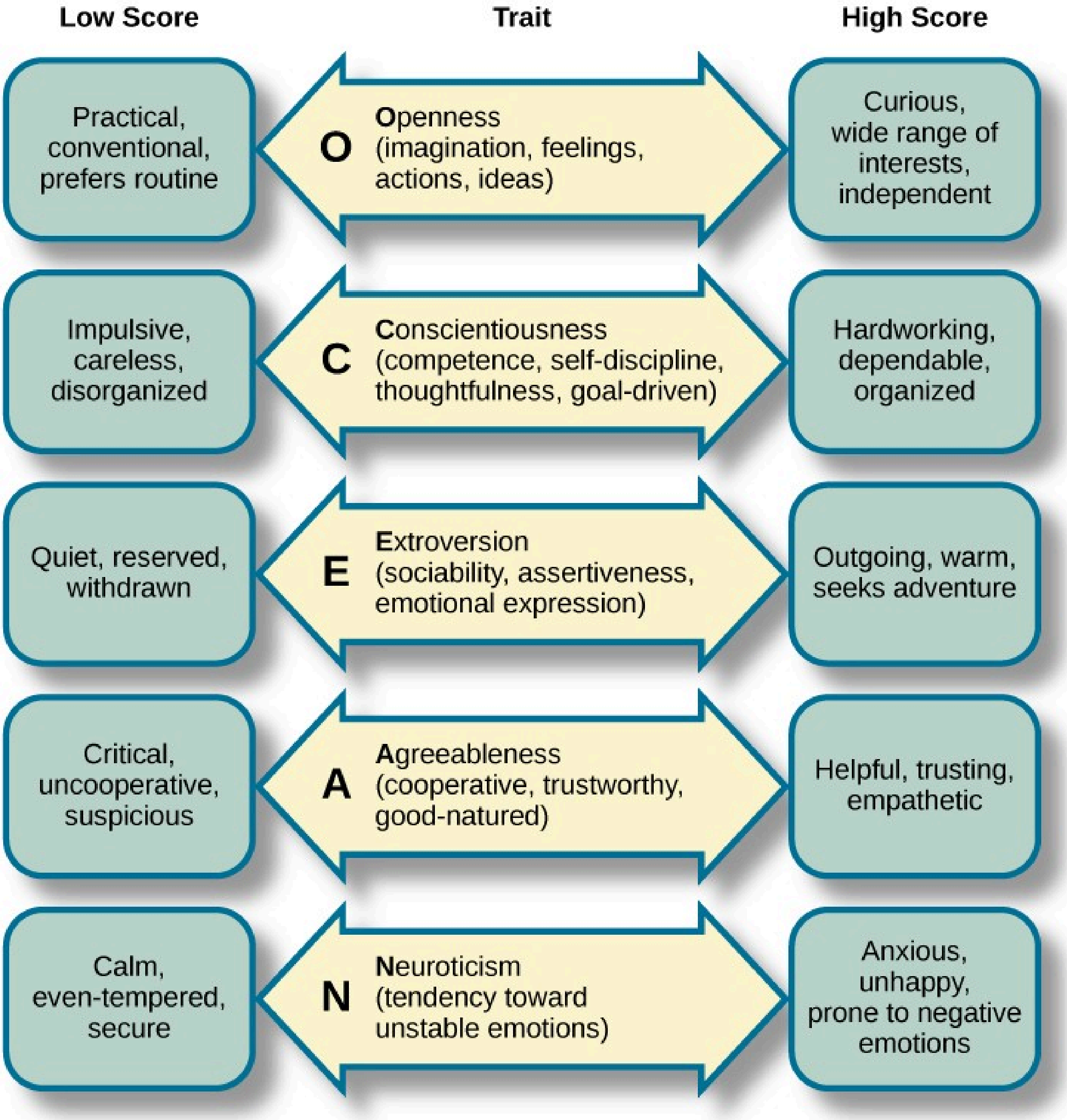


Figure 1.14 Each of the dimensions of the Five Factor model is shown in this figure. The provided description would describe someone who scored highly on that given dimension. Someone with a lower score on a given dimension could be described in opposite terms.

SOCIAL PSYCHOLOGY

Social psychology focuses on how we interact with and relate to others. Social psychologists conduct research on a wide variety of topics that include differences in how we explain our own behavior versus how we explain the behaviors of others, prejudice, and attraction, and how we resolve interpersonal conflicts. Social psychologists have also sought to determine how being among other people changes our own behavior and patterns of thinking.

There are many interesting examples of social psychological research, and you will read about many of these in a later chapter of this textbook. Until then, you will be introduced to one of the most controversial psychological studies ever conducted. Stanley Milgram was an American social psychologist who is most famous for research that he conducted on obedience. After the holocaust, in 1961, a Nazi war criminal, Adolf Eichmann, who was accused of committing mass atrocities, was put on trial. Many people wondered how German soldiers were capable of torturing prisoners in concentration camps, and they were unsatisfied with the excuses given by soldiers that they were simply following orders. At the time, most psychologists agreed that few people would be willing to inflict such extraordinary pain and suffering, simply because they were obeying orders. Milgram decided to conduct research to determine whether or not this was true (**Figure 1.15**).

As you will read later in the text, Milgram found that nearly two-thirds of his participants were willing to deliver what they believed to be lethal shocks to another person, simply because they were instructed to do so by an authority figure (in this case, a man dressed in a lab coat). This was in spite of the fact that participants received payment for simply showing up for the research study and could have chosen not to inflict pain or more serious consequences on another person by withdrawing from the study. No one was actually hurt or harmed in any way, Milgram's experiment was a clever ruse that took advantage of research confederates, those who pretend to be participants in a research study who are actually working for the researcher and have clear, specific directions on how to behave during the research study (Hock, 2009).

Milgram's and others' studies that involved deception and potential emotional harm to study participants catalyzed the development of ethical guidelines for conducting psychological research that discourage the use of deception of research subjects, unless it can be argued not to cause harm and, in general, requiring informed consent of participants.

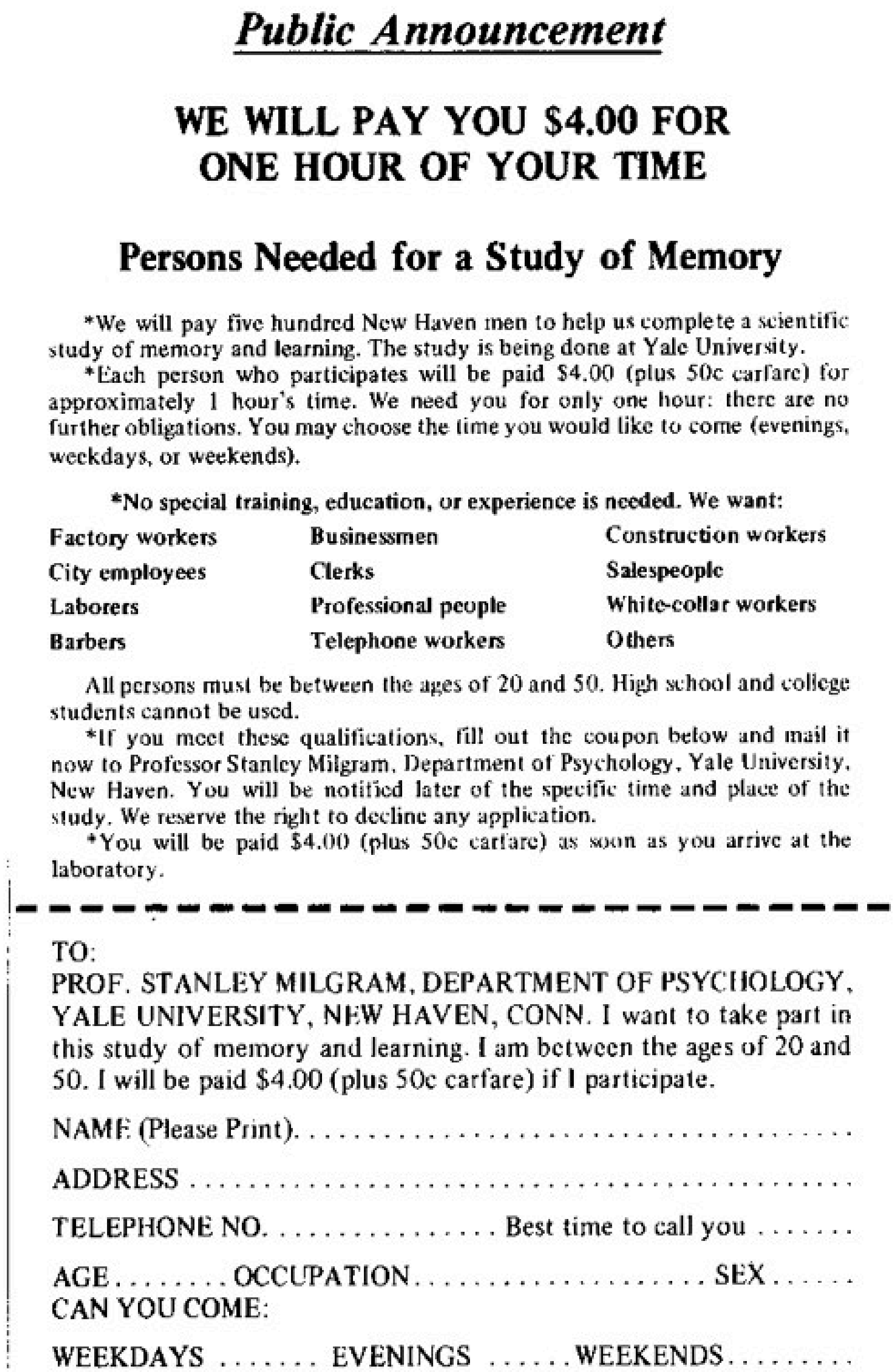


Figure 1.15 Stanley Milgram's research demonstrated just how far people will go in obeying orders from an authority figure. This advertisement was used to recruit subjects for his research.

INDUSTRIAL-ORGANIZATIONAL PSYCHOLOGY

Industrial-Organizational psychology (I-O psychology) is a subfield of psychology that applies psychological theories, principles, and research findings in industrial and organizational settings. I-O psychologists are often involved in issues related to personnel management, organizational structure, and workplace environment. Businesses often seek the aid of I-O psychologists to make the best hiring decisions as well as to create an environment that results in high levels of employee productivity and efficiency. In addition to its applied nature, I-O psychology also involves conducting scientific research on behavior within I-O settings (Riggio, 2013).

HEALTH PSYCHOLOGY

Health psychology focuses on how health is affected by the interaction of biological, psychological, and sociocultural factors. This particular approach is known as the **biopsychosocial model** (**Figure 1.16**). Health psychologists are interested in helping individuals achieve better health through public policy, education, intervention, and research. Health psychologists might conduct research that explores the relationship between one's genetic makeup, patterns of behavior, relationships, psychological stress, and health. They may research effective ways to motivate people to address patterns of behavior that contribute to poorer health (MacDonald, 2013).

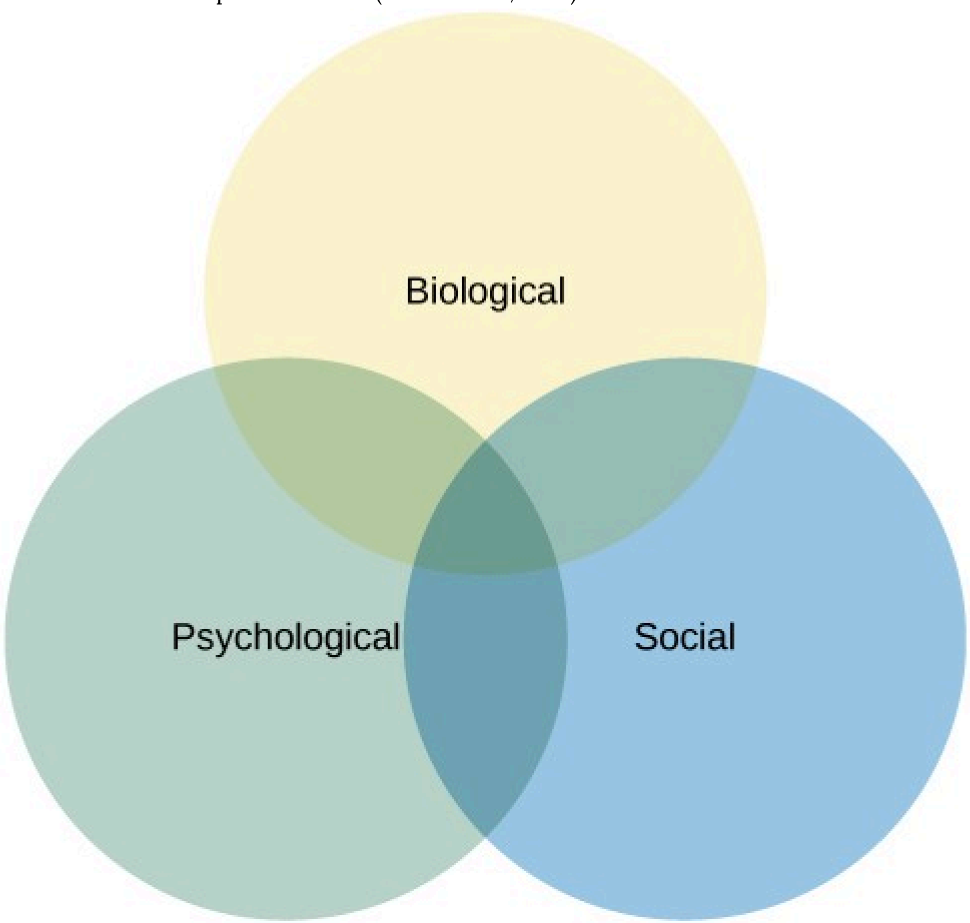


Figure 1.16 The biopsychosocial model suggests that health/illness is determined by an interaction of these three factors.

SPORT AND EXERCISE PSYCHOLOGY

Researchers in **sport and exercise psychology** study the psychological aspects of sport performance, including motivation and performance anxiety, and the effects of sport on mental and emotional wellbeing. Research is also conducted on similar topics as they relate to physical exercise in general. The discipline also includes topics that are broader than sport and exercise but that are related to interactions between mental and physical performance under demanding conditions, such as fire fighting, military operations, artistic performance, and surgery.

CLINICAL PSYCHOLOGY

Clinical psychology is the area of psychology that focuses on the diagnosis and treatment of psychological disorders and other problematic patterns of behavior. As such, it is generally considered to be a more applied area within psychology; however, some clinicians are also actively engaged in scientific research. **Counseling psychology** is a similar discipline that focuses on emotional, social, vocational, and health- related outcomes in individuals who are considered psychologically healthy.

As mentioned earlier, both Freud and Rogers provided perspectives that have been influential in shaping how clinicians interact with people seeking psychotherapy. While aspects of the psychoanalytic theory are still found among some of today's therapists who are trained from a psychodynamic perspective, Roger's ideas about client-centered therapy have been especially influential in shaping how many clinicians operate. Furthermore, both behaviorism and the cognitive revolution have shaped clinical practice in the forms of behavioral therapy, cognitive therapy, and cognitive-behavioral therapy (**Figure 1.17**). Issues related to the diagnosis and treatment of psychological disorders and problematic patterns of behavior will be discussed in detail in later chapters of this textbook.

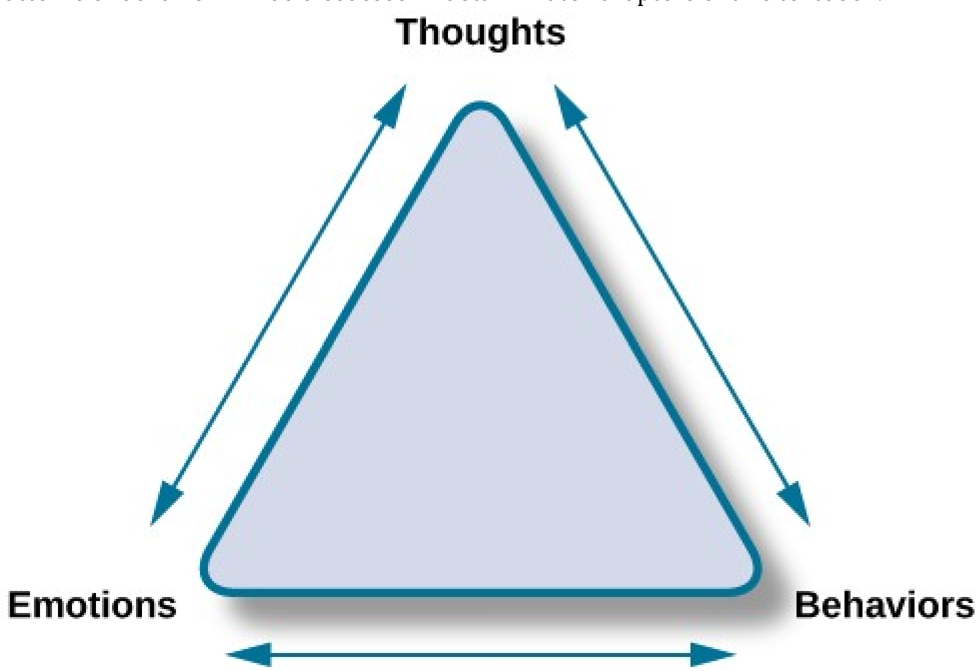


Figure 1.17 Cognitive-behavioral therapists take cognitive processes and behaviors into account when providing psychotherapy. This is one of several strategies that may be used by practicing clinical psychologists.

By far, this is the area of psychology that receives the most attention in popular media, and many people mistakenly assume that all psychology is clinical psychology.

FORENSIC PSYCHOLOGY

Forensic psychology is a branch of psychology that deals questions of psychology as they arise in the context of the justice system. For example, forensic psychologists (and forensic psychiatrists) will assess a person's competency to stand trial, assess the state of mind of a defendant, act as consultants on child custody cases, consult on sentencing and treatment recommendations, and advise on issues such as eyewitness testimony and children's testimony (American Board of Forensic Psychology, 2014). In these capacities, they will typically act as expert witnesses, called by either side in a court case to provide their research- or experience-based opinions. As expert witnesses, forensic psychologists must have a good understanding of the law and provide information in the context of the legal system rather than just within the realm of psychology. Forensic psychologists are also used in the jury selection process and witness preparation. They may also be involved in providing psychological treatment within the criminal justice system. Criminal profilers are a relatively small proportion of psychologists that act as consultants to law enforcement.
LINK TO LEARNING The APA provides career information (http://openstaxcollege.org/l/careers)about various areas of psychology.

Careers in Psychology

Learning Objectives

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

Psychologists can work in many different places doing many different things. In general, anyone wishing to continue a career in psychology at a 4-year institution of higher education will have to earn a doctoral degree in psychology for some specialties and at least a master's degree for others. In most areas of psychology, this means earning a PhD in a relevant area of psychology. Literally, **PhD** refers to a doctor of philosophy degree, but here, philosophy does not refer to the field of philosophy per se. Rather, philosophy in this context refers to many different disciplinary perspectives that would be housed in a traditional college of liberal arts and sciences.

The requirements to earn a PhD vary from country to country and even from school to school, but usually, individuals earning this degree must complete a dissertation. A **dissertation** is essentially a long research paper or bundled published articles describing research that was conducted as a part of the candidate's doctoral training. In the United States, a dissertation generally has to be defended before a committee of expert reviewers before the degree is conferred (**Figure 1.18**).

Figure 1.18 Doctoral degrees are generally conferred in formal ceremonies involving special attire and rites. (credit: Public Affairs Office Fort Wainwright)

Once someone earns her PhD, she may seek a faculty appointment at a college or university. Being on the faculty of a college or university often involves dividing time between teaching, research, and service to the institution and profession. The amount of time spent on each of these primary responsibilities varies dramatically from school to school, and it is not uncommon for faculty to move from place to place in search of the best personal fit among various academic environments. The previous section detailed some of the major areas that are commonly represented in psychology departments around the country; thus, depending on the training received, an individual could be anything from a biological psychologist to a clinical psychologist in an academic setting (**Figure 1.19**).

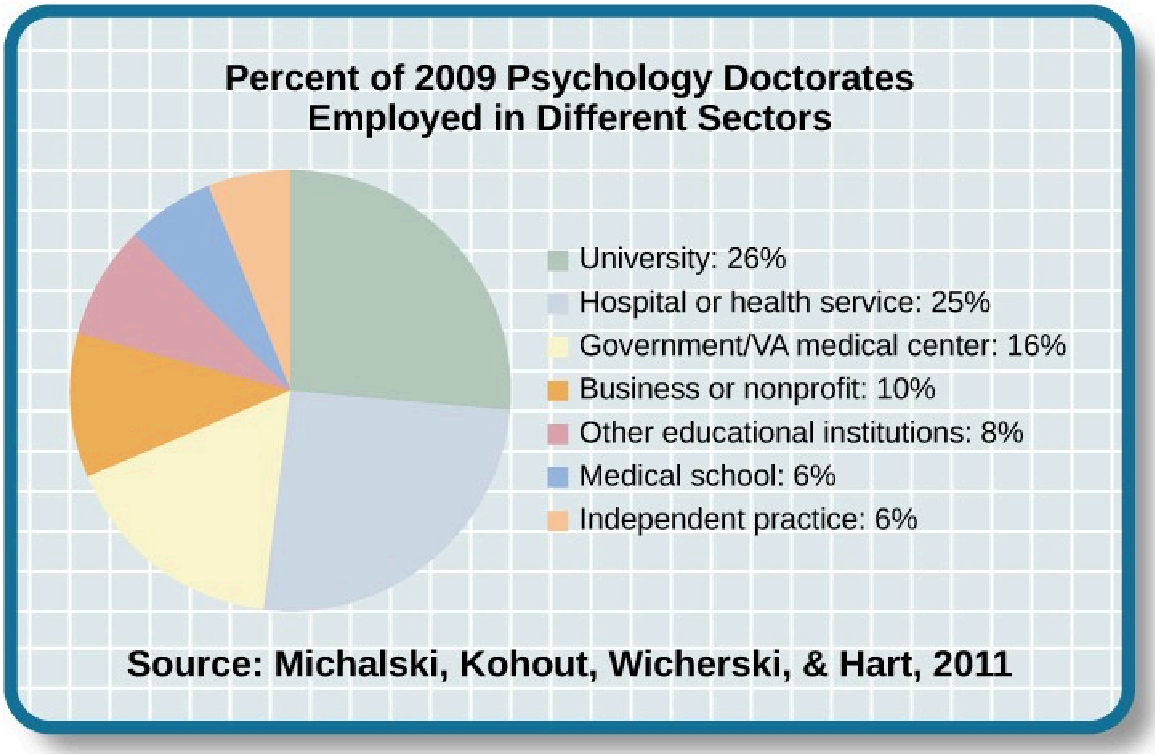


Figure 1.19 Individuals earning a PhD in psychology have a range of employment options.

OTHER CAREERS IN ACADEMIC SETTINGS

Often times, schools offer more courses in psychology than their full-time faculty can teach. In these cases, it is not uncommon to bring in an adjunct faculty member or instructor. Adjunct faculty members and instructors usually have an advanced degree in psychology, but they often have primary careers outside of academia and serve in this role as a secondary job. Alternatively, they may not hold the doctoral degree required by most 4-year institutions and use these opportunities to gain experience in teaching. Furthermore, many 2-year colleges and schools need faculty to teach their courses in psychology. In general, many of the people who pursue careers at these institutions have master's degrees in psychology, although some PhDs make careers at these institutions as well.

Some people earning PhDs may enjoy research in an academic setting. However, they may not be interested in teaching. These individuals might take on faculty positions that are exclusively devoted to conducting research. This type of position would be more likely an option at large, research-focused universities.

In some areas in psychology, it is common for individuals who have recently earned their PhD to seek out positions in **postdoctoral training programs** that are available before going on to serve as faculty. In most cases, young scientists will complete one or two postdoctoral programs before applying for a full-time faculty position. Postdoctoral training programs allow young scientists to further develop their research programs and broaden their research skills under the supervision of other professionals in the field.

CAREER OPTIONS OUTSIDE OF ACADEMIC SETTINGS

Individuals who wish to become practicing clinical psychologists have another option for earning a doctoral degree, which is known as a PsyD. A **PsyD** is a doctor of psychology degree that is increasingly popular among individuals interested in pursuing careers in clinical psychology. PsyD programs generally place less emphasis on research-oriented skills and focus more on application of psychological principles in the clinical context (Norcorss & Castle, 2002).

Regardless of whether earning a PhD or PsyD, in most states, an individual wishing to practice as a licensed clinical or counseling psychologist may complete postdoctoral work under the supervision of a licensed psychologist. Within the last few years, however, several states have begun to remove this requirement, which would allow someone to get an earlier start in his career (Munsey, 2009). After an individual has met the state requirements, his credentials are evaluated to determine whether he can sit for the licensure exam. Only individuals that pass this exam can call themselves licensed clinical or counseling psychologists (Norcross, n.d.). Licensed clinical or counseling psychologists can then work in a number of settings, ranging from private clinical practice to hospital settings. It should be noted that clinical psychologists and psychiatrists do different things and receive different types of education. While both can conduct therapy and counseling, clinical psychologists have a PhD or a PsyD, whereas psychiatrists have a doctor of medicine degree (MD). As such, licensed clinical psychologists can administer and interpret psychological tests, while psychiatrists can prescribe medications.

Individuals earning a PhD can work in a variety of settings, depending on their areas of specialization. For example, someone trained as a biopsychologist might work in a pharmaceutical company to help test the efficacy of a new drug. Someone with a clinical background might become a forensic psychologist and work within the legal system to make recommendations during criminal trials and parole hearings, or serve as an expert in a court case.

While earning a doctoral degree in psychology is a lengthy process, usually taking between 5–6 years of graduate study (DeAngelis, 2010), there are a number of careers that can be attained with a master's degree in psychology. People who wish to provide psychotherapy can become licensed to serve as various types of professional counselors (Hoffman, 2012). Relevant master's degrees are also sufficient for individuals seeking careers as school psychologists (National Association of School Psychologists, n.d.), in some capacities related to sport psychology (American Psychological Association, 2014), or as consultants in various industrial settings (Landers, 2011, June 14). Undergraduate coursework in psychology may be applicable to other careers such as psychiatric social work or psychiatric nursing, where assessments and therapy may be a part of the job.

As mentioned in the opening section of this chapter, an undergraduate education in psychology is associated with a knowledge base and skill set that many employers find quite attractive. It should come as no surprise, then, that individuals earning bachelor's degrees in psychology find themselves in a number of different careers, as shown in **Table 1.1**. Examples of a few such careers can involve serving as case managers, working in sales, working in human resource departments, and teaching in high schools. The rapidly growing realm of healthcare professions is another field in which an education in psychology is helpful and sometimes required. For example, the Medical College Admission Test (MCAT) exam that people must take to be admitted to medical school now includes a section on the psychological foundations of behavior.

Table 1.1 Top Occupations Employing Graduates with a BA in Psychology (Fogg, Harrington, Harrington, & Shatkin, 2012)

Ranking	Occupation
1	Mid- and top-level management (executive, administrator)
2	Sales
3	Social work
4	Other management positions
5	Human resources (personnel, training)
6	Other administrative positions
7	Insurance, real estate, business
8	Marketing and sales
9	Healthcare (nurse, pharmacist, therapist)
10	Finance (accountant, auditor)

LINK TO LEARNING Watch a brief video (http://openstaxcollege.org/l/psyccareers) describing some of the career options available to people earning bachelor's degrees in psychology.

Key Terms

American Psychological Association professional organization representing psychologists in the United States

behaviorism focus on observing and controlling behavior

biopsychology study of how biology influences behavior

biopsychosocial model perspective that asserts that biology, psychology, and social factors interact to determine an individual's health

clinical psychology area of psychology that focuses on the diagnosis and treatment of psychological disorders and other problematic patterns of behavior

cognitive psychology study of cognitions, or thoughts, and their relationship to experiences and actions

counseling psychology area of psychology that focuses on improving emotional, social, vocational, and other aspects of the lives of psychologically healthy individuals

developmental psychology scientific study of development across a lifespan

dissertation long research paper about research that was conducted as a part of the candidate's doctoral training

empirical method method for acquiring knowledge based on observation, including experimentation, rather than a method based only on forms of logical argument or previous authorities

forensic psychology area of psychology that applies the science and practice of psychology to issues within and related to the justice system

functionalism focused on how mental activities helped an organism adapt to its environment

humanism perspective within psychology that emphasizes the potential for good that is innate to all humans

introspection process by which someone examines their own conscious experience in an attempt to break it into its component parts

ology suffix that denotes "scientific study of"

personality psychology study of patterns of thoughts and behaviors that make each individual unique

personality trait consistent pattern of thought and behavior

PhD (doctor of philosophy) doctoral degree conferred in many disciplinary perspectives housed in a traditional college of liberal arts and sciences

postdoctoral training program allows young scientists to further develop their research programs and broaden their research skills under the supervision of other professionals in the field

psyche Greek word for soul

psychoanalytic theory focus on the role of the unconscious in affecting conscious behavior

psychology scientific study of the mind and behavior

PsyD (doctor of psychology) doctoral degree that places less emphasis on research-oriented skills and focuses more on application of psychological principles in the clinical context

sport and exercise psychology area of psychology that focuses on the interactions between mental and emotional factors and physical performance in sports, exercise, and other activities

structuralism understanding the conscious experience through introspection

Discussion Questions

1. Why do you think psychology courses like this one are often requirements of so many different programs of study?
2. Why do you think many people might be skeptical about psychology being a science?
3. Why is an undergraduate education in psychology so helpful in a number of different lines of work?
4. Freud is probably one of the most well-known historical figures in psychology. Where have you encountered references to Freud or his ideas about the role that the unconscious mind plays in determining conscious behavior?
5. In the “Contemporary Psychology” section you were briefly introduced to some of the major areas within psychology. Which are you most interested in learning more about, and why?

References

American Board of Forensic Psychology. (2014). Brochure. Retrieved from http://www.abfp.com/brochure.asp

American Psychological Association. (2014). Retrieved from www.apa.org

American Psychological Association. (2014). Graduate training and career possibilities in exercise and sport psychology. Retrieved from http://www.apadivisions.org/division-47/about/resources/training.aspx?item=1

American Psychological Association. (2019). Maime Phipps Clark, PhD, and Kenneth Clark, PhD. Retrieved from https://www.apa.org/pi/oema/resources/ethnicity-health/psychologists/clark

American Psychological Association. (2011). Psychology as a career. Retrieved from http://www.apa.org/education/undergrad/psych-career.aspx

Ashliman, D. L. (2001). Cupid and Psyche. In Folktexts: A library of folktales, folklore, fairy tales, and mythology. Retrieved from http://www.pitt.edu/~dash/cupid.html

Betancourt, H., & López, S. R. (1993). The study of culture, ethnicity, and race in American psychology. American Psychologist, 48, 629–637.

Black, S. R., Spence, S. A., & Omari, S. R. (2004). Contributions of African Americans to the field of psychology. Journal of Black Studies, 35, 40–64.

Bulfinch, T. (1855). The age of fable: Or, stories of gods and heroes. Boston, MA: Chase, Nichols and Hill.

Buss, D. M. (1989). Sex differences in human mate preferences: Evolutionary hypotheses tested in 37 cultures. Behavioral and Brain Sciences, 12, 1–49.

Carlson, N. R. (2013). Physiology of Behavior (11th ed.). Boston, MA: Pearson.

Confer, J. C., Easton, J. A., Fleischman, D. S., Goetz, C. D., Lewis, D. M. G., Perilloux, C., & Buss, D. M. (2010). Evolutionary psychology. Controversies, questions, prospects, and limitations. *American Psychologist*, 65, 100–126.

Crawford, M., & Marecek, J. (1989). Psychology reconstructs the female 1968–1988. *Psychology of Women Quarterly*, 13, 147–165.

Danziger, K. (1980). The history of introspection reconsidered. *Journal of the History of the Behavioral Sciences*, 16, 241–262.

Darwin, C. (1871). *The descent of man and selection in relation to sex*. London: John Murray.

Darwin, C. (1872). *The expression of the emotions in man and animals*. London: John Murray.

DeAngelis, T. (2010). Fear not. *gradPSYCH Magazine*, 8, 38.

Department of Health and Human Services. (n.d.). Projected future growth of the older population. Retrieved from http://www.aoa.gov/Aging_Statistics/future_growth/future_growth.aspx#age

Endler, J. A. (1986). *Natural Selection in the Wild*. Princeton, NJ: Princeton University Press.

Fogg, N. P., Harrington, P. E., Harrington, T. F., & Shatkin, L. (2012). *College majors handbook with real career paths and payoffs* (3rd ed.). St. Paul, MN: JIST Publishing.

Franko, D. L., et al. (2012). Racial/ethnic differences in adults in randomized clinical trials of binge eating disorder. *Journal of Consulting and Clinical Psychology*, 80, 186–195.

Friedman, H. (2008), Humanistic and positive psychology: The methodological and epistemological divide. *The Humanistic Psychologist*, 36, 113–126.

Gordon, O. E. (1995). A *brief history of psychology*. Retrieved from http://www.psych.utah.edu/gordon/Classes/Psy4905Docs/PsychHistory/index.html#maptop

Greek Myths & Greek Mythology. (2014). *The myth of Psyche and Eros*. Retrieved from http://www.greekmyths-greekmythology.com/psyche-and-eros-myth/

Green, C. D. (2001). Classics in the history of psychology. Retrieved from http://psychclassics.yorku.ca/Krstic/marulic.htm

Greengrass, M. (2004). 100 years of B.F. Skinner. *Monitor on Psychology*, 35, 80.

Halonen, J. S. (2011). *White paper: Are there too many psychology majors?* Prepared for the Staff of the State University System of Florida Board of Governors. Retrieved from http://www.cogdop.org/page_attachments/0000/0200/FLA_White_Paper_for_cogop_posting.pdf

Hock, R. R. (2009). Social psychology. *Forty studies that changed psychology: Explorations into the history of psychological research* (pp. 308–317). Upper Saddle River, NJ: Pearson.

Hoffman, C. (2012). *Careers in clinical, counseling, or school psychology; mental health counseling; clinical social work; marriage & family therapy and related professions*. Retrieved from http://www.indiana.edu/~psyugrad/advising/docs/Careers%20in%20Mental%20Health%20Counseling.pdf

Jang, K. L., Livesly, W. J., & Vernon, P. A. (1996). Heritability of the Big Five personality dimensions and their facets: A twin study. *Journal of Personality*, 64, 577–591.

Johnson, R., & Lubin, G. (2011). College exposed: What majors are most popular, highest paying and most likely to get you a job. *Business Insider.com.* Retrieved from http://www.businessinsider.com/best-college-majors-highest-income-most-employed-georgetwon-study-2011-6?op=1

Knekt, P. P., et al. (2008). Randomized trial on the effectiveness of long- and short-term psychodynamic psychotherapy and solution-focused therapy on psychiatric symptoms during a 3-year follow-up. *Psychological Medicine: A Journal of Research In Psychiatry And The Allied Sciences*, 38, 689–703.

Landers, R. N. (2011, June 14). Grad school: Should I get a PhD or Master's in I/O psychology? [Web log post]. Retrieved from http://neoacademic.com/2011/06/14/grad-school-should-i-get-a-ph-d-or-masters-in-io-psychology/#.UuKKLftOnGg

Macdonald, C. (2013). *Health psychology center presents: What is health psychology?* Retrieved from http://healthpsychology.org/what-is-health-psychology/

McCrae, R. R. & Costa, P. T. (2008). Empirical and theoretical status of the five-factor model of personality traits. In G. J. Boyle, G. Matthews, & D. H. Saklofske (Eds.), *The Sage handbook of personality theory and assessment. Vol. 1 Personality theories and models*. London: Sage.

Michalski, D., Kohout, J., Wicherski, M., & Hart, B. (2011). *2009 Doctorate Employment Survey*. APA Center for Workforce Studies. Retrieved from http://www.apa.org/workforce/publications/09-doc-empl/index.aspx

Miller, G. A. (2003). The cognitive revolution: A historical perspective. *Trends in Cognitive Sciences*, 7, 141–144.

Munakata, Y., McClelland, J. L., Johnson, M. H., & Siegler, R. S. (1997). Rethinking infant knowledge: Toward an adaptive process account of successes and failures in object permanence tasks. *Psychological Review*, 104, 689–713.

Mundasad, S. (2013). *Word-taste synaesthesia: Tasting names, places, and Anne Boleyn*. Retrieved from http://www.bbc.co.uk/news/health-21060207

Munsey, C. (2009). More states forgo a postdoc requirement. *Monitor on Psychology*, 40, 10.

National Association of School Psychologists. (n.d.). *Becoming a nationally certified school psychologist (NCSP)*. Retrieved from http://www.nasponline.org/CERTIFICATION/becomeNCSP.aspx

Nicolas, S., & Ferrand, L. (1999). Wundt's laboratory at Leipzig in 1891. *History of Psychology*, 2, 194–203.

Norcross, J. C. (n.d.) Clinical versus counseling psychology: What's the diff? Available at http://www.csun.edu/~hcpsy002/Clinical%20Versus%20Counseling%20Psychology.pdf

Norcross, J. C., & Castle, P. H. (2002). Appreciating the PsyD: The facts. *Eye on Psi Chi*, 7, 22–26.

O'Connor, J. J., & Robertson, E. F. (2002). *John Forbes Nash*. Retrieved from http://www-groups.dcs.st-and.ac.uk/~history/Biographies/Nash.html

O'Hara, M. (n.d.). Historic review of humanistic psychology. Retrieved from http://www.ahpweb.org/index.php?option=com_k2&view=item&layout=item&id=14&Itemid=24

Person, E. S. (1980). Sexuality as the mainstay of identity: Psychoanalytic perspectives. *Signs*, 5, 605–630.

Rantanen, J., Metsäpelto, R. L., Feldt, T., Pulkkinen, L., & Kokko, K. (2007). Long-term stability in the Big Five personality traits in adulthood. *Scandinavian Journal of Psychology*, 48, 511–518.

Riggio, R. E. (2013). What is industrial/organizational psychology? *Psychology Today*. Retrieved from http://www.psychologytoday.com/blog/cutting-edge-leadership/201303/what-is-industrialorganizational-psychology

Sacks, O. (2007). A neurologists notebook: The abyss, music and amnesia. *The New Yorker*. Retrieved from http://www.newyorker.com/reporting/2007/09/24/070924fa_fact_sacks?currentPage=all

Shedler, J. (2010). The efficacy of psychodynamic psychotherapy. *American Psychologist*, 65(2), 98–109.

Soldz, S., & Vaillant, G. E. (1999). The Big Five personality traits and the life course: A 45-year longitudinal study. *Journal of Research in Personality*, 33, 208–232.

Thorne, B. M., & Henley, T. B. (2005). *Connections in the history and systems of psychology* (3rd ed.). Boston, MA: Houghton Mifflin Company.

Tolman, E. C. (1938). The determiners of behavior at a choice point. *Psychological Review*, 45, 1–41.

U.S. Department of Education, National Center for Education Statistics. (2013). *Digest of Education Statistics*, 2012 (NCES 2014-015).

Weisstein, N. (1993). Psychology constructs the female: Or, the fantasy life of the male psychologist (with some attention to the fantasies of his friends, the male biologist and the male anthropologist). *Feminism and Psychology*, 3, 195–210.

Westen, D. (1998). The scientific legacy of Sigmund Freud, toward a psychodynamically informed psychological science. *Psychological Bulletin*, *124*, 333–371.

WHY SCIENCE

Scientific research has been one of the great drivers of progress in human history, and the dramatic changes we have seen during the past century are due primarily to scientific findings—modern medicine, electronics, automobiles and jets, birth control, and a host of other helpful inventions. Psychologists believe that scientific methods can be used in the behavioral domain to understand and improve the world. Although psychology trails the biological and physical sciences in terms of progress, we are optimistic based on discoveries to date that scientific psychology will make many important discoveries that can benefit humanity. This module outlines the characteristics of the science, and the promises it holds for understanding behavior. The ethics that guide psychological research are briefly described. It concludes with the reasons you should learn about scientific psychology.

Chapter Author: Edward Diener

Ed Diener, Senior Scientist for the Gallup Organization and professor at the University of Virginia and University of Utah, received three of the highest honors in psychology (APA's Distinguished Scientist Award, the APS William James Award, and election to the American Academy of Arts and Sciences) for his groundbreaking research on happiness.

Learning Objectives

Learning Objectives

- Describe how scientific research has changed the world.
- Describe the key characteristics of the scientific approach.
- Discuss a few of the benefits, as well as problems that have been created by science.
- Describe several ways that psychological science has improved the world.
- Describe a number of the ethical guidelines that psychologists follow.

Scientific Advances and World Progress

There are many people who have made positive contributions to humanity in modern times.

Take a careful look at the names on the following list. Which of these individuals do you think has helped humanity the most?

- Mother Teresa
- Albert Schweitzer
- Edward Jenner
- Norman Borlaug
- Fritz Haber

The usual response to this question is “Who on earth are Jenner, Borlaug, and Haber?” Many people know that Mother Teresa helped thousands of people living in the slums of Kolkata (Calcutta). Others recall that Albert Schweitzer opened his famous hospital in Africa and went on to earn the Nobel Peace Prize. The other three historical figures, on the other hand, are far less well known. Jenner, Borlaug, and Haber were scientists whose research discoveries saved millions, and even billions, of lives. Dr. Edward Jenner is often considered the “father of immunology” because he was among the first to conceive of and test vaccinations. His pioneering work led directly to the eradication of smallpox.

Due to the breakthrough work of Dr. Edward Jenner, millions of vaccinations are now administered around the world every year preventing the spread of many treatable diseases while saving the lives of people of all ages. [Image: CDC Global Health, https://goo.gl/hokiWz, CC BY 2.0, https://goo.gl/9uSnqN]

Many other diseases have been greatly reduced because of vaccines discovered using science—measles, pertussis, diphtheria, tetanus, typhoid, cholera, polio, hepatitis—and all are the legacy of Jenner. Fritz Haber and Norman Borlaug saved more than a billion human lives. They created the “Green Revolution” by producing hybrid agricultural crops and synthetic fertilizer. Humanity can now produce food for the seven billion people on the planet, and the starvation that does occur is related to political and economic factors rather than our collective ability to produce food.

If you examine major social and technological changes over the past century most of them can be directly attributed to science. The world in 1914 was very different than the one we see today (Easterbrook, 2003). There were few cars and most people traveled by foot, horseback, or carriage. There were no radios, televisions, birth control pills, artificial hearts or antibiotics. Only a small portion of the world had telephones, refrigeration or electricity. These days we find that 80% of all households have television and 84% have electricity. It is estimated that three quarters of the world’s population has access to a mobile phone! Life expectancy was 47 years in 1900 and 79 years in 2010. The percentage of hungry and malnourished people in the world has dropped substantially across the globe. Even average levels of I.Q. have risen dramatically over the past century due to better nutrition and schooling.

All of these medical advances and technological innovations are the direct result of scientific research and understanding. In the modern age it is easy to grow complacent about the advances of science but make no mistake about it—science has made fantastic discoveries, and continues to do so. These discoveries have completely changed our world.

What Is Science?

What is this process we call "science," which has so dramatically changed the world? Ancient people were more likely to believe in magical and supernatural explanations for natural phenomena such as solar eclipses or thunderstorms. By contrast, scientifically minded people try to figure out the natural world through testing and observation. Specifically, science is the use of **systematic observation** in order to acquire knowledge. For example, children in a science class might combine vinegar and baking soda to observe the bubbly chemical reaction. These **empirical methods** are wonderful ways to learn about the physical and biological world. Science is not magic—it will not solve all human problems, and might not answer all our questions about behavior. Nevertheless, it appears to be the most powerful method we have for acquiring knowledge about the observable world. The essential elements of science are as follows:

Systematic observation is the core of science. Scientists observe the world, in a very organized way. We often measure the phenomenon we are observing. We record our observations so that memory biases are less likely to enter into our conclusions. We are systematic in that we try to observe under controlled conditions, and also systematically vary the conditions of our observations so that we can see variations in the phenomena and understand when they occur and do not occur.

Observation leads to hypotheses we can test. When we develop **hypotheses**and **theories**, we state them in a way that can be tested. For example, you might make the claim that candles made of paraffin wax burn more slowly than do candles of the exact same size and shape made from bee's wax. This claim can be readily tested by timing the burning speed of candles made from these materials.

Science is democratic. People in ancient times may have been willing to accept the views of their kings or pharaohs as absolute truth. These days, however, people are more likely to want to be able to form their own opinions and debate conclusions. Scientists are skeptical and have open discussions about their observations and theories. These debates often occur as scientists publish competing findings with the idea that the best data will win the argument.

Systematic observation is the core of science. [Image: Cvl Neuro, https://goo.gl/Avbju7, CC BY-SA 3.0, *https://goo.gl/ uhHola]*

Science is cumulative. We can learn the important truths discovered by earlier scientists and build on them. Any physics student today knows more about physics than Sir Isaac Newton did even though Newton was possibly the most brilliant physicist of all time. A crucial aspect of scientific progress is that after we learn of earlier advances, we can build upon them and move farther along the path of knowledge.

Psychology as a Science

Even in modern times many people are skeptical that psychology is really a science. To some degree this doubt stems from the fact that many psychological phenomena such as depression, intelligence, and prejudice do not seem to be directly observable in the same way that we can observe the changes in ocean tides or the speed of light. Because thoughts and feelings are invisible many early psychological researchers chose to focus on behavior. You might have noticed that some people act in a friendly and outgoing way while others appear to be shy and withdrawn. If you have made these types of observations then you are acting just like early psychologists who used behavior to draw inferences about various types of personality. By using behavioral measures and rating scales it is possible to measure thoughts and feelings. This is similar to how other researchers explore "invisible" phenomena such as the way that educators measure academic performance or economists measure quality of life.

One important pioneering researcher was Francis Galton, a cousin of Charles Darwin who lived in England during the late 1800s. Galton used patches of color to test people's ability to distinguish between them. He also invented the self-report questionnaire, in which people offered their own expressed judgments or opinions on various matters. Galton was able to use self-reports to examine—among other things—people's differing ability to accurately judge distances. Although he lacked a modern understanding of genetics Galton also had the idea that scientists could look at the behaviors of identical and fraternal twins to estimate the degree to which genetic and social factors contribute to personality; a puzzling issue we currently refer to as the "nature-nurture question."

[Image: XT Inc., https://goo.gl/F1Wvu7, CC BY-NC-SA 2.0, https://goo.gl/Toc0ZF]

In 1875 Francis Galton did pioneering studies of twins to determine how much the similarities and differences in twins were affected by their life experiences. In the course of this work he coined the phrase "Nature versus Nurture". In modern times psychology has become more sophisticated. Researchers now use better measures, more sophisticated study designs and better statistical analyses to explore human nature. Simply take the example of studying the emotion of happiness. How would you go about studying happiness? One straight forward method is to simply ask people about their happiness and to have them use a numbered scale to indicate their feelings. There are, of course, several problems with this. People might lie about their happiness, might not be able to accurately report on their own happiness, or might not use the numerical scale in the same way. With these limitations in mind modern psychologists employ a wide range of methods to assess happiness. They use, for instance, "peer report measures" in which they ask close friends and family members about the happiness of a target individual. Researchers can then compare these ratings to the self-report ratings and check for discrepancies. Researchers also use memory measures, with the idea that dispositionally positive people have an easier time recalling pleasant events and negative people have an easier time recalling unpleasant events. Modern psychologists even use biological measures such as saliva cortisol samples (cortisol is a stress related hormone) or fMRI images of brain activation (the left pre-frontal cortex is one area of brain activity associated with good moods).

Despite our various methodological advances it is true that psychology is still a very young science. While physics and chemistry are hundreds of years old psychology is barely a hundred and fifty years old and most of our major findings have occurred only in the last 60 years. There are legitimate limits to psychological science but it is a science nonetheless.

Psychological Science is Useful

Psychological science is useful for creating interventions that help people live better lives. A growing body of research is concerned with determining which therapies are the most and least effective for the treatment of psychological disorders.

Cognitive Behavioral Therapy has shown to be effective in treating a variety of conditions, including depression. [Image: SalFalco, https://goo.gl/3knLoJ, CC BY-NC 2.0, https://goo.gl/HEXbAA]

For example, many studies have shown that cognitive behavioral therapy can help many people suffering from depression and anxiety disorders (Butler, Chapman, Forman, & Beck, 2006; Hoffman & Smits, 2008). In contrast, research reveals that some types of therapies actually might be harmful on average (Lilienfeld, 2007).

In organizational psychology, a number of psychological interventions have been found by researchers to produce greater productivity and satisfaction in the workplace (e.g., Guzzo, Jette, & Katzell, 1985). Human factor engineers have greatly increased the safety and utility of the products we use. For example, the human factors psychologist Alphonse Chapanis and other researchers redesigned the cockpit controls of aircraft to make them less confusing and easier to respond to, and this led to a decrease in pilot errors and crashes.

Forensic sciences have made courtroom decisions more valid. We all know of the famous cases of imprisoned persons who have been exonerated because of DNA evidence. Equally dramatic cases hinge on psychological findings. For instance, psychologist Elizabeth Loftus has conducted research demonstrating the limits and unreliability of eyewitness testimony and memory. Thus, psychological findings are having practical importance in the world outside the laboratory. Psychological science has experienced enough success to demonstrate that it works, but there remains a huge amount yet to be learned.

Ethics of Scientific Psychology

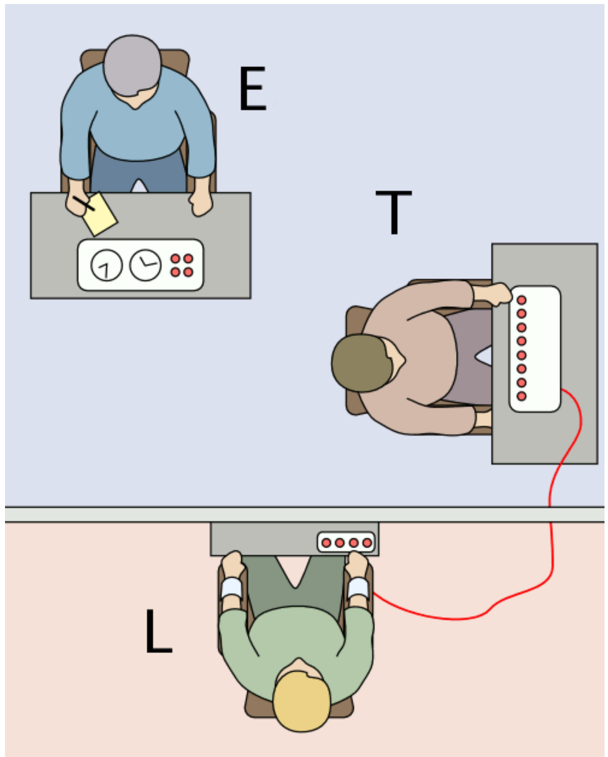


Diagram of the Milgram Experiment in which the "teacher" (T) was asked to deliver a (supposedly) painful electric shock to the "learner"(L). Would this experiment be approved by a review board today? [Image: Fred the Oyster, https://goo.gl/ZIbQz1, CC BY-SA 4.0, https://goo.gl/X3i0tq]

Psychology differs somewhat from the natural sciences such as chemistry in that researchers conduct studies with human research participants. Because of this there is a natural tendency to want to guard research participants against potential psychological harm. For example, it might be interesting to see how people handle ridicule but it might not be advisable to ridicule research participants.

Scientific psychologists follow a specific set of guidelines for research known as a code of **ethics**. There are extensive ethical guidelines for how human participants should be treated in psychological research (Diener & Crandall, 1978; Sales & Folkman, 2000). Following are a few highlights:

- *Informed consent*. In general, people should know when they are involved in research, and understand what will happen to them during the study. They should then be given a free choice as to whether to participate.
- *Confidentiality*. Information that researchers learn about individual participants should not be made public without the consent of the individual.
- *Privacy*. Researchers should not make observations of people in private places such as their bedrooms without their knowledge and consent. Researchers should not seek confidential information from others, such as school

authorities, without consent of the participant or his or her guardian.

- *Benefits*. Researchers should consider the benefits of their proposed research and weigh these against potential risks to the participants. People who participate in psychological studies should be exposed to risk only if they fully understand these risks and only if the likely benefits clearly outweigh the risks.
- *Deception*. Some researchers need to deceive participants in order to hide the true nature of the study. This is typically done to prevent participants from modifying their behavior in unnatural ways. Researchers are required to "debrief" their participants after they have completed the study. Debriefing is an opportunity to educate participants about the true nature of the study.

Why Learn About Scientific Psychology?

I once had a psychology professor who asked my class why we were taking a psychology course. Our responses give the range of reasons that people want to learn about psychology:

- To understand ourselves
- To understand other people and groups
- To be better able to influence others, for example, in socializing children or motivating employees
- To learn how to better help others and improve the world, for example, by doing effective psychotherapy
- To learn a skill that will lead to a profession such as being a social worker or a professor
- To learn how to evaluate the research claims you hear or read about

Because it is interesting, challenging, and fun! People want to learn about psychology because this is exciting in itself, regardless of other positive outcomes it might have. Why do we see movies? Because they are fun and exciting, and we need no other reason. Thus, one good reason to study psychology is that it can be rewarding in itself.

Conclusion

The science of psychology is an exciting adventure. Whether you will become a scientific psychologist, an applied psychologist, or an educated person who knows about psychological research, this field can influence your life and provide fun, rewards, and understanding. My hope is that you learn a lot from the modules in this e-text, and also that you enjoy the experience! I love learning about psychology and neuroscience, and hope you will too!

Outside Resources

Web: Science Heroes- A celebration of people who have made lifesaving discoveries. http://www.scienceheroes.com/index.php?option=com_content&view=article&id=258&Itemid=27

Discussion Questions

1. Some claim that science has done more harm than good. What do you think?
2. Humanity is faced with many challenges and problems. Which of these are due to human behavior, and which are external to human actions?
3. If you were a research psychologist, what phenomena or behaviors would most interest you?
4. Will psychological scientists be able to help with the current challenges humanity faces, such as global warming, war, inequality, and mental illness?
5. What can science study and what is outside the realm of science? What questions are impossible for scientists to study?
6. Some claim that science will replace religion by providing sound knowledge instead of myths to explain the world. They claim that science is a much more reliable source of solutions to problems such as disease than is religion. What do you think? Will science replace religion, and should it?
7. Are there human behaviors that should not be studied? Are some things so sacred or dangerous that we should not study them?

Vocabulary

Empirical methods

Approaches to inquiry that are tied to actual measurement and observation.

Ethics

Professional guidelines that offer researchers a template for making decisions that protect research participants from potential harm and that help steer scientists away from conflicts of interest or other situations that might compromise the integrity of their research.

Hypotheses

A logical idea that can be tested.

Systematic observation

The careful observation of the natural world with the aim of better understanding it. Observations provide the basic data that allow scientists to track, tally, or otherwise organize information about the natural world.

Theories

Groups of closely related phenomena or observations.

References

Butler, A. C., Chapman, J. E., Forman, E. M., & Beck, A. T. (2006). The empirical status of cognitive- behavioral therapy: A review of meta-analyses. Clinical Psychology Review, 26, 17–31.

Diener, E., & Crandall, R. (1978). Ethics in social and behavioral research. Chicago, IL: University of Chicago Press.

Easterbrook, G. (2003). The progress paradox. New York, NY: Random House.

Guzzo, R. A., Jette, R. D., & Katzell, R. A. (1985). The effects of psychologically based intervention programs on worker productivity: A meta-analysis. Personnel Psychology, 38, 275.291.

Hoffman, S. G., & Smits, J. A. J. (2008). Cognitive-behavioral therapy for adult anxiety disorders. Journal of Clinical Psychiatry, 69, 621–32.

Lilienfeld, S. O. (2007). Psychological treatments that cause harm. Perspectives on Psychological Science, 2, 53–70.

Moore, D. (2003). Public lukewarm on animal rights. Gallup News Service, May 21. http://www.gallup.com/poll/8461/public-lukewarm-animal-rights.aspx

Sales, B. D., & Folkman, S. (Eds.). (2000). Ethics in research with human participants. Washington, DC: American Psychological Association.

RESEARCH DESIGNS

Chapter Author: Christie Napa Scollon

Psychologists test research questions using a variety of methods. Most research relies on either correlations or experiments. With correlations, researchers measure variables as they naturally occur in people and compute the degree to which two variables go together. With experiments, researchers actively make changes in one variable and watch for changes in another variable. Experiments allow researchers to make causal inferences. Other types of methods include longitudinal and quasi-experimental designs. Many factors, including practical constraints, determine the type of methods researchers use. Often researchers survey people even though it would be better, but more expensive and time consuming, to track them longitudinally.

Learning Objectives

Type your learning objectives here.

- Articulate the difference between correlational and experimental designs.
- Understand how to interpret correlations.
- Understand how experiments help us to infer causality.
- Understand how surveys relate to correlational and experimental research.
- Explain what a longitudinal study is.
- List a strength and weakness of different research designs.

Research Designs

In the early 1970's, a man named Uri Geller tricked the world: he convinced hundreds of thousands of people that he could bend spoons and slow watches using only the power of his mind. In fact, if you were in the audience, you would have likely believed he had psychic powers. Everything looked authentic—this man had to have paranormal abilities! So, why have you probably never heard of him before? Because when Uri was asked to perform his miracles in line with scientific experimentation, he was no longer able to do them. That is, even though it seemed like he was doing the impossible, when he was tested by science, he proved to be nothing more than a clever magician.

When we look at dinosaur bones to make educated guesses about extinct life, or systematically chart the heavens to learn about the relationships between stars and planets, or study magicians to figure out how they perform their tricks, we are forming observations—the foundation of science. Although we are all familiar with the saying "seeing is believing," conducting science is more than just what your eyes perceive. Science is the result of systematic and intentional study of the natural world. And psychology is no different. In the movie *Jerry Maguire*, Cuba Gooding, Jr. became famous for using the phrase, "Show me the money!" In psychology, as in all sciences, we might say, "Show me the data!"

One of the important steps in scientific inquiry is to test our research questions, otherwise known as hypotheses. However, there are many ways to test hypotheses in psychological research. Which method you choose will depend on the type of questions you are asking, as well as what resources are available to you. All methods have limitations, which is why the best research uses a variety of methods.

Most psychological research can be divided into two types: experimental and correlational research.

Research Methods: Why You Need Them

Just look at any major news outlet and you'll find research routinely being reported. Sometimes the journalist understands the research methodology, sometimes not (e.g., correlational evidence is often incorrectly represented as causal evidence). Often, the media are quick to draw a conclusion for you. After reading this module, you should recognize that the strength of a scientific finding lies in the strength of its methodology. Therefore, in order to be a savvy consumer of research, you need to understand the pros and cons of different methods and the distinctions among them. Plus, understanding how psychologists systematically go about answering research questions will help you to solve problems in other domains, both personal and professional, not just in psychology.

Tradeoffs in Research

Even though there are serious limitations to correlational and quasi-experimental research, they are not poor cousins to experiments and longitudinal designs. In addition to selecting a method that is appropriate to the question, many practical concerns may influence the decision to use one method over another. One of these factors is simply resource availability –how much time and money do you have to invest in the research? (Tip: If you're doing a senior honor's thesis, do not embark on a lengthy longitudinal study unless you are prepared to delay graduation!)

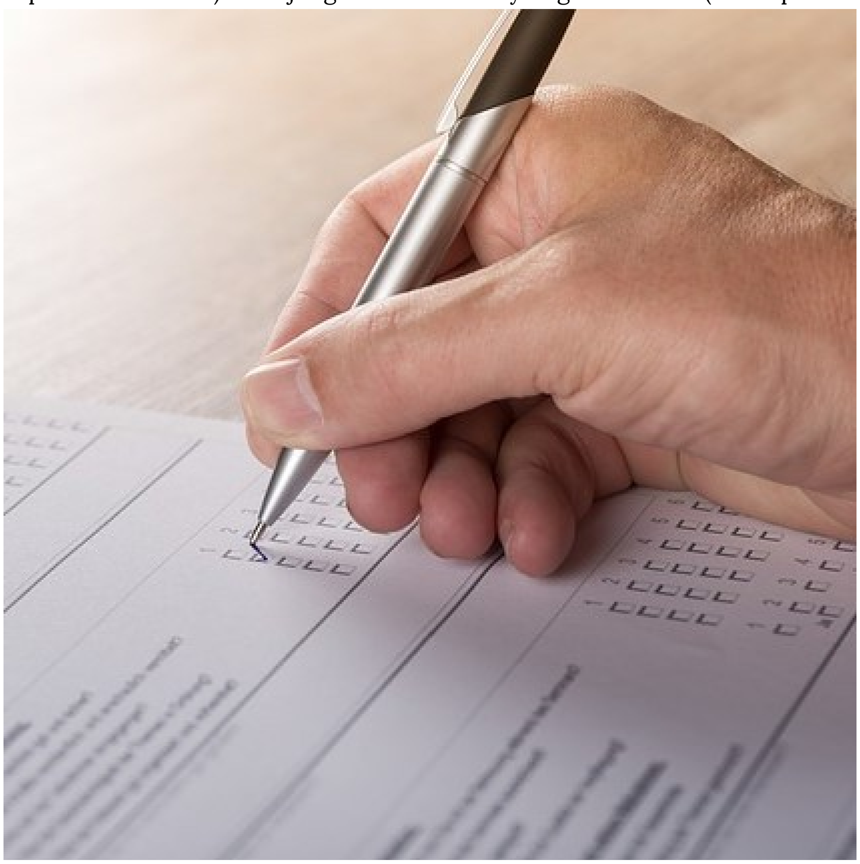
Often, we survey people even though it would be more precise–but much more difficult–to track them longitudinally. Especially in the case of exploratory research, it may make sense to opt for a cheaper and faster method first. Then, if results from the initial study are promising, the researcher can follow up with a more intensive method.

Beyond these practical concerns, another consideration in selecting a research design is the ethics of the study. For example, in cases of brain injury or other neurological abnormalities, it would be unethical for researchers to inflict these impairments on healthy participants. Nonetheless, studying people with these injuries can provide great insight into human psychology (e.g., if we learn that damage to a particular region of the brain interferes with emotions, we may be able to develop treatments for emotional irregularities).

In addition to brain injuries, there are numerous other areas of research that could be useful in understanding the human mind but which pose challenges to a true experimental design– such as the experiences of war, long-term isolation, abusive parenting, or prolonged drug use. However, none of these are conditions we could ethically experimentally manipulate and randomly assign people to. Therefore, ethical considerations are another crucial factor in determining an appropriate research design.

Surveys

A survey is a way of gathering information, using old-fashioned questionnaires or the Internet. Compared to a study conducted in a psychology laboratory, surveys can reach a larger number of participants at a much lower cost. Although surveys are typically used for correlational research, this is not always the case. An experiment can be carried out using surveys as well. For example, King and Napa (1998) presented participants with different types of stimuli on paper: either a survey completed by a happy person or a survey completed by an unhappy person. They wanted to see whether happy people were judged as more likely to get into heaven compared to unhappy people. Can you figure out the independent and dependent variables in this study? Can you guess what the results were? Happy people (vs. unhappy people; the independent variable) were judged as more likely to go to heaven (the dependent variable) compared to unhappy people!



Surveys provide researchers with some significant advantages in gathering data. They make it possible to reach large numbers of people while keeping costs to the researchers and the time commitments of participants relatively low.

Likewise, correlational research can be conducted without the use of surveys. For instance, psychologists LeeAnn Harker and Dacher Keltner (2001) examined the smile intensity of women's college yearbook photos. Smiling in the photos was correlated with being married 10 years later!

Longitudinal Studies

Another powerful research design is the **longitudinal study**. Longitudinal studies track the same people over time. Some longitudinal studies last a few weeks, some a few months, some a year or more. Some studies that have contributed a lot to psychology followed the same people over decades. For example, one study followed more than 20,000 Germans for two decades. From these longitudinal data, psychologist Rich Lucas (2003) was able to determine that people who end up getting married indeed start off a bit happier than their peers who never marry. Longitudinal studies like this provide valuable evidence for testing many theories in psychology, but they can be quite costly to conduct, especially if they follow many people for many years.

Quasi-Experimental Designs

What if you want to study the effects of marriage on a variable? For example, does marriage make people happier? Can you randomly assign some people to get married and others to remain single? Of course not. So how can you study these important variables? You can use a **quasi-experimental design**.

A quasi-experimental design is similar to experimental research, except that random assignment to conditions is not used. Instead, we rely on existing group memberships (e.g., married vs. single). We treat these as the independent variables, even though we don't assign people to the conditions and don't manipulate the variables. As a result, with quasi- experimental designs causal inference is more difficult. For example, married people might differ on a variety of characteristics from unmarried people. If we find that married participants are happier than single participants, it will be hard to say that marriage causes happiness, because the people who got married might have already been happier than the people who have remained single.

What is a reasonable way to study the effects of marriage on happiness? [Image: Nina Matthews Photography, https://goo. gl/IcmLqg, CC BY-NC-SA, *https://goo.gl/HSisdg]*

Because experimental and quasi-experimental designs can seem pretty similar, let's take another example to distinguish them. Imagine you want to know who is a better professor: Dr. Smith or Dr. Khan. To judge their ability, you're going to look at their students' final grades. Here, the independent variable is the professor (Dr. Smith vs. Dr. Khan) and the dependent variable is the students' grades. In an experimental design, you would randomly assign students to one of the two professors and then compare the students' final grades. However, in real life, researchers can't randomly force students to take one professor over the other; instead, the researchers would just have to use the preexisting classes and study them as-is (quasi-experimental design).

Again, the key difference is random assignment to the conditions of the independent variable. Although the quasi-experimental design (where the students choose which professor they want) may seem random, it's most likely not. For example, maybe students heard Dr. Smith sets low expectations, so slackers prefer this class, whereas Dr. Khan sets higher expectations, so smarter students prefer that one. This now introduces a confounding variable (student intelligence) that will almost certainly have an effect on students' final grades, regardless of how skilled the professor is. So, even though a quasi-experimental design is similar to an experimental design (i.e., it has a manipulated independent variable), because there's no random assignment, you can't reasonably draw the same conclusions that you would with an experimental design.

Qualitative Designs

Just as correlational research allows us to study topics we can't experimentally manipulate (e. g., whether you have a large or small income), there are other types of research designs that allow us to investigate these harder-to-study topics. Qualitative designs, including participant observation, case studies, and narrative analysis are examples of such methodologies. Although something as simple as "observation" may seem like it would be a part of all research methods, participant observation is a distinct methodology that involves the researcher embedding him- or herself into a group in order to study its dynamics. For example, Festinger, Riecken, and Shacter (1956) were very interested in the psychology of a particular cult. However, this cult was very secretive and wouldn't grant interviews to outside members. So, in order to study these people, Festinger and his colleagues pretended to be cult members, allowing them access to the behavior and psychology of the cult. Despite this example, it should be noted that the people being observed in a participant observation study usually know that the researcher is there to study them.

Another qualitative method for research is the case study, which involves an intensive examination of specific individuals or specific contexts. Sigmund Freud, the father of psychoanalysis, was famous for using this type of methodology; however, more current examples of case studies usually involve brain injuries. For instance, imagine that researchers want to know how a very specific brain injury affects people's experience of happiness. Obviously, the researchers can't conduct experimental research that involves inflicting this type of injury on people. At the same time, there are too few people who have this type of injury to conduct correlational research. In such an instance, the researcher may examine only one person with this brain injury, but in doing so, the researcher will put the participant through a very extensive round of tests. Hopefully what is learned from this one person can be applied to others; however, even with thorough tests, there is the chance that something unique about this individual (other than the brain injury) will affect his or her happiness. But with such a limited number of possible participants, a case study is really the only type of methodology suitable for researching this brain injury.

The final qualitative method to be discussed in this section is narrative analysis. Narrative analysis centers around the study of stories and personal accounts of people, groups, or cultures. In this methodology, rather than engaging with participants directly, or quantifying their responses or behaviors, researchers will analyze the themes, structure, and dialogue of each person's narrative. That is, a researcher will examine people's personal testimonies in order to learn more about the psychology of those individuals or groups. These stories may be written, audio-recorded, or video-recorded, and allow the researcher not only to study *what* the participant says but *how* he or she says it. Every person has a unique perspective on the world, and studying the way he or she conveys a story can provide insight into that perspective.

Correlational Designs

When scientists passively observe and measure phenomena it is called correlational research. Here, we do not intervene and change behavior, as we do in experiments. In correlational research, we identify patterns of relationships, but we usually cannot infer what causes what. Importantly, with correlational research, you can examine only two variables at a time, no more and no less.

So, what if you wanted to test whether spending on others is related to happiness, but you don't have $20 to give to each participant? You could use a correlational design—which is exactly what Professor Dunn did, too. She asked people how much of their income they spent on others or donated to charity, and later she asked them how happy they were. Do you think these two variables were related? Yes, they were! The more money people reported spending on others, the happier they were.

More details about the correlation

To find out how well two variables correspond, we can plot the relation between the two scores on what is known as a scatterplot (Figure 1). In the scatterplot, each dot represents a data point. (In this case it's individuals, but it could be some other unit.) Importantly, each dot provides us with two pieces of information—in this case, information about how good the person rated the past month (x-axis) and how happy the person felt in the past month (y- axis). Which variable is plotted on which axis does not matter.

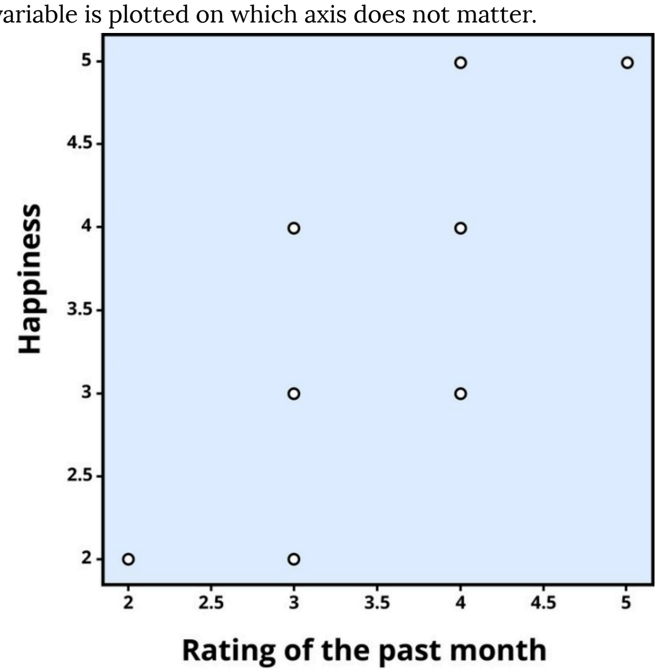


Figure 1. Scatterplot of the association between happiness and ratings of the past month, a positive correlation (r = .81). Each dot represents an individual.

The association between two variables can be summarized statistically using the correlation coefficient (abbreviated as *r*). A **correlation** coefficient provides information about the direction and strength of the association between two variables. For the example above, the direction of the association is positive. This means that people who perceived the past month as being good reported feeling more happy, whereas people who perceived the month as being bad reported feeling less happy.

With a positive correlation, the two variables go up or down together. In a scatterplot, the dots form a pattern that extends from the bottom left to the upper right (just as they do in Figure 1). The *r* value for a positive correlation is indicated by a positive number (although, the positive sign is usually omitted). Here, the *r* value is .81.

A negative correlation is one in which the two variables move in opposite directions. That is, as one variable goes up, the other goes down. Figure 2 shows the association between the average height of males in a country (y-axis) and the pathogen prevalence (or commonness of disease; x-axis) of that country. In this scatterplot, each dot represents a country. Notice how the dots extend from the top left to the bottom right. What does this mean in real-world terms? It means that people are shorter in parts of the world where there is more disease. The *r* value for a negative correlation is indicated by a negative number—that is, it has a minus (−) sign in front of it. Here, it is −.83.

The strength of a correlation has to do with how well the two variables align. Recall that in Professor Dunn's correlational study, spending on others positively correlated with happiness: The more money people reported spending on others, the happier they reported to be. At this point you may be thinking to yourself, I know a very generous person who gave away lots of money to other people but is miserable! Or maybe you know of a very stingy person who is happy as can be. Yes, there might be exceptions. If an association has many exceptions, it is considered a weak correlation.

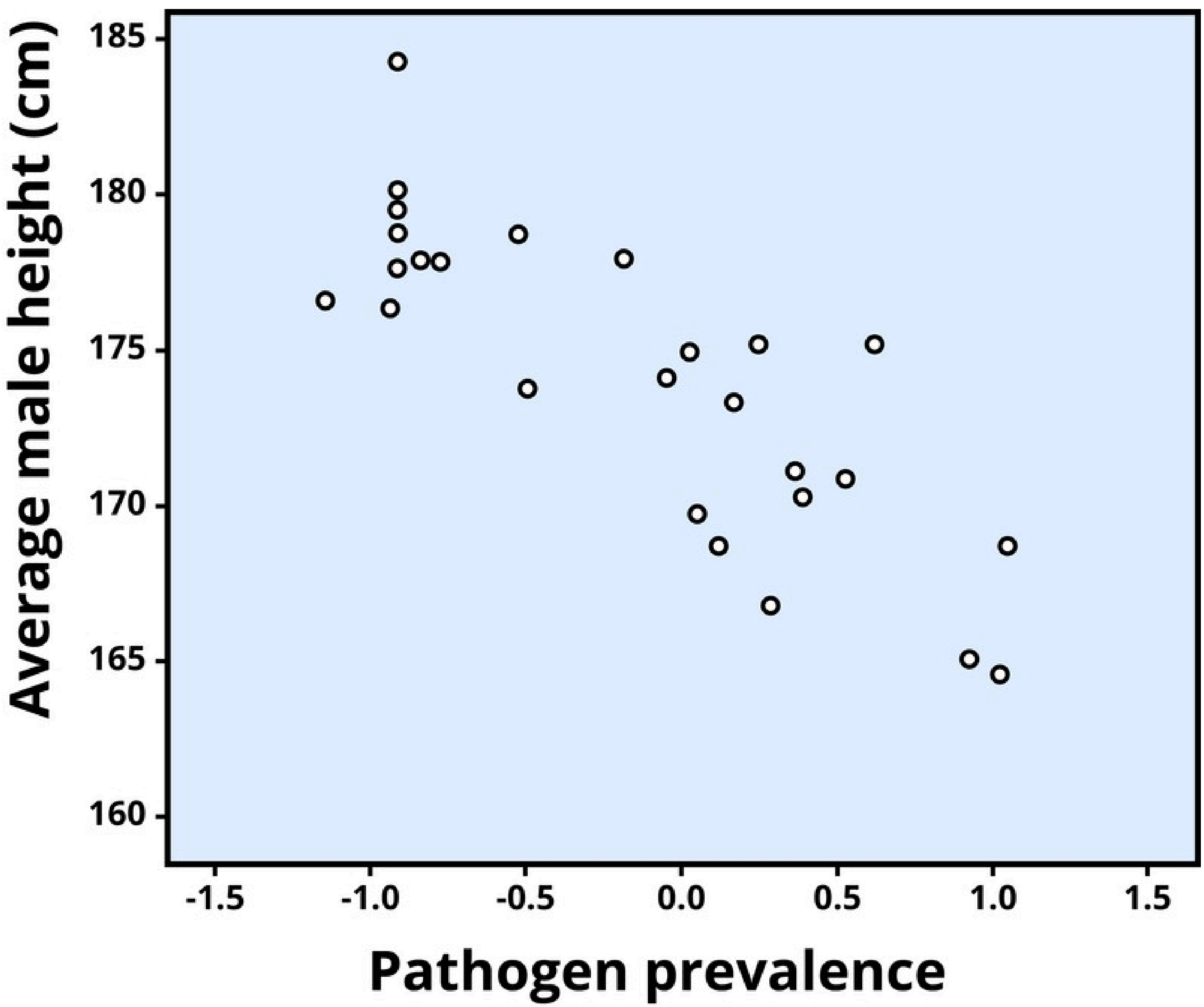


Figure 2. Scatterplot showing the association between average male height and pathogen prevalence, a negative correlation (r = −.83). Each dot represents a country. (Chiao, 2009)

If an association has few or no exceptions, it is considered a strong correlation. A strong correlation is one in which the two variables always, or almost always, go together. In the example of happiness and how good the month has been, the association is strong. The stronger a correlation is, the tighter the dots in the scatterplot will be arranged along a sloped line.

The *r* value of a strong correlation will have a high absolute value. In other words, you disregard whether there is a negative sign in front of the r value, and just consider the size of the numerical value itself. If the absolute value is large, it is a strong correlation. A weak correlation is one in which the two variables correspond some of the time, but not most of the time.

Figure 3 shows the relation between valuing happiness and grade point average (GPA). People who valued happiness more tended to earn slightly lower grades, but there were lots of exceptions to this. The *r* value for a weak correlation will have a low absolute value. If two variables are so weakly related as to be unrelated, we say they are uncorrelated, and the *r value* will be zero or very close to zero. In the previous example, is the correlation between height and pathogen prevalence strong? Compared to Figure 3, the dots in Figure 2 are tighter and less dispersed. The absolute value of −.83 is large. Therefore, it is a strong negative correlation.

Figure 3. Scatterplot showing the association between valuing happiness and GPA, a weak negative correlation (r = −.32). Each dot represents an individual.

Can you guess the strength and direction of the correlation between age and year of birth? If you said this is a strong negative correlation, you are correct! Older people always have lower years of birth than younger people (e.g., 1950 vs. 1995), but at the same time, the older people will have a higher age (e.g., 65 vs. 20). In fact, this is a perfect correlation because there are no exceptions to this pattern. I challenge you to find a 10-year-old born before 2003! You can't.

Problems with the correlation

If generosity and happiness are positively correlated, should we conclude that being generous causes happiness? Similarly, if height and pathogen prevalence are negatively correlated, should we conclude that disease causes shortness?

From a correlation alone, we can't be certain. For example, in the first case it may be that happiness causes generosity, or that generosity causes happiness. Or, a third variable might cause both happiness *and* generosity, creating the illusion of a direct link between the two. For example, wealth could be the third variable that causes both greater happiness and greater generosity. This is why correlation does not mean causation—an often repeated phrase among psychologists.

Experimental Research

If somebody gave you $20 that absolutely had to be spent today, how would you choose to spend it? Would you spend it on an item you've been eyeing for weeks, or would you donate the money to charity? Which option do you think would bring you the most happiness? If you're like most people, you'd choose to spend the money on yourself (duh, right?). Our intuition is that we'd be happier if we spent the money on ourselves.

Knowing that our intuition can sometimes be wrong, Professor Elizabeth Dunn (2008) at the University of British Columbia set out to conduct an experiment on spending and happiness. She gave each of the participants in her experiment $20 and then told them they had to spend the money by the end of the day. Some of the participants were told they must spend the money on themselves, and some were told they must spend the money on others (either charity or a gift for someone). At the end of the day she measured participants' levels of happiness using a self-report questionnaire. (But wait, how do you measure something like happiness when you can't really see it? Psychologists measure many abstract concepts, such as happiness and intelligence, by beginning with **operational definitions** of the concepts. See the Noba modules on Intelligence [**http://noba.to/ncb2h79v**] and Happiness [**http://noba.to/qnw7g32t**], respectively, for more information on specific measurement strategies.)

At the Corner Perk Cafe customers routinely pay for the drinks of strangers. Is this the way to get the most happiness out of a cup of coffee? Elizabeth Dunn's research shows that spending money on others may affect our happiness differently than spending money on ourselves. [Image: The Island Packet, https://goo.gl/DMxA5n]

In an experiment, researchers manipulate, or cause changes, in the **independent variable**, and observe or measure any impact of those changes in the **dependent variable**. The independent variable is the one under the experimenter's control, or the variable that is intentionally altered between groups. In the case of Dunn's experiment, the independent variable was whether participants spent the money on themselves or on others. The dependent variable is the variable that is not manipulated at all, or the one where the effect happens. One way to help remember this is that the dependent variable "depends" on what happens to the independent variable. In our example, the participants' happiness (the dependent variable in this experiment) depends on how the participants spend their money (the independent variable). Thus, any observed changes or group differences in happiness can be attributed to whom the money was spent on. What Dunn and her colleagues found was that, after all the spending had been done, the people who had spent the money on others were happier than those who had spent the money on themselves. In other words, spending on others causes us to be happier than spending on ourselves. Do you find this surprising?

But wait! Doesn't happiness depend on a lot of different factors—for instance, a person's upbringing or life circumstances? What if some people had happy childhoods and that's why they're happier? Or what if some people dropped their toast that morning and it fell jam-side down and ruined their whole day? It is correct to recognize that these factors and many more can easily affect a person's level of happiness. So how can we accurately conclude that spending money on others causes happiness, as in the case of Dunn's experiment?

The most important thing about experiments is **random assignment**. Participants don't get to pick which condition they are in (e.g., participants didn't choose whether they were supposed to spend the money on themselves versus others). The experimenter assigns them to a particular condition based on the flip of a coin or the roll of a die or any other random method. Why do researchers do this? With Dunn's study, there is the obvious reason: you can imagine which condition most people would choose to be in, if given the choice. But another equally important reason is that random assignment makes it so the groups, on average, are similar on all characteristics except what the experimenter manipulates.

By randomly assigning people to conditions (self-spending versus other-spending), some people with happy childhoods should end up in each condition. Likewise, some people who had dropped their toast that morning (or experienced some other disappointment) should end up in each condition. As a result, the distribution of all these factors will generally be consistent across the two groups, and this means that on average the two groups will be relatively equivalent on all these factors. Random assignment is critical to experimentation because if the only difference between the two groups is the independent variable, we can infer that the independent variable is the cause of any observable difference (e.g., in the amount of happiness they feel at the end of the day).

Here's another example of the importance of random assignment: Let's say your class is going to form two basketball teams, and you get to be the captain of one team. The class is to be divided evenly between the two teams. If you get to pick the players for your team first, whom will you pick? You'll probably pick the tallest members of the class or the most athletic. You probably won't pick the short, uncoordinated people, unless there are no other options. As a result, your team will be taller and more athletic than the other team. But what if we want the teams to be fair? How can we do this when we have people of varying height and ability? All we have to do is randomly assign players to the two teams. Most likely, some tall and some short people will end up on your team, and some tall and some short people will end up on the other team. The average height of the teams will be approximately the same. That is the power of random assignment!

Other considerations

In addition to using random assignment, you should avoid introducing confounds into your experiments. **Confounds** are things that could undermine your ability to draw causal inferences. For example, if you wanted to test if a new happy pill will make people happier, you could randomly assign participants to take the happy pill or not (the independent variable) and compare these two groups on their self-reported happiness (the dependent variable). However, if some participants know they are getting the happy pill, they might develop expectations that influence their self-reported happiness. This is sometimes known as a **placebo** **effect**. Sometimes a person just knowing that he or she is receiving special treatment or something new is enough to actually cause changes in behavior or perception: In other words, even if the participants in the happy pill condition were to report being happier, we wouldn't know if the pill was actually making them happier or if it was the placebo effect—an example of a confound.

A related idea is **participant demand**. This occurs when participants try to behave in a way they think the experimenter wants them to behave. Placebo effects and participant demand often occur unintentionally. Even **experimenter expectations** can influence the outcome of a study. For example, if the experimenter knows who took the happy pill and who did not, and the dependent variable is the experimenter's observations of people's happiness, then the experimenter might perceive improvements in the happy pill group that are not really there.

One way to prevent these confounds from affecting the results of a study is to use a double- blind procedure. In a double-blind procedure, neither the participant nor the experimenter knows which condition the participant is in. For example, when participants are given the happy pill or the fake pill, they don't know which one they are receiving. This way the participants shouldn't experience the placebo effect, and will be unable to behave as the researcher expects (participant demand). Likewise, the researcher doesn't know which pill each participant is taking (at least in the beginning—later, the researcher will get the results for data-analysis purposes), which means the researcher's expectations can't influence his or her observations. Therefore, because both parties are "blind" to the condition, neither will be able to behave in a way that introduces a confound. At the end of the day, the only difference between groups will be which pills the participants received, allowing the researcher to determine if the happy pill actually caused people to be happier.

Discussion Questions

1. What are some key differences between experimental and correlational research?
2. Why might researchers sometimes use methods other than experiments?
3. How do surveys relate to correlational and experimental designs?

Vocabulary

Confounds

Factors that undermine the ability to draw causal inferences from an experiment.

Correlation

Measures the association between two variables, or how they go together.

Dependent variable

The variable the researcher measures but does not manipulate in an experiment.

Experimenter expectations

When the experimenter's expectations influence the outcome of a study.

Independent variable

The variable the researcher manipulates and controls in an experiment.

Longitudinal study

A study that follows the same group of individuals over time.

Operational definitions

How researchers specifically measure a concept.

Participant demand

When participants behave in a way that they think the experimenter wants them to behave.

Placebo effect

When receiving special treatment or something new affects human behavior.

Quasi-experimental design

An experiment that does not require random assignment to conditions.

Random assignment

Assigning participants to receive different conditions of an experiment by chance.

References

Chiao, J. (2009). Culture–gene coevolution of individualism – collectivism and the serotonin transporter gene. Proceedings of the Royal Society B, 277, 529-537. doi: 10.1098/ rspb.2009.1650

Dunn, E. W., Aknin, L. B., & Norton, M. I. (2008). Spending money on others promotes happiness. Science, 319(5870), 1687–1688. doi:10.1126/science.1150952

Festinger, L., Riecken, H.W., & Schachter, S. (1956). When prophecy fails. Minneapolis, MN: University of Minnesota Press.

Harker, L. A., & Keltner, D. (2001). Expressions of positive emotion in women\'s college yearbook pictures and their relationship to personality and life outcomes across adulthood. Journal of Personality and Social Psychology, 80, 112–124.

King, L. A., & Napa, C. K. (1998). What makes a life good? Journal of Personality and Social Psychology, 75, 156–165.

Lucas, R. E., Clark, A. E., Georgellis, Y., & Diener, E. (2003). Re-examining adaptation and the setpoint model of happiness: Reactions to changes in marital status. Journal of Personality and Social Psychology, 84, 527–539.

Outside Resources

Article: Harker and Keltner study of yearbook photographs and marriage http://psycnet.apa.org/journals/psp/80/1/112/

Article: Rich Lucas's longitudinal study on the effects of marriage on happiness http://psycnet.apa.org/journals/psp/84/3/527/

Article: Spending money on others promotes happiness. Elizabeth Dunn's research https://www.sciencemag.org/content/319/5870/1687.abstract

Article: What makes a life good? http://psycnet.apa.org/journals/psp/75/1/156/

THINKING LIKE A PSYCHOLOGICAL SCIENTIST

We are bombarded every day with claims about how the world works, claims that have a direct impact on how we think about and solve problems in society and our personal lives. This module explores important considerations for evaluating the trustworthiness of such claims by contrasting between scientific thinking and everyday observations (also known as "anecdotal evidence").

Learning Objectives

- Compare and contrast conclusions based on scientific and everyday inductive reasoning.
- Understand why scientific conclusions and theories are trustworthy, even if they are not able to be proven.
- Articulate what it means to think like a psychological scientist, considering qualities of good scientific explanations and theories.
- Discuss science as a social activity, comparing and contrasting facts and values.

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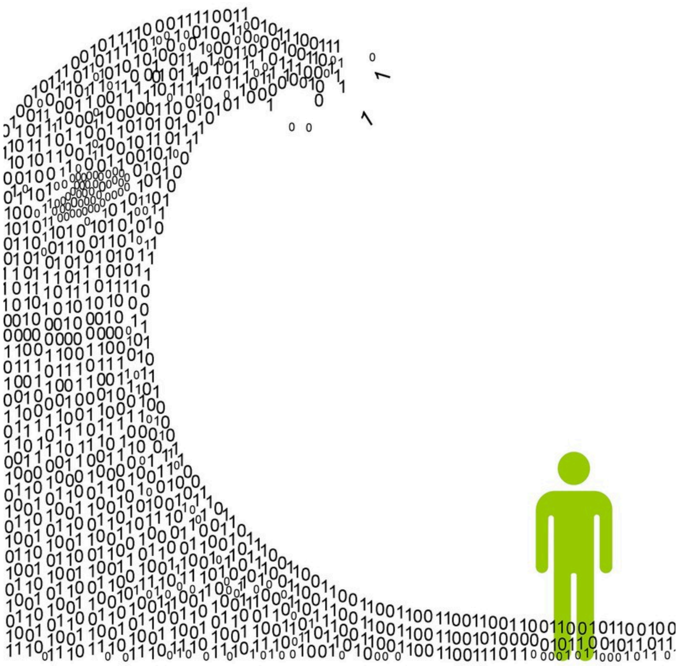
Introduction

Why are some people so much happier than others? Is it harmful for children to have imaginary companions? How might students study more effectively?

Even if you've never considered these questions before, you probably have some guesses about their answers. Maybe you think getting rich or falling in love leads to happiness.



[Image: Mark Smiciklas, https://goo.gl/TnZCoH, CC BY-NC 2.0, https://goo.gl/AGYuo9]

Perhaps you view imaginary friends as expressions of a dangerous lack of realism. What's more, if you were to ask your friends, they would probably also have opinions about these questions—opinions that may even differ from your own.

Today, people are overwhelmed with information although it varies in quality.

A quick internet search would yield even more answers. We live in the “Information Age,” with people having access to more explanations and answers than at any other time in history. But, although the *quantity* of information is continually increasing, it's always good practice to consider the *quality* of what you read or watch: Not all information is equally trustworthy. The trustworthiness of information is especially important in an era when “fake news,” urban myths, misleading “click-bait,” and conspiracy theories compete for our attention alongside well-informed conclusions grounded in evidence. Determining what information is well-informed is a crucial concern and a central task of science. Science is a way of using observable **data** to help explain and understand the world around us in a trustworthy way.

In this module, you will learn about scientific thinking. You will come to understand how scientific research informs our knowledge and helps us create theories. You will also come to appreciate how scientific reasoning is different from the types of reasoning people often use to form personal opinions.

Scientific Versus Everyday Reasoning

Each day, people offer statements as if they are facts, such as, “It looks like rain today,” or, “Dogs are very loyal.” These conclusions represent **hypotheses** about the world: best guesses as to how the world works. Scientists also draw conclusions, claiming things like, “There is an 80% chance of rain today,” or, “Dogs tend to protect their human companions.” You’ll notice that the two examples of scientific claims use less certain language and are more likely to be associated with probabilities. Understanding the similarities and differences between scientific and everyday (non-scientific) statements is essential to our ability to accurately evaluate the trustworthiness of various claims.

Scientific and everyday reasoning both employ **induction**: drawing general conclusions from specific observations. For example, a person’s opinion that cramming for a test increases performance may be based on her memory of passing an exam after pulling an all-night study session. Similarly, a researcher’s conclusion *against* cramming might be based on studies comparing the test performances of people who studied the material in different ways (e.g., cramming versus study sessions spaced out over time). In these scenarios, both scientific and everyday conclusions are drawn from a limited **sample** of potential observations.

The process of induction, alone, does not seem suitable enough to provide trustworthy information—given the contradictory results. What should a student who wants to perform well on exams do? One source of information encourages her to cram, while another suggests that spacing out her studying time is the best strategy. To make the best decision with the information at hand, we need to appreciate the differences between personal opinions and scientific statements, which requires an understanding of science and the nature of scientific reasoning.

Accuracy	Explanations and theories match real-world observations	E.g. Although people say, "opposites attract," theories that focus on the role of partner similarity do a better job of explaining the observed data
Consistency	A theory has few exceptions and shows agreement with other theories within and across disciplines.	E.g. The theory of evolution explains many findings across biology and psychology predicting, for example, that humans are better able to solve problems presented in concrete rather than abstract terms
Scope	Extent to which a theory extends beyond currently available data, explaining a wide array of phenomena.	E.g. There is a theory that people use mental "short cuts" when making decision rather than weighing every single piece of evidence. This can be seen in consumer purchasing behavior, in romantic relationships, in charitable donations, and in health choices.
Simplicity	When multiple explanations are equally good at explaining the data, the simplest should be selected.	E.g. The simplest explanation for why "good" people sometimes do "bad" things is because they succumb to some outside influence
Fruitfulness	The usefulness of the theory in guiding new research by predicting new, testable relationships.	E.g. The explanation that competition leads to improved performance can be tested by researching different types of competition

Table 1. Features of good scientific theories (Kuhn, 2011)

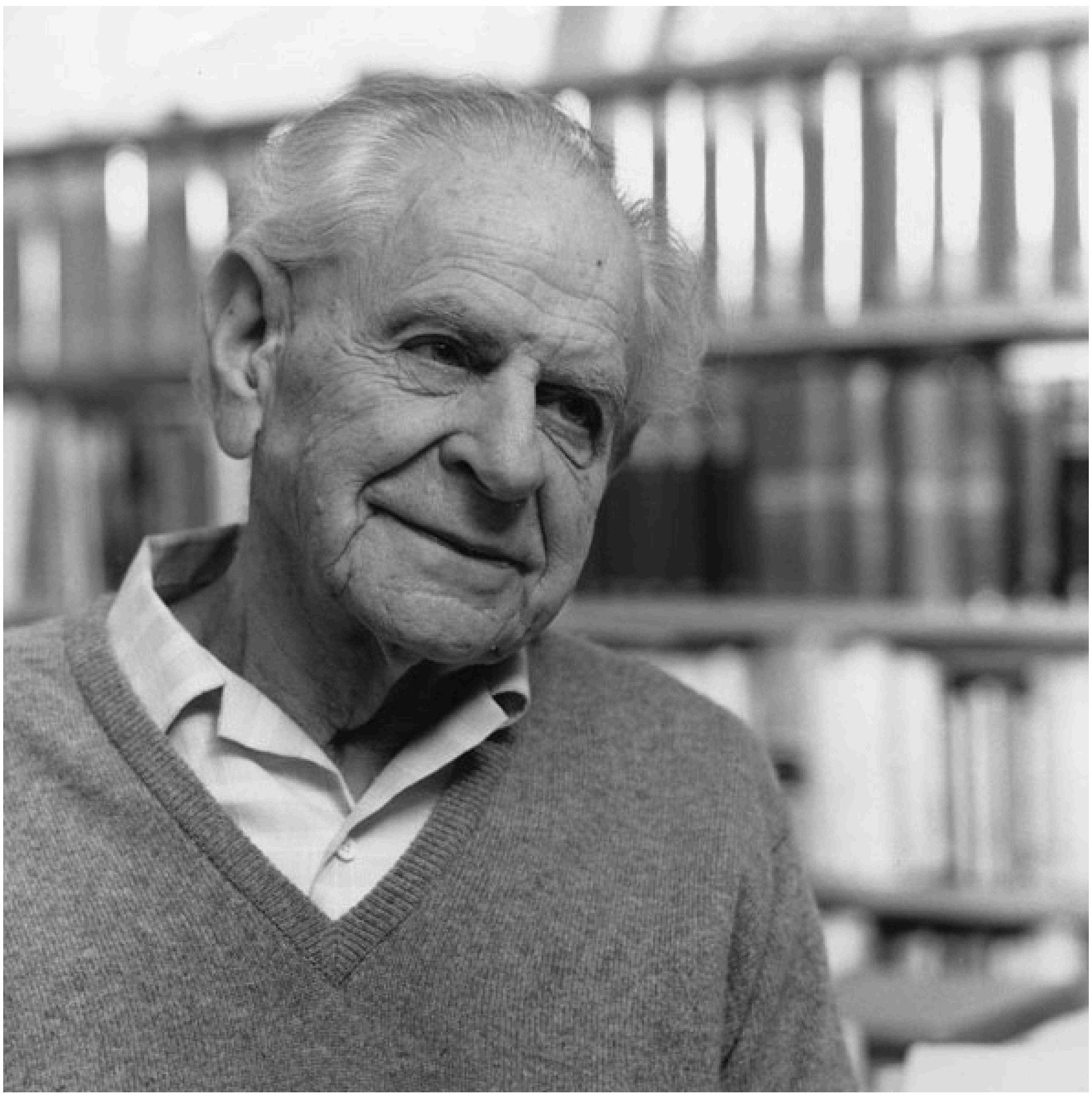
There are generally agreed-upon features that distinguish scientific thinking—and the theories and data generated by it—from everyday thinking. A short list of some of the commonly cited features of scientific theories and data is shown in Table 1.

One additional feature of modern science not included in this list but prevalent in scientists' thinking and theorizing is falsifiability, a feature that has so permeated scientific practice that it warrants additional clarification. In the early 20th century, Karl Popper (1902-1994) suggested that science can be distinguished from **pseudoscience** (or just everyday reasoning) because scientific claims are capable of being **falsified**. That is, a claim can be conceivably demonstrated to be untrue. For example, a person might claim that "all people are right handed." This claim can be tested and—ultimately—thrown out because it can be shown to be false: There are people who are left-handed. An easy rule of thumb is to not get confused by the term "falsifiable" but to understand that—more or less—it means testable.

On the other hand, some claims cannot be tested and falsified. Imagine, for instance, that a magician claims that he can teach people to move objects with their minds. The trick, he explains, is to *truly believe* in one's ability for it to work. When his students fail to budge chairs with their minds, the magician scolds, "Obviously, you don't truly believe." The magician's claim does not qualify as falsifiable because there is no way to disprove it. It is unscientific.

Popper was particularly irritated about nonscientific claims because he believed they were a threat to the science of psychology. Specifically, he was dissatisfied with Freud's explanations for mental illness. Freud believed that when a person suffers a mental illness it is often due to problems stemming from childhood. For instance, imagine a person who grows up to be an obsessive perfectionist. If she were raised by messy, relaxed parents, Freud might argue that her adult perfectionism is a reaction to her early family experiences—an effort to maintain order and routine instead of chaos. Alternatively, imagine the same person being raised by harsh, orderly parents. In this case, Freud might argue that her adult tidiness is simply her internalizing her parents' way of being. As you can see, according to Freud's rationale, both opposing scenarios are possible; no matter what the disorder, Freud's theory could explain its childhood origin—thus failing to meet the principle of falsifiability.

Popper argued against statements that could not be falsified. He claimed that they blocked scientific progress: There was no way to advance, refine, or refute knowledge based on such claims. Popper's solution was a powerful one: *If science showed all the possibilities that were not true, we would be left only with what is true*. That is, we need to be able to articulate— beforehand—the kinds of evidence that will disprove our hypothesis and cause us to abandon it. Karl Popper was an influential thinker regarding scientific theory and reasoning.



[Image: Lucinda Douglas-Menzies, https://goo.gl/ uuqxCe]

This may seem counterintuitive. For example, if a scientist wanted to establish a comprehensive understanding of why car accidents happen, she would systematically test all potential causes: alcohol consumption, speeding, using a cell phone, fiddling with the radio, wearing sandals, eating, chatting with a passenger, etc. A complete understanding could only be achieved once all possible explanations were explored and either falsified or not. After all the testing was concluded, the evidence would be evaluated against the criteria for falsification, and only the real causes of accidents would remain. The scientist could dismiss certain claims (e.g., sandals lead to car accidents) and keep only those supported by research (e.g., using a mobile phone while driving increases risk). It might seem absurd that a scientist would need to investigate so many alternative explanations, but it is exactly how we rule out bad claims. Of course, many explanations are complicated and involve multiple causes—as with car accidents, as well as psychological phenomena.

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Test Yourself 1: Can It Be Falsified?

Which of the following hypotheses can be falsified? For each, be sure to consider what kind of data could be collected to demonstrate that a statement is not true.

Chocolate tastes better than pasta.

We live in the most violent time in history.

Time can run backward as well as forward.

There are planets other than Earth that have water on them.

[See answer at end of this module]

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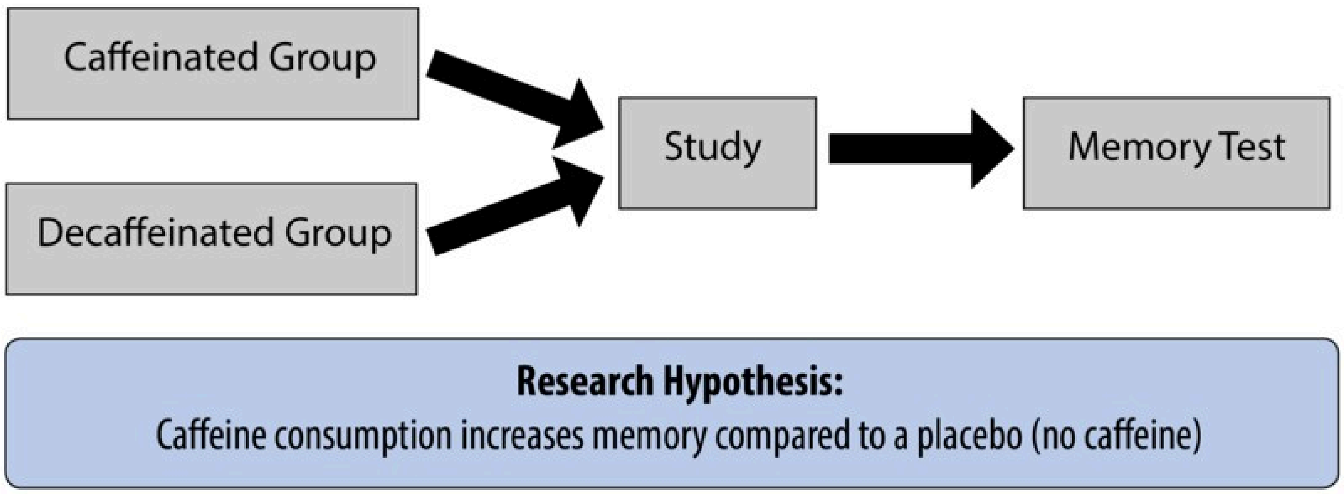
Although the idea of falsification remains central to scientific data and theory development, these days it's not used strictly the way Popper originally envisioned it. To begin with, scientists aren't solely interested in demonstrating what *isn't*. Scientists are also interested in providing descriptions and explanations for the way things *are*. We want to describe different causes and the various conditions under which they occur. We want to discover when young children start speaking in complete sentences, for example, or whether people are happier on the weekend, or how exercise impacts depression. These explorations require us to draw conclusions from limited samples of data. In some cases, these data seem to fit with our hypotheses and in others they do not. This is where interpretation and probability come in.

The Interpretation of Research Results

Imagine a researcher wanting to examine the hypothesis—a specific prediction based on previous research or scientific theory—that caffeine enhances memory. She knows there are several published studies that suggest this might be the case, and she wants to further explore the possibility. She designs an experiment to test this hypothesis. She randomly assigns some participants a cup of fully caffeinated tea and some a cup of herbal tea. All the participants are instructed to drink up, study a list of words, then complete a memory test. There are three possible outcomes of this proposed study:



The caffeine group performs better (support for the hypothesis).

The no-caffeine group performs better (evidence against the hypothesis).

There is no difference in the performance between the two groups (also evidence against the hypothesis).

Let's look, from a scientific point of view, at how the researcher should interpret each of these three possibilities.

First, if the results of the memory test reveal that the caffeine group performs better, this is a piece of evidence in favor of the hypothesis: It appears, at least in this case, that caffeine is associated with better memory. It does not, however, *prove* that caffeine is associated with better memory. There are still many questions left unanswered. How long does the memory boost last? Does caffeine work the same way with people of all ages? Is there a difference in memory performance between people who drink caffeine regularly and those who never drink it? Could the results be a freak occurrence? Because of these uncertainties, we do not say that a study—especially a single study—*proves* a hypothesis. Instead, we say the results of the study offer evidence in support of the hypothesis. Even if we tested this across 10 thousand or 100 thousand people we still could not use the word "proven" to describe this phenomenon.

This is because inductive reasoning is based on **probabilities**. Probabilities are always a matter of degree; they may be extremely likely or unlikely. Science is better at shedding light on the likelihood—or probability—of something than at proving it. In this way, data is still highly useful even if it doesn't fit Popper's absolute standards.

The science of meteorology helps illustrate this point. You might look at your local weather forecast and see a high likelihood of rain. This is because the meteorologist has used **inductive reasoning** to create her forecast. She has taken current observations—lots of dense clouds coming toward your city—and compared them to historical weather patterns associated with rain, making a reasonable prediction of a high probability of rain. The meteorologist has not *proven* it will rain, however, by pointing out the oncoming clouds.

Proof is more associated with deductive reasoning. **Deductive reasoning** starts with general principles that are applied to specific instances (the reverse of inductive reasoning). When the general principles, or *premises*, are true, and the structure of the argument is valid, the conclusion is, by definition, *proven*; it must be so. A deductive truth *must* apply in all relevant circumstances. For example, all living cells contain DNA. From this, you can reason– deductively–that any specific living cell (of an elephant, or a person, or a snake) will therefore contain DNA. Given the complexity of psychological phenomena, which involve many contributing factors, it is nearly impossible to make these types of broad statements with certainty.

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Test Yourself 2: Inductive or Deductive?

The stove was on and the water in the pot was boiling over. The front door was standing open. These clues suggest the homeowner left unexpectedly and in a hurry.

Gravity is associated with mass. Because the moon has a smaller mass than the Earth, it should have weaker gravity.

Students don't like to pay for high priced textbooks. It is likely that many students in the class will opt not to purchase a book.

To earn a college degree, students need 100 credits. Janine has 85 credits, so she cannot graduate.

[See answer at end of this module]

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The second possible result from the caffeine-memory study is that the group who had *no* caffeine demonstrates better memory. This result is the opposite of what the researcher expects to find (her hypothesis). Here, the researcher must admit the evidence does not support her hypothesis. She must be careful, however, not to extend that interpretation to other claims. For example, finding increased memory in the no-caffeine group would not be evidence that caffeine harms memory. Again, there are too many unknowns. Is this finding a freak occurrence, perhaps based on an unusual sample? Is there a problem with the design of the study? The researcher doesn't know. She simply knows that she was not able to observe support for her hypothesis.

There is at least one additional consideration: The researcher originally developed her caffeine- benefits-memory hypothesis based on conclusions drawn from previous research. That is, previous studies found results that suggested caffeine boosts memory. The researcher's single study should not outweigh the conclusions of many studies. Perhaps the earlier research employed participants of different ages or who had different baseline levels of caffeine intake. This new study simply becomes a piece of fabric in the overall quilt of studies of the caffeine- memory relationship. It does not, on its own, definitively falsify the hypothesis.

Finally, it's possible that the results show no difference in memory between the two groups. How should the researcher interpret this? How would you? In this case, the researcher once again has to admit that she has not found support for her hypothesis.

Interpreting the results of a study—regardless of outcome—rests on the quality of the observations from which those results are drawn. If you learn, say, that each group in a study included only four participants, or that they were all over 90 years old, you might have concerns. Specifically, you should be concerned that the observations, even if accurate, aren't **representative** of the general population. This is one of the defining differences between conclusions drawn from personal anecdotes and those drawn from scientific observations. **Anecdotal evidence**—derived from personal experience and unsystematic observations (e. g., "common sense,")—is limited by the quality and representativeness of observations, and by memory shortcomings. Well-designed research, on the other hand, relies on observations that are systematically recorded, of high quality, and representative of the **population** it claims to describe.

Why Should I Trust Science If It Can't Prove Anything?

It's worth delving a bit deeper into why we ought to trust the scientific inductive process, even when it relies on limited samples that don't offer absolute "proof." To do this, let's examine a widespread practice in psychological science: null-hypothesis significance testing.

To understand this concept, let's begin with another research example. Imagine, for instance, a researcher is curious about the ways maturity affects academic performance. She might have a hypothesis that mature students are more likely to be responsible about studying and completing homework and, therefore, will do better in their courses. To test this hypothesis, the researcher needs a measure of maturity and a measure of course performance. She might calculate the **correlation**—or relationship—between student age (her measure of maturity) and points earned in a course (her measure of academic performance). Ultimately, the researcher is interested in the likelihood—or probability— that these two variables closely relate to one another. **Null-hypothesis significance testing** (NHST)assesses the probability that the collected data (the observations) would be the same if there were no relationship between the variables in the study. Using our example, the NHST would test the probability that the researcher would find a link between age and class performance if there were, in reality, no such link.

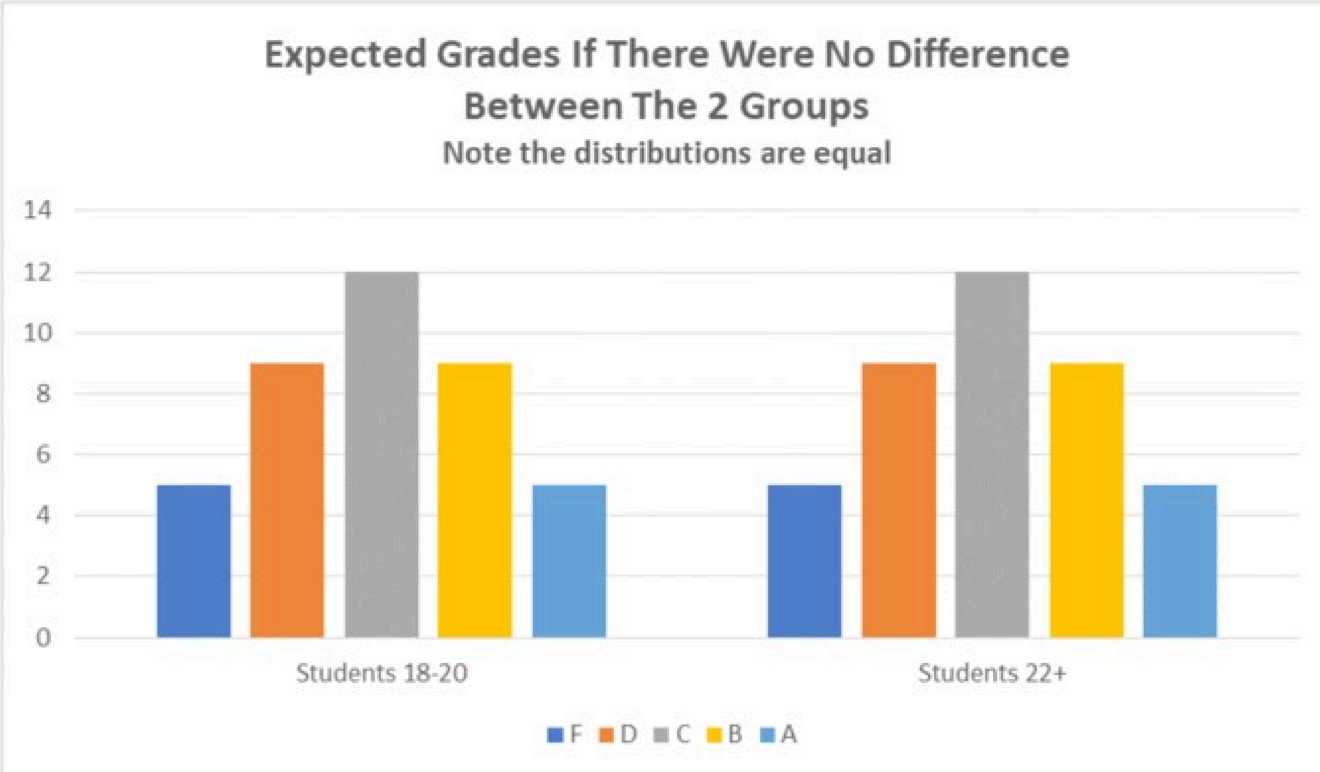
Is there a relationship between student age and academic performance? How could we research this question? How confident can we be that our observations reflect reality? [Image: Jeremy Wilburn, https://goo.gl/i9MoJb, CC BY-NC-ND 2.0, https://goo.gl/SjTsDg]

Now, here's where it gets a little complicated. NHST involves a *null hypothesis*, a statement that two variables are *not* related (in this case, that student maturity and academic performance are *not* related in any meaningful way). NHST also involves an *alternative hypothesis*, a statement that two variables *are* related (in this case, that student maturity and academic performance go together). To evaluate these two hypotheses, the researcher collects data. The researcher then compares what she expects to find (probability) with what she actually finds (the collected data) to determine whether she can falsify, or reject, the null hypothesis in favor of the alternative hypothesis.

How does she do this? By looking at the **distribution** of the data. The distribution is the spread of values—in our example, the numeric values of students' scores in the course. The researcher will test her hypothesis by comparing the observed distribution of grades earned by older students to those earned by younger students, recognizing that some distributions are more or less likely. Your intuition tells you, for example, that the chances of every single person in the course getting a perfect score are lower than their scores being distributed across all levels of performance.

The researcher can use a probability table to assess the likelihood of any distribution she finds in her class. These tables reflect the work, over the past 200 years, of mathematicians and scientists from a variety of fields. You can see, in Table 2a, an example of an expected distribution if the grades were normally distributed (most are average, and relatively few are amazing or terrible). In Table 2b, you can see possible results of this imaginary study, and can clearly see how they differ from the expected distribution.

In the process of testing these hypotheses, there are four possible outcomes. These are determined by two factors: 1) reality, and 2) what the researcher finds (see Table 3). The best possible outcome is *accurate detection*. This means that the researcher's conclusion mirrors reality. In our example, let's pretend the more mature students do perform slightly better. If this is what the researcher finds in her data, her analysis qualifies as an accurate detection of reality. Another form of accurate detection is when a researcher finds no evidence for a phenomenon, but that phenomenon doesn't actually exist anyway! Using this same example, let's now pretend that maturity has *nothing* to do with academic performance. Perhaps academic performance is instead related to intelligence or study habits. If the researcher finds no evidence for a link between maturity and grades and none actually exists, she will have also achieved accurate detection.



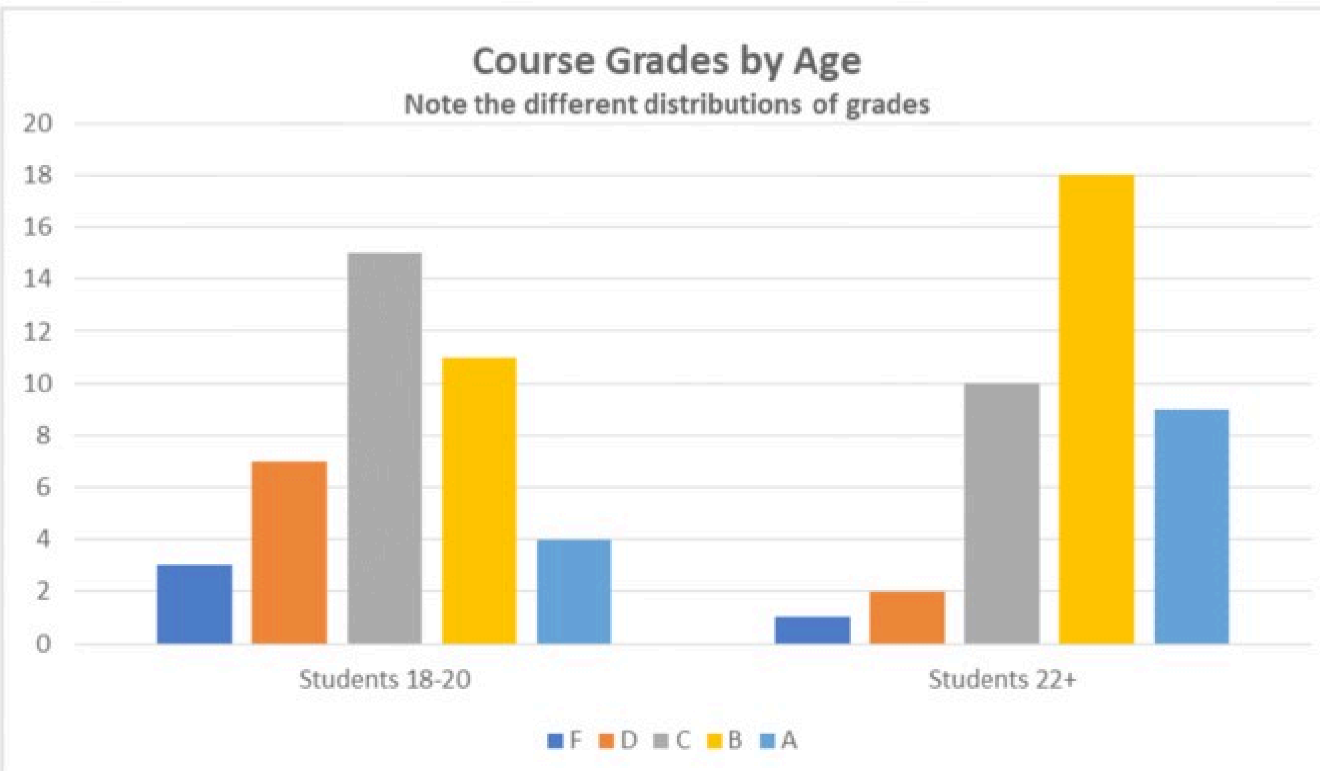


Table 2a (Above): Expected grades if there were no difference between the two groups. Table 2b (Below): Course grades by age

There are a couple of ways that research conclusions might be wrong. One is referred to as a **type I error**—when the researcher concludes there *is* a relationship between two variables but, in reality, there is *not*. Back to our example: Let's now pretend there's no relationship between maturity and grades, but the researcher still finds one. Why does this happen? It may be that her sample, by chance, includes older students who *also* have better study habits and perform better: The researcher has "found" a relationship (the data appearing to show age as significantly correlated with academic performance), but the truth is that the apparent relationship is purely coincidental—the result of these specific older students in this particular sample having better-than-average study habits (the real cause of the relationship). They may have always had superior study habits, even when they were young.

Another possible outcome of NHST is a **type II error**, when the data fail to show a relationship between variables that actually exists. In our example, this time pretend that maturity *is* —in reality—associated with academic performance, but the researcher *doesn't* find it in her sample. Perhaps it was just her bad luck that her older students are just having an off day, suffering from test anxiety, or were uncharacteristically careless with their homework: The peculiarities of her particular sample, by chance, prevent the researcher from identifying the real relationship between maturity and academic performance.

These types of errors might worry you, that there is just no way to tell if data are any good or not. Researchers share your concerns, and address them by using **probability values** (p- values) to set a threshold for type I or type II errors. When researchers write that a particular finding is "significant at a $p < .05$ level," they're saying that if the same study were repeated 100 times, we should expect this result to occur—by chance—fewer than five times. That is, in this case, a Type I error is unlikely. Scholars sometimes argue over the exact threshold that should be used for probability. The most common in psychological science are .05 (5% chance), .01 (1% chance), and .001 (1/10th of 1% chance). Remember, psychological science doesn't rely on definitive proof; it's about the probability of seeing a specific result. This is also why it's so important that scientific findings be replicated in additional studies.

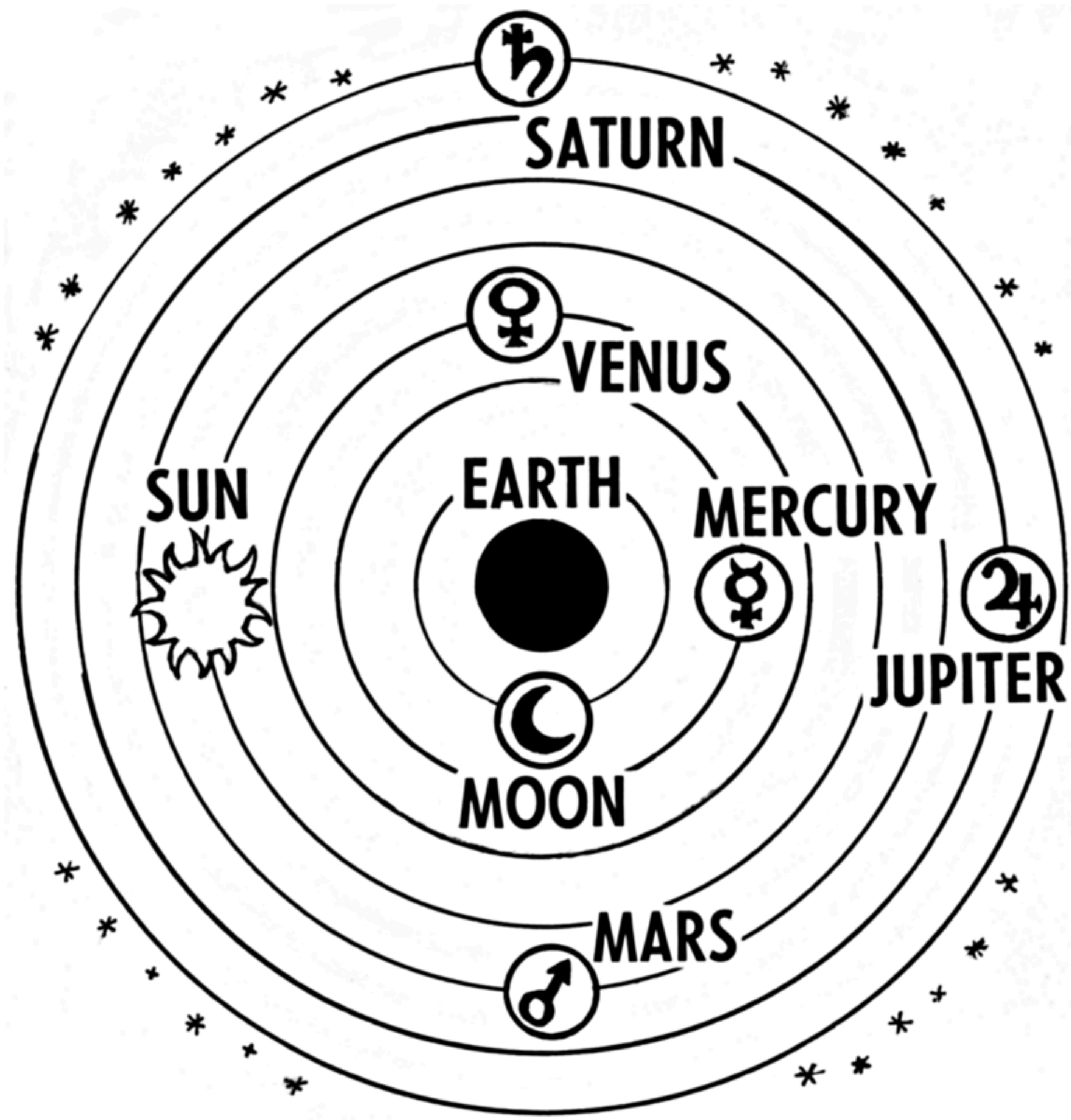
		In reality there is . . .	
		a relationship	***no*** **relationship**
The researcher finds . . .	**a relationship** (Alternative Hypothesis)	Accurate Detection!	***Type I Error***
	no **relationship** (Null hypothesis)	***Type II Error***	Accurate Detection!

Table 3: Accurate detection and errors in research

It's because of such methodologies that science is generally trustworthy. Not all claims and explanations are equal; some conclusions are better bets, so to speak. Scientific claims are more likely to be correct and predict real outcomes than "common sense" opinions and personal anecdotes. This is because researchers consider how to best prepare and measure their subjects, systematically collect data from large and—ideally—representative samples, and test their findings against probability.

Scientific Theories

The knowledge generated from research is organized according to scientific theories. A **scientific theory** is a comprehensive framework for making sense of evidence regarding a particular phenomenon. When scientists talk about a theory, they mean something different from how the term is used in everyday conversation. In common usage, a theory is an educated guess—as in, "I have a theory about which team will make the playoffs," or, "I have a theory about why my sister is always running late for appointments." Both of these beliefs are liable to be heavily influenced by many untrustworthy factors, such as personal opinions and memory biases. A scientific theory, however, enjoys support from many research studies, collectively providing evidence, including, but not limited to, that which has falsified competing explanations. A key component of good theories is that they describe, explain, and predict in a way that can be **empirically** tested and potentially falsified.



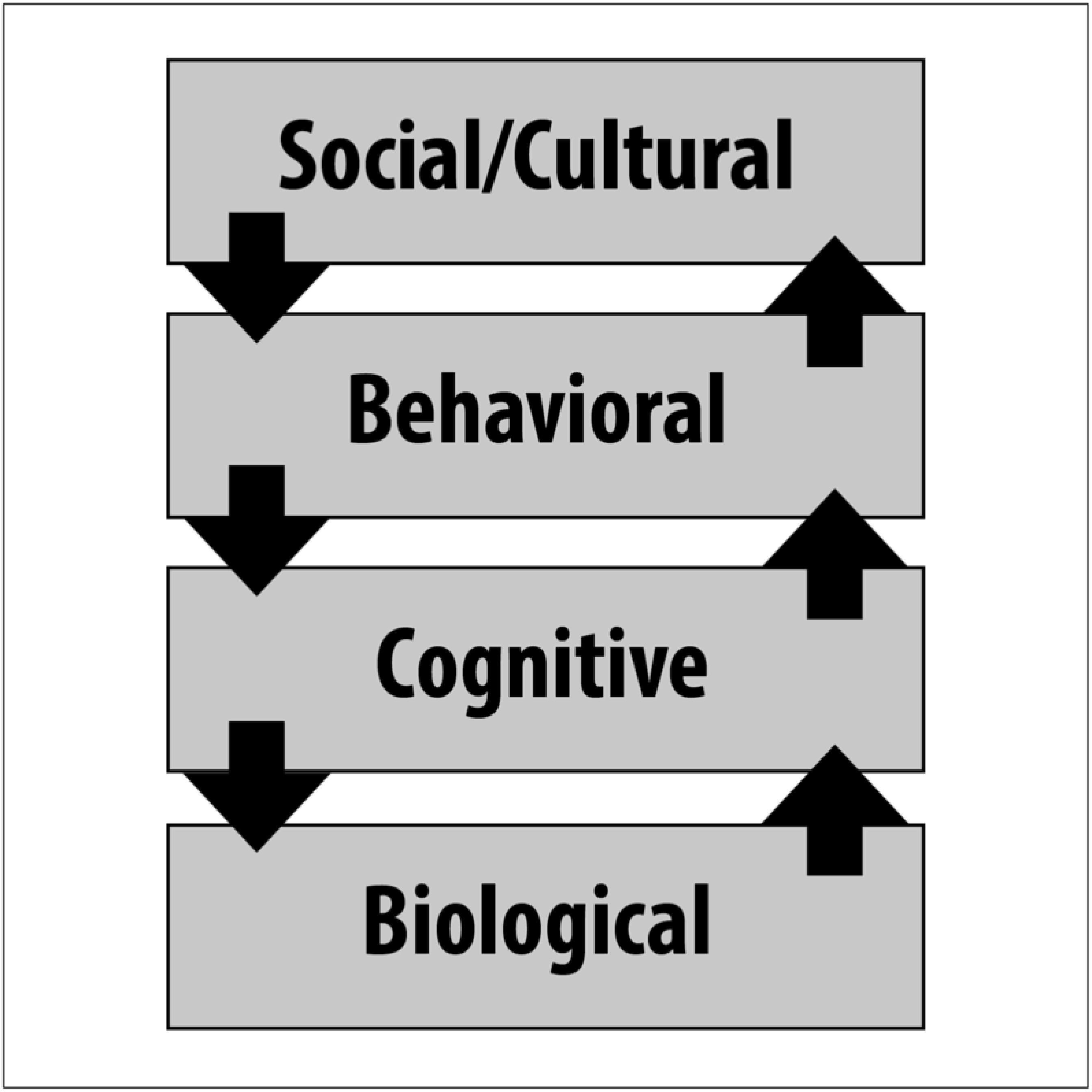
Early theories placed the Earth at the center of the solar system. We now know that the Earth revolves around the sun. [Image: Pearson Scott Foresman, https://goo.gl/W3izMR, Public Domain]

Theories are open to revision if new evidence comes to light that compels reexamination of the accumulated, relevant data. In ancient times, for instance, people thought the Sun traveled around the Earth. This seemed to make sense and fit with many observations. In the 16th century, however, astronomers began systematically charting visible objects in the sky, and, over a 50-year period, with repeated testing, critique, and refinement, they provided evidence for a revised theory: The Earth and other cosmic objects revolve around the Sun. In science, we believe what the best and most data tell us. If better data come along, we must be willing to change our views in accordance with the new evidence.

Is Science Objective?

Thomas Kuhn (2012), a historian of science, argued that science, as an activity conducted by humans, is a social activity. As such, it is—according to Kuhn—subject to the same psychological influences of all human activities. Specifically, Kuhn suggested that there is no such thing as **objective** theory or data; all of science is informed by values. Scientists cannot help but let personal/cultural values, experiences, and opinions influence the types of questions they ask and how they make sense of what they find in their research. Kuhn's argument highlights a distinction between **facts** (information about the world), and **values** (beliefs about the way the world is or ought to be). This distinction is an important one, even if it is not always clear.

To illustrate the relationship between facts and values, consider the problem of global warming. A vast accumulation of evidence (facts) substantiates the adverse impact that human activity has on the levels of greenhouse gases in Earth's atmosphere leading to changing weather patterns. There is also a set of beliefs (values), shared by many people, that influences their choices and behaviors in an attempt to address that impact (e.g., purchasing electric vehicles, recycling, bicycle commuting). Our values—in this case, that Earth as we know it is in danger and should be protected—influence how we engage with facts. People (including scientists) who strongly endorse this value, for example, might be more attentive to research on renewable energy.



The primary point of this illustration is that (contrary to the image of scientists as outside observers to the facts, gathering them neutrally and without bias from the natural world) all science—especially social sciences like psychology—involves values and interpretation. As a result, science functions best when people with diverse values and backgrounds work collectively to understand complex natural phenomena.

Indeed, science can benefit from multiple perspectives. One approach to achieving this is through levels of analysis. **Levels of analysis** is the idea that a single phenomenon may be explained at different levels simultaneously. Remember the question concerning cramming for a test versus studying over time? It can be answered at a number of different levels of analysis. At a low level, we might use brain scanning technologies to investigate whether biochemical processes differ between the two study strategies. At a higher level—the level of thinking—we might investigate processes of decision making (what to study) and ability to focus, as they relate to cramming versus spaced practice. At even higher levels, we might be interested in real world behaviors, such as how long people study using each of the strategies. Similarly, we might be interested in how the presence of others influences learning across these two strategies. Levels of analysis suggests that one level is not more correct—or truer—than another; their appropriateness depends on the specifics of the question asked. Ultimately, levels of analysis would suggest that we cannot understand the world around us, including human psychology, by reducing the phenomenon to only the biochemistry of genes and dynamics of neural networks. But, neither can we understand humanity without considering the functions of the human nervous system.

Science in Context

There are many ways to interpret the world around us. People rely on common sense, personal experience, and faith, in combination and to varying degrees. All of these offer legitimate benefits to navigating one's culture, and each offers a unique perspective, with specific uses and limitations. Science provides another important way of understanding the world and, while it has many crucial advantages, as with all methods of interpretation, it also has limitations. Understanding the limits of science—including its subjectivity and uncertainty— does not render it useless. Because it is systematic, using testable, reliable data, it can allow us to determine **causality** and can help us **generalize** our conclusions. By understanding how scientific conclusions are reached, we are better equipped to use science as a tool of knowledge.

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Answer – Test Yourself 1: Can It Be Falsified?

Answer explained: There are 4 hypotheses presented. Basically, the question asks "which of these could be tested and demonstrated to be false?". We can eliminate answers A, B and C. A is a matter of personal opinion. C is a concept for which there are currently no existing measures. B is a little trickier. A person could look at data on wars, assaults, and other forms of violence to draw a conclusion about which period is the most violent. The problem here is that we do not have data for all time periods, and there is no clear guide to which data should be used to address this hypothesis. The best answer is D, because we have the means to view other planets and to determine whether there is water on them (for example, Mars has ice).

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Answer – Test Yourself 2: Inductive or Deductive

Answer explained: This question asks you to consider whether each of 5 examples represents inductive or deductive reasoning. 1) Inductive—it is possible to draw the conclusion—the homeowner left in a hurry—from specific observations such as the stove being on and the door being open. 2) Deductive—starting with a general principle (gravity is associated with mass), we draw a conclusion about the moon having weaker gravity than does the Earth because it has smaller mass. 3) Deductive—starting with a general principle (students do not like to pay for textbooks) it is possible to make a prediction about likely student behavior (they will not purchase textbooks). Note that this is a case of prediction rather than using observations. 4) Deductive—starting with a general principle (students need 100 credits to graduate) it is possible to draw a conclusion about Janine (she cannot graduate because she has fewer than the 100 credits required).

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Outside Resources

Article: A meta-analysis of research on combating mis-information

http://journals.sagepub.com/doi/full/10.1177/0956797617714579

Article: Fixing the Problem of Liberal Bias in Social Psychology

https://www.scientificamerican.com/article/fixing-the-problem-of-liberal-bias-in-social-psychology/

Article: Flat out science rejection is rare, but motivated rejection of key scientific claims is relatively common.

https://blogs.scientificamerican.com/guest-blog/who-are-you-calling-anti-science/

Article: How Anecdotal Evidence Can Undermine Scientific Results

https://www.scientificamerican.com/article/how-anecdotal-evidence-can-undermine-scientific-results/

Article: How fake news is affecting your memory

http://www.nature.com/news/how-facebook-fake-news-and-friends-are-warping-your-memory-1.21596

Article: New Study Indicates Existence of Eight Conservative Social Psychologists

https://heterodoxacademy.org/2016/01/07/new-study-finds-conservative-social-psychologists/

Article: The Objectivity Thing (or, Why Science Is a Team Sport)

https://blogs.scientificamerican.com/doing-good-science/httpblogsscientificamericancomdo ing-good-science20110720the-objectivity-thing-or-why-science-is-a-team-sport/

Article: Thomas Kuhn: the man who changed the way the world looked at science

https://www.theguardian.com/science/2012/aug/19/thomas-kuhn-structure-scientific-revolutions

Video: Karl Popper's Falsification – Karl Popper believed that human knowledge progresses through 'falsification'. A theory or idea shouldn't be described as scientific unless it could, in principle, be proven false.

https://www.youtube.com/watch?v=wf-sGqBsWv4

Video: Karl Popper, Science, and Pseudoscience: Crash Course Philosophy #8

https://www.youtube.com/watch?v=-X8Xfl0JdTQ

Video: Simple visualization of Type I and Type II errors

https://www.youtube.com/watch?v=Dsa9ly4OSBk

Web: An overview and history of the concept of fake news.

https://en.wikipedia.org/wiki/Fake_news

Web: Heterodox Academy – an organization focused on improving "the quality of research and education in universities by increasing viewpoint diversity, mutual understanding, and constructive disagreement".

https://heterodoxacademy.org/

Web: The People's Science – An orgnization dedicated to removing barriers between scientists and society. See examples of how researchers, including psychologists, are sharing their research with students, colleagues and the general public.

http://thepeoplesscience.org/science-topic/human-sciences/

Discussion Questions

1. When you think of a “scientist,” what image comes to mind? How is this similar to or different from the image of a scientist described in this module?
2. What makes the inductive reasoning used in the scientific process different than the inductive reasoning we employ in our daily lives? How do these differences influence our trust in the conclusions?
3. Why aren’t horoscopes considered scientific?
4. If science cannot “prove” something, why do you think so many media reports of scientific research use this word? As an educated consumer of research, what kinds of questions should you ask when reading these secondary reports?
5. In thinking about the application of research in our lives, which is more meaningful: individual research studies and their conclusions or scientific theories? Why?
6. Although many people believe the conclusions offered by science generally, there is often a resistance to specific scientific conclusions or findings. Why might this be?

Vocabulary

Anecdotal evidence

A piece of biased evidence, usually drawn from personal experience, used to support a conclusion that may or may not be correct.

Causality

In research, the determination that one variable causes—is responsible for—an effect.

Correlation

In statistics, the measure of relatedness of two or more variables.

Data (also called observations)

In research, information systematically collected for analysis and interpretation.

Deductive reasoning

A form of reasoning in which a given premise determines the interpretation of specific observations (e.g., All birds have feathers; since a duck is a bird, it has feathers).

Distribution

In statistics, the relative frequency that a particular value occurs for each possible value of a given variable.

Empirical

Concerned with observation and/or the ability to verify a claim.

Fact

Objective information about the world.

Falsify

In science, the ability of a claim to be tested and—possibly—refuted; a defining feature of science.

Generalize

In research, the degree to which one can extend conclusions drawn from the findings of a study to other groups or situations not included in the study.

Hypothesis

A tentative explanation that is subject to testing.

Induction

To draw general conclusions from specific observations.

Inductive reasoning

A form of reasoning in which a general conclusion is inferred from a set of observations (e. g., noting that "the driver in that car was texting; he just cut me off then ran a red light!" (a specific observation), which leads to the general conclusion that texting while driving is dangerous).

Levels of analysis

In science, there are complementary understandings and explanations of phenomena.

Null-hypothesis significance testing (NHST)

In statistics, a test created to determine the chances that an alternative hypothesis would produce a result as extreme as the one observed if the null hypothesis were actually true.

Objective

Being free of personal bias.

Population

In research, all the people belonging to a particular group (e.g., the population of left handed people).

Probability

A measure of the degree of certainty of the occurrence of an event.

Probability values

In statistics, the established threshold for determining whether a given value occurs by chance.

Pseudoscience

Beliefs or practices that are presented as being scientific, or which are mistaken for being scientific, but which are not scientific (e.g., astrology, the use of celestial bodies to make predictions about human behaviors, and which presents itself as founded in astronomy, the actual scientific study of celestial objects. Astrology is a pseudoscience unable to be falsified, whereas astronomy is a legitimate scientific discipline).

Representative

In research, the degree to which a sample is a typical example of the population from which it is drawn.

Sample

In research, a number of people selected from a population to serve as an example of that population.

Scientific theory

An explanation for observed phenomena that is empirically well-supported, consistent, and fruitful (predictive).

Type I error

In statistics, the error of rejecting the null hypothesis when it is true.

Type II error

In statistics, the error of failing to reject the null hypothesis when it is false.

Value

Belief about the way things should be.

References

Kuhn, T. S. (2012). *The structure of scientific revolutions: 50th anniversary edition*. Chicago, USA: University of Chicago Press.

Kuhn, T. S. (2011). Objectivity, value judgment, and theory choice, in T. S. Kuhn (Ed.), *The essential tension: Selected studies in scientific tradition and change* (pp. 320-339). Chicago: University of Chicago Press. Retrieved from http://ebookcentral.proquest.com

STATISTICAL THINKING

As our society increasingly calls for evidence-based decision making, it is important to consider how and when we can draw valid inferences from data. This module will use four recent research studies to highlight key elements of a statistical investigation.

Learning Objectives

- Define basic elements of a statistical investigation.
- Describe the role of p-values and confidence intervals in statistical inference.
- Describe the role of random sampling in generalizing conclusions from a sample to a population.
- Describe the role of random assignment in drawing cause-and-effect conclusions.
- Critique statistical studies.

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Introduction

Does drinking coffee actually increase your life expectancy? A recent study (Freedman, Park, Abnet, Hollenbeck, & Sinha, 2012) found that men who drank at least six cups of coffee a day had a 10% lower chance of dying (women 15% lower) than those who drank none. Does this mean you should pick up or increase your own coffee habit?

Modern society has become awash in studies such as this; you can read about several such studies in the news every day. Moreover, data abound everywhere in modern life. Conducting such a study well, and interpreting the results of such studies well for making informed decisions or setting policies, requires understanding basic ideas of statistics, the science of gaining insight from data. Rather than relying on anecdote and intuition, statistics allows us to systematically study phenomena of interest.

[Image: Duncan, https://goo.gl/vbMyTm, CC BY-NC 2.0, https://goo.gl/l8UUGY]

People around the world differ in their preferences for drinking coffee versus drinking tea. Would the results of the coffee study be the same in Canada as in China?

Key components to a statistical investigation are:

Planning the study: Start by asking a testable research question and deciding how to collect data. For example, how long was the study period of the coffee study? How many people were recruited for the study, how were they recruited, and from where? How old were they? What other variables were recorded about the individuals, such as smoking habits, on the comprehensive lifestyle questionnaires? Were changes made to the participants' coffee habits during the course of the study?

Examining the data: What are appropriate ways to examine the data? What graphs are relevant, and what do they reveal? What descriptive statistics can be calculated to summarize relevant aspects of the data, and what do they reveal? What patterns do you see in the data? Are there any individual observations that deviate from the overall pattern, and what do they reveal? For example, in the coffee study, did the proportions differ when we compared the smokers to the non-smokers?

Inferring from the data: What are valid statistical methods for drawing inferences "beyond" the data you collected? In the coffee study, is the 10%–15% reduction in risk of death something that could have happened just by chance?

Drawing conclusions: Based on what you learned from your data, what conclusions can you draw? Who do you think these conclusions apply to? (Were the people in the coffee study older? Healthy? Living in cities?) Can you draw a **cause-and-effect** conclusion about your treatments? (Are scientists now saying that the coffee drinking is the cause of the decreased risk of death?)

Notice that the numerical analysis ("crunching numbers" on the computer) comprises only a small part of overall statistical investigation. In this module, you will see how we can answer some of these questions and what questions you should be asking about any statistical investigation you read about.

Distributional Thinking

When data are collected to address a particular question, an important first step is to think of meaningful ways to organize and examine the data. The most fundamental principle of statistics is that data vary. The pattern of that variation is crucial to capture and to understand. Often, careful presentation of the data will address many of the research questions without requiring more sophisticated analyses. It may, however, point to additional questions that need to be examined in more detail.

Example 1: Researchers investigated whether cancer pamphlets are written at an appropriate level to be read and understood by cancer patients (Short, Moriarty, & Cooley, 1995). Tests of reading ability were given to 63 patients. In addition, readability level was determined for a sample of 30 pamphlets, based on characteristics such as the lengths of words and sentences in the pamphlet. The results, reported in terms of grade levels, are displayed in Table 1.

Patients' reading levels	< 3	3	4	5	6	7	8	9	10	11	12	> 12	**Total**
Count (number of patients)	6	4	4	3	3	2	6	5	4	7	2	17	**63**

Pamphlet's readability levels	6	7	8	9	10	11	12	13	14	15	16	**Total**
Count (number of pamphlets)	3	3	8	4	1	1	4	2	1	2	1	**30**

Table 1. Frequency tables of patient reading levels and pamphlet readability levels.

These two variables reveal two fundamental aspects of statistical thinking: Data *vary*. More specifically, values of a variable (such as reading level of a cancer patient or readability level of a cancer pamphlet) vary.

Analyzing the pattern of variation, called the **distribution** of the variable, often reveals insights.

Addressing the research question of whether the cancer pamphlets are written at appropriate levels for the cancer patients requires comparing the two distributions. A naïve comparison might focus only on the centers of the distributions. Both medians turn out to be ninth grade, but considering only medians ignores the variability and the overall distributions of these data. A more illuminating approach is to compare the entire distributions, for example with a graph, as in Figure 1.

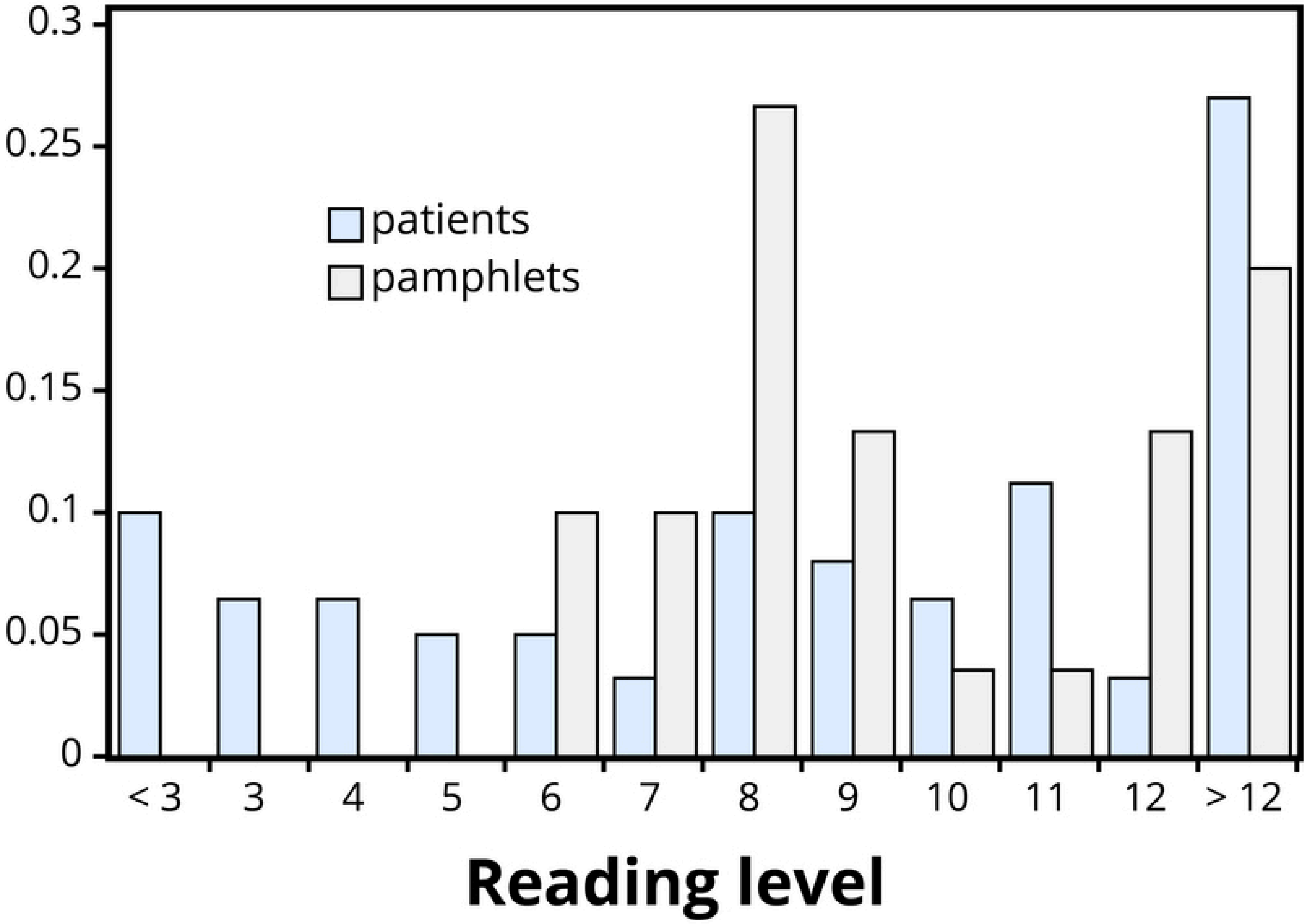

Figure 1: Comparison of patient reading levels and pamphlet readability levels.

Figure 1 makes clear that the two distributions are not well aligned at all. The most glaring discrepancy is that many patients (17/63, or 27%, to be precise) have a reading level below that of the most readable pamphlet. These patients will need help to understand the information provided in the cancer pamphlets. Notice that this conclusion follows from considering the distributions as a whole, not simply measures of center or variability, and that the graph contrasts those distributions more immediately than the frequency tables.

Statistical Significance

Even when we find patterns in data, often there is still uncertainty in various aspects of the data. For example, there may be potential for measurement errors (even your own body temperature can fluctuate by almost 1 °F over the course of the day). Or we may only have a "snapshot" of observations from a more long-term process or only a small subset of individuals from the population of interest. In such cases, how can we determine whether patterns we see in our small set of data is convincing evidence of a systematic phenomenon in the larger process or population?

Example 2: In a study reported in the November 2007 issue of *Nature*, researchers investigated whether pre-verbal infants take into account an individual's actions toward others in evaluating that individual as appealing or aversive (Hamlin, Wynn, & Bloom, 2007). In one component of the study, 10-month-old infants were shown a "climber" character (a piece of wood with "googly" eyes glued onto it) that could not make it up a hill in two tries. Then the infants were shown two scenarios for the climber's next try, one where the climber was pushed to the top of the hill by another character ("helper"), and one where the climber was pushed back down the hill by another character ("hinderer"). The infant was alternately shown these two scenarios several times. Then the infant was presented with two pieces of wood (representing the helper and the hinderer characters) and asked to pick one to play with. The researchers found that of the 16 infants who made a clear choice, 14 chose to play with the helper toy.

Correlation does not equal causation: When babies get their first teeth their saliva production increases but this does not mean that increased saliva causes them to get their teeth. [Image: Ben McLeod, https://goo.gl/0EkXpV, CC BY-NC-SA 2.0, https://goo.gl/Toc0ZF]

One possible explanation for this clear majority result is that the helping behavior of the one toy increases the infants' likelihood of choosing that toy. But are there other possible explanations? What about the color of the toy? Well, prior to collecting the data, the researchers arranged so that each color and shape (red square and blue circle) would be seen by the same number of infants. Or maybe the infants had right-handed tendencies and so picked whichever toy was closer to their right hand? Well, prior to collecting the data, the researchers arranged it so half the infants saw the helper toy on the right and half on the left. Or, maybe the shapes of these wooden characters (square, triangle, circle) had an effect? Perhaps, but again, the researchers controlled for this by rotating which shape was the helper toy, the hinderer toy, and the climber. When designing experiments, it is important to *control* for as many variables as might affect the responses as possible.

It is beginning to appear that the researchers accounted for all the other plausible explanations. But there is one more important consideration that cannot be controlled—if we did the study again with these 16 infants, they might not make the same choices. In other words, there is some *randomness* inherent in their selection process. Maybe each infant had no genuine preference at all, and it was simply "random luck" that led to 14 infants picking the helper toy. Although this random component cannot be controlled, we can apply a *probability model* to investigate the pattern of results that would occur in the long run if random chance were the only factor.

If the infants were equally likely to pick between the two toys, then each infant had a 50% chance of picking the helper toy. It's like each infant tossed a coin, and if it landed heads, the infant picked the helper toy. So if we tossed a coin 16 times, could it land heads 14 times? Sure, it's possible, but it turns out to be very unlikely. Getting 14 (or more) heads in 16 tosses is about as likely as tossing a coin and getting 9 heads in a row. This probability is referred to as a **p-value**. The p-value tells you how often a random process would give a result at least as extreme as what was found in the actual study, assuming there was nothing other than random chance at play.

So, if we assume that each infant was choosing equally, then the probability that 14 or more out of 16 infants would choose the helper toy is found to be 0.0021. We have only two logical possibilities: either the infants have a genuine preference for the helper toy, or the infants have no preference (50/50) and an outcome that would occur only 2 times in 1,000 iterations happened in this study. Because this p-value of 0.0021 is quite small, we conclude that the study provides very strong evidence that these infants have a genuine preference for the helper toy. We often compare the p-value to some cut-off value (called the level of **significance**, typically around 0.05). If the p-value is smaller than that cut- off value, then we reject the hypothesis that only random chance was at play here. In this case, these researchers would conclude that *significantly* more than half of the infants in the study chose the helper toy, giving strong evidence of a genuine preference for the toy with the helping behavior.

Generalizability

One limitation to the previous study is that the conclusion only applies to the 16 infants in the study. We don't know much about how those 16 infants were selected. Suppose we want to select a subset of individuals (a **sample**) from a much larger group of individuals (the **population**) in such a way that conclusions fro population. This is the question faced by pollsters every day.

Generalizability is an important research consideration: The results of studies with widely representative samples are more likely to generalize to the population. [Image: Mike PD, https://goo.gl/ynFCMC, CC BY-NC-SA 2.0, https://goo.gl/Toc0ZF]

Example 3: The General Social Survey (GSS) is a survey on societal trends conducted every other year in the United States. Based on a sample of about 2,000 adult Americans, researchers make claims about what percentage of the U.S. population consider themselves to be "liberal," what percentage consider themselves "happy," what percentage feel "rushed" in their daily lives, and many other issues. The key to making these claims about the larger population of all American adults lies in how the sample is selected. The goal is to select a sample that is representative of the population, and a common way to achieve this goal is to select a **random sample** that gives every member of the population an equal chance of being selected for the sample.

In its simplest form, random sampling involves numbering every member of the population and then using a computer to randomly select the subset to be surveyed. Most polls don't operate exactly like this, but they do use probability-based sampling methods to select individuals from nationally representative panels.

In 2004, the GSS reported that 817 of 977 respondents (or 83.6%) indicated that they always or sometimes feel rushed. This is a clear majority, but we again need to consider variation due to *random sampling*. Fortunately, we can use the same probability model we did in the previous example to investigate the probable size of this error. (Note, we can use the coin-tossing model when the actual population size is much, much larger than the sample size, as then we can still consider the probability to be the same for every individual in the sample.) This probability model predicts that the sample result will be within 3 percentage points of the population value (roughly 1 over the square root of the sample size, the **margin of error**). A statistician would conclude, with 95% confidence, that between 80.6% and 86.6% of all adult Americans in 2004 would have responded that they sometimes or always feel rushed.

The key to the margin of error is that when we use a probability sampling method, we can make claims about how often (in the long run, with repeated random sampling) the sample result would fall within a certain distance from the unknown population value by chance (meaning by random sampling variation) alone. Conversely, non-random samples are often suspect to bias, meaning the sampling method systematically over-represents some segments of the population and under-represents others. We also still need to consider other sources of bias, such as individuals not responding honestly. These sources of error are not measured by the margin of error.

Cause and Effect Conclusions

In many research studies, the primary question of interest concerns differences between groups. Then the question becomes how were the groups formed (e.g., selecting people who already drink coffee vs. those who don't). In some studies, the researchers actively form the groups themselves. But then we have a similar question–could any differences we observe in the groups be an artifact of that group-formation process? Or maybe the difference we observe in the groups is so large that we can discount a "fluke" in the group-formation process as a reasonable explanation for what we find?

Example 4: A psychology study investigated whether people tend to display more creativity when they are thinking about intrinsic or extrinsic motivations (Ramsey & Schafer, 2002, based on a study by Amabile, 1985). The subjects were 47 people with extensive experience with creative writing. Subjects began by answering survey questions about either intrinsic motivations for writing (such as the pleasure of self-expression) or extrinsic motivations (such as public recognition). Then all subjects were instructed to write a haiku, and those poems were evaluated for creativity by a panel of judges. The researchers conjectured beforehand that subjects who were thinking about intrinsic motivations would display more creativity than subjects who were thinking about extrinsic motivations. The creativity scores from the 47 subjects in this study are displayed in Figure 2, where higher scores indicate more creativity.

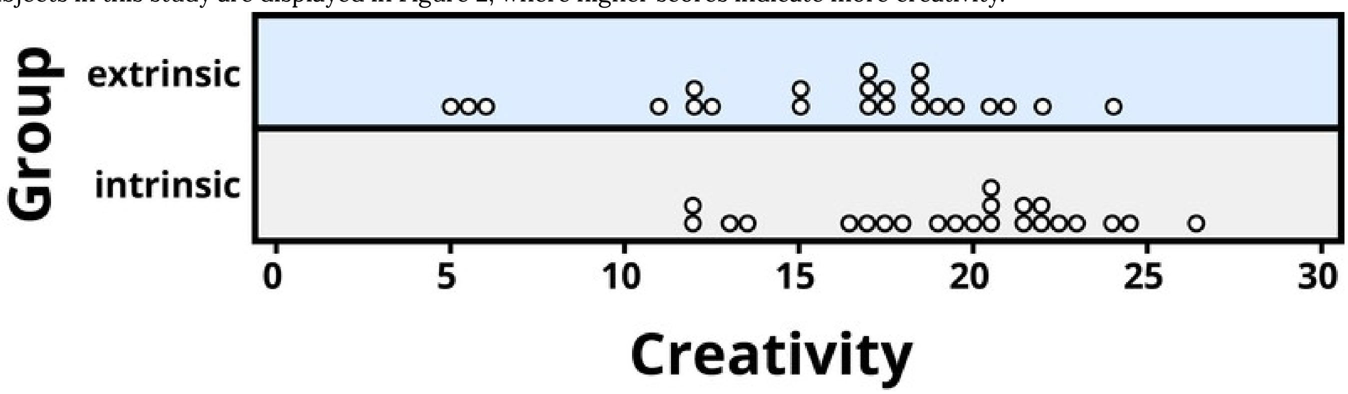

Figure 2. Creativity scores separated by type of motivation.

In this example, the key question is whether the type of motivation *affects* creativity scores. In particular, do subjects who were asked about intrinsic motivations tend to have higher creativity scores than subjects who were asked about extrinsic motivations?

Figure 2 reveals that both motivation groups saw considerable variability in creativity scores, and these scores have considerable overlap between the groups. In other words, it's certainly not always the case that those with extrinsic motivations have higher creativity than those with intrinsic motivations, but there may still be a statistical *tendency* in this direction. (Psychologist Keith Stanovich (2013) refers to people's difficulties with thinking about such probabilistic tendencies as "the Achilles heel of human cognition.")

The mean creativity score is 19.88 for the intrinsic group, compared to 15.74 for the extrinsic group, which supports the researchers' conjecture. Yet comparing only the means of the two groups fails to consider the variability of creativity scores in the groups. We can measure variability with statistics using, for instance, the standard deviation: 5.25 for the extrinsic group and 4.40 for the intrinsic group. The standard deviations tell us that most of the creativity scores are within about 5 points of the mean score in each group. We see that the mean score for the intrinsic group lies within one standard deviation of the mean score for extrinsic group. So, although there is a tendency for the creativity scores to be higher in the intrinsic group, on average, the difference is not extremely large.

We again want to consider possible explanations for this difference. The study only involved individuals with extensive creative writing experience. Although this limits the population to which we can generalize, it does not explain why the mean creativity score was a bit larger for the intrinsic group than for the extrinsic group. Maybe women tend to receive higher creativity scores? Here is where we need to focus on how the individuals were assigned to the motivation groups. If only women were in the intrinsic motivation group and only men in the extrinsic group, then this would present a problem because we wouldn't know if the intrinsic group did better because of the different type of motivation or because they were women. However, the researchers guarded against such a problem by **randomly assigning** the individuals to the motivation groups. Like flipping a coin, each individual was just as likely to be assigned to either type of motivation. Why is this helpful? Because this random assignment tends to balance out all the variables related to creativity we can think of, and even those we don't think of in advance, between the two groups. So we should have a similar male/female split between the two groups; we should have a similar age distribution between the two groups; we should have a similar distribution of educational background between the two groups; and so on. Random assignment should produce groups that are as similar as possible except for the type of motivation, which presumably eliminates all those other variables as possible explanations for the observed tendency for higher scores in the intrinsic group.

But does this always work? No, so by "luck of the draw" the groups may be a little different prior to answering the motivation survey. So then the question is, is it possible that an unlucky random assignment is responsible for the observed difference in creativity scores between the groups? In other words, suppose each individual's poem was going to get the same creativity score no matter which group they were assigned to, that the type of motivation in no way impacted their score. Then how often would the random-assignment process alone lead to a difference in mean creativity scores as large (or larger) than 19.88 – 15.74 = 4.14 points?

We again want to apply to a probability model to approximate a p-value, but this time the model will be a bit different. Think of writing everyone's creativity scores on an index card, shuffling up the index cards, and then dealing out 23 to the extrinsic motivation group and 24 to the intrinsic motivation group, and finding the difference in the group means. We (better yet, the computer) can repeat this process over and over to see how often, when the scores don't change, random assignment leads to a difference in means at least as large as 4.41. Figure 3 shows the results from 1,000 such hypothetical random assignments for these scores.

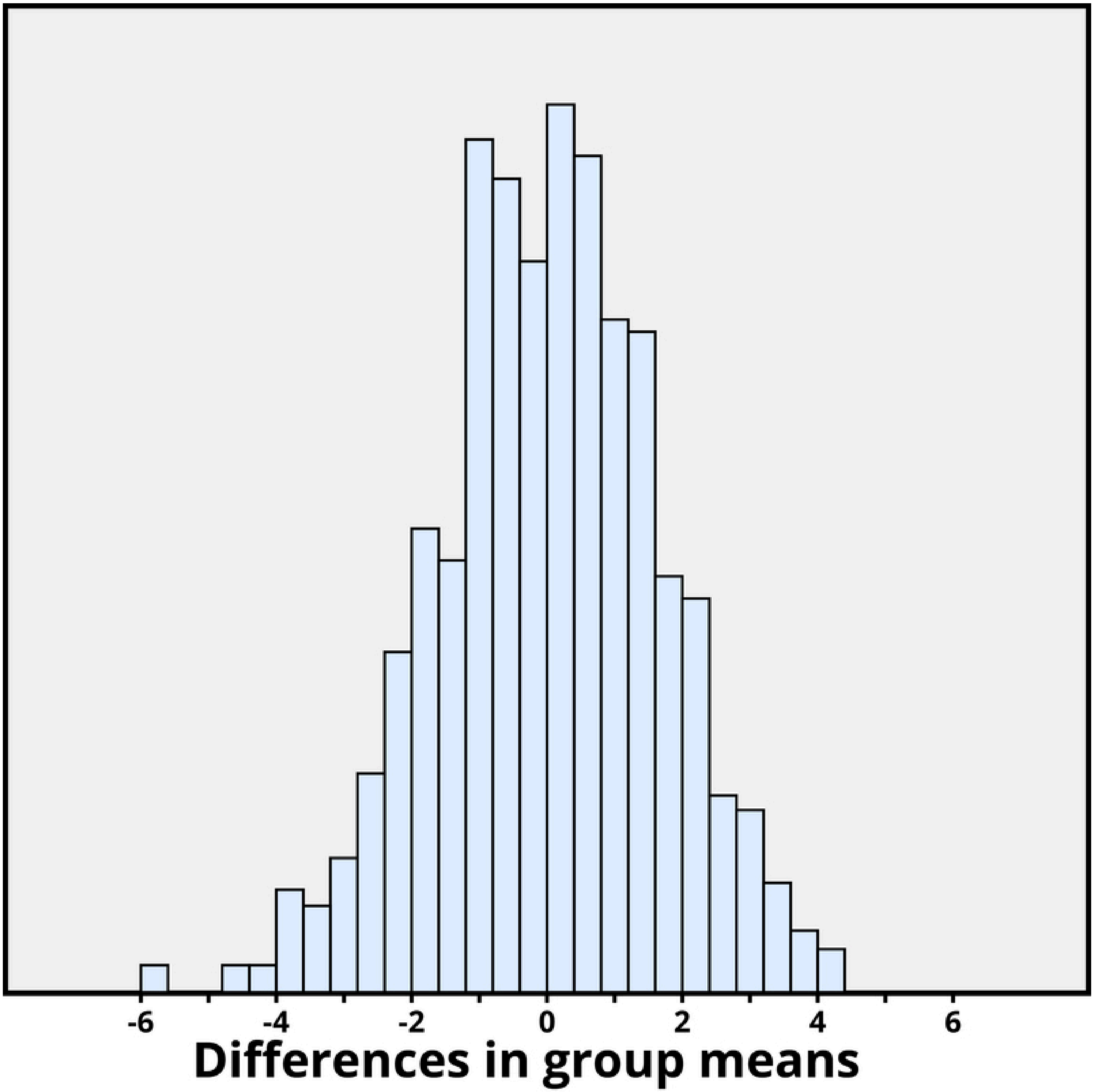

Figure 3. Differences in group means under random assignment alone.

Only 2 of the 1,000 simulated random assignments produced a difference in group means of 4.41 or larger. In other words, the approximate p-value is 2/1000 = 0.002. This small p-value indicates that it would be very surprising for the random assignment process alone to produce such a large difference in group means. Therefore, as with Example 2, we have strong evidence that focusing on intrinsic motivations tends to increase creativity scores, as compared to thinking about extrinsic motivations.

Notice that the previous statement implies a cause-and-effect relationship between motivation and creativity score; is such a strong conclusion justified? Yes, because of the random assignment used in the study. That should have balanced out any other variables between the two groups, so now that the small p-value convinces us that the higher mean in the intrinsic group wasn't just a coincidence, the only reasonable explanation left is the difference in the type of motivation. Can we generalize this conclusion to everyone?

Not necessarily—we could cautiously generalize this conclusion to individuals with extensive experience in creative writing similar the individuals in this study, but we would still want to know more about how these individuals were selected to participate.

Conclusion

Researchers employ the scientific method that involves a great deal of statistical thinking: generate a hypothesis -> design a study to test that hypothesis -> conduct the study -> analyze the data -> report the results. [Image: widdowquinn, https://goo.gl/9l8Dht, CC BY-NC-SA 2.0, https://goo.gl/Toc0ZF]

Statistical thinking involves the careful design of a study to collect meaningful data to answer a focused research question, detailed analysis of patterns in the data, and drawing conclusions that go beyond the observed data. Random sampling is paramount to generalizing results from our sample to a larger population, and random assignment is key to drawing cause-and-effect conclusions. With both kinds of randomness, probability models help us assess how much random variation we can expect in our results, in order to determine whether our results could happen by chance alone and to estimate a margin of error.

So where does this leave us with regard to the coffee study mentioned at the beginning of this module? We can answer many of the questions:

This was a 14-year study conducted by researchers at the National Cancer Institute.

The results were published in the June issue of the *New England Journal of Medicine*, a respected, peer-reviewed journal.

The study reviewed coffee habits of more than 402,000 people ages 50 to 71 from six states and two metropolitan areas. Those with cancer, heart disease, and stroke were excluded at the start of the study. Coffee consumption was assessed once at the start of the study.

About 52,000 people died during the course of the study.

People who drank between two and five cups of coffee daily showed a lower risk as well, but the amount of reduction increased for those drinking six or more cups.

The sample sizes were fairly large and so the p-values are quite small, even though percent reduction in risk was not extremely large (dropping from a 12% chance to about 10%–11%).

Whether coffee was caffeinated or decaffeinated did not appear to affect the results.

This was an observational study, so no cause-and-effect conclusions can be drawn between coffee drinking and increased longevity, contrary to the impression conveyed by many news headlines about this study. In particular, it's possible that those with chronic diseases don't tend to drink coffee.

This study needs to be reviewed in the larger context of similar studies and consistency of results across studies, with the constant caution that this was not a randomized experiment. Whereas a statistical analysis can still "adjust" for other potential confounding variables, we are not yet convinced that researchers have identified them all or completely isolated why this decrease in death risk is evident. Researchers can now take the findings of this study and develop more focused studies that address new questions.

Outside Resources

Apps: Interactive web applets for teaching and learning statistics include the collection at http://www.rossmanchance.com/applets/P-Value extravaganza

A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.library.upei.ca/upeiintropsychology/?p=611

Web: Inter-university Consortium for Political and Social Research
http://www.icpsr.umich.edu/index.html
Web: The Consortium for the Advancement of Undergraduate Statistics
https://www.causeweb.org/

Discussion Questions

Find a recent research article in your field and answer the following: What was the primary research question? How were individuals selected to participate in the study? Were summary results provided? How strong is the evidence presented in favor or against the research question? Was random assignment used? Summarize the main conclusions from the study, addressing the issues of statistical significance, statistical confidence, generalizability, and cause and effect. Do you agree with the conclusions drawn from this study, based on the study design and the results presented?

Is it reasonable to use a random sample of 1,000 individuals to draw conclusions about all U.S. adults? Explain why or why not.

Vocabulary

Cause-and-effect
Related to whether we say one variable is causing changes in the other variable, versus other variables that may be related to these two variables.
Confidence interval
An interval of plausible values for a population parameter; the interval of values within the margin of error of a statistic.
Distribution
The pattern of variation in data.
Generalizability
Related to whether the results from the sample can be generalized to a larger population.
Margin of error
The expected amount of random variation in a statistic; often defined for 95% confidence level.
Parameter
A numerical result summarizing a population (e.g., mean, proportion).
Population
A larger collection of individuals that we would like to generalize our results to.
P-value
The probability of observing a particular outcome in a sample, or more extreme, under a conjecture about the larger population or process.
Random assignment
Using a probability-based method to divide a sample into treatment groups.
Random sampling
Using a probability-based method to select a subset of individuals for the sample from the population.
Sample
The collection of individuals on which we collect data.
Statistic
A numerical result computed from a sample (e.g., mean, proportion).
Statistical significance
A result is statistically significant if it is unlikely to arise by chance alone.

References

Amabile, T. (1985). Motivation and creativity: Effects of motivational orientation on creative writers. *Journal of Personality and Social Psychology*, 48(2), 393–399.

Freedman, N. D., Park, Y., Abnet, C. C., Hollenbeck, A. R., & Sinha, R. (2012). Association of coffee drinking with total and cause-specific mortality. *New England Journal of Medicine*, 366, 1891–1904.

Hamlin, J. K., Wynn, K., & Bloom, P. (2007). Social evaluation by preverbal infants. *Nature*, 452 (22), 557–560.

Ramsey, F., & Schafer, D. (2002). *The statistical sleuth: A course in methods of data analysis*. Belmont, CA: Duxbury.

Short, T., Moriarty, H., & Cooley, M. E. (1995). Readability of educational materials for patients with cancer. *Journal of Statistics Education*, 3(2).

Stanovich, K. (2013). *How to think straight about psychology* (10th ed.). Upper Saddle River, NJ: Pearson.

FACTORS INFLUENCING LEARNING

Learning is a complex process that defies easy definition and description. This module reviews some of the philosophical issues involved with defining learning and describes in some detail the characteristics of learners and of encoding activities that seem to affect how well people can acquire new memories, knowledge, or skills. At the end, we consider a few basic principles that guide whether a particular attempt at learning will be successful or not.

Learning Objectives

- Consider what kinds of activities constitute learning.
- Name multiple forms of learning.
- List some individual differences that affect learning.
- Describe the effect of various encoding activities on learning.
- Describe three general principles of learning.

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Introduction

What do you do when studying for an exam? Do you read your class notes and textbook (hopefully not for the very first time)? Do you try to find a quiet place without distraction? Do you use flash cards to test your knowledge? The choices you make reveal your theory of learning, but there is no reason for you to limit yourself to your own intuitions. There is a vast and vibrant science of learning, in which researchers from psychology, education, and neuroscience study basic principles of learning and memory.

When you study for a test, you incorporate your past knowledge into learning this new knowledge. That is, depending on your previous experiences, you will "learn" the material in different ways. [Image: UBC Learning Commons, https://goo.gl/eT0jvd, CC BY 2.0, https://goo.gl/BRvSA7]

In fact, learning is a much broader domain than you might think. Consider: Is listening to music a form of learning? More often, it seems listening to music is a way of avoiding learning. But we know that your brain's response to auditory information changes with your experience with that information, a form of learning called auditory **perceptual learning** (Polley, Steinberg, & Merzenich, 2006). Each time we listen to a song, we hear it differently because of our experience. When we exhibit changes in behavior without having intended to learn something, that is called **implicit learning** (Seger, 1994), and when we exhibit changes in our behavior that reveal the influence of past experience even though we are not attempting to use that experience, that is called **implicit memory** (Richardson-Klavehn & Bjork, 1988).

Other well-studied forms of learning include the types of learning that are general across species. We can't ask a slug to learn a poem or a lemur to learn to bat left-handed, but we can assess learning in other ways. For example, we can look for a change in our responses to things when we are repeatedly stimulated. If you live in a house with a grandfather clock, you know that what was once an annoying and intrusive sound is now probably barely audible to you. Similarly, poking an earthworm again and again is likely to lead to a reduction in its retraction from your touch. These phenomena are forms of **nonassociative learning**, in which single repeated exposure leads to a change in behavior (Pinsker, Kupfermann, Castelluci, & Kandel, 1970). When our response lessens with exposure, it is called **habituation**, and when it increases (like it might with a particularly annoying laugh), it is called **sensitization**. Animals can also learn about relationships between things, such as when an alley cat learns that the sound of janitors working in a restaurant precedes the dumping of delicious new garbage (an example of stimulus-stimulus learning called **classical conditioning**), or when a dog learns to roll over to get a treat (a form of stimulus-response learning called **operant conditioning**). These forms of learning will be covered in the module on Conditioning and Learning (http://noba.to/ajxhcqdr).

Here, we'll review some of the conditions that affect learning, with an eye toward the type of explicit learning we do when trying to learn something. Jenkins (1979) classified experiments on learning and memory into four groups of factors (renamed here): learners, encoding activities, materials, and retrieval. In this module, we'll focus on the first two categories; the module on Memory (http://noba.to/bdc4uger) will consider other factors more generally.

Learners

People bring numerous individual differences with them into memory experiments, and many of these variables affect learning. In the classroom, motivation matters (Pintrich, 2003), though experimental attempts to induce motivation with money yield only modest benefits (Heyer & O'Kelly, 1949). Learners are, however, quite able to allocate more effort to learning prioritized over unimportant materials (Castel, Benjamin, Craik, & Watkins, 2002).

In addition, the organization and planning skills that a learner exhibits matter a lot (Garavalia & Gredler, 2002), suggesting that the efficiency with which one organizes self-guided learning is an important component of learning. We will return to this topic soon.

One well-studied and important variable is **working memory** capacity. Working memory describes the form of memory we use to hold onto information temporarily. Working memory is used, for example, to keep track of where we are in the course of a complicated math problem, and what the relevant outcomes of prior steps in that problem are. Higher scores on working memory measures are predictive of better reasoning skills (Kyllonen & Christal, 1990), reading comprehension (Daneman & Carpenter, 1980), and even better control of attention (Kane, Conway, Hambrick, & Engle, 2008).

Anxiety also affects the quality of learning. For example, people with math anxiety have a smaller capacity for remembering math-related information in working memory, such as the results of carrying a digit in arithmetic (Ashcraft & Kirk, 2001). Having students write about their specific anxiety seems to reduce the worry associated with tests and increases performance on math tests (Ramirez & Beilock, 2011).

Research attests that we can hold between 5 and 9 individual pieces of information in our working memory at once. This is partly why in the 1950s Bell Labs developed a 7-digit phone number system. [Image: Diamondmagna, https://goo.gl/xeUxfw, CC BY-SA 3.0, https://goo.gl/eLCn2O]

One good place to end this discussion is to consider the role of expertise. Though there probably is a finite capacity on our ability to store information (Landauer, 1986), in practice, this concept is misleading. In fact, because the usual bottleneck to remembering something is our ability to *access* information, not our space to *store* it, having more knowledge or expertise actually enhances our ability to learn new information. A classic example can be seen in comparing a chess master with a chess novice on their ability to learn and remember the positions of pieces on a chessboard (Chase & Simon, 1973). In that experiment, the master remembered the location of many more pieces than the novice, even after only a very short glance. Maybe chess masters are just smarter than the average chess beginner, and have better memory? No: The advantage the expert exhibited only was apparent when the pieces were arranged in a plausible format for an ongoing chess game; when the pieces were placed randomly, both groups did equivalently poorly. Expertise allowed the master to **chunk** (Simon, 1974) multiple pieces into a smaller number of pieces of information—but only when that information was structured in such a way so as to allow the application of that expertise.

Encoding Activities

What we do when we're learning is very important. We've all had the experience of reading something and suddenly coming to the realization that we don't remember a single thing, even the sentence that we just read. *How* we go about **encoding** information determines a lot about how much we remember.

You might think that the most important thing is to *try* to learn. Interestingly, this is not true, at least not completely. Trying to learn a list of words, as compared to just evaluating each word for its part of speech (i.e., noun, verb, adjective) does help you *recall* the words—that is, it helps you remember and write down more of the words later. But it actually impairs your ability to *recognize* the words—to judge on a later list which words are the ones that you studied (Eagle & Leiter, 1964). So this is a case in which **incidental learning**—that is, learning without the intention to learn—is better than **intentional learning**.

Such examples are not particularly rare and are not limited to recognition. Nairne, Pandeirada, and Thompson (2008) showed, for example, that survival processing—thinking about and rating each word in a list for its relevance in a survival scenario—led to much higher recall than intentional learning (and also higher, in fact, than other encoding activities that are also known to lead to high levels of recall). Clearly, merely intending to learn something is not enough. *How* a learner actively processes the material plays a large role; for example, reading words and evaluating their meaning leads to better learning than reading them and evaluating the way that the words look or sound (Craik & Lockhart, 1972). These results suggest that individual differences in motivation will not have a large effect on learning unless learners also have accurate ideas about how to effectively learn material when they care to do so.

So, do learners know how to effectively encode material? People allowed to freely allocate their time to study a list of words do remember those words better than a group that doesn't have control over their own study time, though the advantage is relatively small and is limited to the subset of learners who choose to spend more time on the more difficult material (Tullis & Benjamin, 2011).

In addition, learners who have an opportunity to review materials that they select for restudy often learn more than another group that is asked to restudy the materials that they *didn't* select for restudy (Kornell & Metcalfe, 2006). However, this advantage also appears to be relatively modest (Kimball, Smith, & Muntean, 2012) and wasn't apparent in a group of older learners (Tullis & Benjamin, 2012). Taken together, all of the evidence seems to support the claim that self-control of learning can be effective, but only when learners have good ideas about what an effective learning strategy is.

Motivation to learn doesn't make much of a difference unless learners use effective strategies for encoding the information they want to retain. Although they're not flashy, methods like spaced practice, interleaving, and frequent testing are among the most effective ways to apply your efforts. [Image: Cali4beach, https://goo.gl/twjIVg, CC BY 2.0, https://goo.gl/BRvSA7]

One factor that appears to have a big effect and that learners do not always appear to understand is the effect of scheduling repetitions of study. If you are studying for a final exam next week and plan to spend a total of five hours, what is the best way to distribute your study? The evidence is clear that *spacing* one's repetitions apart in time is superior than *massing* them all together (Baddeley & Longman, 1978; Bahrick, Bahrick, Bahrick, & Bahrick, 1993; Melton, 1967). Increasing the spacing between consecutive presentations appears to benefit learning yet further (Landauer & Bjork, 1978).

A similar advantage is evident for the practice of interleaving multiple skills to be learned: For example, baseball batters improved more when they faced a mix of different types of pitches than when they faced the same pitches blocked by type (Hall, Domingues, & Cavazos, 1994).

Students also showed better performance on a test when different types of mathematics problems were interleaved rather than blocked during learning (Taylor & Rohrer, 2010).

One final factor that merits discussion is the role of testing. Educators and students often think about testing as a way of assessing knowledge, and this is indeed an important use of tests. But tests themselves affect memory, because retrieval is one of the most powerful ways of enhancing learning (Roediger & Butler, 2013). Self-testing is an underutilized and potent means of making learning more durable.

General Principles of Learning

We've only begun to scratch the surface here of the many variables that affect the quality and content of learning (Mullin, Herrmann, & Searleman, 1993). But even within this brief examination of the differences between people and the activities they engage in can we see some basic principles of the learning process.

The value of effective metacognition

To be able to guide our own learning effectively, we must be able to evaluate the progress of our learning accurately and choose activities that enhance learning efficiently. It is of little use to study for a long time if a student cannot discern between what material she has or has not mastered, and if additional study activities move her no closer to mastery. **Metacognition** describes the knowledge and skills people have in monitoring and controlling their own learning and memory. We can work to acquire better metacognition by paying attention to our successes and failures in estimating what we do and don't know, and by using testing often to monitor our progress.

Transfer-appropriate processing

Sometimes, it doesn't make sense to talk about whether a particular encoding activity is good or bad for learning. Rather, we can talk about whether that activity is good for learning *as revealed by a particular test*. For example, although reading words for meaning leads to better performance on a test of recall or recognition than paying attention to the pronunciation of the word, it leads to *worse* performance on a test that taps knowledge of that pronunciation, such as whether a previously studied word rhymes with another word (Morris, Bransford, & Franks, 1977). The principle of **transfer-appropriate processing** states that memory is "better" when the test taps the same type of knowledge as the original encoding activity. When thinking about how to learn material, we should always be thinking about the situations in which we are likely to need access to that material. An emergency responder who needs access to learned procedures under conditions of great stress should learn differently from a hobbyist learning to use a new digital camera.

The value of forgetting

In order to not forget things, we employ a variety of tricks (like scribbling a quick note on your hand). However, if we were unable to forget information, it would interfere with learning new or contradictory material. [Image: Andrea Maria Cannata, https://goo.gl/ylTbGG, CC BY-NC 2.0, https://goo.gl/qOP7mj]

Forgetting is sometimes seen as the enemy of learning, but, in fact, forgetting is a highly desirable part of the learning process. The main bottleneck we face in using our knowledge is being able to access it. We have all had the experience of retrieval failure—that is, not being able to remember a piece of information that we know we have, and that we can access easily once the right set of cues is provided. Because access is difficult, it is important to jettison information that is not needed —that is, to forget it. Without forgetting, our minds would become cluttered with out-of-date or irrelevant information. And, just imagine how complicated life would be if we were unable to forget the names of past acquaintances, teachers, or romantic partners.

But the value of forgetting is even greater than that. There is lots of evidence that *some* forgetting is a prerequisite for *more* learning. For example, the previously discussed benefits of distributing practice opportunities may arise in part because of the greater forgetting that takes places between those spaced learning events. It is for this reason that some encoding activities that are difficult and lead to the appearance of slow learning actually lead to superior learning in the long run (Bjork, 2011). When we opt for learning activities that enhance learning quickly, we must be aware that these are not always the same techniques that lead to durable, long-term learning.

Conclusion

To wrap things up, let's think back to the questions we began the module with. What might you now do differently when preparing for an exam? Hopefully, you will think about testing yourself frequently, developing an accurate sense of what you do and do not know, how you are likely to use the knowledge, and using the scheduling of tasks to your advantage. If you are learning a new skill or new material, using the scientific study of learning as a basis for the study and practice decisions you make is a good bet.

Outside Resources

Video: The First 20 hours – How to Learn Anything – Watch a video by Josh Kaufman about how we can get really good at almost anything with 20 hours of efficient practice.

https://www.youtube.com/watch?v=5MgBikgcWnY

Video: The Learning Scientists – Terrific YouTube Channel with videos covering such important topics as interleaving, spaced repetition, and retrieval practice. https://www.youtube.com/channel/UCjbAmxL6GZXiaoXuNE7cIYg

Video: What we learn before we're born – In this video, science writer Annie Murphy Paul answers the question "When does learning begin?" She covers through new research that shows how much we learn in the womb – from the lilt of our native language to our soon- to-be-favorite foods. https://www.ted.com/talks/annie_murphy_paul_what_we_learn_before_we_re_born

Web: Neuroscience News – This is a science website dedicated to neuroscience research, with this page addressing fascinating new memory research. http://neurosciencenews.com/neuroscience-terms/memory-research/

Web: The Learning Scientists – A website created by three psychologists who wanted to make scientific research on learning more accessible to students, teachers, and other educators.

http://www.learningscientists.org/

Discussion Questions

1. How would you best design a computer program to help someone learn a new foreign language? Think about some of the principles of learning outlined in this module and how those principles could be instantiated in “rules” in a computer program.
2. Would you rather have a really good memory or really good metacognition? How might you train someone to develop better metacognition if he or she doesn’t have a very good memory, and what would be the consequences of that training?
3. In what kinds of situations not discussed here might you find a benefit of forgetting on learning?

Vocabulary

Chunk

The process of grouping information together using our knowledge.

Classical conditioning

Describes stimulus-stimulus associative learning.

Encoding

The pact of putting information into memory.

Habituation

Occurs when the response to a stimulus decreases with exposure.

Implicit learning

Occurs when we acquire information without intent that we cannot easily express.

Implicit memory

A type of long-term memory that does not require conscious thought to encode. It's the type of memory one makes without intent.

Incidental learning

Any type of learning that happens without the intention to learn.

Intentional learning

Any type of learning that happens when motivated by intention.

Metacognition

Describes the knowledge and skills people have in monitoring and controlling their own learning and memory.

Nonassociative learning

Occurs when a single repeated exposure leads to a change in behavior.

Operant conditioning

Describes stimulus-response associative learning.

Perceptual learning

Occurs when aspects of our perception changes as a function of experience.

Sensitization

Occurs when the response to a stimulus increases with exposure

Transfer-appropriate processing

A principle that states that memory performance is superior when a test taps the same cognitive processes as the original encoding activity.

Working memory

The form of memory we use to hold onto information temporarily, usually for the purposes of manipulation.

References

Ashcraft, M. H., & Kirk, E. P. (2001). The relationships among working memory, math anxiety, and performance. Journal of Experimental Psychology: General, 130, 224–237.

Baddeley, A. D., & Longman, D. J. A. (1978). The influence of length and frequency of training session on the rate of learning to type. Ergonomics, 21, 627–635.

Bahrick, H. P., Bahrick, L. E., Bahrick, A. S., & Bahrick, P. O. (1993). Maintenance of foreign language vocabulary and the spacing effect. Psychological Science, 4, 316–321.

Bjork, R. A. (2011). On the symbiosis of learning, remembering, and forgetting. In A. S. Benjamin (Ed.), Successful remembering and successful forgetting: A Festschrift in honor of Robert A. Bjork (pp. 1–22). London, UK: Psychology Press.

Castel, A. D., Benjamin, A. S., Craik, F. I. M., & Watkins, M. J. (2002). The effects of aging on selectivity and control in short-term recall. Memory & Cognition, 30, 1078–1085.

Chase, W. G., & Simon, H. A. (1973). Perception in chess. Cognitive Psychology, 4, 55–81.

Craik, F. I. M., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. Journal of Verbal Learning and Verbal Behavior, 11, 671–684.

Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. Journal of Verbal Learning and Verbal Behavior, 19, 450–466.

Eagle, M., & Leiter, E. (1964). Recall and recognition in intentional and incidental learning. Journal of Experimental Psychology, 68, 58–63.

Garavalia, L. S., & Gredler, M. E. (2002). Prior achievement, aptitude, and use of learning strategies as predictors of college student achievement. College Student Journal, 36, 616– 626.

Hall, K. G., Domingues, D. A., & Cavazos, R. (1994). Contextual interference effects with skilled baseball players. Perceptual and Motor Skills, 78, 835–841.

Heyer, A. W., Jr., & O'Kelly, L. I. (1949). Studies in motivation and retention: II. Retention of nonsense syllables learned under different degrees of motivation. Journal of Psychology: Interdisciplinary and Applied, 27, 143–152.

Jenkins, J. J. (1979). Four points to remember: A tetrahedral model of memory experiments. In L. S. Cermak & F. I. M. Craik (Eds.), Levels of processing and human memory (pp. 429–446). Hillsdale, NJ: Erlbaum.

Kane, M. J., Conway, A. R. A., Hambrick, D. Z., & Engle, R. W. (2008). Variation in working memory capacity as variation in executive attention and control. In A. R. A. Conway, C. Jarrold, M. J. Kane, A. Miyake, & J. N. Towse (Eds.), Variation in Working Memory (pp. 22–48). New York, NY: Oxford University Press.

Kimball, D. R., Smith, T. A., & Muntean, W. J. (2012). Does delaying judgments of learning really improve the efficacy of study decisions? Not so much. Journal of Experimental Psychology: Learning, Memory, and Cognition, 38, 923–954.

Kornell, N., & Metcalfe, J. (2006). Study efficacy and the region of proximal learning framework. Journal of Experimental Psychology: Learning, Memory, & Cognition, 32, 609–622.

Kyllonen, P. C., & Christal, R. E. (1990). Reasoning ability is (little more than) working memory capacity. Intelligence, 14, 389–433.

Landauer, T. K. (1986). How much do people remember? Some estimates of the quantity of learned information in long-term memory. Cognitive Science, 10, 477–493.

Landauer, T. K., & Bjork, R. A. (1978). Optimum rehearsal patterns and name learning. In M. M. Gruneberg, P. E. Morris, & R. N. Sykes (Eds.), Practical aspects of memory (pp. 625–632). London: Academic Press.

Melton, A. W. (1967). Repetition and retrieval from memory. Science, 158, 532.

Morris, C. D., Bransford, J. D., & Franks, J. J. (1977). Levels of processing versus transfer appropriate processing. Journal of Verbal Learning and Verbal Behavior, 16, 519–533.

Mullin, P. A., Herrmann, D. J., & Searleman, A. (1993). Forgotten variables in memory theory and research. Memory, 1, 43–64.

Nairne, J. S., Pandeirada, J. N. S., & Thompson, S. R. (2008). Adaptive memory: the comparative value of survival processing. Psychological Science, 19, 176–180.

Pinsker, H., Kupfermann, I., Castelluci, V., & Kandel, E. (1970). Habituation and dishabituation of the gill-withdrawal reflex in Aplysia. Science, 167, 1740–1742.

Pintrich, P. R. (2003). A motivational science perspective on the role of student motivation in learning and teaching contexts. Journal of Educational Psychology, 95, 667–686.

Polley, D. B., Steinberg, E. E., & Merzenich, M. M. (2006). Perceptual learning directs auditory cortical map reorganization through top-down influences. The Journal of Neuroscience, 26, 4970–4982.

Ramirez, G., & Beilock, S. L. (2011). Writing about testing worries boosts exam performance in the classroom. Science, 331, 211–213.

Richardson-Klavehn, A. & Bjork, R.A. (1988). Measures of memory. Annual Review of Psychology, 39, 475–543.

Roediger, H. L., & Butler, A.C. (2013). Retrieval practice (testing) effect. In H. L. Pashler (Ed.), Encyclopedia of the mind. Los Angeles, CA: Sage Publishing Co.

Seger, C. A. (1994). Implicit learning. Psychological Bulletin, 115, 163–196.

Simon, H. A. (1974). How big is a chunk? Science, 4124, 482–488.

Taylor, K., & Rohrer, D. (2010). The effects of interleaved practice. Applied Cognitive Psychology, 24, 837–848.

Tullis, J. G., & Benjamin, A. S. (2012). Consequences of restudy choices in younger and older learners. Psychonomic Bulletin & Review, 19, 743–749.

Tullis, J. G., & Benjamin, A. S. (2011). On the effectiveness of self-paced learning. Journal of Memory and Language, 64, 109–118.

MEMORY (ENCODING, STORAGE, RETRIEVAL)

"Memory" is a single term that reflects a number of different abilities: holding information briefly while working with it (working memory), remembering episodes of one's life (episodic memory), and our general knowledge of facts of the world (semantic memory), among other types. Remembering episodes involves three processes: encoding information (learning it, by perceiving it and relating it to past knowledge), storing it (maintaining it over time), and then retrieving it (accessing the information when needed). Failures can occur at any stage, leading to forgetting or to having false memories. The key to improving one's memory is to improve processes of encoding and to use techniques that guarantee effective retrieval. Good encoding techniques include relating new information to what one already knows, forming mental images, and creating associations among information that needs to be remembered. The key to good retrieval is developing effective cues that will lead the rememberer back to the encoded information. Classic mnemonic systems, known since the time of the ancient Greeks and still used by some today, can greatly improve one's memory abilities.

Learning Objectives

Define and note differences between the following forms of memory: working memory, episodic memory, semantic memory, collective memory.

Describe the three stages in the process of learning and remembering.

Describe strategies that can be used to enhance the original learning or encoding of information.

Describe strategies that can improve the process of retrieval.

Describe why the classic mnemonic device, the method of loci, works so well.

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- Define and note differences between the following forms of memory: working memory, episodic memory, semantic memory, collective memory.
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- Describe strategies that can improve the process of retrieval.
- Describe why the classic mnemonic device, the method of loci, works so well.

Introduction

In 2013, Simon Reinhard 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!

In some ways memory is like file drawers where you store mental information. Memory is also a series of processes: how does that information get filed to begin with and how does it get retrieved when needed? [Image: M Cruz, https://goo.gl/DhOMgp, CC BY-SA 4.0, https://goo.gl/SWjq94]

When most of us witness a performance like that of Simon Reinhard, we think one of two things: First, maybe he's cheating somehow. (No, he is not.) Second, Simon must have abilities more advanced than the rest of humankind. After all, psychologists established many years ago that the normal memory span for adults is about 7 digits, with some of us able to recall a few more and others a few less (Miller, 1956). That is why the first phone numbers were limited to 7 digits—psychologists determined that many errors occurred (costing the phone company money) when the number was increased to even 8 digits. But in normal testing, no one gets 50 digits correct in a row, much less 240. So, does

Simon Reinhard simply have a photographic memory? He does not. Instead, Simon has taught himself simple strategies for remembering that have greatly increased his capacity for remembering virtually any type of material—digits, words, faces and names, poetry, historical dates, and so on. Twelve years earlier, before he started training his memory abilities, he had a digit span of 7, just like most of us. Simon has been training his abilities for about 10 years as of this writing, and has risen to be in the top two of "memory athletes." In 2012, he came in second place in the World Memory Championships (composed of 11 tasks), held in London. He currently ranks second in the world, behind another German competitor, Johannes Mallow. In this module, we reveal what psychologists and others have learned about memory, and we also explain the general principles by which you can improve your own memory for factual material.

Varieties of Memory

For most of us, remembering digits relies on *short-term memory*, or *working memory*—the ability to hold information in our minds for a brief time and work with it (e.g., multiplying 24 x 17 without using paper would rely on working memory). Another type of memory is **episodic memory**—the ability to remember the episodes of our lives. If you were given the task of recalling everything you did 2 days ago, that would be a test of episodic memory; you would be required to mentally travel through the day in your mind and note the main events. **Semantic memory** is our storehouse of more-or-less permanent knowledge, such as the meanings of words in a language (e.g., the meaning of "parasol") and the huge collection of facts about the world (e.g., there are 196 countries in the world, and 206 bones in your body). *Collective memory* refers to the kind of memory that people in a group share (whether family, community, schoolmates, or citizens of a state or a country). For example, residents of small towns often strongly identify with those towns, remembering the local customs and historical events in a unique way. That is, the community's collective memory passes stories and recollections between neighbors and to future generations, forming a memory system unto itself.

To be a good chess player you have to learn to increase working memory so you can plan ahead for several offensive moves while simultaneously anticipating – through use of memory – how the other player could counter each of your planned moves. [Image: karpidis, https://goo.gl/EhzMKM, CC BY-SA 2.0, https://goo.gl/jSSrcO]

Psychologists continue to debate the classification of types of memory, as well as which types rely on others (Tulving, 2007), but for this module we will focus on episodic memory. Episodic memory is usually what people think of when they hear the word "memory." For example, when people say that an older relative is "losing her memory" due to Alzheimer's disease, the type of memory-loss they are referring to is the inability to recall events, or episodic memory. (Semantic memory is actually preserved in early-stage Alzheimer's disease.) Although remembering specific events that have happened over the course of one's entire life (e.g., your experiences in sixth grade) can be referred to as **autobiographical memory**, we will focus primarily on the episodic memories of more recent events.

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

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.

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).

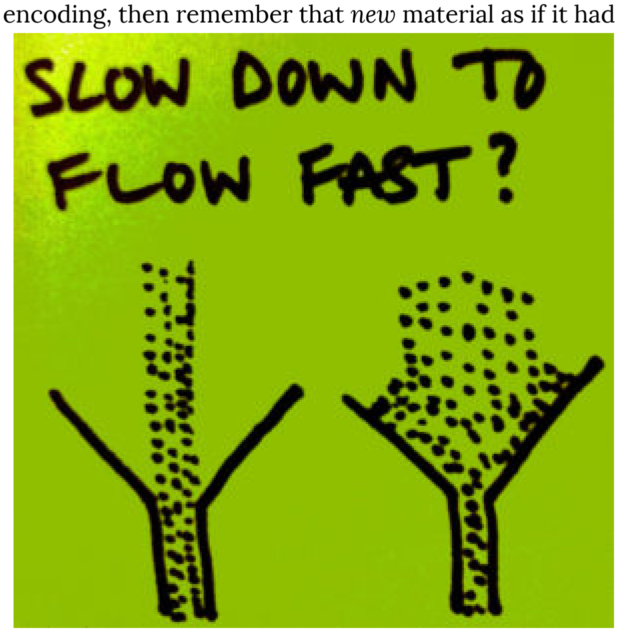
A giraffe in the context of a zoo or its natural habitat may register as nothing more than ordinary, but put it in another setting – in the middle of a campus or a busy city – and its level of distinctiveness increases dramatically. Distinctiveness is a key attribute to remembering events. [Image: Colin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

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).



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 (Craik & Lockhart, 1972), 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 (Bower & Reitman, 1972). 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 (Hunt & McDaniel, 1993). 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 (Deese, 1959; Roediger & McDermott, 1995). 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 (Stadler, Roediger, & McDermott, 1999). 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 (1977) 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 (1977) gave her participants: "The karate champion hit the cinder block." After hearing or seeing this sentence, participants who were given a memory test 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 (see also McDermott & Chan, 2006).

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.

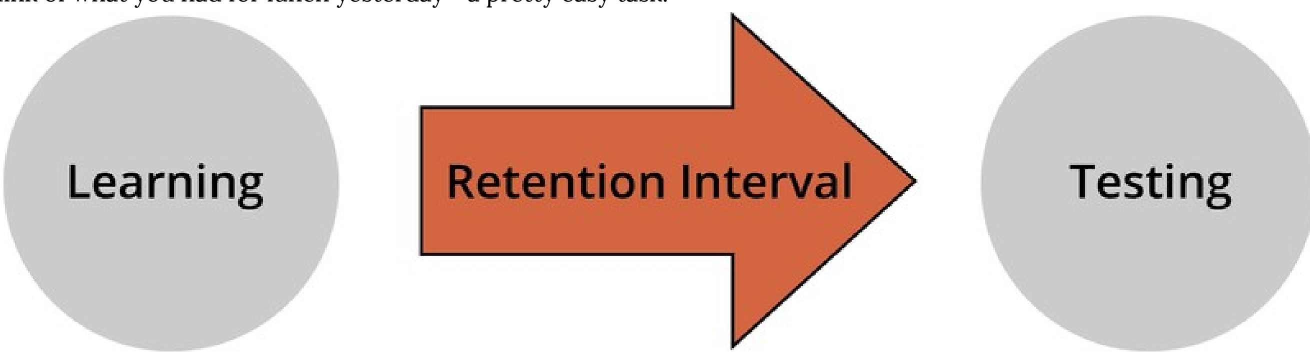
Storage

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.

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,

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).

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.

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 (see Loftus [2005] for a review). Of course, if correct information is given during the retention interval, the witness's memory will usually be improved.

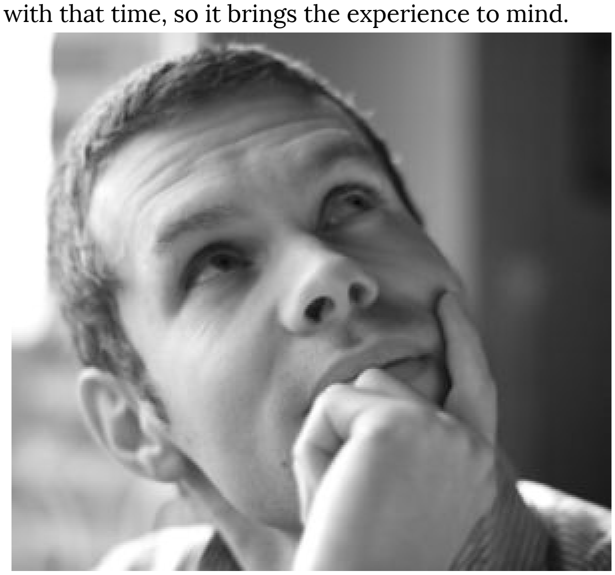
Although interference may arise between the occurrence of an event and the attempt to recall it, *the effect itself is always expressed when we retrieve memories*, the topic to which we turn next.

Retrieval

Endel Tulving argued that "the key process in memory is retrieval" (1991, p. 91). Why should retrieval be given more prominence than encoding or storage? For one thing, if information were encoded and stored but could not be retrieved, it would be useless. As discussed previously in this module, we encode and store thousands of events—conversations, sights and sounds—every day, creating memory traces. However, we later access only a tiny portion of what we've taken in. Most of our memories will never be used—in the sense of being brought back to mind, consciously. This fact seems so obvious that we rarely reflect on it. All those events that happened to you in the fourth grade that seemed so important then? Now, many years later, you would struggle to remember even a few. You may wonder if the traces of those memories still exist in some latent form. Unfortunately, with currently available methods, it is impossible to know.

Psychologists distinguish information that is available in memory from that which is accessible (Tulving & Pearlstone, 1966). *Available* information is the information that is stored in memory —but precisely how much and what types are stored cannot be known. That is, all we can know is what information we can retrieve—*accessible* information. The assumption is that accessible information represents only a tiny slice of the information available in our brains. Most of us have had the experience of trying to remember some fact or event, giving up, and then—all of a sudden!—it comes to us at a later time, even after we've stopped trying to remember it. Similarly, we all know the experience of failing to recall a fact, but then, if we are given several choices (as in a multiple-choice test), we are easily able to recognize it.

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.



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.

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).

To sum up how memory cues function: for a retrieval cue to be effective, a match must exist between the cue and the desired target memory; furthermore, to produce the best retrieval, the cue-target relationship should be distinctive. Next, we will see how the encoding specificity principle can work in practice.

Psychologists measure memory performance by using production tests (involving recall) or recognition tests (involving the selection of correct from incorrect information, e.g., a multiple- choice test). For example, with our list of 100 words, one group of people might be asked to recall the list in any order (a free recall test), while a different group might be asked to circle the 100 studied words out of a mix with another 100, unstudied words (a recognition test). In this situation, the recognition test would likely produce better performance from participants than the recall test.

We usually think of recognition tests as being quite easy, because the cue for retrieval is a copy of the actual event that was presented for study. After all, what could be a better cue than the exact target (memory) the person is trying to access? In most cases, this line of reasoning is true; nevertheless, recognition tests do not provide perfect indexes of what is stored in memory. That is, you can fail to recognize a target staring you right in the face, yet be able to recall it later with a different set of cues (Watkins & Tulving, 1975). For example, suppose you had the task of recognizing the surnames of famous authors. At first, you might think that being given the actual last name would always be the best cue. However, research has shown this not necessarily to be true (Muter, 1984). When given names such as Tolstoy, Shaw, Shakespeare, and Lee, subjects might well say that Tolstoy and Shakespeare are famous authors, whereas Shaw and Lee are not. But, when given a cued recall test using first names, people often recall items (produce them) that they had failed to recognize before. For example, in this instance, a cue like *George Bernard* often leads to a recall of "Shaw," even though people initially failed to recognize *Shaw* as a famous author's name. Yet, when given the cue "William," people may not come up with Shakespeare, because William is a common name that matches many people (the cue overload principle at work). This strange fact—that recall can sometimes lead to better performance than recognition—can be explained by the encoding specificity principle. As a cue, *George Bernard* matches the way the famous writer is stored in memory better than does his surname, Shaw, does (even though it is the target). Further, the match is quite distinctive with *George Bernard*, but the cue *William is much more overloaded* (*Prince William*, *William Yeats*, *William* Faulkner, will.i.am).

The phenomenon we have been describing is called the *recognition failure of recallable words*, which highlights the point that a cue will be most effective depending on how the information has been encoded (Tulving & Thomson, 1973). The point is, the cues that work best to evoke retrieval are those that recreate the event or name to be remembered, whereas sometimes even the target itself, such as *Shaw* in the above example, is not the best cue. Which cue will be most effective depends on how the information has been encoded.

Whenever we think about our past, we engage in the act of retrieval. We usually think that retrieval is an objective act because we tend to imagine that retrieving a memory is like pulling a book from a shelf, and after we are done with it, we return the book to the shelf just as it was. However, research shows this assumption to be false; far from being a static repository of data, the memory is constantly changing. In fact, every time we retrieve a memory, it is altered. For example, the act of retrieval itself (of a fact, concept, or event) makes the retrieved memory much more likely to be retrieved again, a phenomenon called the *testing effect* or the *retrieval practice effect* (Pyc & Rawson, 2009; Roediger & Karpicke, 2006). However, retrieving some information can actually cause us to forget other information related to it, a phenomenon called *retrieval-induced forgetting* (Anderson, Bjork, & Bjork, 1994). Thus the act of retrieval can be a double-edged sword—strengthening the memory just retrieved (usually by a large amount) but harming related information (though this effect is often relatively small).

As discussed earlier, retrieval of distant memories is reconstructive. We weave the concrete bits and pieces of events in with assumptions and preferences to form a coherent story (Bartlett, 1932). For example, if during your 10th birthday, your dog got to your cake before you did, you would likely tell that story for years afterward. Say, then, in later years you misremember where the dog actually found the cake, but repeat that error over and over during subsequent retellings of the story. Over time, that inaccuracy would become a basic fact of the event in your mind. Just as retrieval practice (repetition) enhances accurate memories, so will it strengthen errors or false memories (McDermott, 2006). Sometimes memories can even be manufactured just from hearing a vivid story. Consider the following episode, recounted by Jean Piaget, the famous developmental psychologist, from his childhood:

> One of my first memories would date, if it were true, from my second year. I can still see, most clearly, the following scene, in which I believed until I was about 15. I was sitting in my pram . . . when a man tried to kidnap me. I was held in by the strap fastened round me while my nurse bravely tried to stand between me and the thief. She received various scratches, and I can still vaguely see those on her face. . . . When I was about 15, my parents received a letter from my former nurse saying that she had been converted to the Salvation Army. She wanted to confess her past faults, and in particular to return the watch she had been given as a reward on this occasion. She had made up the whole story, faking the scratches. I therefore must have heard, as a child, this story, which my parents believed, and projected it into the past in the form of a visual memory. . . . Many real memories are doubtless of the same order. (Norman & Schacter, 1997, pp. 187–188)

Piaget's vivid account represents a case of a pure reconstructive memory. He heard the tale told repeatedly, and doubtless told it (and thought about it) himself. The repeated telling cemented the events as though they had really happened, just as we are all open to the possibility of having "many real memories … of the same order." The fact that one can remember precise details (the location, the scratches) does not necessarily indicate that the memory is true, a point that has been confirmed in laboratory studies, too (e.g., Norman & Schacter, 1997).

Putting It All Together: Improving Your Memory

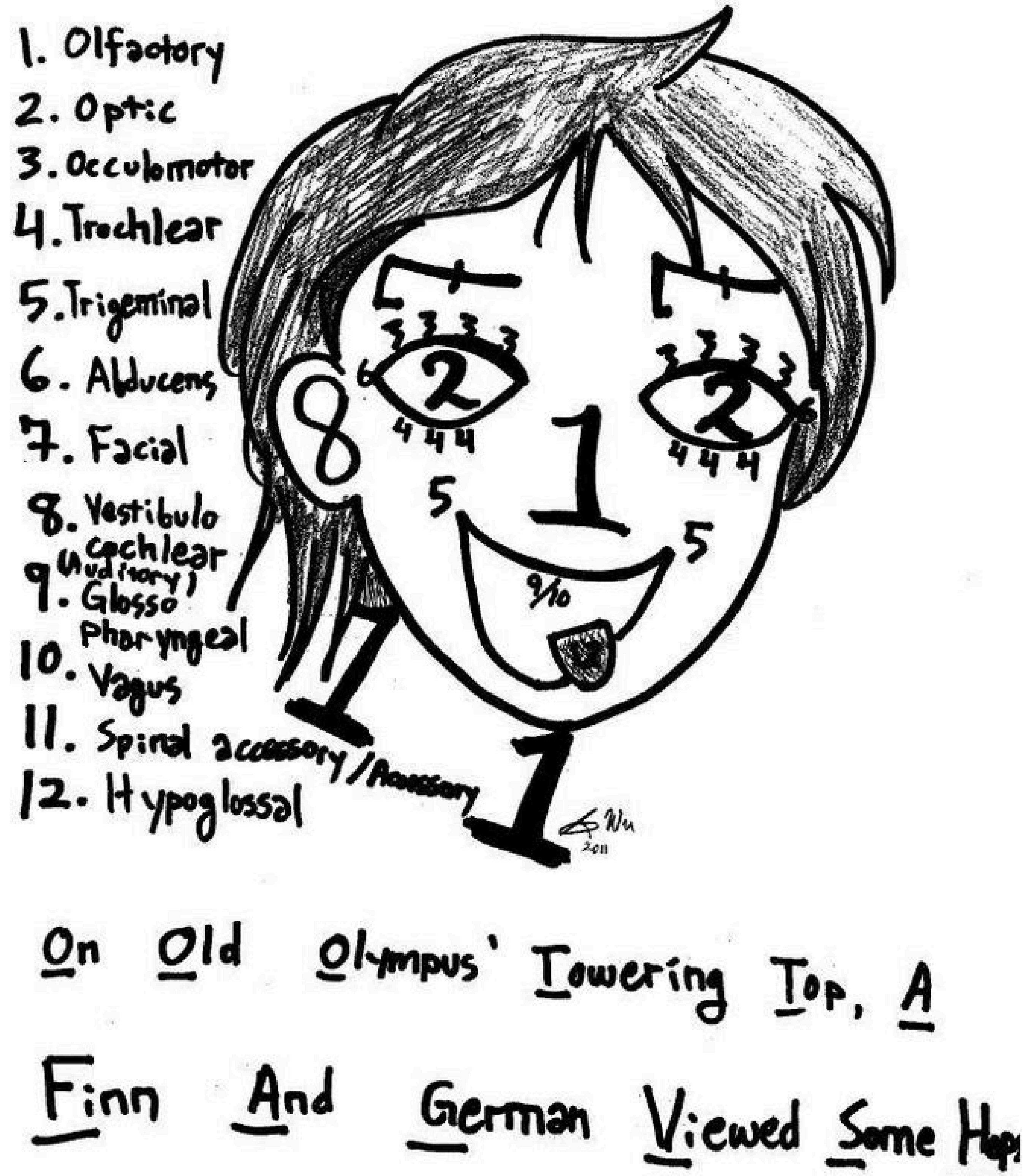
A central theme of this module has been the importance of the encoding and retrieval processes, and their interaction. To recap: to improve learning and memory, we need to encode information in conjunction with excellent cues that will bring back the remembered events when we need them. But how do we do this? Keep in mind the two critical principles we have discussed: to maximize retrieval, we should construct *meaningful* cues that remind us of the original experience, and those cues should be *distinctive* and *not associated with other memories*. These two conditions are critical in maximizing cue effectiveness (Nairne, 2002).

So, how can these principles be adapted for use in many situations? Let's go back to how we started the module, with Simon Reinhard's ability to memorize huge numbers of digits. Although it was not obvious, he applied these same general memory principles, but in a more deliberate way. In fact, all **mnemonic devices**, or memory aids/tricks, rely on these fundamental principles. 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).

is a gun. 11 is penny-one, hot dog bun.
is a shoe. 12 is penny-two, airplane glue.
is a tree. 13 is penny-three, bumble bee.
is a door. 14 is penny-four, grocery store.
is knives. 15 is penny-five, big beehive.
is sticks. 16 is penny-six, magic tricks.
is oven. 17 is penny-seven, go to heaven.
is plate. 18 is penny-eight, golden gate.
is wine. 19 is penny-nine, ball of twine.
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.



Example of a mneumonic system created by a student to study cranial nerves. [Image: Kelidimari, https://goo.gl/kiA1kP, CC BY-SA 3.0, https://goo.gl/SCkRfm]

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.

Many books exist on how to improve memory using mnemonic devices, but all involve forming distinctive encoding operations and then having an infallible set of memory cues. We should add that to develop and use these memory systems beyond the basic peg system outlined above takes a great amount of time and concentration. The World Memory Championships are held every year and the records keep improving. However, for most common purposes, just keep in mind that to remember well you need to encode information in a distinctive way and to have good cues for retrieval. You can adapt a system that will meet most any purpose.

Outside Resources

Book: Brown,P.C.,Roediger,H.L.&McDaniel,M.A.(2014).Makeitstick:Thescienceof successful learning. Cambridge, MA: Harvard University Press.

https://www.amazon.com/Make-Stick-Science-Successful-Learning/dp/0674729013

Student 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.

https://www.youtube.com/watch?v=iMPIWkFtd88

Student Video 2: Kara McCord's – Flashbulb Memories. This is a student-made video illustrating this phenomenon of autobiographical memory. It was one of the winning entries in the 2014 Noba Student Video Award.

https://www.youtube.com/watch?v=mPhW9bUI4F0

Student Video 3: Ang Rui Xia & Ong Jun Hao's – The Misinformation Effect. Another student-made video exploring the misinformation effect. Also an award winner from 2014.

https://www.youtube.com/watch?v=gsn9iKmOJLQ

Video: Simon Reinhard breaking the world record in speedcards.

http://vimeo.com/12516465

Web: Retrieval Practice, a website with research, resources, and tips for both educators and learners around the memory-strengthening skill of retrieval practice.

http://www.retrievalpractice.org/

Discussion Questions

1. Mnemonists like Simon Reinhard develop mental "journeys," which enable them to use the method of loci. Develop your own journey, which contains 20 places, in order, that you know well. One example might be: the front walkway to your parents' apartment; their doorbell; the couch in their living room; etc. Be sure to use a set of places that you know well and that have a natural order to them (e.g., the walkway comes before the doorbell). Now you are more than halfway toward being able to memorize a set of 20 nouns, in order, rather quickly. As an optional second step, have a friend make a list of 20 such nouns and read them to you, slowly (e.g., one every 5 seconds). Use the method to attempt to remember the 20 items.
2. Recall a recent argument or misunderstanding you have had about memory (e.g., a debate over whether your girlfriend/boyfriend had agreed to something). In light of what you have just learned about memory, how do you think about it? Is it possible that the disagreement can be understood by one of you making a pragmatic inference?
3. Think about what you've learned in this module and about how you study for tests. On the basis of what you have learned, is there something you want to try that might help your study habits?

Vocabulary

Autobiographical memory
Memory for the events of one's life.
Consolidation
The process occurring after encoding that is believed to stabilize memory traces.
Cue overload principle
The principle stating that the more memories that are associated to a particular retrieval cue, the less effective the cue will be in prompting retrieval of any one memory.
Distinctiveness
The principle that unusual events (in a context of similar events) will be recalled and recognized better than uniform (nondistinctive) events.
Encoding
The initial experience of perceiving and learning events.
Encoding specificity principle
The hypothesis that a retrieval cue will be effective to the extent that information encoded from the cue overlaps or matches information in the engram or memory trace.
Engrams
A term indicating the change in the nervous system representing an event; also, memory trace.
Episodic memory
Memory for events in a particular time and place.
Flashbulb memory
Vivid personal memories of receiving the news of some momentous (and usually emotional) event.
Memory traces
A term indicating the change in the nervous system representing an event.
Misinformation effect
When erroneous information occurring after an event is remembered as having been part of the original event.
Mnemonic devices
A strategy for remembering large amounts of information, usually involving imaging events occurring on a journey or with some other set of memorized cues.
Recoding
The ubiquitous process during learning of taking information in one form and converting it to another form, usually one more easily remembered.
Retrieval
The process of accessing stored information.
Retroactive interference The phenomenon whereby events that occur after some particular event of interest will usually cause forgetting of the original event.
Semantic memory
The more or less permanent store of knowledge that people have.
Storage
The stage in the learning/memory process that bridges encoding and retrieval; the persistence of memory over time.

References

Anderson, M. C., Bjork, R., & Bjork, E. L. (1994). Remembering can cause forgetting: Retrieval dynamics in long-term memory. *Journal of Experimental Psychology-Learning Memory and Cognition*, 20, 1063–1087.

Bartlett, F. C. (1932). *Remembering: A study in experimental and social psychology*. Cambridge: Cambridge University Press.

Bower, G. H., & Reitman, J. S. (1972). Mnemonic elaboration in multilist learning. *Journal of Verbal Learning and Verbal Behavior*, 11, 478–485.

Brewer, W. F. (1977). Memory for the pragmatic implications of sentences. *Memory & Cognition*, 5(6), 673–678.

Brown, R., & Kulik, J. (1977). Flashbulb memories. *Cognition*, 5, 73–99.

Chan, J.C.K. & McDermott, K.B. (2006). Remembering pragmatic inferences. *Applied Cognitive Psychology*, 20, 633-639.

Craik, F. I. M., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior*, 11, 671–684.

Deese, J. (1959). On the prediction of occurrence of particular verbal intrusions in immediate recall. *Journal of Experimental Psychology*, 58, 17.

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

Hunt, R. (2003). Two contributions of distinctive processing to accurate memory. *Journal of Memory and Language*, 48, 811–825.

Hunt, R., & McDaniel, M. A. (1993). The enigma of organization and distinctiveness. *Journal of Memory and Language*, 32, 421-445.

Loftus, E. F. (2005). Planting misinformation in the human mind: A 30-year investigation of the malleability of memory. *Learning & Memory*, 12, 361–366.

McDermott, K. B. (2006). Paradoxical effects of testing: Repeated retrieval attempts enhance the likelihood of later accurate and false recall. *Memory & Cognition*, 34, 261–267.

McGeoch, J. A. (1932). Forgetting and the law of disuse. *Psychological Review*, 39(4), 352.

Melton, A. W. (1963). Implications of short-term memory for a general theory of memory. *Journal of Verbal Learning and Verbal Behavior*, 2, 1–21.

Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review*, 63, 81–97.

Muter, P. (1984). Recognition and recall of words with a single meaning. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 10, 198–202.

Nairne, J. S. (2002). The myth of the encoding-retrieval match. *Memory*, 10, 389–395.

Norman, K. A., & Schacter, D. L. (1997). False recognition in younger and older adults: Exploring the characteristics of illusory memories. *Memory & Cognition*, 25, 838–848.

Pyc, M. A., & Rawson, K. A. (2009). Testing the retrieval effort hypothesis: Does greater difficulty correctly recalling information lead to higher levels of memory? *Journal of Memory and Language*, 60, 437–447.

Roediger, H. L. (1980). The effectiveness of four mnemonics in ordering recall. *Journal of Experimental Psychology: Human Learning and Memory*, 6, 558.

Roediger, H. L., & Karpicke, J. D. (2006). Test-enhanced learning: Taking memory tests improves long-term retention. *Psychological Science*, 17, 249–255.

Roediger, H. L., & McDermott, K. B. (1995). Creating false memories: Remembering words not presented in lists. *Journal of Experimental Psychology-Learning Memory and Cognition*, 21, 803–814.

Stadler, M. A., Roediger, H. L., & McDermott, K. B. (1999). Norms for word lists that create false memories. *Memory & Cognition*, 27, 494–500.

Talarico, J. M., & Rubin, D. C. (2003). Confidence, not consistency, characterizes flashbulb memories. *Psychological Science*, 14, 455–461.

Tulving, E. (2007). Are there 256 different kinds of memory? In J.S. Nairne (Ed.), *The foundations of remembering: Essays in honor of Henry L. Roediger, III* (pp. 39–52). New York: Psychology Press.

Tulving, E. (1991). Interview. *Journal of Cognitive Neuroscience*, 3, 89–94

Tulving, E., & Bower, G. H. (1975). The logic of memory representations. *The psychology of learning and motivation*, 8, 265-301.

Tulving, E., & Pearlstone, Z. (1966). Availability versus accessibility of information in memory for words. *Journal of Verbal Learning and Verbal Behavior*, 5, 381–391.

Tulving, E., & Thomson, D. M. (1973). Encoding specificity and retrieval processes in episodic memory. *Psychological Review*, 80, 352–373.

Tulving, E., & Thomson, D. M. (1973). Encoding specificity and retrieval processes in episodic memory. *Psychological Review*, 80, 352–373.

Watkins, M. J. (1975). Inhibition in recall with extralist "cues." *Journal of Verbal Learning and Verbal Behavior*, 14, 294–303.

Watkins, M. J., & Tulving, E. (1975). Episodic memory: When recognition fails. *Journal of Experimental Psychology: General*, 104, 5–29.

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EYEWITNESS TESTIMONY AND MEMORY BIASES

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

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.

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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 bepresumed. 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.

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]

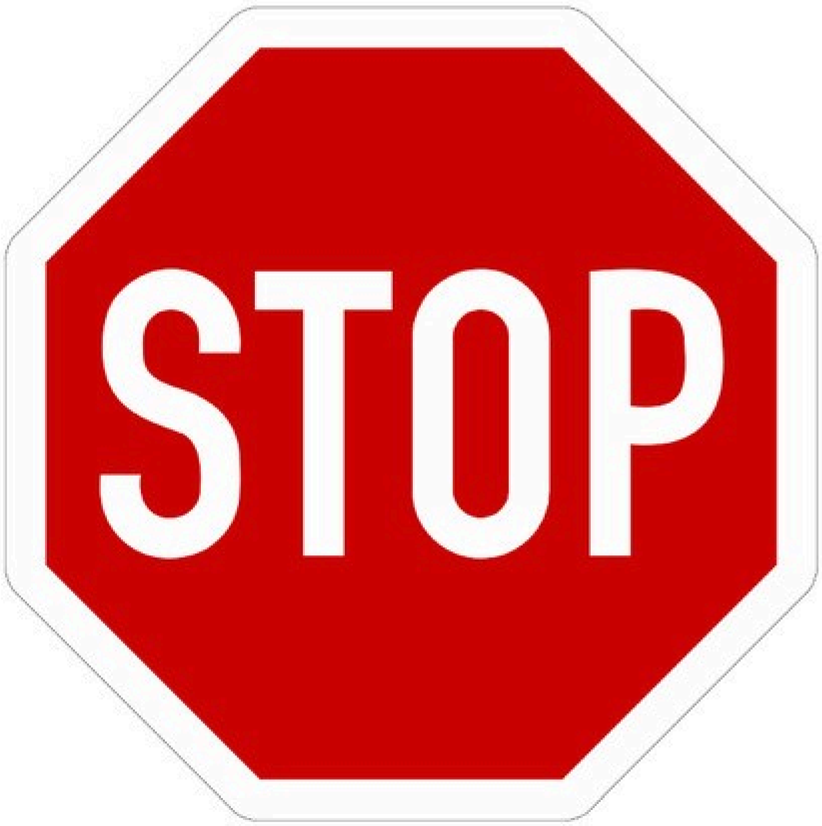
Why Is Eyewitness Testimony an Important Area of Psychological Research?

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 (**http://www.innocenceproject.org/**).

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



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.

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.

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.

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.

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).

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]

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 researchers photoshopped 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).

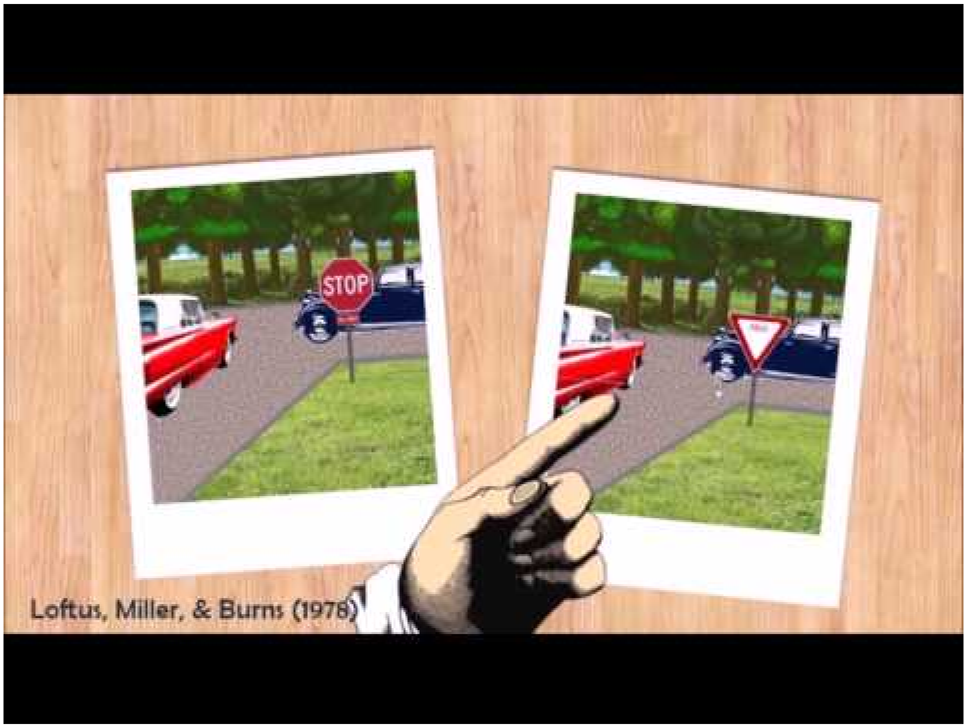
Conclusion

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.



A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.library.upei.ca/upeiintropsychology/?p=745

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.

A YouTube element has been excluded from this version of the text. You can view it online here: [*https://pressbooks.library.upei.ca/upeiintropsychology/?p=745*](https://pressbooks.library.upei.ca/upeiintropsychology/?p=745)

Vocabulary

False memories
Memory for an event that never actually occurred, implanted by experimental manipulation or other means.

Foils
Any member of a lineup (whether live or photograph) other than the suspect.

Misinformation effect
A memory error caused by exposure to incorrect information between the original event (e. g., a crime) and later memory test (e.g., an interview, lineup, or day in court).

Mock witnesses
A research subject who plays the part of a witness in a study.

Photo spreads
A selection of normally small photographs of faces given to a witness for the purpose of identifying a perpetrator.

Schema (plural: schemata)
A memory template, created through repeated exposure to a particular class of objects or events.

References

Alba, J. W., & Hasher, L. (1983). Is memory schematic? Psychological Bulletin, 93, 203–231. Berkowitz, S. R., Laney, C., Morris, E. K., Garry, M., & Loftus, E. F. (2008). Pluto behaving badly: False beliefs and their consequences. American Journal of Psychology, 121, 643–660

Bernstein, D. M., & Loftus, E. F. (2009b). The consequences of false memories for food preferences and choices. Perspectives on Psychological Science, 4, 135–139.

Bernstein, D. M., & Loftus, E. F., (2009a). How to tell if a particular memory is true or false. Perspectives on Psychological Science, 4, 370–374.

Bernstein, D. M., Laney, C., Morris, E. K., & Loftus, E. F. (2005). False memories about food can lead to food avoidance. Social Cognition, 23, 11–34.

Bornstein, B. H., Deffenbacher, K. A., Penrod, S. D., & McGorty, E. K. (2012). Effects of exposure time and cognitive operations on facial identification accuracy: A meta-analysis of two variables associated with initial memory strength. Psychology, Crime, & Law, 18, 473–490.

Braun, K. A., Ellis, R., & Loftus, E. F. (2002). Make my memory: How advertising can change our memories of the past. Psychology and Marketing, 19, 1–23.

Brewer, W. F., & Treyens, J. C. (1981). Role of schemata in memory for places. Cognitive Psychology, 13, 207–230.

Brigham, J. C., Bennett, L. B., Meissner, C. A., & Mitchell, T. L. (2007). The influence of race on eyewitness memory. In R. C. L. Lindsay, D. F. Ross, J. D. Read, & M. P. Toglia (Eds.), Handbook of eyewitness psychology, Vol. 2: Memory for people (pp. 257–281). Mahwah, NJ: Lawrence Erlbaum.

Brown, A. S. (1991). A review of tip of the tongue experience. Psychological Bulletin, 109, 79–91.

Deffenbacher, K. A., Bornstein, B. H., Penrod, S. D., & McGorty, E. K. (2004). A meta-analytic review of the effects of high stress on eyewitness memory. Law and Human Behavior, 28, 687–706.

Garrett, B. L. (2011). Convicting the innocent. Cambridge, MA: Harvard University Press. Heaps, C., & Nash, M. (1999). Individual differences in imagination inflation. Psychonomic Bulletin and Review, 6, 313–138.

Hyman, I. E., Jr., Husband, T. H., & Billings, F. J. (1995). False memories of childhood experiences. Applied Cognitive Psychology, 9, 181–197.

Laney, C., & Loftus, E. F. (2008). Emotional content of true and false memories. Memory, 16, 500–516.

Lindsay, D. S., Hagen, L., Read, J. D., Wade, K. A., & Garry, M. (2004). True photographs and false memories. Psychological Science, 15, 149–154.

Loftus, E. F., & Pickrell, J. E. (1995). The formation of false memories. Psychiatric Annals, 25, 720–725.

Loftus, E. F., Ketcham, K. (1994). The myth of repressed memory. New York, NY: St. Martin's Press.

Mazzoni, G. A. L., Loftus, E. F., Seitz, A., & Lynn, S.J. (1999). Changing beliefs and memories through dream interpretation. Applied Cognitive Psychology, 13, 125–144.

Porter, S., Yuille, J. C., & Lehman, D. R. (1999). The nature of real, implanted, and fabricated memories for emotional childhood events: Implications for the recovered memory debate. Law and Human Behavior, 23, 517–537.

Seamon, J. G., Philbin, M. M., & Harrison, L. G. (2006). Do you remember proposing marriage to the Pepsi machine? False recollections from a campus walk. Psychonomic Bulletin& Review, 13, 752–7596.

Steblay, N. M., & Loftus, E. F. (2012). Eyewitness memory and the legal system. In E. Shafir (Ed.), The behavioural foundations of public policy (pp. 145–162). Princeton, NJ: Princeton University Press.

Technical Working Group for Eyewitness Evidence. (1999). Eyewitness evidence: A trainer\'s manual for law enforcement. Research Report. Washington, DC: U.S. Department of Justice.

Wade, K. A., Garry, M., Read, J. D., & Lindsay, S. A. (2002). A picture is worth a thousand lies. Psychonomic Bulletin and Review, 9, 597–603.

Wells, G. L., & Olson, E. A. (2003). Eyewitness testimony. Annual Review of Psychology, 54, 277– 295.
Wells, G. L., Small, M., Penrod, S., Malpass, R. S., Fulero, S. M., & Brimacombe, C. A. E. (1998). Eyewitness identification procedures: Recommendations for lineups and photospreads. Law and Human Behavior, 22, 603–647

Discussion Questions

1. Imagine that you are a juror in a murder case where an eyewitness testifies. In what ways might your knowledge of memory errors affect your use of this testimony?
2. How true to life do you think television shows such as CSI or Law & Order are in their portrayals of eyewitnesses?
3. Many jurisdictions in the United States use “show-ups,” where an eyewitness is brought to a suspect (who may be standing on the street or in handcuffs in the back of a police car) and asked, “Is this the perpetrator?” Is this a good or bad idea, from a psychological perspective? Why?

FORGETTING AND AMNESIA

This module explores the causes of everyday forgetting and considers pathological forgetting in the context of amnesia. Forgetting is viewed as an adaptive process that allows us to be efficient in terms of the information we retain.

Learning Objectives

- Identify five reasons we forget and give examples of each.
- Describe how forgetting can be viewed as an adaptive process.
- Explain the difference between anterograde and retrograde amnesia.

Chapter Authors: Nicole Dudukovic & Brice Kuhl

Introduction

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?

Causes of Forgetting

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]

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.

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

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).

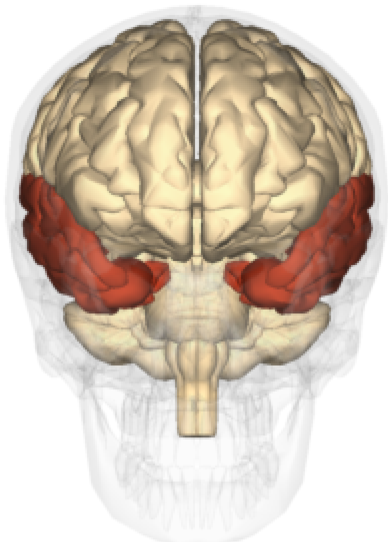
Adaptive Forgetting

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.

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]

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).

Amnesia



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.

Conclusion

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.

Outside Resources

Web: Brain Case Study: Patient HM
https://bigpictureeducation.com/brain-case-study-patient-hm
Web: Self-experiment, Penny demo
http://www.indiana.edu/~p1013447/dictionary/penny.htm
Web: The Man Who Couldn't Remember
http://www.pbs.org/wgbh/nova/body/corkin-hm-memory.html

Discussion Questions

1. Is forgetting good or bad? Do you agree with the authors that forgetting is an adaptive process? Why or why not?
2. Can we ever prove that something is forgotten? Why or why not?
3. Which of the five reasons for forgetting do you think explains the majority of incidences of forgetting? Why?
4. How is real-life amnesia different than amnesia that is portrayed on TV and in film?

Vocabulary

Anterograde amnesia
Inability to form new memories for facts and events after the onset of amnesia.
Consolidation
Process by which a memory trace is stabilized and transformed into a more durable form.
Decay
The fading of memories with the passage of time.
Declarative memory
Conscious memories for facts and events.
Dissociative amnesia
Loss of autobiographical memories from a period in the past in the absence of brain injury or disease.
Encoding
Process by which information gets into memory.
Interference
Other memories get in the way of retrieving a desired memory
Medial temporal lobes
Inner region of the temporal lobes that includes the hippocampus.
Retrieval
Process by which information is accessed from memory and utilized.
Retrograde amnesia
Inability to retrieve memories for facts and events acquired before the onset of amnesia.
Temporally graded retrograde amnesia
Inability to retrieve memories from just prior to the onset of amnesia with intact memory for more remote events.

References

Anderson, J. R., & Milson, R. (1989). Human memory: An adaptive perspective. *Psychological Review*, 96, 703–719.

Anderson, M. C., & Green, C. (2001). Suppressing unwanted memories by executive control. Nature, 410, 366–369.

Bahrick, H. P., Bahrick, P. O., & Wittinger, R. P. (1975). Fifty years of memory for names and faces: A cross-sectional approach. Journal of Experimental Psychology: General, 104, 54–75.

Bjork, R. A. (1989). Retrieval inhibition as an adaptive mechanism in human memory. In H. L. Roediger, III, & F. I. M. Craik (Eds.), Varieties of Memory and Consciousness (pp. 309– 330). Hillsdale, NJ: Erlbaum.

Corkin, S. (2002). What's new with the amnesic patient H. M.? *Nature Reviews Neuroscience*, 3, 153–160.

Craik, F. I. M., Govoni, R., Naveh-Benjamin, M., & Anderson, N. D. (1996). The effects of divided attention on encoding and retrieval processes in human memory. *Journal of Experimental Psychology: General*, 125, 159–180.

Ebbinghaus, H. (1913). Memory. A contribution to experimental psychology. New York: Teachers College/Columbia University (Engl. ed.). (Original work published in 1885.)

Hertel, P. T., & Calcaterra, G. (2005). Intentional forgetting benefits from thought substitution. Psychonomic Bulletin & Review, 12, 484–489.

Hodges, J. R. (1994). Retrograde amnesia. In A. Baddeley, B. A. Wilson, & F. Watts (Eds.), Handbook of Memory Disorders (pp. 81–107). New York: Wiley.

Kihlstrom, J. F. (2005). Dissociative disorders. Annual Review of Clinical Psychology, 1, 227– 253.

Kopelman, M. (2000). Focal retrograde amnesia and the attribution of causality: An exceptionally critical review. Cognitive Neuropsychology, 17, 585–621.

Levy, B. J., & Anderson, M. C. (2002). Inhibitory processes and the control of memory retrieval. Trends in Cognitive Sciences, 6, 299–305.

Luria, A. R. (1968). The mind of a mnemonist: A little book about a vast memory (L. Solataroff, Trans.). New York: Basic Books.

McGaugh, J. L. (2000). Memory: A century of consolidation. Science, 287, 248–251. McGeoch, J. A. (1932). Forgetting and the law of disuse. Psychological Reviews, 39, 352– 370.

Mensink, G., & Raaijmakers, J. G. (1988). A model for interference and forgetting. *Psychological Review*, 95, 434–455.

Nickerson, R. S., & Adams, M. J. (1979). Long-term memory for a common object. *Cognitive Psychology*, 11, 287–307.

Reed, J. M. & Squire, L. R. (1998). Retrograde amnesia for facts and events: Findings from four new cases. Journal of Neuroscience, 18, 3943–3954.

Schacter, D. L. (1999). The seven sins of memory: Insights from psychology and cognitive neuroscience. American Psychologist, 54, 182–203.

Scoville, W. B. & Milner, B. (1957). Loss of recent memory after bilateral hippocampal lesions. Journal of Neurology, Neurosurgery, & Psychiatry, 20, 11–21.

Squire, L. R., & Alvarez, P. (1995). Retrograde amnesia and memory consolidation: A neurobiological perspective. Current Opinions in Neurobiology, 5, 169–177.

Tulving, E., & Pearlstone, Z. (1966). Availability versus accessibility of information in memory for words. Journal of Verbal Learning and Verbal Behavior, 5, 381–391.

Wixted, J. T. (2004). The psychology and neuroscience of forgetting. *Annual Reviews of Psychology*, 55, 235–269.

CONDITIONING AND LEARNING

Mark E. Bouton

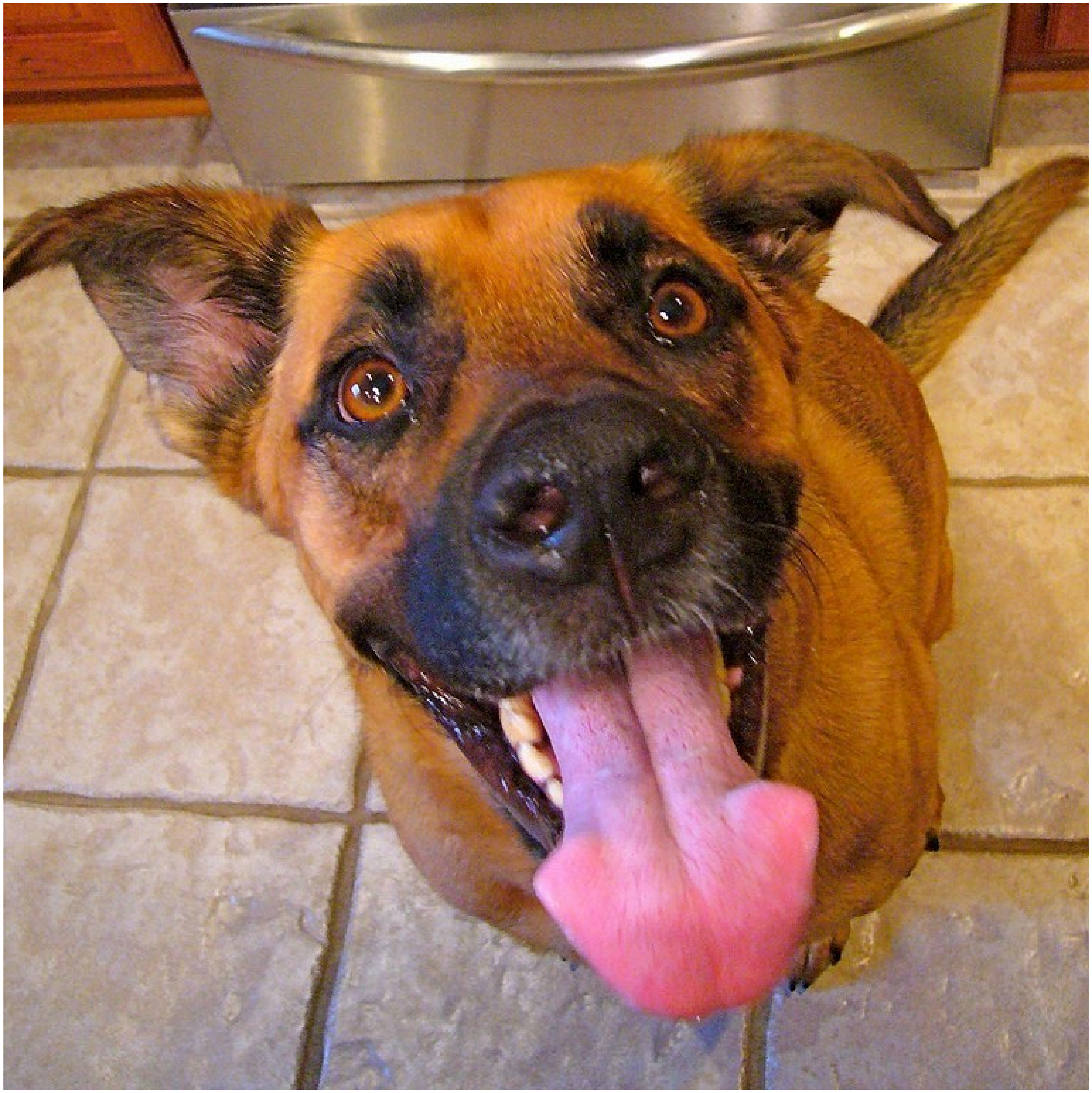
Basic principles of learning are always operating and always influencing human behavior. This module discusses the two most fundamental forms of learning – classical (Pavlovian) and instrumental (operant) conditioning. Through them, we respectively learn to associate 1) stimuli in the environment, or 2) our own behaviors, with significant events, such as rewards and punishments. The two types of learning have been intensively studied because they have powerful effects on behavior, and because they provide methods that allow scientists to analyze learning processes rigorously. This module describes some of the most important things you need to know about classical and instrumental conditioning, and it illustrates some of the many ways they help us understand normal and disordered behavior in humans. The module concludes by introducing the concept of observational learning, which is a form of learning that is largely distinct from classical and operant conditioning.

Learning Objectives

Distinguish between classical (Pavlovian) conditioning and instrumental (operant) conditioning.
Understand some important facts about each that tell us how they work.
Understand how they work separately and together to influence human behavior in the world outside the laboratory.
Students will be able to list the four aspects of observational learning according to Social Learning Theory.

Two Types of Conditioning

Although Ivan Pavlov won a Nobel Prize for studying digestion, he is much more famous for something else: working with a dog, a bell, and a bowl of saliva. Many people are familiar with the classic study of "Pavlov's dog," but rarely do they understand the significance of its discovery. In fact, Pavlov's work helps explain why some people get anxious just looking at a crowded bus, why the sound of a morning alarm is so hated, and even why we swear off certain foods we've only tried once. Classical (or Pavlovian) conditioning is one of the fundamental ways we learn about the world around us. But it is far more than just a theory of learning; it is also arguably a theory of identity. For, once you understand classical conditioning, you'll recognize that your favorite music, clothes, even political candidate, might all be a result of the same process that makes a dog drool at the sound of bell.



The Pavlov in All of Us: Does your dog learn to beg for food because you reinforce her by feeding her from the table? [Image: David Mease, https://goo.gl/R9cQV7, CC BY-NC 2.0, https://goo.gl/FIlc2e]

Around the turn of the 20th century, scientists who were interested in understanding the behavior of animals and humans began to appreciate the importance of two very basic forms of learning. One, which was first studied by the Russian physiologist Ivan Pavlov, is known as **classical**, or **Pavlovian** **conditioning**. In his famous experiment, Pavlov rang a bell and then gave a dog some food. After repeating this pairing multiple times, the dog eventually treated the bell as a signal for food, and began salivating in anticipation of the treat. This kind of result has been reproduced in the lab using a wide range of signals (e.g., tones, light, tastes, settings) paired with many different events besides food (e.g., drugs, shocks, illness; see below).

We now believe that this same learning process is engaged, for example, when humans associate a drug they've taken with the environment in which they've taken it; when they associate a stimulus (e.g., a symbol for vacation, like a big beach towel) with an emotional event (like a burst of happiness); and when they associate the flavor of a food with getting food poisoning. Although classical conditioning may seem "old" or "too simple" a theory, it is still widely studied today for at least two reasons: First, it is a straightforward test of associative learning that can be used to study other, more complex behaviors. Second, because classical conditioning is always occurring in our lives, its effects on behavior have important implications for understanding normal and disordered behavior in humans.

In a general way, classical conditioning occurs whenever neutral stimuli are associated with psychologically significant events. With food poisoning, for example, although having fish for dinner may not normally be something to be concerned about (i.e., a "neutral stimuli"), if it causes you to get sick, you will now likely associate that neutral stimuli (the fish) with the psychologically significant event of getting sick. These paired events are often described using terms that can be applied to any situation.

The dog food in Pavlov's experiment is called the **unconditioned stimulus (US)** because it elicits an **unconditioned response (UR)**. That is, without any kind of "training" or "teaching," the stimulus produces a natural or instinctual reaction. In Pavlov's case, the food (US) automatically makes the dog drool (UR). Other examples of unconditioned stimuli include loud noises (US) that startle us (UR), or a hot shower (US) that produces pleasure (UR).

On the other hand, a conditioned stimulus produces a conditioned response. A **conditioned** **stimulus (CS)** is a signal that has no importance to the organism until it is paired with something that does have importance. For example, in Pavlov's experiment, the bell is the conditioned stimulus. Before the dog has learned to associate the bell (CS) with the presence of food (US), hearing the bell means nothing to the dog. However, after multiple pairings of the bell with the presentation of food, the dog starts to drool at the sound of the bell. This drooling in response to the bell is the **conditioned response (CR)**. Although it can be confusing, the conditioned response is almost always the same as the unconditioned response. However, it is called the conditioned response because it is conditional on (or, depends on) being paired with the conditioned stimulus (e.g., the bell). To help make this clearer, consider becoming really hungry when you see the logo for a fast food restaurant. There's a good chance you'll start salivating. Although it is the actual eating of the food (US) that normally produces the salivation (UR), simply seeing the restaurant's logo (CS) can trigger the same reaction (CR).

Another example you are probably very familiar with involves your alarm clock. If you're like most people, waking up early usually makes you unhappy. In this case, waking up early (US) produces a natural sensation of grumpiness (UR). Rather than waking up early on your own, though, you likely have an alarm clock that plays a tone to wake you. Before setting your alarm to that particular tone, let's imagine you had neutral feelings about it (i.e., the tone had no prior meaning for you). However, now that you use it to wake up every morning, you psychologically "pair" that tone (CS) with your feelings of grumpiness in the morning (UR).

After enough pairings, this tone (CS) will automatically produce your natural response of grumpiness (CR). Thus, this linkage between the unconditioned stimulus (US; waking up early) and the conditioned stimulus (CS; the tone) is so strong that the unconditioned response (UR; being grumpy) will become a conditioned response (CR; e.g., hearing the tone at any point in the day—whether waking up or walking down the street—will make you grumpy). Modern studies of classical conditioning use a very wide range of CSs and USs and measure a wide range of conditioned responses.

Although classical conditioning is a powerful explanation for how we learn many different things, there is a second form of conditioning that also helps explain how we learn. First studied by Edward Thorndike, and later extended by B. F. Skinner, this second type of conditioning is known as **instrumental** or **operant conditioning**. Operant conditioning occurs when a *behavior* (as opposed to a stimulus) is associated with the occurrence of a significant event. In the best-known example, a rat in a laboratory learns to press a lever in a cage (called a "Skinner box") to receive food. Because the rat has no "natural" association between pressing a lever and getting food, the rat has to learn this connection. At first, the rat may simply explore its cage, climbing on top of things, burrowing under things, in search of food. Eventually while poking around its cage, the rat accidentally presses the lever, and a food pellet drops in. This voluntary behavior is called an **operant** behavior, because it "operates" on the environment (i.e., it is an action that the animal itself makes).

Receiving a reward can condition you toward certain behaviors. For example, when you were a child, your mother may have offered you this deal: "Don't make a fuss when we're in the supermarket and you'll get a treat on the way out." [Image: Oliver Hammond, https://goo.gl/xFKiZL, CC BY-NC-SA 2.0, https://goo.gl/Toc0ZF]

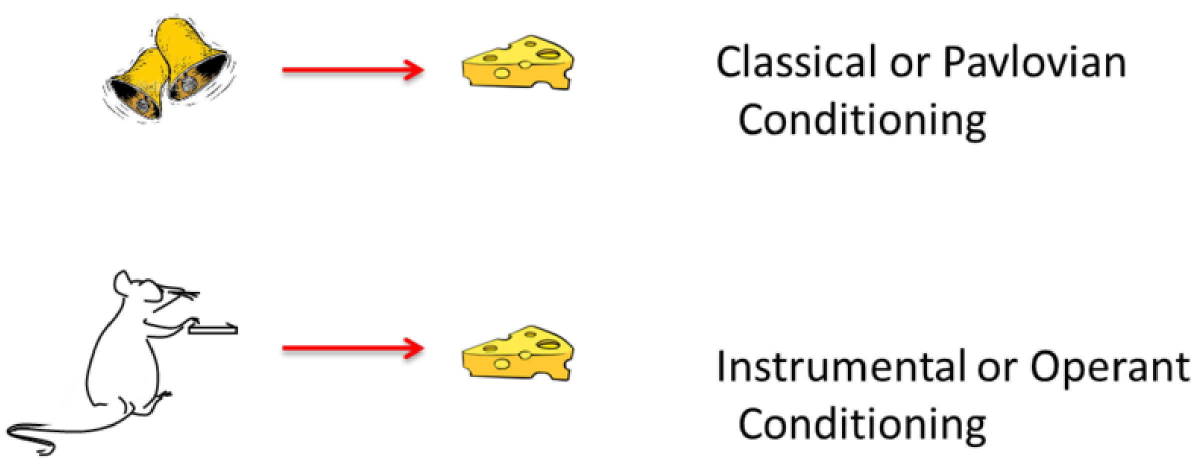
Now, once the rat recognizes that it receives a piece of food every time it presses the lever, the behavior of lever-pressing becomes reinforced. That is, the food pellets serve as **reinforcer**s because they strengthen the rat's desire to engage with the environment in this particular manner. In a parallel example, imagine that you're playing a street-racing video game. As you drive through one city course multiple times, you try a number of different streets to get to the finish line. On one of these trials, you discover a shortcut that dramatically improves your overall time. You have learned this new path through operant conditioning.

That is, by engaging with your environment (operant responses), you performed a sequence of behaviors that that was positively reinforced (i.e., you found the shortest distance to the finish line). And now that you've learned how to drive this course, you will perform that same sequence of driving behaviors (just as the rat presses on the lever) to receive your reward of a faster finish.

Operant conditioning research studies how the effects of a behavior influence the probability that it will occur again. For example, the effects of the rat's lever-pressing behavior (i.e., receiving a food pellet) influences the probability that it will keep pressing the lever. For, according to Thorndike's **law of effect**, when a behavior has a positive (satisfying) effect or consequence, it is likely to be repeated in the future. However, when a behavior has a negative (painful/ annoying) consequence, it is less likely to be repeated in the future. Effects that increase behaviors are referred to as reinforcers, and effects that decrease them are referred to as **punishers**.

An everyday example that helps to illustrate operant conditioning is striving for a good grade in class—which could be considered a reward for students (i.e., it produces a positive emotional response). In order to get that reward (similar to the rat learning to press the lever), the student needs to modify his/her behavior. For example, the student may learn that speaking up in class gets him/her participation points (a reinforcer), so the student speaks up repeatedly. However, the student also learns that s/he shouldn't speak up about just anything; talking about topics unrelated to school actually costs points. Therefore, through the student's freely chosen behaviors, s/he learns which behaviors are reinforced and which are punished.

An important distinction of operant conditioning is that it provides a method for studying how consequences influence "voluntary" behavior. The rat's decision to press the lever is voluntary, in the sense that the rat is free to make and repeat that response whenever it wants.



[Image courtesy of Bernard W. Balleine]

Classical conditioning, on the other hand, is just the opposite—depending instead on "involuntary" behavior (e.g., the dog doesn't choose to drool; it just does). So, whereas the rat must actively participate and perform some kind of behavior to attain its reward, the dog in Pavlov's experiment is a passive participant. One of the lessons of operant conditioning research, then, is that voluntary behavior is strongly influenced by its consequences.

The illustration on the left summarizes the basic elements of classical and instrumental conditioning. The two types of learning differ in many ways. However, modern thinkers often emphasize the fact that they differ—as illustrated here—in *what* is learned. In classical conditioning, the animal behaves as if it has learned to associate a *stimulus* with a significant event. In operant conditioning, the animal behaves as if it has learned to associate a *behavior* with a significant event. Another difference is that the response in the classical situation (e. g., salivation) is *elicited* by a stimulus that comes before it, whereas the response in the operant case is not elicited by any particular stimulus. Instead, operant responses are said to be *emitted*. The word “emitted” further conveys the idea that operant behaviors are essentially voluntary in nature.

Understanding classical and operant conditioning provides psychologists with many tools for understanding learning and behavior in the world outside the lab. This is in part because the two types of learning occur continuously throughout our lives. It has been said that “much like the laws of gravity, the laws of learning are always in effect” (Spreat & Spreat, 1982).

Useful Things to Know about Classical Conditioning

Classical Conditioning Has Many Effects on Behavior

A classical CS (e.g., the bell) does not merely elicit a simple, unitary reflex. Pavlov emphasized salivation because that was the only response he measured. But his bell almost certainly elicited a whole *system* of responses that functioned to get the organism ready for the upcoming US (food) (see Timberlake, 2001). For example, in addition to salivation, CSs (such as the bell) that signal that food is near also elicit the secretion of gastric acid, pancreatic enzymes, and insulin (which gets blood glucose into cells). All of these responses prepare the body for digestion. Additionally, the CS elicits approach behavior and a state of excitement. And presenting a CS for food can also cause animals whose stomachs are full to eat more food if it is available. In fact, food CSs are so prevalent in modern society, humans are likewise inclined to eat or feel hungry in response to cues associated with food, such as the sound of a bag of potato chips opening, the sight of a well-known logo (e.g., Coca-Cola), or the feel of the couch in front of the television.

Classical conditioning is also involved in other aspects of eating. Flavors associated with certain nutrients (such as sugar or fat) can become preferred without arousing any awareness of the pairing. For example, protein is a US that your body automatically craves more of once you start to consume it (UR): since proteins are highly concentrated in meat, the flavor of meat becomes a CS (or cue, that proteins are on the way), which perpetuates the cycle of craving for yet more meat (this automatic bodily reaction now a CR).

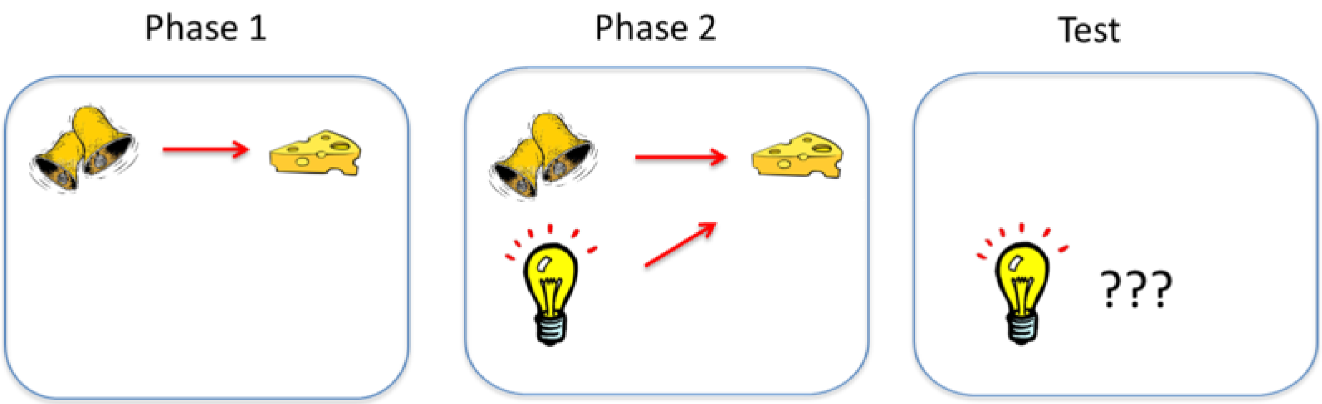
In a similar way, flavors associated with stomach pain or illness become avoided and *dis*liked. For example, a person who gets sick after drinking too much tequila may acquire a profound dislike of the taste and odor of tequila—a phenomenon called **taste aversion conditioning**. The fact that flavors are often associated with so many consequences of eating is important for animals (including rats and humans) that are frequently exposed to new foods. And it is clinically relevant. For example, drugs used in chemotherapy often make cancer patients sick. As a consequence, patients often acquire aversions to foods eaten just before treatment, or even aversions to such things as the waiting room of the chemotherapy clinic itself (see Bernstein, 1991; Scalera & Bavieri, 2009).

Classical conditioning occurs with a variety of significant events. If an experimenter sounds a tone just before applying a mild shock to a rat's feet, the tone will elicit fear or anxiety after one or two pairings. Similar **fear conditioning** plays a role in creating many anxiety disorders in humans, such as phobias and panic disorders, where people associate cues (such as closed spaces, or a shopping mall) with panic or other emotional trauma (see Mineka & Zinbarg, 2006). Here, rather than a physical response (like drooling), the CS triggers an emotion.

Another interesting effect of classical conditioning can occur when we ingest drugs. That is, when a drug is taken, it can be associated with the cues that are present at the same time (e. g., rooms, odors, drug paraphernalia). In this regard, if someone associates a particular smell with the sensation induced by the drug, whenever that person smells the same odor afterward, it may cue responses (physical and/or emotional) related to taking the drug itself. But drug cues have an even more interesting property: They elicit responses that often "compensate" for the upcoming effect of the drug (see Siegel, 1989). For example, morphine itself suppresses pain; however, if someone is used to taking morphine, a cue that signals the "drug is coming soon" can actually make the person more sensitive to pain. Because the person knows a pain suppressant will soon be administered, the body becomes more sensitive, anticipating that "the drug will soon take care of it." Remarkably, such **conditioned compensatory responses** in turn decrease the impact of the drug on the body—because the body has become more sensitive to pain.

This conditioned compensatory response has many implications. For instance, a drug user will be most "tolerant" to the drug in the presence of cues that have been associated with it (because such cues elicit compensatory responses). As a result, overdose is usually not due to an increase in dosage, but to taking the drug in a new place without the familiar cues— which would have otherwise allowed the user to tolerate the drug (see Siegel, Hinson, Krank, & McCully, 1982). Conditioned compensatory responses (which include heightened pain sensitivity and decreased body temperature, among others) might also cause discomfort, thus motivating the drug user to continue usage of the drug to reduce them. This is one of several ways classical conditioning might be a factor in drug addiction and dependence.

A final effect of classical cues is that they motivate ongoing operant behavior (see Balleine, 2005). For example, if a rat has learned via operant conditioning that pressing a lever will give it a drug, in the presence of cues that signal the "drug is coming soon" (like the sound of the lever squeaking), the rat will work harder to press the lever than if those cues weren't present (i.e., there is no squeaking lever sound). Similarly, in the presence of food-associated cues (e. g., smells), a rat (or an overeater) will work harder for food. And finally, even in the presence of negative cues (like something that signals fear), a rat, a human, or any other organism will work harder to avoid those situations that might lead to trauma. Classical CSs thus have many effects that can contribute to significant behavioral phenomena.



[Image courtesy of Bernard W. Balleine]

The Learning Process

As mentioned earlier, classical conditioning provides a method for studying basic learning processes. Somewhat counterintuitively, though, studies show that pairing a CS and a US together is not sufficient for an association to be learned between them. Consider an effect called **blocking** (see Kamin, 1969). In this effect, an animal first learns to associate one CS– call it stimulus A–with a US. In the illustration above, the sound of a bell (stimulus A) is paired with the presentation of food. Once this association is learned, in a second phase, a second stimulus—stimulus B—is presented alongside stimulus A, such that the two stimuli are paired with the US together. In the illustration, a light is added and turned on at the same time the bell is rung. However, because the animal has already learned the association between stimulus A (the bell) and the food, the animal doesn't learn an association between stimulus B (the light) and the food. That is, the conditioned response only occurs during the presentation of stimulus A, because the earlier conditioning of A "blocks" the conditioning of B when B is added to A. The reason? Stimulus A already predicts the US, so the US is not surprising when it occurs with Stimulus B.

Learning depends on such a surprise, or a discrepancy between what occurs on a conditioning trial and what is already predicted by cues that are present on the trial. To learn something through classical conditioning, there must first be some **prediction error**, or the chance that a conditioned stimulus won't lead to the expected outcome. With the example of the bell and the light, because the bell always leads to the reward of food, there's no "prediction error" that the addition of the light helps to correct. However, if the researcher suddenly requires that the bell and the light both occur in order to receive the food, the bell alone will produce a prediction error that the animal has to learn.

Blocking and other related effects indicate that the learning process tends to take in the most valid predictors of significant events and ignore the less useful ones. This is common in the real world. For example, imagine that your supermarket puts big star-shaped stickers on products that are on sale. Quickly, you learn that items with the big star-shaped stickers are cheaper. However, imagine you go into a similar supermarket that not only uses these stickers, but also uses bright orange price tags to denote a discount. Because of blocking (i.e., you already know that the star-shaped stickers indicate a discount), you don't have to learn the color system, too. The star-shaped stickers tell you everything you need to know (i.e. there's no prediction error for the discount), and thus the color system is irrelevant.

Classical conditioning is strongest if the CS and US are intense or salient. It is also best if the CS and US are relatively new and the organism hasn't been frequently exposed to them before. And it is especially strong if the organism's biology has prepared it to associate a particular CS and US. For example, rats and humans are naturally inclined to associate an illness with a flavor, rather than with a light or tone. Because foods are most commonly experienced by taste, if there is a particular food that makes us ill, associating the flavor (rather than the appearance—which may be similar to other foods) with the illness will more greatly ensure we avoid that food in the future, and thus avoid getting sick. This sorting tendency, which is set up by evolution, is called **preparedness**.

There are many factors that affect the strength of classical conditioning, and these have been the subject of much research and theory (see Rescorla & Wagner, 1972; Pearce & Bouton, 2001). Behavioral neuroscientists have also used classical conditioning to investigate many of the basic brain processes that are involved in learning (see Fanselow & Poulos, 2005; Thompson & Steinmetz, 2009).

Erasing Classical Learning

After conditioning, the response to the CS can be eliminated if the CS is presented repeatedly without the US. This effect is called **extinction**, and the response is said to become "extinguished." For example, if Pavlov kept ringing the bell but never gave the dog any food afterward, eventually the dog's CR (drooling) would no longer happen when it heard the CS (the bell), because the bell would no longer be a predictor of food. Extinction is important for many reasons. For one thing, it is the basis for many therapies that clinical psychologists use to eliminate maladaptive and unwanted behaviors. Take the example of a person who has a debilitating fear of spiders: one approach might include systematic exposure to spiders. Whereas, initially the person has a CR (e.g., extreme fear) every time s/he sees the CS (e.g., the spider), after repeatedly being shown pictures of spiders in neutral conditions, pretty soon the CS no longer predicts the CR (i.e., the person doesn't have the fear reaction when seeing spiders, having learned that spiders no longer serve as a "cue" for that fear). Here, repeated exposure to spiders without an aversive consequence causes extinction.

Psychologists must accept one important fact about extinction, however: it does not necessarily destroy the original learning (see Bouton, 2004). For example, imagine you strongly associate the smell of chalkboards with the agony of middle school detention. Now imagine that, after years of encountering chalkboards, the smell of them no longer recalls the agony of detention (an example of extinction). However, one day, after entering a new building for the first time, you suddenly catch a whiff of a chalkboard and WHAM!, the agony of detention returns. This is called **spontaneous recovery**: following a lapse in exposure to the CS after extinction has occurred, sometimes re-exposure to the CS (e.g., the smell of chalkboards) can evoke the CR again (e.g., the agony of detention).

Another related phenomenon is the **renewal effect**: After extinction, if the CS is tested in a new **context**, such as a different room or location, the CR can also return. In the chalkboard example, the action of entering a new building—where you don't expect to smell chalkboards —suddenly renews the sensations associated with detention. These effects have been interpreted to suggest that extinction *inhibits* rather than erases the learned behavior, and this inhibition is mainly expressed in the context in which it is learned (see "context" in theKey Vocabulary section below).

This does not mean that extinction is a bad treatment for behavior disorders. Instead, clinicians can increase its effectiveness by using basic research on learning to help defeat these relapse effects (see Craske et al., 2008). For example, conducting extinction therapies in contexts where patients might be most vulnerable to relapsing (e.g., at work), might be a good strategy for enhancing the therapy's success.

Useful Things to Know about Instrumental Conditioning

Most of the things that affect the strength of classical conditioning also affect the strength of instrumental learning–whereby we learn to associate our actions with their outcomes. As noted earlier, the "bigger" the reinforcer (or punisher), the stronger the learning. And, if an instrumental behavior is no longer reinforced, it will also be extinguished. Most of the rules of associative learning that apply to classical conditioning also apply to instrumental learning, but other facts about instrumental learning are also worth knowing.

Instrumental Responses Come Under Stimulus Control

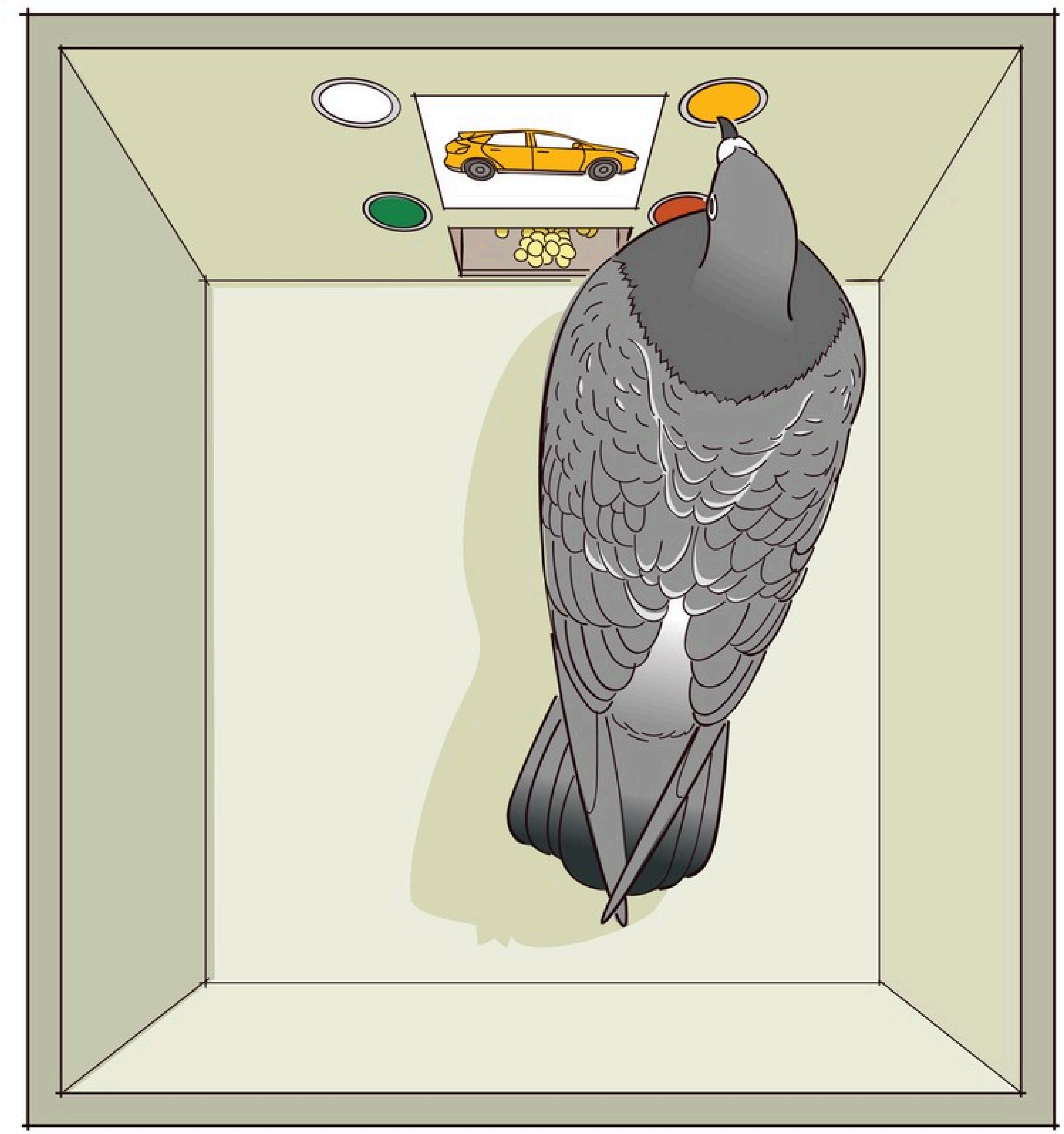
As you know, the classic operant response in the laboratory is lever-pressing in rats, reinforced by food. However, things can be arranged so that lever-pressing only produces pellets when a particular stimulus is present. For example, lever-pressing can be reinforced only when a light in the Skinner box is turned on; when the light is off, no food is released from lever- pressing. The rat soon learns to discriminate between the light-on and light-off conditions, and presses the lever only in the presence of the light (responses in light-off are extinguished). In everyday life, think about waiting in the turn lane at a traffic light. Although you know that green means go, only when you have the green *arrow* do you turn. In this regard, the operant behavior is now said to be under **stimulus control**. And, as is the case with the traffic light, in the real world, stimulus control is probably the rule.

The stimulus controlling the operant response is called a **discriminative stimulus**. It can be associated directly with the response, or the reinforcer (see below). However, it usually does not elicit the response the way a classical CS does. Instead, it is said to "set the occasion for" the operant response. For example, a canvas put in front of an artist does not elicit painting behavior or compel her to paint. It allows, or sets the occasion for, painting to occur.

Stimulus-control techniques are widely used in the laboratory to study perception and other psychological processes in animals. For example, the rat would not be able to respond appropriately to light-on and light-off conditions if it could not see the light. Following this logic, experiments using stimulus-control methods have tested how well animals see colors, hear ultrasounds, and detect magnetic fields. That is, researchers pair these discriminative stimuli with those they know the animals already understand (such as pressing the lever). In this way, the researchers can test if the animals can learn to press the lever only when an ultrasound is played, for example.

These methods can also be used to study "higher" cognitive processes. For example, pigeons can learn to peck at different buttons in a Skinner box when pictures of flowers, cars, chairs, or people are shown on a miniature TV screen (see Wasserman, 1995). Pecking button 1 (and no other) is reinforced in the presence of a flower image, button 2 in the presence of a chair image, and so on. Pigeons can learn the discrimination readily, and, under the right conditions, will even peck the correct buttons associated with pictures of *new* flowers, cars, chairs, and people they have never seen before. The birds have learned to **categorize** the sets of stimuli. Stimulus-control methods can be used to study how such categorization is learned.

Operant Conditioning Involves Choice

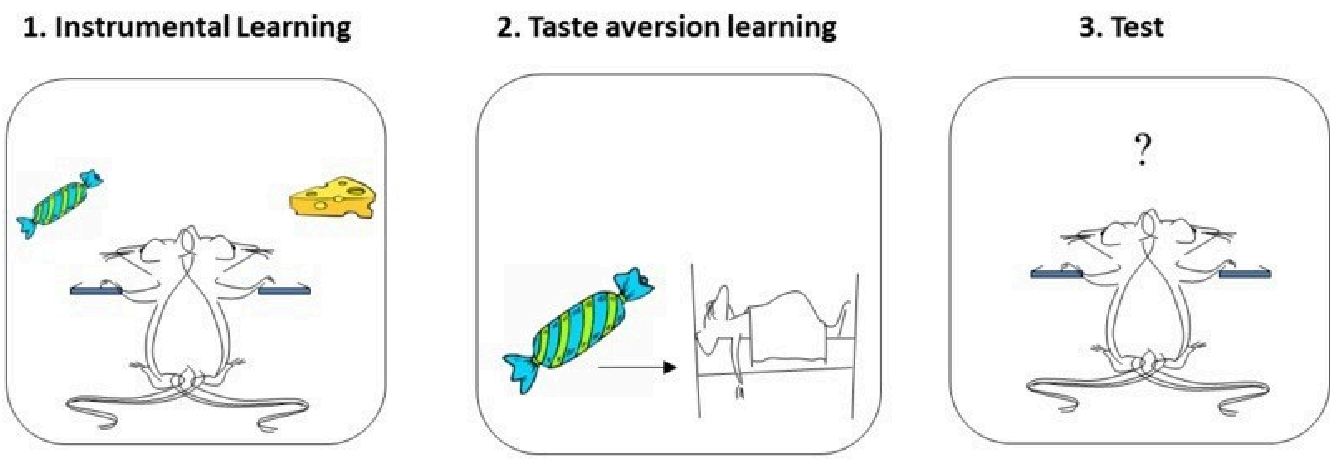


Another thing to know about operant conditioning is that the response always requires choosing one behavior over others. The student who goes to the bar on Thursday night chooses to drink instead of staying at home and studying. The rat chooses to press the lever instead of sleeping or scratching its ear in the back of the box. The alternative behaviors are each associated with their own reinforcers. And the tendency to perform a particular action depends on both the reinforcers earned for it and the reinforcers earned for its alternatives.

To investigate this idea, choice has been studied in the Skinner box by making two levers available for the rat (or two buttons available for the pigeon), each of which has its own reinforcement or payoff rate. A thorough study of choice in situations like this has led to a rule called the **quantitative law of effect** (see Herrnstein, 1970), which can be understood without going into quantitative detail: The law acknowledges the fact that the effects of reinforcing one behavior depend crucially on how much reinforcement is earned for the behavior's alternatives. For example, if a pigeon learns that pecking one light will reward two food pellets, whereas the other light only rewards one, the pigeon will only peck the first light. However, what happens if the first light is more strenuous to reach than the second one? Will the cost of energy outweigh the bonus of food? Or will the extra food be worth the work? In general, a given reinforcer will be less reinforcing if there are many alternative reinforcers in the environment. For this reason, alcohol, sex, or drugs may be less powerful reinforcers if the person's environment is full of other sources of reinforcement, such as achievement at work or love from family members.

Cognition in Instrumental Learning

Modern research also indicates that reinforcers do more than merely strengthen or "stamp in" the behaviors they are a consequence of, as was Thorndike's original view. Instead, animals learn about the specific consequences of each behavior, and will perform a behavior depending on how much they currently want—or "value"—its consequence.



[Image courtesy of Bernard W. Balleine]

This idea is best illustrated by a phenomenon called the **reinforcer devaluation effect** (see Colwill & Rescorla, 1986). A rat is first trained to perform two instrumental actions (e.g., pressing a lever on the left, and on the right), each paired with a different reinforcer (e.g., a sweet sucrose solution, and a food pellet). At the end of this training, the rat tends to press both levers, alternating between the sucrose solution and the food pellet. In a second phase, one of the reinforcers (e.g., the sucrose) is then separately paired with illness. This conditions a taste aversion to the sucrose. In a final test, the rat is returned to the Skinner box and allowed to press either lever freely. No reinforcers are presented during this test (i.e., no sucrose or food comes from pressing the levers), so behavior during testing can only result from the rat's memory of what it has learned earlier. Importantly here, the rat chooses *not* to perform the response that once produced the reinforcer that it now has an aversion to (e.g., it won't press the sucrose lever). This means that the rat has learned and remembered the reinforcer associated with each response, and can combine that knowledge with the knowledge that the reinforcer is now "bad." Reinforcers do not merely stamp in responses; the animal learns much more than that. The behavior is said to be "**goal-directed**" (see Dickinson & Balleine, 1994), because it is influenced by the current value of its associated goal (i.e., how much the rat wants/doesn't want the reinforcer).

Things can get more complicated, however, if the rat performs the instrumental actions frequently and repeatedly. That is, if the rat has spent many months learning the value of pressing each of the levers, the act of pressing them becomes automatic and routine. And here, this once goal-directed action (i.e., the rat pressing the lever for the goal of getting sucrose/food) can become a **habit**. Thus, if a rat spends many months performing the lever- pressing behavior (turning such behavior into a habit), even when sucrose is again paired with illness, the rat will continue to press that lever (see Holland, 2004). After all the practice, the instrumental response (pressing the lever) is no longer sensitive to reinforcer devaluation. The rat continues to respond automatically, regardless of the fact that the sucrose from this lever makes it sick.

Habits are very common in human experience, and can be useful. You do not need to relearn each day how to make your coffee in the morning or how to brush your teeth. Instrumental behaviors can eventually become habitual, letting us get the job done while being free to think about other things.

Putting Classical and Instrumental Conditioning Together

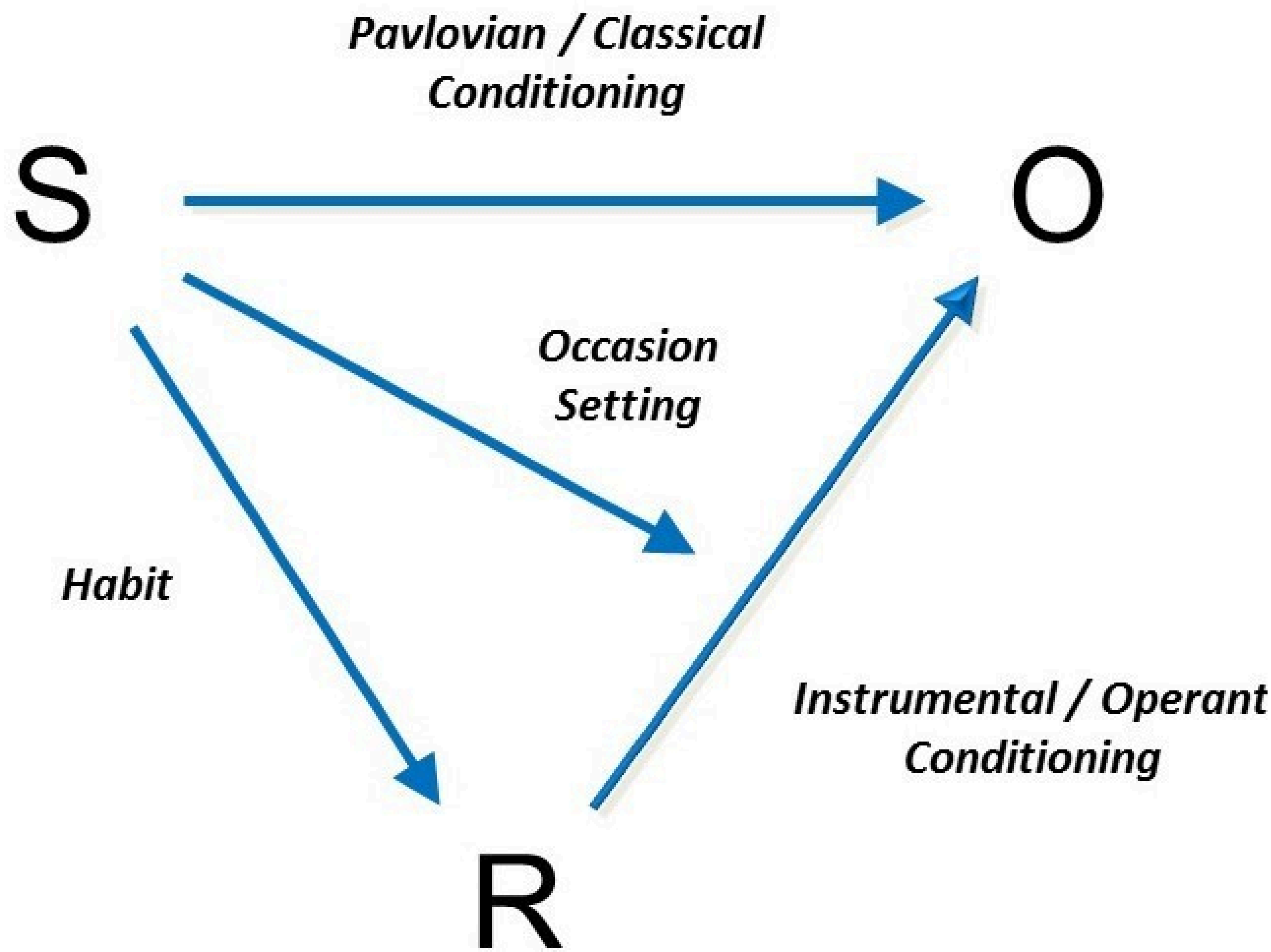
Classical and operant conditioning are usually studied separately. But outside of the laboratory they almost always occur at the same time. For example, a person who is reinforced for drinking alcohol or eating excessively learns these behaviors in the presence of certain stimuli —a pub, a set of friends, a restaurant, or possibly the couch in front of the TV. These stimuli are also available for association with the reinforcer. In this way, classical and operant conditioning are always intertwined.

The figure below summarizes this idea, and helps review what we have discussed in this module. Generally speaking, any reinforced or punished operant response (R) is paired with an outcome (O) in the presence of some stimulus or set of stimuli (S).

The figure illustrates the types of associations that can be learned in this very general scenario.

For one thing, the organism will learn to associate the response *and* the outcome (R – O). This is instrumental conditioning. The learning process here is probably similar to classical conditioning, with all its emphasis on surprise and prediction error. And, as we discussed while considering the reinforcer devaluation effect, once R – O is learned, the organism will be ready to perform the response if the outcome is desired or valued. The value of the reinforcer can also be influenced by other reinforcers earned for other behaviors in the situation. These factors are at the heart of instrumental learning.

Second, the organism can also learn to associate the stimulus with the reinforcing outcome (S – O). This is the classical conditioning component, and as we have seen, it can have many consequences on behavior. For one thing, the stimulus will come to evoke a system of responses that help the organism prepare for the reinforcer (not shown in the figure): The drinker may undergo changes in body temperature; the eater may salivate and have an increase in insulin secretion. In addition, the stimulus will evoke approach (if the outcome is positive) or retreat (if the outcome is negative). Presenting the stimulus will also prompt the instrumental response.



The third association in the diagram is the one between the stimulus and the response (S – R). As discussed earlier, after a lot of practice, the stimulus may begin to elicit the response directly. This is habit learning, whereby the response occurs relatively automatically, without much mental processing of the relation between the action and the outcome and the outcome's current value.

The final link in the figure is between the stimulus and the response-outcome association [S – (R – O)]. More than just entering into a simple association with the R or the O, the stimulus can signal that the R – O relationship is now in effect. This is what we mean when we say that the stimulus can "set the occasion" for the operant response: It sets the occasion for the response-reinforcer relationship. Through this mechanism, the painter might begin to paint when given the right tools and the opportunity enabled by the canvas. The canvas theoretically signals that the behavior of painting will now be reinforced by positive consequences.

The figure provides a framework that you can use to understand almost any learned behavior you observe in yourself, your family, or your friends. If you would like to understand it more deeply, consider taking a course on learning in the future, which will give you a fuller appreciation of how classical learning, instrumental learning, habit learning, and occasion setting actually work and interact.

Observational Learning

Not all forms of learning are accounted for entirely by classical and operant conditioning. Imagine a child walking up to a group of children playing a game on the playground. The game looks fun, but it is new and unfamiliar. Rather than joining the game immediately, the child opts to sit back and watch the other children play a round or two. Observing the others, the child takes note of the ways in which they behave while playing the game. By watching the behavior of the other kids, the child can figure out the rules of the game and even some strategies for doing well at the game. This is called **observational learning**.

Children observing a social model (an experienced chess player) to learn the rules and strategies of the game of chess. [Image: David R. Tribble, https://goo.gl/nWsgxI, CC BY-SA 3.0, https://goo.gl/ uhHola]

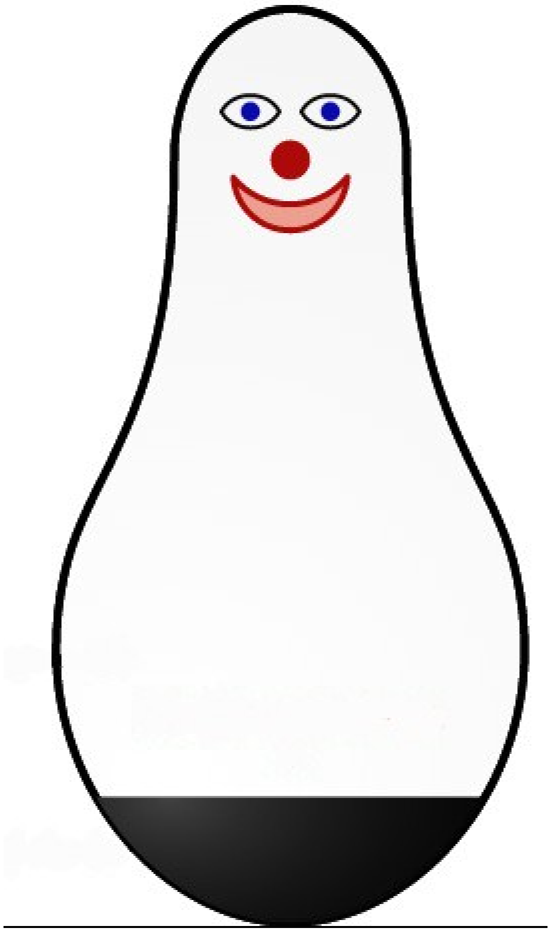
Observational learning is a component of Albert Bandura's **Social Learning Theory** (Bandura, 1977), which posits that individuals can learn novel responses via observation of key others' behaviors. Observational learning does not necessarily require reinforcement, but instead hinges on the presence of others, referred to as **social models**. Social models are typically of higher status or authority compared to the observer, examples of which include parents, teachers, and police officers. In the example above, the children who already know how to play the game could be thought of as being authorities—and are therefore social models—even though they are the same age as the observer. By observing how the social models behave, an individual is able to learn how to act in a certain situation. Other examples of observational learning might include a child learning to place her napkin in her lap by watching her parents at the dinner table, or a customer learning where to find the ketchup and mustard after observing other customers at a hot dog stand.

Bandura theorizes that the observational learning process consists of four parts. The first is *attention*—as, quite simply, one must pay attention to what s/he is observing in order to learn. The second part is *retention*: to learn one must be able to retain the behavior s/he is observing in memory.The third part of observational learning, *initiation*, acknowledges that the learner must be able to execute (or initiate) the learned behavior. Lastly, the observer must possess the *motivation* to engage in observational learning. In our vignette, the child must want to learn how to play the game in order to properly engage in observational learning.

Researchers have conducted countless experiments designed to explore observational learning, the most famous of which is Albert Bandura's "Bobo doll experiment."

In this experiment (Bandura, Ross & Ross 1961), Bandura had children individually observe an adult social model interact with a clown doll ("Bobo"). For one group of children, the adult interacted aggressively with Bobo: punching it, kicking it, throwing it, and even hitting it in the face with a toy mallet. Another group of children watched the adult interact with other toys, displaying no aggression toward Bobo. In both instances the adult left and the children were allowed to interact with Bobo on their own. Bandura found that children exposed to the aggressive social model were significantly more likely to behave aggressively toward Bobo, hitting and kicking him, compared to those exposed to the non-aggressive model. The researchers concluded that the children in the aggressive group used their observations of the adult social model's behavior to determine that aggressive behavior toward Bobo was acceptable.

While reinforcement was not required to elicit the children's behavior in Bandura's first experiment, it is important to acknowledge that consequences do play a role within observational learning. A future adaptation of this study (Bandura, Ross, & Ross, 1963) demonstrated that children in the aggression group showed less aggressive behavior if they witnessed the adult model receive punishment for aggressing against Bobo. Bandura referred to this process as **vicarious reinforcement**, as the children did not experience the reinforcement or punishment directly, yet were still influenced by observing it.



Bobo [Image: © Sémhur / Wikimedia Commons / CC-BY-SA-3.0 (or Free Art License), https://goo.gl/uhHola]

Conclusion

We have covered three primary explanations for how we learn to behave and interact with the world around us. Considering your own experiences, how well do these theories apply to you? Maybe when reflecting on your personal sense of fashion, you realize that you tend to select clothes others have complimented you on (operant conditioning). Or maybe, thinking back on a new restaurant you tried recently, you realize you chose it because its commercials play happy music (classical conditioning). Or maybe you are now always on time with your assignments, because you saw how others were punished when they were late (observational learning). Regardless of the activity, behavior, or response, there's a good chance your "decision" to do it can be explained based on one of the theories presented in this module.

Outside Resources

Article: Rescorla, R. A. (1988). Pavlovian conditioning: It's not what you think it is. American Psychologist, 43, 151–160.

Book: Bouton, M. E. (2007). Learning and behavior: A contemporary synthesis. Sunderland, MA: Sinauer Associates.

Book: Bouton, M. E. (2009). Learning theory. In B. J. Sadock, V. A. Sadock, & P. Ruiz (Eds.), Kaplan & Sadock's comprehensive textbook of psychiatry (9th ed., Vol. 1, pp. 647–658). New York, NY: Lippincott Williams & Wilkins.

Book: Domjan, M. (2010). The principles of learning and behavior (6th ed.). Belmont, CA: Wadsworth.

Video: Albert Bandura discusses the Bobo Doll Experiment.

https://www.youtube.com/watch?v=eqNaLerMNOE

Discussion Questions

1. Describe three examples of Pavlovian (classical) conditioning that you have seen in your own behavior, or that of your friends or family, in the past few days.
2. Describe three examples of instrumental (operant) conditioning that you have seen in your own behavior, or that of your friends or family, in the past few days.
3. Drugs can be potent reinforcers. Discuss how Pavlovian conditioning and instrumental conditioning can work together to influence drug taking.
4. In the modern world, processed foods are highly available and have been engineered to be highly palatable and reinforcing. Discuss how Pavlovian and instrumental conditioning can work together to explain why people often eat too much.
5. How does blocking challenge the idea that pairings of a CS and US are sufficient to cause Pavlovian conditioning? What is important in creating Pavlovian learning?
6. How does the reinforcer devaluation effect challenge the idea that reinforcers merely "stamp in" the operant response? What does the effect tell us that animals actually learn in operant conditioning?
7. With regards to social learning do you think people learn violence from observing violence in movies? Why or why not?
8. What do you think you have learned through social learning? Who are your social models?

Vocabulary

Blocking

In classical conditioning, the finding that no conditioning occurs to a stimulus if it is combined with a previously conditioned stimulus during conditioning trials. Suggests that information, surprise value, or prediction error is important in conditioning.

Categorize

To sort or arrange different items into classes or categories.

Classical conditioning

The procedure in which an initially neutral stimulus (the conditioned stimulus, or CS) is paired with an unconditioned stimulus (or US). The result is that the conditioned stimulus begins to elicit a conditioned response (CR). Classical conditioning is nowadays considered important as both a behavioral phenomenon and as a method to study simple associative learning. Same as Pavlovian conditioning.

Conditioned compensatory response

In classical conditioning, a conditioned response that opposes, rather than is the same as, the unconditioned response. It functions to reduce the strength of the unconditioned response. Often seen in conditioning when drugs are used as unconditioned stimuli.

Conditioned response (CR)

The response that is elicited by the conditioned stimulus after classical conditioning has taken place.

Conditioned stimulus (CS)

An initially neutral stimulus (like a bell, light, or tone) that elicits a conditioned response after it has been associated with an unconditioned stimulus.

Context

Stimuli that are in the background whenever learning occurs. For instance, the Skinner box or room in which learning takes place is the classic example of a context. However, "context" can also be provided by internal stimuli, such as the sensory effects of drugs (e.g., being under the influence of alcohol has stimulus properties that provide a context) and mood states (e. g., being happy or sad). It can also be provided by a specific period in time—the passage of time is sometimes said to change the "temporal context."

Discriminative stimulus

In operant conditioning, a stimulus that signals whether the response will be reinforced. It is said to "set the occasion" for the operant response.

Extinction

Decrease in the strength of a learned behavior that occurs when the conditioned stimulus is presented without the unconditioned stimulus (in classical conditioning) or when the behavior is no longer reinforced (in instrumental conditioning). The term describes both the procedure (the US or reinforcer is no longer presented) as well as the result of the procedure (the learned response declines). Behaviors that have been reduced in strength through extinction are said to be "extinguished."

Fear conditioning A type of classical or Pavlovian conditioning in which the conditioned stimulus (CS) is associated with an aversive unconditioned stimulus (US), such as a foot shock. As a consequence of learning, the CS comes to evoke fear. The phenomenon is thought to be involved in the development of anxiety disorders in humans.

Goal-directed behavior

Instrumental behavior that is influenced by the animal's knowledge of the association between the behavior and its consequence and the current value of the consequence. Sensitive to the reinforcer devaluation effect.

Habit

Instrumental behavior that occurs automatically in the presence of a stimulus and is no longer influenced by the animal's knowledge of the value of the reinforcer. Insensitive to the reinforcer devaluation effect.

Instrumental conditioning

Process in which animals learn about the relationship between their behaviors and their consequences. Also known as operant conditioning.

Law of effect

The idea that instrumental or operant responses are influenced by their effects. Responses that are followed by a pleasant state of affairs will be strengthened and those that are followed by discomfort will be weakened. Nowadays, the term refers to the idea that operant or instrumental behaviors are lawfully controlled by their consequences.

Observational learning

Learning by observing the behavior of others.

Operant

A behavior that is controlled by its consequences. The simplest example is the rat's lever- pressing, which is controlled by the presentation of the reinforcer.

Operant conditioning

See instrumental conditioning.

Pavlovian conditioning

See classical conditioning.

Prediction error

When the outcome of a conditioning trial is different from that which is predicted by the conditioned stimuli that are present on the trial (i.e., when the US is surprising). Prediction error is necessary to create Pavlovian conditioning (and associative learning generally). As learning occurs over repeated conditioning trials, the conditioned stimulus increasingly predicts the unconditioned stimulus, and prediction error declines. Conditioning works to correct or reduce prediction error.

Preparedness

The idea that an organism's evolutionary history can make it easy to learn a particular association. Because of preparedness, you are more likely to associate the taste of tequila, and not the circumstances surrounding drinking it, with getting sick. Similarly, humans are more likely to associate images of spiders and snakes than flowers and mushrooms with aversive outcomes like shocks.

Punisher

A stimulus that decreases the strength of an operant behavior when it is made a consequence of the behavior.

Quantitative law of effect

A mathematical rule that states that the effectiveness of a reinforcer at strengthening an operant response depends on the amount of reinforcement earned for all alternative behaviors. A reinforcer is less effective if there is a lot of reinforcement in the environment for other behaviors.

Reinforcer

Any consequence of a behavior that strengthens the behavior or increases the likelihood that

it will be performed it again.

Reinforcer devaluation effect

The finding that an animal will stop performing an instrumental response that once led to a reinforcer if the reinforcer is separately made aversive or undesirable.

Renewal effect

Recovery of an extinguished response that occurs when the context is changed after extinction. Especially strong when the change of context involves return to the context in which conditioning originally occurred. Can occur after extinction in either classical or instrumental conditioning.

Social Learning Theory

The theory that people can learn new responses and behaviors by observing the behavior of others.

Social models

Authorities that are the targets for observation and who model behaviors.

Spontaneous recovery

Recovery of an extinguished response that occurs with the passage of time after extinction. Can occur after extinction in either classical or instrumental conditioning.

Stimulus control

When an operant behavior is controlled by a stimulus that precedes it.

Taste aversion learning

The phenomenon in which a taste is paired with sickness, and this causes the organism to reject—and dislike—that taste in the future.

Unconditioned response (UR)

In classical conditioning, an innate response that is elicited by a stimulus before (or in the absence of) conditioning.

Unconditioned stimulus (US)

In classical conditioning, the stimulus that elicits the response before conditioning occurs.

Vicarious reinforcement

Learning that occurs by observing the reinforcement or punishment of another person.

References

Balleine, B. W. (2005). Neural basis of food-seeking: Affect, arousal, and reward in corticostratolimbic circuits. *Physiology & Behavior*, 86, 717–730.

Bandura, A. (1977). *Social learning theory*. Englewood Cliffs, NJ: Prentice Hall

Bandura, A., Ross, D., Ross, S (1963). Imitation of film-mediated aggressive models. *Journal of Abnormal and Social Psychology* 66(1), 3 – 11.

Bandura, A.; Ross, D.; Ross, S. A. (1961). "Transmission of aggression through the imitation of aggressive models". *Journal of Abnormal and Social Psychology* 63(3), 575–582.

Bernstein, I. L. (1991). Aversion conditioning in response to cancer and cancer treatment. *Clinical Psychology Review*, 11, 185–191.

Bouton, M. E. (2004). Context and behavioral processes in extinction. *Learning & Memory*, 11, 485–494.

Colwill, R. M., & Rescorla, R. A. (1986). Associative structures in instrumental learning. In G. H. Bower (Ed.), *The psychology of learning and motivation*, (Vol. 20, pp. 55–104). New York, NY: Academic Press.

Craske, M. G., Kircanski, K., Zelikowsky, M., Mystkowski, J., Chowdhury, N., & Baker, A. (2008). Optimizing inhibitory learning during exposure therapy. *Behaviour Research and Therapy*, 46, 5–27.

Dickinson, A., & Balleine, B. W. (1994). Motivational control of goal-directed behavior. *Animal Learning & Behavior*, 22, 1–18.

Fanselow, M. S., & Poulos, A. M. (2005). The neuroscience of mammalian associative learning. *Annual Review of Psychology*, 56, 207–234.

Herrnstein, R. J. (1970). On the law of effect. Journal of the Experimental Analysis of Behavior, 13, 243–266.

Holland, P. C. (2004). Relations between Pavlovian-instrumental transfer and reinforcer devaluation. *Journal of Experimental Psychology: Animal Behavior Processes*, 30, 104–117.

Kamin, L. J. (1969). Predictability, surprise, attention, and conditioning. In B. A. Campbell & R.

M. Church (Eds.), *Punishment and aversive behavior* (pp. 279–296). New York, NY: Appleton- Century-Crofts.

Mineka, S., & Zinbarg, R. (2006). A contemporary learning theory perspective on the etiology of anxiety disorders: It's not what you thought it was. *American Psychologist*, *61*, 10–26.

Pearce, J. M., & Bouton, M. E. (2001). Theories of associative learning in animals. *Annual Review of Psychology*, 52, 111–139.

Rescorla, R. A., & Wagner, A. R. (1972). A theory of Pavlovian conditioning: Variations in the effectiveness of reinforcement and nonreinforcement. In A. H. Black & W. F. Prokasy (Eds.), *Classical conditioning II: Current research and theory* (pp. 64–99). New York, NY: Appleton- Century-Crofts.

Scalera, G., & Bavieri, M. (2009). Role of conditioned taste aversion on the side effects of chemotherapy in cancer patients. In S. Reilly & T. R. Schachtman (Eds.), *Conditioned taste aversion: Behavioral and neural processes* (pp. 513–541). New York, NY: Oxford University Press.

Siegel, S. (1989). Pharmacological conditioning and drug effects. In A. J. Goudie & M. Emmett- Oglesby (Eds.), *Psychoactive drugs* (pp. 115–180). Clifton, NY: Humana Press.

Siegel, S., Hinson, R. E., Krank, M. D., & McCully, J. (1982). Heroin "overdose" death: Contribution of drug associated environmental cues. *Science*, *216*, 436–437.

Spreat, S., & Spreat, S. R. (1982). Learning principles. In V. Voith & P. L. Borchelt (Eds.), *Veterinary clinics of North America: Smallanimalpractice* (pp. 593–606). Philadelphia, PA: W. B. Saunders.

Thompson, R. F., & Steinmetz, J. E. (2009). The role of the cerebellum in classical conditioning of discrete behavioral responses. *Neuroscience*, 162, 732–755.

Timberlake, W. L. (2001). Motivational modes in behavior systems. In R. R. Mowrer & S. B. Klein (Eds.), *Handbook of contemporary learning theories* (pp. 155–210). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Wasserman, E. A. (1995). The conceptual abilities of pigeons. *American Scientist*, 83, 246–255.

ATTENTION

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.

Chapter Author: Frances Friedrich

Learning Objectives

Learning Objectives

Understand why selective attention is important and how it can be studied.

Learn about different models of when and how selection can occur.

Understand how divided attention or multitasking is studied, and implications of multitasking in situations such as distracted driving.

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)

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 capacity** for information processing, and that we can only attend to or be consciously aware of a small amount of information at any given time.

Are you reading these words right here right now? If so, it's only because you directed your attention toward them. [Image: CC BY 2.0, https://goo.gl/BRvSA7]

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?

Selective Attention

The Cocktail Party

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.

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: Ross, https://goo.gl/TVDfTn, CC BY-NC-SA 2.0, https://goo.gl/Toc0ZF]

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:

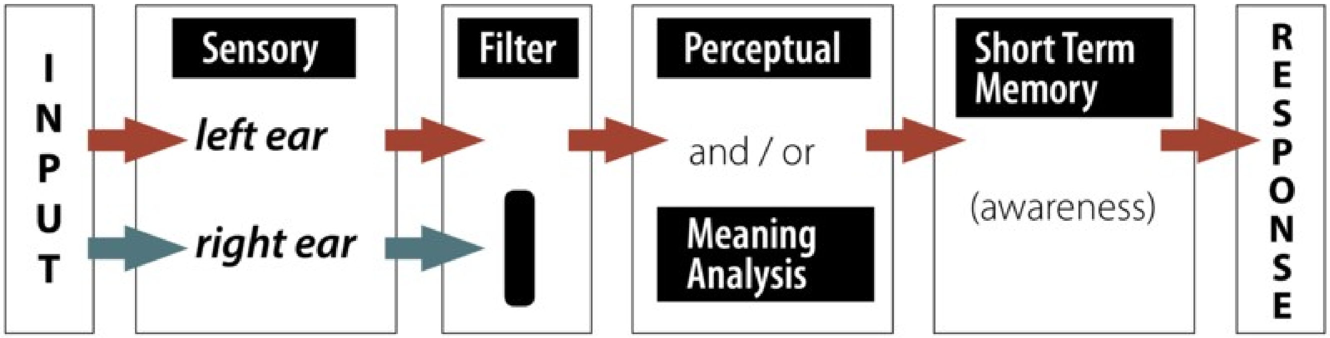


Figure 1: This figure shows information going in both the left and right ears. Some basic sensory information, such as pitch, is processed, but the filter only allows the information from one ear to be processed further. Only the information from the left ear is transferred to short-term memory (STM) 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 shadowthe 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.

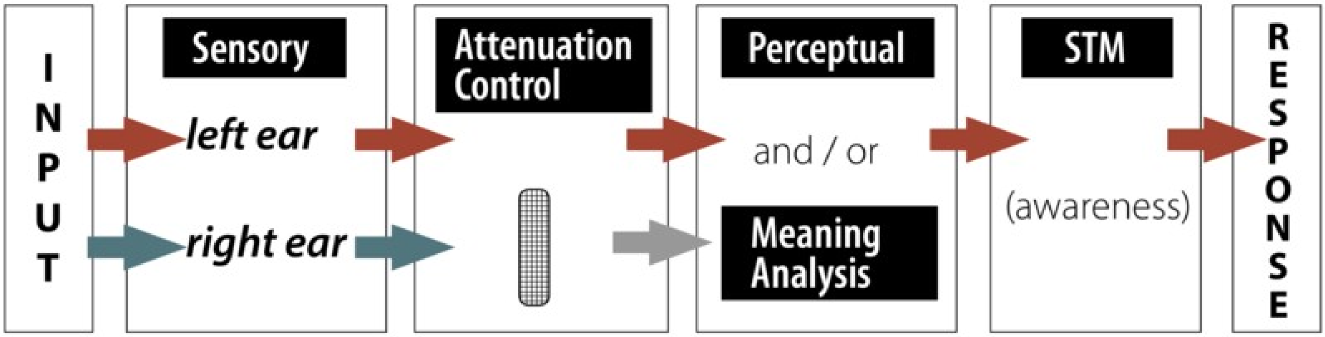


Figure 2

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.

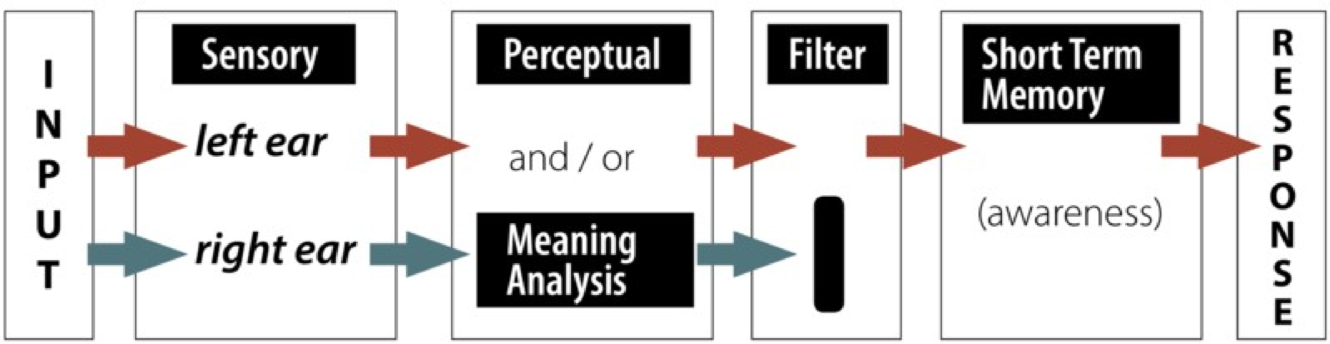


Figure 3

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 nonselected 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.

———————————————————————————————————

Focus Topic 1: 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 of establishing what the threshold for consciousness is or of even determining what type of threshold is 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 the stimuli can be or the extent to which unconscious material can affect behavior is not settled (e.g., Bargh & Morsella, 2008; Greenwald, 1992; Merikle, 2000).

Divided Attention and Multitasking

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

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: CC0 Public Domain, https://goo.gl/m25gce]

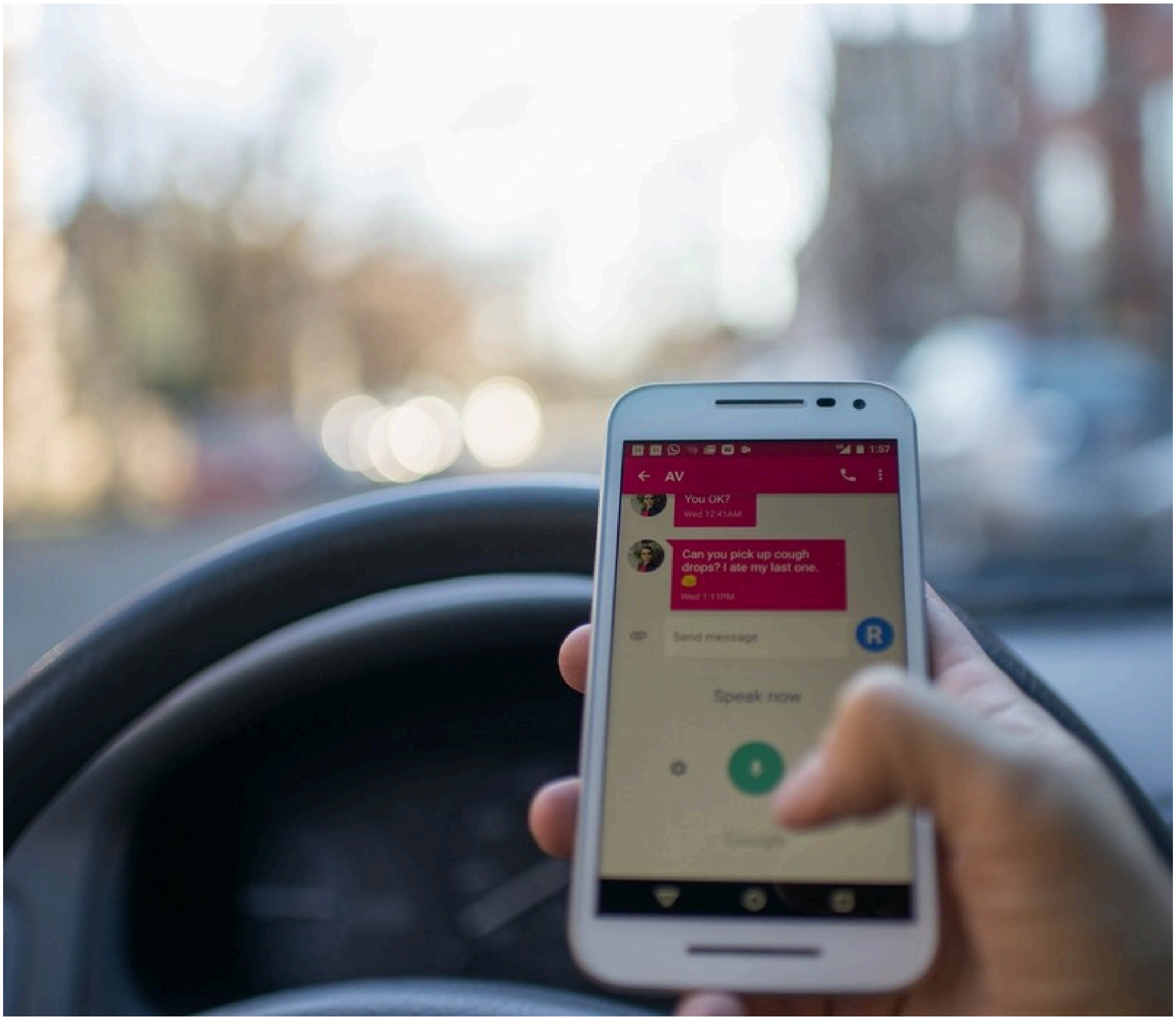
In a classic study that examined this type of divided attention task, two participants were trained to take dictation for spoken words while reading unrelated material for comprehension (Spelke, Hirst, & Neisser, 1976). In divided attention tasks such as these, each task is evaluated separately, in order 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 *taskswitching* 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?

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).



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: CC0 Public Domain, https://goo.gl/m25gce]

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).

Summary

It may be useful to think of attention as a mental resource, one that is needed to focus on and fully process important information, especially when there is a lot of distracting "noise" threatening to obscure the message. Our selective attention system allows us to find or track an object or conversation in the midst of distractions. Whether the selection process occurs early or late in the analysis of those events has been the focus of considerable research, and in fact how selection occurs may very well depend on the specific conditions. With respect to divided attention, in general we can only perform one cognitively demanding task at a time, and we may not even be aware of unattended events even though they might seem too obvious to miss (check out some examples in the Outside Resources below). This type of inattention blindness can occur even in well-learned tasks, such as driving while talking on a cell phone. Understanding how attention works is clearly important, even for our everyday lives.

Outside Resources

Video: Here's a wild example of how much we fail to notice when our attention is captured by one element of a scene.
http://www.youtube.com/watch?v=ubNF9QNEQLA&feature=related

Video: Try this test to see how well you can focus on a task in the face of a lot of distraction.
http://www.youtube.com/watch?v=Ahg6qcgoay4&NR=1

Discussion Questions

1. Discuss the implications of the different models of selective attention for everyday life. For instance, what advantages and disadvantages would be associated with being able to filter out all unwanted information at a very early stage in processing? What are the implications of processing all ignored information fully, even if you aren't consciously aware of that information?
2. Think of examples of when you feel you can successfully multitask and when you can't. Discuss what aspects of the tasks or the situation seem to influence divided attention performance. How accurate do you think you are in judging your own multitasking ability?
3. What are the public policy implications of current evidence of inattentional blindness as a result of distracted driving? Should this evidence influence traffic safety laws? What additional studies of distracted driving would you propose?

Vocabulary

Dichotic listening
An experimental task in which two messages are presented to different ears.
Divided attention
The ability to flexibly allocate attentional resources between two or more concurrent tasks.
Inattentional blindness
The failure to notice a fully visible object when attention is devoted to something else.
Limited capacity
The notion that humans have limited mental resources that can be used at a given time.
Selective attention
The ability to select certain stimuli in the environment to process, while ignoring distracting information.
Shadowing
A task in which the individual is asked to repeat an auditory message as it is presented.
Subliminal perception
The ability to process information for meaning when the individual is not consciously aware of that information.

References

Bargh, J., & Morsella, E. (2008). The unconscious mind. Perspectives on Psychological Science, 3(1), 73–79.

Beilock, S. L., & Carr, T. H. (2001). On the fragility of skilled performance: What governs choking under pressure? Journal of Experimental Psychology: General, 130, 701–725.

Broadbent, D. A. (1958). Perception and communication. London, England: Pergamon Press.

Cheesman, J., & Merikle, P. (1986). Distinguishing conscious from unconscious perceptual processes. Canadian Journal of Psychology, 40, 343–367.

Cheesman, J., & Merikle, P. (1984). Priming with and without awareness. Perception and Psychophysics, 36, 387–395.

Cherry, E. C. (1953). Experiments on the recognition of speech with one and two ears. Journal of the Acoustical Society of America, 25, 975–979.

Deutsch, J. A., & Deutsch, D. (1963). Attention: some theoretical considerations. Psychological Review, 70, 80–90.

Greenwald, A. G. (1992). New Look 3: Unconscious cognition reclaimed. American Psychologist, 47, 766–779.

Hirst, W. C., Neisser, U., & Spelke, E. S. (1978). Divided attention. Human Nature, 1, 54–61. James, W. (1983). The principles of psychology. Cambridge, MA: Harvard University Press. (Original work published 1890)

Johnston, W. A., & Heinz, S. P. (1978). Flexibility and capacity demands of attention. Journal of Experimental Psychology: General, 107, 420–435.

Merikle, P. (2000). Subliminal perception. In A. E. Kazdin (Ed.), Encyclopedia of psychology (Vol. 7, pp. 497–499). New York, NY: Oxford University Press.

Monsell, S. (2003). Task switching. Trends in Cognitive Science, 7(3), 134–140. Moray, N. (1959). Attention in dichotic listening: Affective cues and the influence of instructions. Quarterly Journal of Experimental Psychology, 11, 56–60.

Neisser, U. (1979). The control of information pickup in selective looking. In A. D. Pick (Ed.), Perception and its development: A tribute to Eleanor J. Gibson (pp. 201–219). Hillsdale, NJ: Lawrence Erlbaum Associates.

Simons, D. J., & Chabris, C. F. (1999). Gorillas in our midst: Sustained inattentional blindness for dynamic events. Perception, 28, 1059–1074.

Spelke, E. S., Hirst, W. C., & Neisser, U. (1976). Skills of divided attention. Cognition, 4, 215–250.

Strayer, D. L., & Drews, F. A. (2007). Cell-phone induced inattention blindness. Current Directions in Psychological Science, 16, 128–131.

Strayer, D. L., & Johnston, W. A. (2001). Driven to distraction: Dual-task studies of simulated driving and conversing on a cellular telephone. Psychological Science, 12, 462–466.

Strayer, D. L., Watson, J. M., & Drews, F. A. (2011) Cognitive distraction while multitasking in the automobile. In Brian Ross (Ed.), The Psychology of Learning and Motivation (Vol. 54, pp. 29–58). Burlington, VT: Academic Press.

Treisman, A. (1960). Contextual cues in selective listening. Quarterly Journal of Experimental Psychology, 12, 242–248.

Watson, J. M., & Strayer, D. L. (2010). Supertaskers: Profiles in extraordinary multitasking ability. Psychonomic Bulletin & Review, 17, 479–485.

THE BRAIN

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The human brain is responsible for all behaviors, thoughts, and experiences described in this textbook. This module provides an introductory overview of the brain, including some basic neuroanatomy, and brief descriptions of the neuroscience methods used to study it.

Introduction

Any textbook on psychology would be incomplete without reference to the brain. Every behavior, thought, or experience described in the other modules must be implemented in the brain. A detailed understanding of the human brain can help us make sense of human experience and behavior. For example, one well-established fact about human cognition is that it is limited. We cannot do two complex tasks at once: We cannot read and carry on a conversation at the same time, text and drive, or surf the Internet while listening to a lecture, at least not successfully or safely. We cannot even pat our head and rub our stomach at the same time (with exceptions, see "A Brain Divided"). Why is this? Many people have suggested that such limitations reflect the fact that the behaviors draw on the same resource; if one behavior uses up most of the resource there is not enough resource left for the other. But what might this limited resource be in the brain?

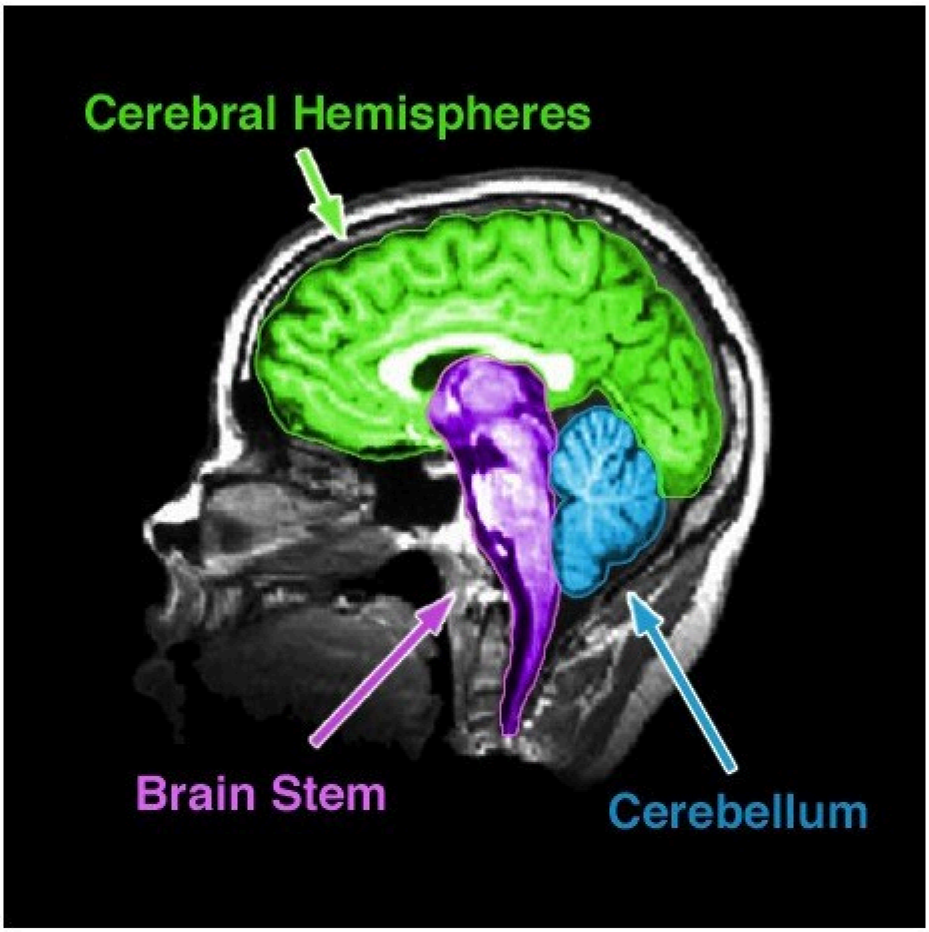


Figure 1. An MRI of the human brain delineating three major structures: the cerebral hemispheres, brain stem, and cerebellum.

The brain uses oxygen and glucose, delivered via the blood. The brain is a large consumer of these **metabolites**, using 20% of the oxygen and calories we consume despite being only 2% of our total weight. However, as long as we are not oxygen-deprived or malnourished, we have more than enough oxygen and glucose to fuel the brain. Thus, insufficient "brain fuel" cannot explain our limited capacity. Nor is it likely that our limitations reflect too few neurons. The average human brain contains 100 billion neurons. It is also not the case that we use only 10% of our brain, a myth that was likely started to imply we had untapped potential. Modern neuroimaging (see “Studying the Human Brain”) has shown that we use all parts of brain, just at different times, and certainly more than 10% at any one time.

If we have an abundance of brain fuel and neurons, how can we explain our limited cognitive abilities? Why can’t we do more at once? The most likely explanation is the way these neurons are wired up. We know, for instance, that many neurons in the visual cortex (the part of the brain responsible for processing visual information) are hooked up in such a way as to inhibit each other (Beck & Kastner, 2009). When one neuron fires, it suppresses the firing of other nearby neurons. If two neurons that are hooked up in an inhibitory way both fire, then neither neuron can fire as vigorously as it would otherwise. This competitive behavior among neurons limits how much visual information the brain can respond to at the same time. Similar kinds of competitive wiring among neurons may underlie many of our limitations. Thus, although talking about limited resources provides an intuitive description of our limited capacity behavior, a detailed understanding of the brain suggests that our limitations more likely reflect the complex way in which neurons talk to each other rather than the depletion of any specific resource.

Learning Objectives

- Name and describe the basic function of the brain stem, cerebellum, and cerebral hemispheres.
- Name and describe the basic function of the four cerebral lobes: occipital, temporal, parietal, and frontal cortex.
- Describe a split-brain patient and at least two important aspects of brain function that these patients reveal.
- Distinguish between gray and white matter of the cerebral hemispheres.
- Name and describe the most common approaches to studying the human brain.
- Distinguish among four neuroimaging methods: PET, fMRI, EEG, and DOI.
- Describe the difference between spatial and temporal resolution with regard to brain function.

The Anatomy of the Brain

There are many ways to subdivide the mammalian brain, resulting in some inconsistent and ambiguous **nomenclature** over the history of neuroanatomy (Swanson, 2000). For simplicity, we will divide the brain into three basic parts: the brain stem, cerebellum, and cerebral hemispheres (see Figure 1). In Figure 2, however, we depict other prominent groupings (Swanson, 2000) of the six major subdivisions of the brain (Kandal, Schwartz, & Jessell, 2000).

Brain Stem

The **brain stem** is sometimes referred to as the "trunk" of the brain. It is responsible for many of the neural functions that keep us alive, including regulating our respiration (breathing), heart rate, and digestion. In keeping with its function, if a patient sustains severe damage to the brain stem he or she will require "life support" (i.e., machines are used to keep him or her alive). Because of its vital role in survival, in many countries a person who has lost brain stem function is said to be "brain dead," although other countries require significant tissue loss in the cortex (of the cerebral hemispheres), which is responsible for our conscious experience, for the same diagnosis. The brain stem includes the medulla, pons, midbrain, and diencephalon (which consists of thalamus and hypothalamus). Collectively, these regions also are involved in our sleep–wake cycle, some sensory and motor function, as well as growth and other hormonal behaviors.

Cerebellum

The **cerebellum** is the distinctive structure at the back of the brain. The Greek philosopher and scientist Aristotle aptly referred to it as the "small brain" ("parencephalon" in Greek, "cerebellum" in Latin) in order to distinguish it from the "large brain" ("encephalon" in Greek, "**cerebrum**" in Latin). The cerebellum is critical for coordinated movement and posture. More recently, neuroimaging studies (see "Studying the Human Brain") have implicated it in a range of cognitive abilities, including language.

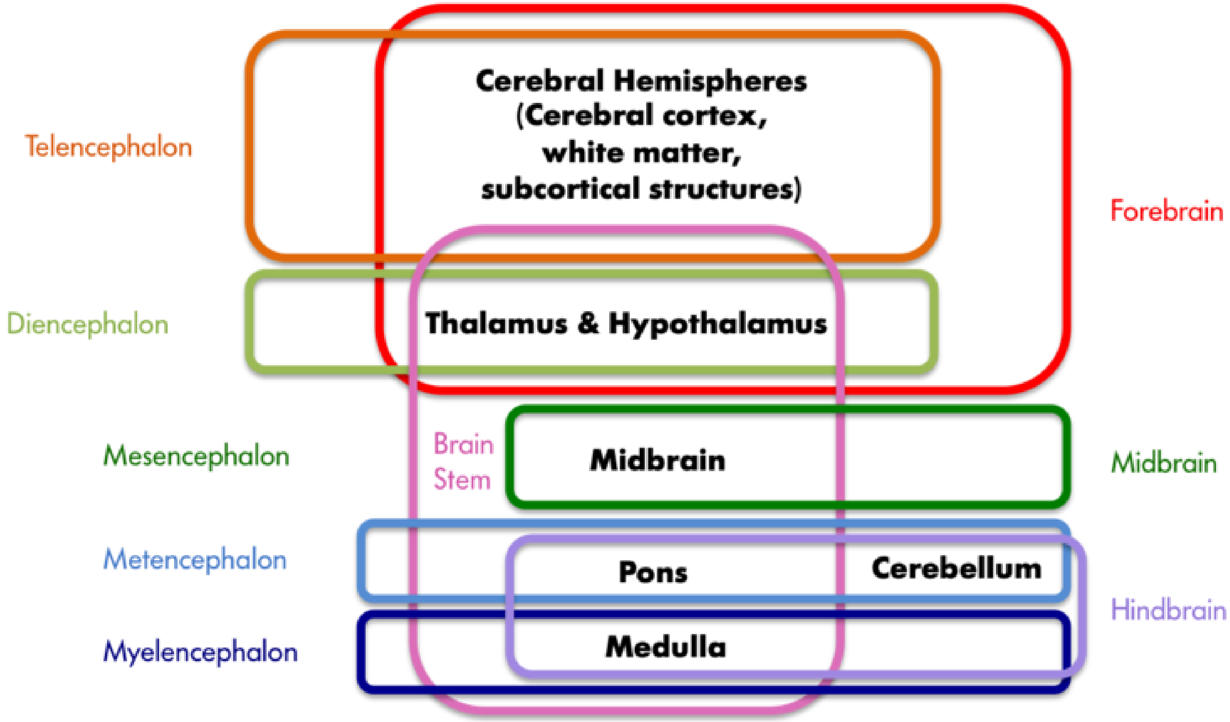


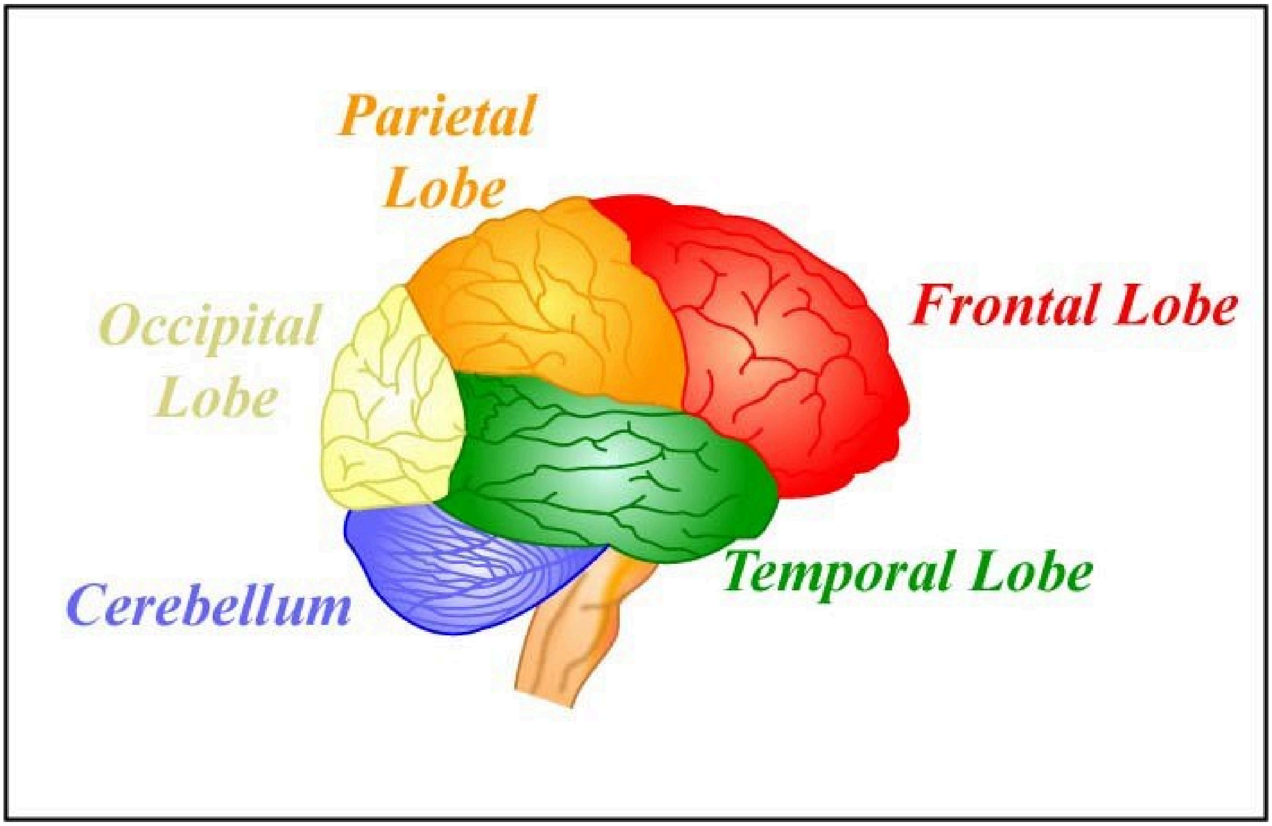
Figure 2. A sample of neuroanatomy nomenclature. The colored boxes indicate the different groupings of the seven structures printed in black, with the labels matching the color of the boxes. The hindbrain, midbrain, and forebrain nomenclature stems from the development of the vertebrate brain; these three areas differentiate early in embryonic development and later give rise to the structures listed in black. These three areas further subdivide into the telencephalon, diencephalon, mesencephalon, metencephalon, and myelencephalon at a later stage of development.

It is perhaps not surprising that the cerebellum's influence extends beyond that of movement and posture, given that it contains the greatest number of neurons of any structure in the brain. However, the exact role it plays in these higher functions is still a matter of further study.

Cerebral Hemispheres

The **cerebral hemispheres** are responsible for our cognitive abilities and conscious experience. They consist of the **cerebral cortex** and accompanying white matter ("cerebrum" in Latin) as well as the **subcortical** structures of the basal ganglia, amygdala, and hippocampal formation. The cerebral cortex is the largest and most visible part of the brain, retaining the Latin name (cerebrum) for "large brain" that Aristotle coined. It consists of two hemispheres (literally two half spheres) and gives the brain its characteristic gray and convoluted appearance; the folds and grooves of the cortex are called **gyri** and **sulci** (**gyrus** and **sulcus** if referring to just one), respectively.

The two cerebral hemispheres can be further subdivided into four lobes: the occipital, temporal, parietal, and frontal lobes. The **occipital lobe** is responsible for vision, as is much of the temporal lobe.



The four lobes of the brain and the cerebellum. [Image: MIT OpenCourseWare, https://goo.gl/RwUEVt, CC BY-NC-SA 2.0, https://goo.gl/Toc0ZF]

The **temporal lobe** is also involved in auditory processing, memory, and multisensory integration (e.g., the convergence of vision and audition). The **parietal lobe** houses the **somatosensory (body sensations) cortex** and structures involved in visual attention, as well as multisensory convergence zones. The **frontal lobe** houses the **motor cortex** and structures involved in motor planning, language, judgment, and decision-making. Not surprisingly then, the frontal lobe is proportionally larger in humans than in any other animal.

The subcortical structures are so named because they reside beneath the cortex. The **basal ganglia** are critical to voluntary movement and as such make contact with the cortex, the thalamus, and the brain stem. The amygdala and hippocampal formation are part of the **limbic system**, which also includes some cortical structures. The limbic system plays an important role in emotion and, in particular, in aversion and gratification.

A Brain Divided

The two cerebral hemispheres are connected by a dense bundle of white matter tracts called the corpus callosum. Some functions are replicated in the two hemispheres. For example, both hemispheres are responsible for sensory and motor function, although the sensory and motor cortices have a **contralateral** (or opposite-side) representation; that is, the left cerebral hemisphere is responsible for movements and sensations on the right side of the body and the right cerebral hemisphere is responsible for movements and sensations on the left side of the body. Other functions are **lateralized**; that is, they reside primarily in one hemisphere or the other. For example, for right-handed and the majority of left-handed individuals, the left hemisphere is most responsible for language.

There are some people whose two hemispheres are not connected, either because the corpus callosum was surgically severed (**callosotomy**) or due to a genetic abnormality. These **split- brain patients** have helped us understand the functioning of the two hemispheres. First, because of the contralateral representation of sensory information, if an object is placed in only the left or only the right **visual hemifield**, then only the right or left hemisphere, respectively, of the split-brain patient will see it. In essence, it is as though the person has two brains in his or her head, each seeing half the world. Interestingly, because language is very often localized in the left hemisphere, if we show the right hemisphere a picture and ask the patient what she saw, she will say she didn't see anything (because only the left hemisphere can speak and it didn't see anything). However, we know that the right hemisphere sees the picture because if the patient is asked to press a button whenever she sees the image, the left hand (which is controlled by the right hemisphere) will respond despite the left hemisphere's denial that anything was there. There are also some advantages to having disconnected hemispheres. Unlike those with a fully functional corpus callosum, a split-brain patient can simultaneously search for something in his right and left visual fields (Luck, Hillyard, Mangun, & Gazzaniga, 1989) and can do the equivalent of rubbing his stomach and patting his head at the same time (Franz, Eliason, Ivry, & Gazzaniga, 1996). In other words, they exhibit less competition between the hemispheres.

Gray Versus White Matter

The cerebral hemispheres contain both grey and white matter, so called because they appear grayish and whitish in dissections or in an MRI (magnetic resonance imaging; see, "Studying the Human Brain"). The **gray matter** is composed of the neuronal cell bodies (see module, "Neurons"). The cell bodies (or soma) contain the genes of the cell and are responsible for metabolism (keeping the cell alive) and synthesizing proteins. In this way, the cell body is the workhorse of the cell. The **white matter** is composed of the axons of the neurons, and, in particular, axons that are covered with a sheath of **myelin** (fatty support cells that are whitish in color). Axons conduct the electrical signals from the cell and are, therefore, critical to cell communication. People use the expression "use your gray matter" when they want a person to think harder. The "gray matter" in this expression is probably a reference to the cerebral hemispheres more generally; the gray cortical sheet (the convoluted surface of the cortex) being the most visible. However, both the gray matter and white matter are critical to proper functioning of the mind. Losses of either result in deficits in language, memory, reasoning, and other mental functions. See Figure 3 for MRI slices showing both the inner white matter that connects the cell bodies in the gray cortical sheet.

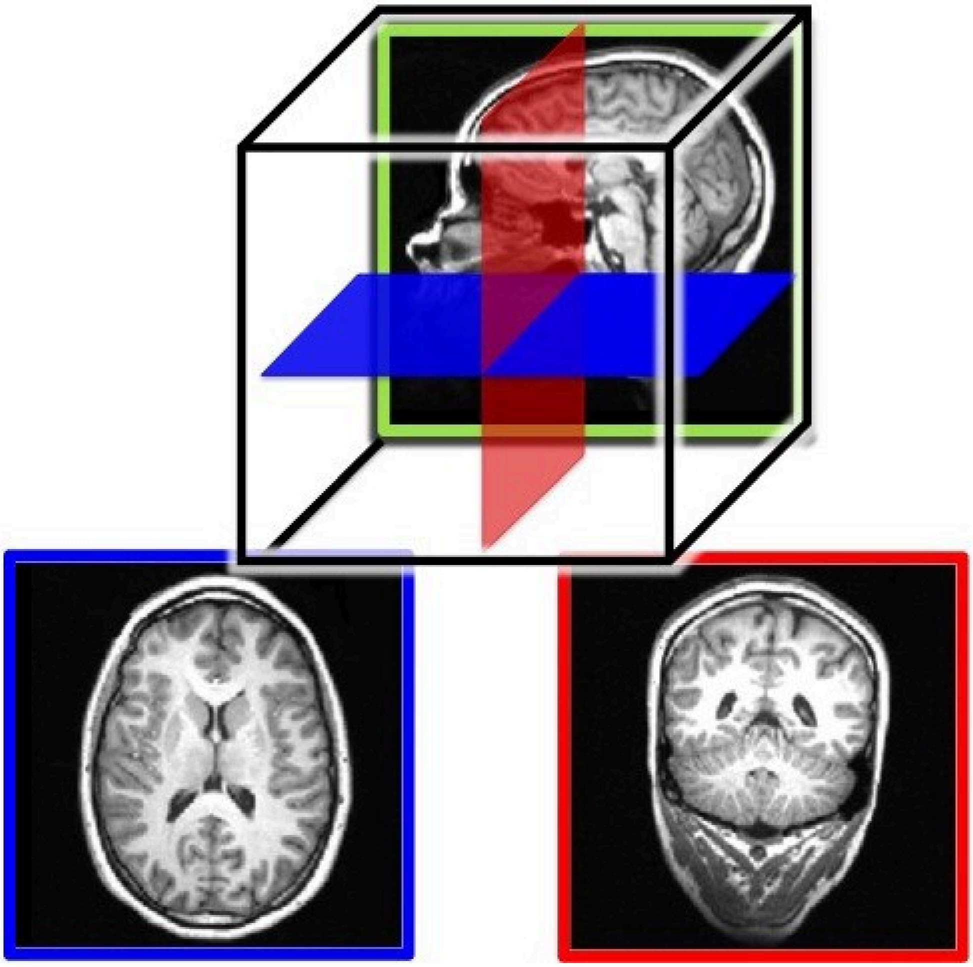


Figure 3. MRI slices of the human brain. Both the outer gray matter and inner white matter are visible in each image. The brain is a three-dimensional (3-D) structure, but an image is two-dimensional (2-D). Here, we show example slices of the three possible 2-D cuts through the brain: a saggital slice (top image), a horizontal slice (bottom left), which is also know as a transverse or axial slice, and a coronal slice (bottom right). The bottom two images are color coded to match the illustration of the relative orientations of the three slices in the top image.

Studying the Human Brain

How do we know what the brain does? We have gathered knowledge about the functions of the brain from many different methods. Each method is useful for answering distinct types of questions, but the strongest evidence for a specific role or function of a particular brain area is **converging evidence**; that is, similar findings reported from multiple studies using different methods.

One of the first organized attempts to study the functions of the brain was **phrenology**, a popular field of study in the first half of the 19th century. Phrenologists assumed that various features of the brain, such as its uneven surface, are reflected on the skull; therefore, they attempted to correlate bumps and indentations of the skull with specific functions of the brain. Forexample, they would claim that a very artistic person has ridges on the head that vary in size and location from those of someone who is very good at spatial reasoning. Although the assumption that the skull reflects the underlying brain structure has been proven wrong, phrenology nonetheless significantly impacted current-day neuroscience and its thinking about the functions of the brain. That is, different parts of the brain are devoted to very specific functions that can be identified through scientific inquiry.

Neuroanatomy

Dissection of the brain, in either animals or cadavers, has been a critical tool of neuroscientists since 340 BC when Aristotle first published his dissections. Since then this method has advanced considerably with the discovery of various staining techniques that can highlight particular cells. Because the brain can be sliced very thinly, examined under the microscope, and particular cells highlighted, this method is especially useful for studying specific groups of neurons or small brain structures; that is, it has a very high **spatial resolution**. Dissections allow scientists to study changes in the brain that occur due to various diseases or experiences (e.g., exposure to drugs or brain injuries).

Virtual dissection studies with living humans are also conducted. Here, the brain is imaged using computerized axial tomography (CAT) or MRI scanners; they reveal with very high precision the various structures in the brain and can help detect changes in gray or white matter. These changes in the brain can then be correlated with behavior, such as performance on memory tests, and, therefore, implicate specific brain areas in certain cognitive functions.

Changing the Brain

Some researchers induce **lesions** or **ablate** (i.e., remove) parts of the brain in animals. If the animal's behavior changes after the lesion, we can infer that the removed structure is important for that behavior. Lesions of human brains are studied in patient populations only; that is, patients who have lost a brain region due to a stroke or other injury, or who have had surgical removal of a structure to treat a particular disease (e.g., a callosotomy to control epilepsy, as in split-brain patients). From such **case studies**, we can infer brain function by measuring changes in the behavior of the patients before and after the lesion.

Because the brain works by generating electrical signals, it is also possible to change brain function with electrical stimulation. **Transcranial magnetic stimulation (TMS)** refers to a technique whereby a brief magnetic pulse is applied to the head that temporarily induces a weak electrical current in the brain. Although effects of TMS are sometimes referred to as temporary virtual lesions, it is more appropriate to describe the induced electricity as interference with neurons' normal communication with each other. TMS allows very precise study of when events in the brain happen so it has a good **temporal resolution**, but its application is limited only to the surface of the cortex and cannot extend to deep areas of the brain.

Transcranial direct current stimulation (tDCS) is similar to TMS except that it uses electrical current directly, rather than inducing it with magnetic pulses, by placing small electrodes on the skull. A brain area is stimulated by a low current (equivalent to an AA battery) for a more extended period of time than TMS. When used in combination with cognitive training, tDCS has been shown to improve performance of many cognitive functions such as mathematical ability, memory, attention, and coordination (e.g., Brasil-Neto, 2012; Feng, Bowden, & Kautz, 2013; Kuo & Nitsche, 2012).

Neuroimaging

Neuroimaging tools are used to study the brain in action; that is, when it is engaged in a specific task. **Positron emission tomography (PET)** records blood flow in the brain. The PET scanner detects the radioactive substance that is injected into the bloodstream of the participant just before or while he or she is performing some task (e.g., adding numbers). Because active neuron populations require metabolites, more blood and hence more radioactive substance flows into those regions. PET scanners detect the injected radioactive substance in specific brain regions, allowing researchers to infer that those areas were active during the task. **Functional magnetic resonance imaging (fMRI)** also relies on blood flow in the brain. This method, however, measures the changes in oxygen levels in the blood and does not require any substance to be injected into the participant. Both of these tools have good spatial resolution (although not as precise as dissection studies), but because it takes at least several seconds for the blood to arrive to the active areas of the brain, PET and fMRI have poor temporal resolution; that is, they do not tell us very precisely when the activity occurred.

A researcher looking at the areas of activation in the brain of a study participant who had an fMRI scan – areas of brain activation are determined by the amount of blood flow to a certain area – the more blood flow, the higher the activation of that area of the brain. [Image: National Institute of Mental Health, CC0 Public Domain, https://goo.gl/m25gce]

Electroencephalography (EEG), on the other hand, measures the electrical activity of the brain, and therefore, it has a much greater temporal resolution (millisecond precision rather than seconds) than PET or fMRI. Like tDCS, electrodes are placed on the participant's head when he or she is performing a task. In this case, however, many more electrodes are used, and they measure rather than produce activity. Because the electrical activity picked up at any particular electrode can be coming from anywhere in the brain, EEG has poor spatial resolution; that is, we have only a rough idea of which part of the brain generates the measured activity.

Diffuse optical imaging (DOI) can give researchers the best of both worlds: high spatial and temporal resolution, depending on how it is used. Here, one shines infrared light into the brain, and measures the light that comes back out. DOI relies on the fact that the properties of the light change when it passes through oxygenated blood, or when it encounters active neurons. Researchers can then infer from the properties of the collected light what regions in the brain were engaged by the task. When DOI is set up to detect changes in blood oxygen levels, the temporal resolution is low and comparable to PET or fMRI. However, when DOI is set up to directly detect active neurons, it has both high spatial and temporal resolution.

Because the spatial and temporal resolution of each tool varies, strongest evidence for what role a certain brain area serves comes from converging evidence. For example, we are more likely to believe that the hippocampal formation is involved in memory if multiple studies using a variety of tasks and different neuroimaging tools provide evidence for this hypothesis. The brain is a complex system, and only advances in brain research will show whether the brain can ever really understand itself.

Outside Resources

Video: Brain Bank at Harvard (National Geographic video)
http://video.nationalgeographic.com/video/science/health-human-body-sci/human-body/brain-bank-sci/

Video: Frontal Lobes and Behavior (video #25)
http://www.learner.org/resources/series142.html

Video: Organization and Evaluation of Human Brain Function video (video #1)
http://www.learner.org/resources/series142.html

Video: Videos of a split-brain patient
http://youtu.be/ZMLzP1VCANo

Video: Videos of a split-brain patient (video #5)
http://www.learner.org/resources/series142.html

Web: Atlas of the Human Brain: interactive demos and brain sections
http://www.thehumanbrain.info/

Web: Harvard University Human Brain Atlas: normal and diseased brain scans
http://www.med.harvard.edu/aanlib/home.html

Discussion Questions

1. In what ways does the segmentation of the brain into the brain stem, cerebellum, and cerebral hemispheres provide a natural division?
2. How has the study of split-brain patients been informative?
3. What is behind the expression "use your gray matter," and why is it not entirely accurate?
4. Why is converging evidence the best kind of evidence in the study of brain function?
5. If you were interested in whether a particular brain area was involved in a specific behavior, what neuroscience methods could you use?
6. If you were interested in the precise time in which a particular brain process occurred, which neuroscience methods could you use?

Vocabulary

Ablation

Surgical removal of brain tissue.

Axial plane

See “horizontal plane.”

Basal ganglia

Subcortical structures of the cerebral hemispheres involved in voluntary movement.

Brain stem

The “trunk” of the brain comprised of the medulla, pons, midbrain, and diencephalon.

Callosotomy

Surgical procedure in which the corpus callosum is severed (used to control severe epilepsy).

Case study

A thorough study of a patient (or a few patients) with naturally occurring lesions.

Cerebellum

The distinctive structure at the back of the brain, Latin for “small brain.”

Cerebral cortex

The outermost gray matter of the cerebrum; the distinctive convolutions characteristic of the mammalian brain.

Cerebral hemispheres

The cerebral cortex, underlying white matter, and subcortical structures.

Cerebrum

Usually refers to the cerebral cortex and associated white matter, but in some texts includes the subcortical structures.

Contralateral

Literally “opposite side”; used to refer to the fact that the two hemispheres of the brain process sensory information and motor commands for the opposite side of the body (e.g., the left hemisphere controls the right side of the body).

Converging evidence

Similar findings reported from multiple studies using different methods.

Coronal plane

A slice that runs from head to foot; brain slices in this plane are similar to slices of a loaf of bread, with the eyes being the front of the loaf.

Diffuse optical imaging (DOI)

A neuroimaging technique that infers brain activity by measuring changes in light as it is passed through the skull and surface of the brain.

Electroencephalography (EEG)

A neuroimaging technique that measures electrical brain activity via multiple electrodes on the scalp.

Frontal lobe

The front most (anterior) part of the cerebrum; anterior to the central sulcus and responsible for motor output and planning, language, judgment, and decision-making.

Functional magnetic resonance imaging (fMRI)

Functional magnetic resonance imaging (fMRI): A neuroimaging technique that infers brain activity by measuring changes in oxygen levels in the blood.

Gray matter

The outer grayish regions of the brain comprised of the neurons’ cell bodies.

Gyri

(plural) Folds between sulci in the cortex.

Gyrus

A fold between sulci in the cortex.

Horizontal plane

A slice that runs horizontally through a standing person (i.e., parallel to the floor); slices of brain in this plane divide the top and bottom parts of the brain; this plane is similar to slicing a hamburger bun.

Lateralized

To the side; used to refer to the fact that specific functions may reside primarily in one

hemisphere or the other (e.g., for the majority individuals, the left hemisphere is most responsible for language).

Lesion

A region in the brain that suffered damage through injury, disease, or medical intervention.

Limbic system

Includes the subcortical structures of the amygdala and hippocampal formation as well as some cortical structures; responsible for aversion and gratification.

Metabolite

A substance necessary for a living organism to maintain life.

Motor cortex

Region of the frontal lobe responsible for voluntary movement; the motor cortex has a contralateral representation of the human body.

Myelin

Fatty tissue, produced by glial cells (see module, "Neurons") that insulates the axons of the neurons; myelin is necessary for normal conduction of electrical impulses among neurons.

Nomenclature

Naming conventions.

Occipital lobe

The back most (posterior) part of the cerebrum; involved in vision.

Parietal lobe The part of the cerebrum between the frontal and occipital lobes; involved in bodily sensations, visual attention, and integrating the senses.

Phrenology

A now-discredited field of brain study, popular in the first half of the 19th century that correlated bumps and indentations of the skull with specific functions of the brain.

Positron emission tomography (PET)

A neuroimaging technique that measures brain activity by detecting the presence of a radioactive substance in the brain that is initially injected into the bloodstream and then pulled in by active brain tissue.

Sagittal plane

A slice that runs vertically from front to back; slices of brain in this plane divide the left and right side of the brain; this plane is similar to slicing a baked potato lengthwise.

Somatosensory (body sensations) cortex

The region of the parietal lobe responsible for bodily sensations; the somatosensory cortex has a contralateral representation of the human body.

Spatial resolution

A term that refers to how small the elements of an image are; high spatial resolution means the device or technique can resolve very small elements; in neuroscience it describes how small of a structure in the brain can be imaged.

Split-brain patient

A patient who has had most or all of his or her corpus callosum severed.

Subcortical

Structures that lie beneath the cerebral cortex, but above the brain stem.

Sulci

(plural) Grooves separating folds of the cortex.

Sulcus

A groove separating folds of the cortex.

Temporal lobe

The part of the cerebrum in front of (anterior to) the occipital lobe and below the lateral fissure; involved in vision, auditory processing, memory, and integrating vision and audition.

Temporal resolution

A term that refers to how small a unit of time can be measured; high temporal resolution means capable of resolving very small units of time; in neuroscience it describes how precisely in time a process can be measured in the brain.

Transcranial direct current stimulation (tDCS)

A neuroscience technique that passes mild electrical current directly through a brain area by placing small electrodes on the skull.

Transcranial magnetic stimulation (TMS)

A neuroscience technique whereby a brief magnetic pulse is applied to the head that temporarily induces a weak electrical current that interferes with ongoing activity.

Transverse plane

See “horizontal plane.”

Visual hemifield

The half of visual space (what we see) on one side of fixation (where we are looking); the left hemisphere is responsible for the right visual hemifield, and the right hemisphere is responsible for the left visual hemifield.

White matter

The inner whitish regions of the cerebrum comprised of the myelinated axons of neurons in the cerebral cortex.

References

Beck, D. M., & Kastner, S. (2009). Top-down and bottom-up mechanisms in biasing competition in the human brain. *Vision Research*, 49, 1154–1165.

Brasil-Neto, J. P. (2012). Learning, memory, and transcranial direct current stimulation. *Frontiers in Psychiatry*, 3(80). doi: 10.3389/fpsyt.2012.00080.

Feng, W. W., Bowden, M. G., & Kautz, S. (2013). Review of transcranial direct current stimulation in poststroke recovery. *Topics in Stroke Rehabilitation*, 20, 68–77.

Franz, E. A., Eliassen, J. C., Ivry, R. B., & Gazzaniga, M. S. (1996). Dissociation of spatial and temporal coupling in the bimanual movements of callosotomy patients. *Psychological Science*, 7, 306–310.

Kandal, E. R., Schwartz, J. H., & Jessell, T. M. (Eds.) (2000). *Principles of neural science* (Vol. 4). New York, NY: McGraw-Hill.

Kuo, M. F., & Nitsche, M. A. (2012). Effects of transcranial electrical stimulation on cognition. *Clinical EEG and Neuroscience*, 43, 192–199.

Luck, S. J., Hillyard, S. A., Mangun, G. R., & Gazzaniga, M. S. (1989). Independent hemispheric attentional systems mediate visual search in split-brain patients. *Nature*, 342, 543–545.

Swanson, L. (2000). What is the brain? *Trends in Neurosciences*, 23, 519–527.

NEURONS

Sharon Furtak

This module on the biological basis of behavior provides an overview of the basic structure of neurons and their means of communication. Neurons, cells in the central nervous system, receive information from our sensory systems (vision, audition, olfaction, gustation, and somatosensation) about the world around us; in turn, they plan and execute appropriate behavioral responses, including attending to a stimulus, learning new information, speaking, eating, mating, and evaluating potential threats. The goal of this module is to become familiar with the anatomical structure of neurons and to understand how neurons communicate by electrochemical signals to process sensory information and produce complex behaviors through networks of neurons. Having a basic knowledge of the fundamental structure and function of neurons is a necessary foundation as you move forward in the field of psychology.

Learning Objectives

- Differentiate the functional roles between the two main cell classes in the brain, neurons and glia.
- Describe how the forces of diffusion and electrostatic pressure work collectively to facilitate electrochemical communication.
- Define resting membrane potential, excitatory postsynaptic potentials, inhibitory postsynaptic potentials, and action potentials.
- Explain features of axonal and synaptic communication in neurons.

Introduction

Imagine trying to string words together into a meaningful sentence without knowing the meaning of each word or its function (i.e., Is it a verb, a noun, or an adjective?). In a similar fashion, to appreciate how groups of cells work together in a meaningful way in the brain as a whole, we must first understand how individual cells in the brain function. Much like words, brain cells, called *neurons*, have an underlying structure that provides the foundation for their functional purpose. Have you ever seen a neuron? Did you know that the basic structure of a neuron is similar whether it is from the brain of a rat or a human? How do the billions of neurons in our brain allow us to do all the fun things we enjoy, such as texting a friend, cheering on our favorite sports team, or laughing?

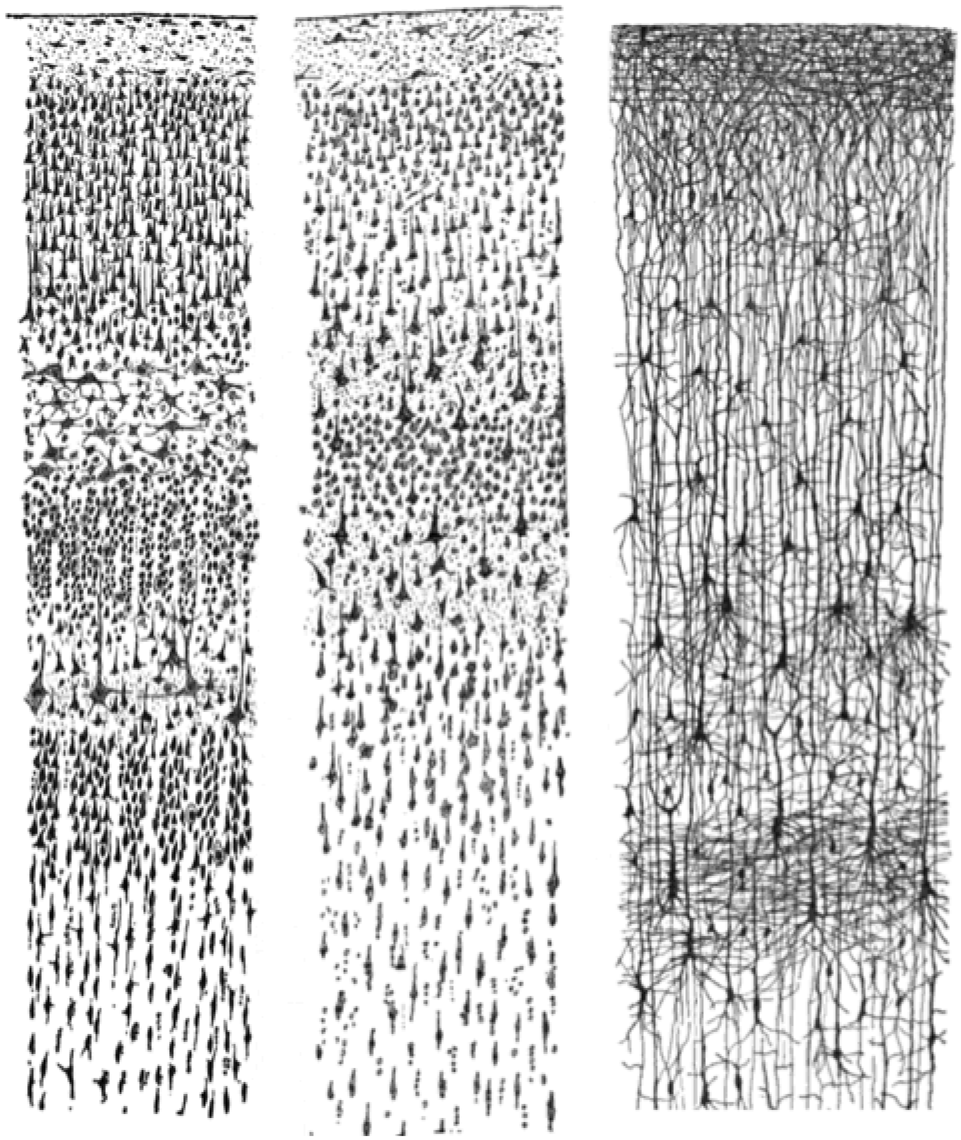


Figure 1. Three drawings by Santiago Ramón y Cajal, taken from "Comparative study of the sensory areas of the human cortex", pages 314, 361, and 363. Left: Nissl-stained visual cortex of a human adult. Middle: Nissl-stained motor cortex of a human adult. Right: Golgi-stained cortex of a 1 1/2 month old infant. [Image: Santiago Ramon y Cajal, https://goo.gl/zOb2l1, CC0 Public Domain, https://goo.gl/m25gce]

Our journey in answering these questions begins more than 100 years ago with a scientist named Santiago Ramón y Cajal. Ramón y Cajal (1911) boldly concluded that discrete individual neurons are the structural and functional units of the nervous system. He based his conclusion on the numerous drawings he made of Golgi-stained tissue, a stain named after the scientist who discovered it, Camillo Golgi. Scientists use several types of stains to visualize cells. Each stain works in a unique way, which causes them to look differently when viewed under a microscope. For example, a very common Nissl stain labels only the main part of the cell (i.e., the cell body; see left and middle panels of Figure 1). In contrast, a Golgi stain fills the cell body and all the processes that extend outward from it (see right panel of Figure 1). A more notable characteristic of a Golgi stain is that it only stains approximately 1– 2% of neurons (Pasternak & Woolsey, 1975; Smit & Colon, 1969), permitting the observer to distinguish one cell from another. These qualities allowed Cajal to examine the full anatomical structure of individual neurons for the first time. This significantly enhanced our appreciation of the intricate networks their processes form. Based on his observation of Golgi-stained tissue, Cajal suggested neurons were distinguishable processing units rather than continuous structures. This was in opposition to the dominant theory at the time proposed by Joseph von Gerlach, which stated that the nervous system was composed of a continuous network of nerves (for review see, Lopez-Munoz, Boya, & Alamo, 2006). Camillo Golgi himself had been an avid supporter of Gerlach's theory. Despite their scientific disagreement, Cajal and Camillo Golgi shared the Nobel Prize for Medicine in 1906 for their combined contribution to the advancement of science and our understanding of the structure of the nervous system. This seminal work paved the pathway to our current understanding of the basic structure of the nervous system described in this module (for review see: De Carlos & Borrell, 2007; Grant, 2007).

Before moving forward, there will be an introduction to some basic terminology regarding the anatomy of neurons in the section called "The Structure of the Neuron," below. Once we have reviewed this fundamental framework, the remainder of the module will focus on the electrochemical signals through which neurons communicate. While the electrochemical process might sound intimidating, it will be broken down into digestible sections. The first subsection, "Resting Membrane Potential," describes what occurs in a neuron at rest, when it is theoretically not receiving or sending signals. Building upon this knowledge, we will examine the electrical conductance that occurs within a single neuron when it receives signals. Finally, the module will conclude with a description of the electrical conductance, which results in communication between neurons through a release of chemicals. At the end of the module, you should have a broad concept of how each cell and large groups of cells send and receive information by electrical and chemical signals.

A note of encouragement: This module introduces a vast amount of technical terminology that at times may feel overwhelming. Do not get discouraged or bogged down in the details. Utilize the glossary at the end of the module as a quick reference guide; tab the glossary page so that you can easily refer to it while reading the module. The glossary contains all terms in bold typing. Terms in italics are additional significant terms that may appear in other modules but are not contained within the glossary. On your first read of this module, I suggest focusing on the broader concepts and functional aspects of the terms instead of trying to commit all the terminology to memory. That is right, I said read first! I highly suggest reading this module at least twice, once prior to *and* again following the course lecture on this material. Repetition is the best way to gain clarity and commit to memory the challenging concepts and detailed vocabulary presented here.

The Structure of the Neuron

Basic Nomenclature

There are approximately 100 billion neurons in the human brain (Williams & Herrup, 1988). Each neuron has three main components: dendrites, the soma, and the axon (see Figure 2). **Dendrites** are processes that extend outward from the **soma**, or cell body, of a neuron and typically branch several times. Dendrites receive information from thousands of other neurons and are the main source of input of the neuron. The **nucleus**, which is located within the soma, contains genetic information, directs protein synthesis, and supplies the energy and the resources the neuron needs to function. The main source of output of the neuron is the **axon**. The axon is a process that extends far away from the soma and carries an important signal called an action potential to another neuron. The place at which the axon of one neuron comes in close contact to the dendrite of another neuron is a **synapse** (see Figures 2–3). Typically, the axon of a neuron is covered with an insulating substance called a **myelin sheath** that allows the signal and communication of one neuron to travel rapidly to another neuron.

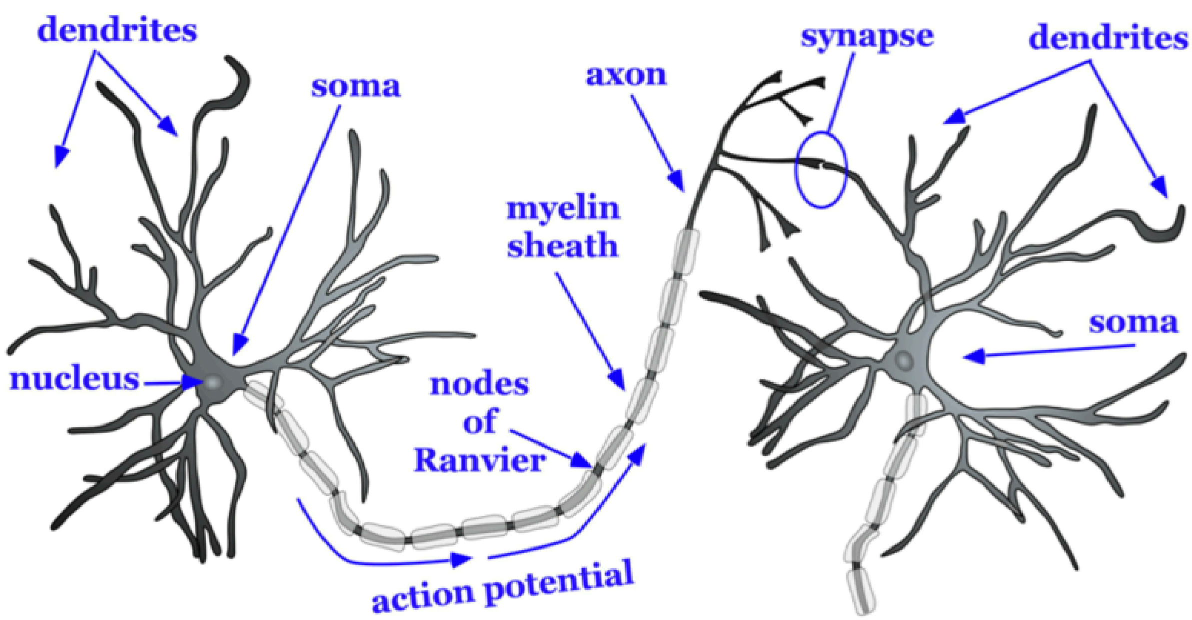


Figure 2. Basic structure of a neuron.

The axon splits many times, so that it can communicate, or synapse, with several other neurons (see Figure 2). At the end of the axon is a **terminal button**, which forms synapses with **spines**, or protrusions, on the dendrites of neurons. Synapsesform between the *presynaptic* terminal button (neuron sending the signal) and the *postsynaptic* membrane (neuron receiving the signal; see Figure 3). Here we will focus specifically on synapses between the terminal button of an axon and a dendritic spine; however, synapses can also form between the terminal button of an axon and the soma or the axon of another neuron.

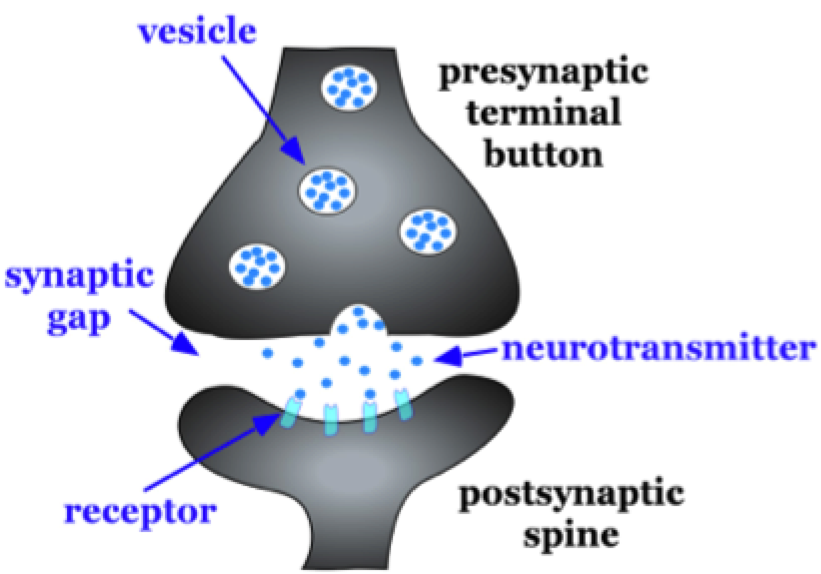
A very small space called a **synaptic gap** or a synaptic cleft, approximately 5 nm (nanometers), exists between the presynaptic terminal button and the postsynaptic dendritic spine. To give you a better idea of the size, a dime is 1.35 mm (millimeter) thick. There are 1,350,000 nm in the thickness of a dime. In the presynaptic terminal button, there are **synaptic vesicles** that package together groups of chemicals called **neurotransmitters** (see Figure 3).

Neurotransmitters are released from the presynaptic terminal button, travel across the synaptic gap, and activate ion channels on the postsynaptic spine by binding to *receptor sites*. We will discuss the role of receptors in more detail later in the module.

Types of Cells in the Brain

Not all neurons are created equal! There are neurons that help us receive information about the world around us, *sensory* neurons. There are *motor* neurons that allow us to initiate movement and behavior, ultimately allowing us to interact with the world around us. Finally, there are *interneurons*, which process the sensory input from our environment into meaningful representations, plan the appropriate behavioral response, and connect to the motor neurons to execute these behavioral plans.

There are three main categories of neurons, each defined by its specific structure. The structures of these three different types of neurons support their unique functions. *Unipolar neurons* are structured in such a way that is ideal for relaying information forward, so they have one neurite (axon) and no dendrites. They are involved in transmission of physiological information from the body's periphery such as communicating body temperature through the spinal cord up to the brain. *Bipolar neurons* are involved in sensory perception such as perception of light in the retina of the eye. They have one axon and one dendrite which help acquire and pass sensory information to various centers in the brain. Finally, *multipolarneurons* are the most common and they communicate sensory and motor information in the brain. For example, their firing causes muscles in the body to contract. Multipolar neurons have one axon and many dendrites which allows them to communicate with other neurons. One of the most prominent neurons is a pyramidal neuron, which falls under the multipolar category.



It gets its name from the triangular or pyramidal shape of its soma (for examples see, Furtak, Moyer, & Brown, 2007). In addition to neurons, there is a second type of cell in the brain called *glia* cells. Glia cells have several functions, just a few of which we will discuss here. One type of glia cell, called *oligodendroglia*, forms the Figure 3. Characteristics of a synapse.

myelin sheaths mentioned above (Simons & Trotter, 2007; see Fig. 2). Oligodendroglia wrap their dendritic processes around the axons of neurons many times to form the myelin sheath. One cell will form the myelin sheath on several axons. Other types of glia cells, such as *microglia* and *astrocytes*, digest debris of dead neurons, carry nutritional support from blood vessels to the neurons, and help to regulate the ionic composition of the extracellular fluid. While glial cells play a vital role in neuronal support, they do not participate in the communication between cells in the same fashion as neurons do.

Communication Within and Between Neurons

Thus far, we have described the main characteristics of neurons, including how their processes come in close contact with one another to form *synapses*. In this section, we consider the conduction of communication within a neuron and how this signal is transmitted to the next neuron. There are two stages of this electrochemical action in neurons. The first stage is the electrical conduction of dendritic input to the initiation of an action potential within a neuron. The second stage is a chemical transmission across the synaptic gap between the presynaptic neuron and the postsynaptic neuron of the synapse. To understand these processes, we first need to consider what occurs within a neuron when it is at a steady state, called *resting membrane potential.*

Resting Membrane Potential

The intracellular (inside the cell) fluid and extracellular (outside the cell) fluid of neurons is composed of a combination of ions (electrically charged molecules; see Figure 4). Cations are positively charged ions, and anions are negatively charged ions. The composition of intracellular and extracellular fluid is similar to salt water, containing sodium (Na+), potassium (K+), chloride (Cl−), and anions (A−).

The **cell membrane**, which is composed of a lipid bilayer of fat molecules, separates the cell from the surrounding extracellular fluid. There are proteins that span the membrane, forming **ion channels** that allow particular ions to pass between the intracellular and extracellular fluid (see Figure 4). These ions are in different concentrations inside the cell relative to outside the cell, and the ions have different electrical charges. Due to this difference in concentration and charge, two forces act to maintain a steady state when the cell is at rest: diffusion and electrostatic pressure. **Diffusion** is the force on molecules to move from areas of high concentration to areas of low concentration. **Electrostatic pressure** is the force on two ions with similar charge to repel each other and the force of two ions with opposite charge to attract to one another. Remember the saying, opposites attract?

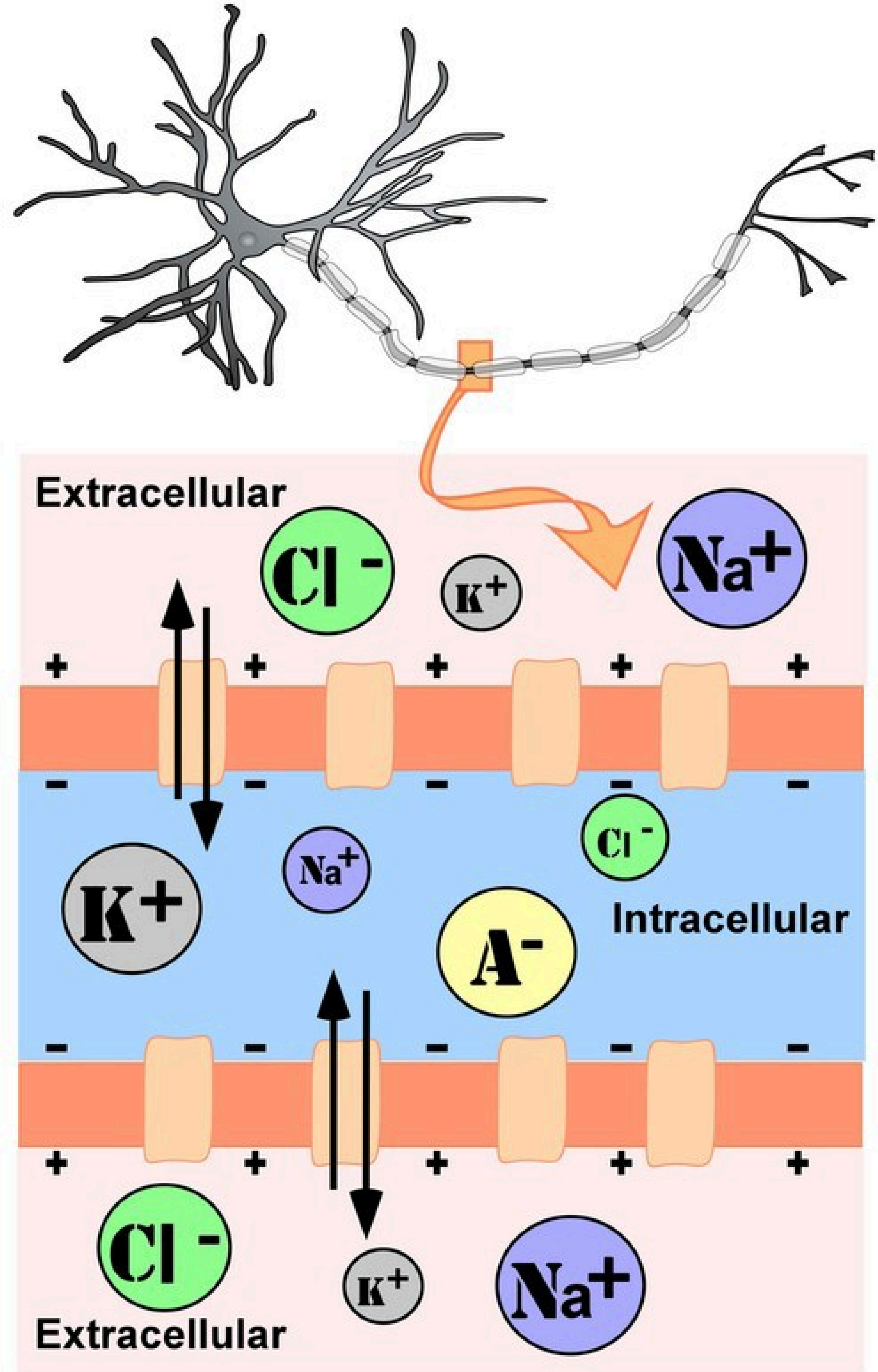


Figure 4. Representation of ion concentrations inside (intracellular) and outside (extracellular) a neuron in the unmylenated segment of the axon.

Regardless of the ion, there exists a membrane potential at which the force of diffusion is equal and opposite of the force of electrostatic pressure. This voltage, called the *equilibrium potential*, is the voltage at which no ions flow. Since there are several ions that can permeate the cell's membrane, the baseline electrical charge inside the cell compared with outside the cell, referred to as **resting membrane potential**, is based on the collective drive of force on several ions. Relative to the extracellular fluid, the membrane potential of a neuron at rest is negatively charged at approximately -70 mV (see Figure 5). These are very small voltages compared with the voltages of batteries and electrical outlets, which we encounter daily, that range from 1.5 to 240 V.

Let us see how these two forces, diffusion and electrostatic pressure, act on the four groups of ions mentioned above.

Anions (A-): Anions are highly concentrated inside the cell and contribute to the negative charge of the resting membrane potential. Diffusion and electrostatic pressure are not forces that determine A– concentration because A– is impermeable to the cell membrane. There are no ion channels that allow for A– to move between the intracellular and extracellular fluid.

Potassium (K+): The cell membrane is very permeable to potassium at rest, but potassium remains in high concentrations inside the cell. Diffusion pushes K+ outside the cell because it is in high concentration inside the cell. However, electrostatic pressure pushes K+ inside the cell because the positive charge of K+ is attracted to the negative charge inside the cell. In combination, these forces oppose one another with respect to K+.

Chloride (Cl-): The cell membrane is also very permeable to chloride at rest, but chloride remains in high concentration outside the cell. Diffusion pushes Cl– inside the cell because it is in high concentration outside the cell. However, electrostatic pressure pushes Cl– outside the cell because the negative charge of Cl– is attracted to the positive charge outside the cell. Similar to K+, these forces oppose one another with respect to Cl–.

Sodium (Na+): The cell membrane is not very permeable to sodium at rest. Diffusion pushes Na+ inside the cell because it is in high concentration outside the cell. Electrostatic pressure also pushes Na+ inside the cell because the positive charge of Na+ is attracted to the negative charge inside the cell. Both of these forces push Na+ inside the cell; however, Na+ cannot permeate the cell membrane and remains in high concentration outside the cell. The small amounts of Na+ inside the cell are removed by a **sodium-potassium pump**, which uses the neuron's energy (adenosine triphosphate, ATP) to pump 3 Na+ ions out of the cell in exchange for bringing 2 K+ ions inside the cell.

Action Potential

Now that we have considered what occurs in a neuron at rest, let us consider what changes occur to the resting membrane potential when a neuron receives input, or information, from the presynaptic terminal button of another neuron. Our understanding of the electrical signals or potentials that occurs within a neuron results from the seminal work of Hodgkin and Huxleythat began in the 1930s at a well-known marine biology lab in Woodshole, MA. Their work, for which they won the Nobel Prize in Medicine in 1963, has resulted in the general model of electrochemical transduction that is described here (Hodgkin & Huxley, 1952). Hodgkin and Huxley studied a very large axon in the squid, a common species for that region of the United States. The giant axon of the squid is roughly 100 times larger than that of axons in the mammalian brain, making it much easier to see. Activation of the giant axon is responsible for a withdrawal response the squid uses when trying to escape from a predator, such as large fish, birds, sharks, and even humans. When was the last time you had calamari? The large axon size is no mistake in nature's design; it allows for very rapid transmission of an electrical signal, enabling a swift escape motion in the squid from its predators.

While studying this species, Hodgkin and Huxley noticed that if they applied an electrical stimulus to the axon, a large, transient electrical current conducted down the axon. This transient electrical current is known as an **action potential** (see Figure 5). An action potential is an all-or-nothing response that occurs when there is a change in the charge or potential of the cell from its resting membrane potential (-70 mV) in a more positive direction, which is a *depolarization* (see Figure 5). What is meant by an all-or-nothing response? I find that this concept is best compared to the binary code used in computers, where there are only two possibilities, 0 or 1. There is no halfway or in-between these possible values; for example, 0.5 does not exist in binary code. There are only two possibilities, either the value of 0 or the value of 1. The action potential is the same in this respect. There is no halfway; it occurs, or it does not occur. There is a specific membrane potential that the neuron must reach to initiate an action potential. This membrane potential, called the **threshold of excitation**, is typically around -50 mV. If the threshold of excitation is reached, then an action potential is triggered.

How is an action potential initiated? At any one time, each neuron is receiving hundreds of inputs from the cells that synapse with it. These inputs can cause several types of fluctuations in the neuron's membrane potentials (see Figure 5):

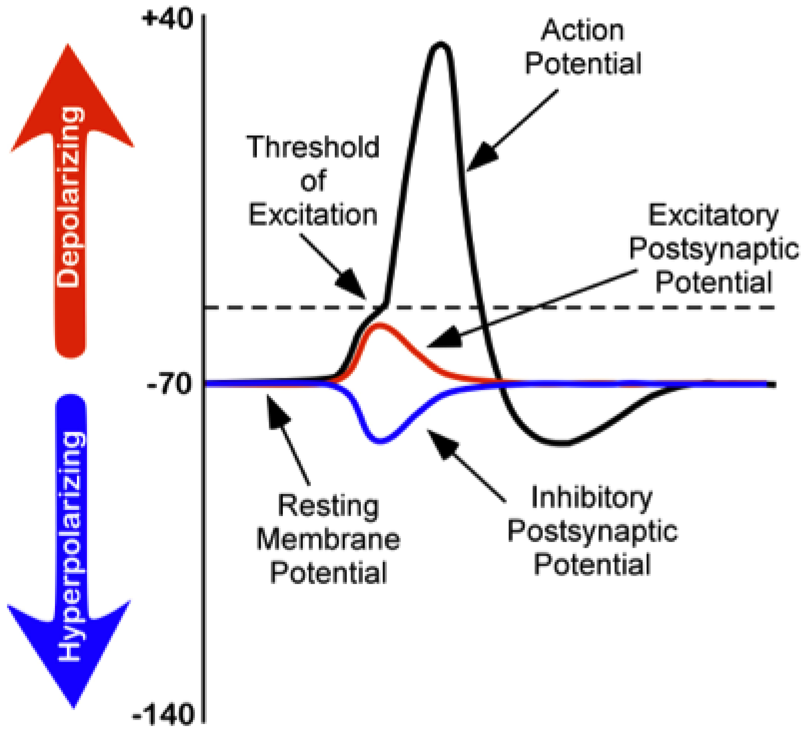


Figure 5. Changes in membrane potentials of neurons.

excitatory postsynaptic potentials (EPSPs): a *depolarizing* current that causes the membrane potential to become more positive and closer to the threshold of excitation; or **inhibitory postsynaptic potentials** (IPSPs): a *hyperpolarizing* current that causes the membrane potential to become more negative and further away from the threshold of excitation.

These postsynaptic potentials, EPSPs and IPSPs, *summate* or add together in time and space. The IPSPs make the membrane potential more negative, but how much so depends on the strength of the IPSPs. The EPSPs make the membrane potential more positive; again, how much more positive depends on the strength of the EPSPs. If you have two small EPSPs at the same time and the same synapse then the result will be a large EPSP. If you have a small EPSP and a small IPSP at the same time and the same synapse then they will cancel each other out. Unlike the action potential, which is an all-or-nothing response, IPSPs and EPSPs are smaller and *graded* potentials, varying in strength. The change in voltage during an action potential is approximately 100 mV. In comparison, EPSPs and IPSPs are changes in voltage between 0.1 to 40 mV. They can be different strengths, or gradients, and they are measured by how far the membrane potentials diverge from the resting membrane potential.

I know the concept of summation can be confusing. As a child, I use to play a game in elementary school with a very large parachute where you would try to knock balls out of the center of the parachute. This game illustrates the properties of summation rather well. In this game, a group of children next to one another would work in unison to produce waves in the parachute in order to cause a wave large enough to knock the ball out of the parachute. The children would initiate the waves at the same time and in the same direction. The additive result was a larger wave in the parachute, and the balls would bounce out of the parachute.

However, if the waves they initiated occurred in the opposite direction or with the wrong timing, the waves would cancel each other out, and the balls would remain in the center of the parachute. EPSPs or IPSPs in a neuron work in the same fashion to the properties of the waves in the parachute; they either add or cancel each other out. If you have two EPSPs, then they sum together and become a larger depolarization. Similarly, if two IPSPs come into the cell at the same time, they will sum and become a larger hyperpolarization in membrane potential. However, if two inputs were opposing one another, moving the potential in opposite directions, such as an EPSP and an IPSP, their sum would cancel each other out.

At any moment in time, each cell is receiving mixed messages, both EPSPs and IPSPs. If the summation of EPSPs is strong enough to depolarize the membrane potential to reach the threshold of excitation, then it initiates an action potential. The action potential then travels down the axon, away from the soma, until it reaches the ends of the axon (the terminal button). In the terminal button, the action potential triggers the release of neurotransmitters from the presynaptic terminal button into the synaptic gap. These neurotransmitters, in turn, cause EPSPs and IPSPs in the postsynaptic dendritic spines of the next cell (see Figures 4 & 6). The neurotransmitter released from the presynaptic terminal button binds with **ionotropic receptors** in a lock-and-key fashion on the post-synaptic dendritic spine. Ionotropic receptors are receptors on ion channels that open, allowing some ions to enter or exit the cell, depending upon the presence of a particular neurotransmitter. The type of neurotransmitter and the permeability of the ion channel it activates will determine if an EPSP or IPSP occurs in the dendrite of the post-synaptic cell. These EPSPs and IPSPs summate in the same fashion described above and the entire process occurs again in another cell.

The Change in Membrane Potential During an Action Potential

We discussed previously which ions are involved in maintaining the resting membrane potential. Not surprisingly, some of these same ions are involved in the action potential. When the cell becomes depolarized (more positively charged) and reaches the threshold of excitation, this causes a voltage-dependent Na+ channel to open. A voltage-dependent ion channel is a channel that opens, allowing some ions to enter or exit the cell, depending upon when the cell reaches a particular membrane potential. When the cell is at resting membrane potential, these voltage-dependent Na+ channels are closed. As we learned earlier, both diffusion and electrostatic pressure are pushing Na+ inside the cells. However, Na+ cannot permeate the membrane when the cell is at rest. Now that these channels are open, Na+ rushes inside the cell, causing the cell to become very positively charged relative to the outside of the cell. This is responsible for the rising or depolarizing phase of the action potential (see Figure 5). The inside of the cell becomes very positively charged, +40mV. At this point, the Na+ channels close and become *refractory*. This means the Na+ channels cannot reopen again until after the cell returns to the resting membrane potential. Thus, a new action potential cannot occur during the refractory period. The refractory period also ensures the action potential can only move in one direction down the axon, away from the soma. As the cell becomes more depolarized, a second type of voltage-dependent channel opens; this channel is permeable to K+. With the cell very positive relative to the outside of the cell (depolarized) and the high concentration of K+ within the cell, both the force of diffusion and the force of electrostatic pressure drive K+ outside of the cell. The movement of K+ out of the cell causes the cell potential to return back to the resting membrane potential, the falling or hyperpolarizing phase of the action potential (see

Figure 5). A short hyperpolarization occurs partially due to the gradual closing of the K+ channels. With the Na+ closed, electrostatic pressure continues to push K+ out of the cell. In addition, the sodium-potassium pump is pushing Na+ out of the cell. The cell returns to the resting membrane potential, and the excess extracellular K+ diffuses away. This exchange of Na+ and K+ ions happens very rapidly, in less than 1 msec. The action potential occurs in a wave-like motion down the axon until it reaches the terminal button. Only the ion channels in very close proximity to the action potential are affected.

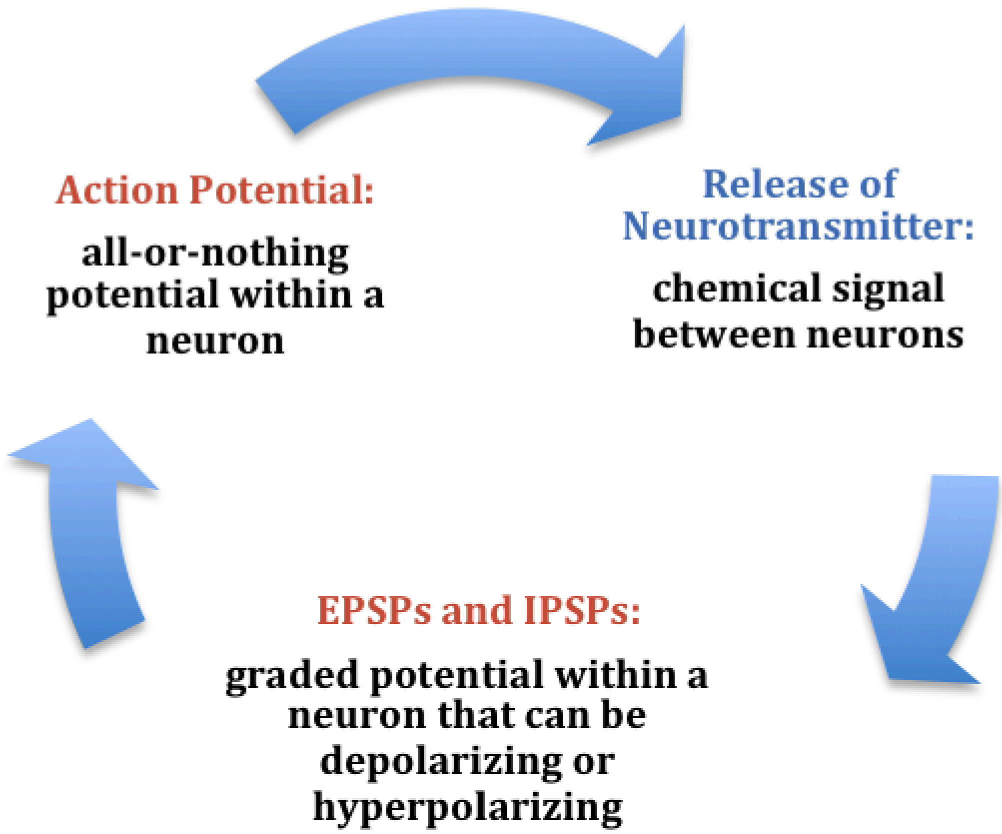


Figure 6. Summary of the electrochemical communication within and between neurons.

Earlier you learned that axons are covered in myelin. Let us consider how myelin speeds up the process of the action potential. There are gaps in the myelin sheaths called *nodes of Ranvier*. The myelin insulates the axon and does not allow any fluid to exist between the myelin and cell membrane. Under the myelin, when the Na+ and K+ channels open, no ions flow between the intracellular and extracellular fluid. This saves the cell from having to expend the energy necessary to rectify or regain the resting membrane potential. (Remember, the pumps need ATP to run.) Under the myelin, the action potential degrades some, but is still large enough in potential to trigger a new action potential at the next node of Ranvier. Thus, the action potential actively jumps from node to node; this process is known as *saltatory conduction*.

In the presynaptic terminal button, the action potential triggers the release of neurotransmitters (see Figure 3). Neurotransmitters cross the synaptic gap and open subtypes of receptors in a lock-and-key fashion (see Figure 3). Depending on the type of neurotransmitter, an EPSP or IPSP occurs in the dendrite of the post-synaptic cell. Neurotransmitters that open Na+ or calcium (Ca+) channels cause an EPSP; an example is the NMDA receptors, which are activated by glutamate (the main excitatory neurotransmitter in the brain). In contrast, neurotransmitters that open Cl- or K+ channels cause an IPSP; an example is gamma-aminobutryric acid (GABA) receptors, which are activated by GABA, the main inhibitory neurotransmitter in the brain. Once the EPSPs and IPSPs occur in the postsynaptic site, the process of communication within and between neurons cycles on (see Figure 6). A neurotransmitter that does not bind to receptors is broken down and inactivated by enzymes or glial cells, or it is taken back into the presynaptic terminal button in a process called *reuptake*, which will be discussed further in the module on psychopharmacology.

Outside Resources

Video Series:

Neurobiology/Biopsychology – Tutorial animations of action potentials, resting membrane potentials, and synaptic transmission.
http://www.sumanasinc.com/webcontent/animations/neurobiology.html

Video: An animation of an action potential

http://www.youtube.com/watch?v=ifD1YG07fB8

Video: An animation of neurotransmitter actions at the synapse

http://www.youtube.com/watch?v=90cj4NX87Yk

Video: An interactive animation that allows students to observe the results of manipulations to excitatory and inhibitory post-synaptic potentials. Also includes animations and explanations of transmission and neural circuits.
https://apps.childrenshospital.org/clinical/animation/neuron/

Video: Another animation of an action potential

http://www.youtube.com/watch?v=-SHBnExxub8&list=PL968773A54EF13D21

Video: Another animation of neurotransmitter actions at the synapse

http://www.youtube.com/watch?v=LT3VKAr4roo&list=PL968773A54EF13D21

Video: Domino Action Potential: This hands-on activity helps students grasp the complex process of the action potential, as well as become familiar with the characteristics of transmission (e.g., all-or-none response, refractory period). https://www.youtube.com/watch?v=xzvZ11EutBY

Video: For perspective on techniques in neuroscience to look inside the brain
https://www.youtube.com/watch?v=s4smjT1qwZU

Video: The Behaving Brain is the third program in the DISCOVERING PSYCHOLOGY series. This program looks at the structure and composition of the human brain: how neurons function, how information is collected and transmitted, and how chemical reactions relate to thought and behavior.

http://www.learner.org/series/discoveringpsychology/03/e03expand.html

Video: You can grow new brain cells. Here\'s how. -Can we, as adults, grow new neurons?

Neuroscientist Sandrine Thuret says that we can, and she offers research and practical advice on how we can help our brains better perform neurogenesis—improving mood, increasing memory formation and preventing the decline associated with aging along the way.

https://www.youtube.com/watch?v=B_tjKYvEziI

Web: For more information on the Nobel Prize shared by Ramón y Cajal and Golgi

http://www.nobelprize.org/nobel_prizes/medicine/laureates/1906/

Discussion Questions

1. What structures of a neuron are the main input and output of that neuron?
2. What does the statement mean that communication within and between cells is an electrochemical process?
3. How does myelin increase speed and efficiency of the action potential?
4. How does diffusion and electrostatic pressure contribute to the resting membrane potential and the action potential?
5. Describe the cycle of communication within and between neurons.

Vocabulary

Action potential
A transient all-or-nothing electrical current that is conducted down the axon when the membrane potential reaches the threshold of excitation.
Axon
Part of the neuron that extends off the soma, splitting several times to connect with other neurons; main output of the neuron.
Cell membrane
A bi-lipid layer of molecules that separates the cell from the surrounding extracellular fluid.
Dendrite
Part of a neuron that extends away from the cell body and is the main input to the neuron.
Diffusion
The force on molecules to move from areas of high concentration to areas of low concentration.
Electrostatic pressure
The force on two ions with similar charge to repel each other; the force of two ions with opposite charge to attract to one another.
Excitatory postsynaptic potentials
A depolarizing postsynaptic current that causes the membrane potential to become more positive and move towards the threshold of excitation.
Inhibitory postsynaptic potentials
A hyperpolarizing postsynaptic current that causes the membrane potential to become more negative and move away from the threshold of excitation.
Ion channels
Proteins that span the cell membrane, forming channels that specific ions can flow through between the intracellular and extracellular space.
Ionotropic receptor
Ion channel that opens to allow ions to permeate the cell membrane under specific conditions, such as the presence of a neurotransmitter or a specific membrane potential.
Myelin sheath
Substance around the axon of a neuron that serves as insulation to allow the action potential to conduct rapidly toward the terminal buttons.
Neurotransmitters
Chemical substance released by the presynaptic terminal button that acts on the postsynaptic cell.
Nucleus
Collection of nerve cells found in the brain which typically serve a specific function.
Resting membrane potential
The voltage inside the cell relative to the voltage outside the cell while the cell is a rest (approximately -70 mV).
Sodium-potassium pump
An ion channel that uses the neuron's energy (adenosine triphosphate, ATP) to pump three Na+ ions outside the cell in exchange for bringing two K+ ions inside the cell.
Soma
Cell body of a neuron that contains the nucleus and genetic information, and directs protein synthesis.
Spines

Protrusions on the dendrite of a neuron that form synapses with terminal buttons of the presynaptic axon.

Synapse

Junction between the presynaptic terminal button of one neuron and the dendrite, axon, or soma of another postsynaptic neuron.

Synaptic gap

Also known as the synaptic cleft; the small space between the presynaptic terminal button and the postsynaptic dendritic spine, axon, or soma.

Synaptic vesicles

Groups of neurotransmitters packaged together and located within the terminal button.

Terminal button

The part of the end of the axon that form synapses with postsynaptic dendrite, axon, or soma.

Threshold of excitation

Specific membrane potential that the neuron must reach to initiate an action potential.

References

De Carlos, J. A., & Borrell, J. (2007). A historical reflection of the contributions of Cajal and Golgi to the foundations of neuroscience. *Brain Res Rev*, 55(1), 8-16. doi: 10.1016/j. brainresrev.2007.03.010

Furtak, S. C., Moyer, J. R., Jr., & Brown, T. H. (2007). Morphology and ontogeny of rat perirhinal cortical neurons. *J Comp Neurol*, 505(5), 493-510. doi: 10.1002/cne.21516

Grant, G. (2007). How the 1906 Nobel Prize in Physiology or Medicine was shared between Golgi and Cajal. *Brain Res Rev*, 55(2), 490-498. doi: 10.1016/j.brainresrev.2006.11.004

Hodgkin, A. L., & Huxley, A. F. (1952). A quantitative description of membrane current and its application to conduction and excitation in nerve. *J Physiol*, 117(4), 500-544.

Lopez-Munoz, F., Boya, J., & Alamo, C. (2006). Neuron theory, the cornerstone of neuroscience, on the centenary of the Nobel Prize award to Santiago Ramon y Cajal. *Brain Res Bull*, 70 (4-6), 391-405. doi: 10.1016/j.brainresbull.2006.07.010

Pasternak, J. F., & Woolsey, T. A. (1975). On the "selectivity" of the Golgi-Cox method. *J Comp Neurol*, 160(3), 307-312. doi: 10.1002/cne.901600304

Ramón y Cajal, S. (1911). Histology of the nervous system of man and vertebrates. New York, NY: Oxford University Press.

Simons, M., & Trotter, J. (2007). Wrapping it up: the cell biology of myelination. *Curr Opin Neurobiol*, 17(5), 533-540. doi: 10.1016/j.conb.2007.08.003

Smit, G. J., & Colon, E. J. (1969). Quantitative analysis of the cerebral cortex. I. Aselectivity of the Golgi-Cox staining technique. *Brain Res*, 13(3), 485-510.

Williams, R. W., & Herrup, K. (1988). The control of neuron number. *Annu Rev Neurosci*, 11, 423-453. doi: 10.1146/annurev.ne.11.030188.002231

THE NERVOUS SYSTEM

Aneeq Ahmad

The mammalian nervous system is a complex biological organ, which enables many animals including humans to function in a coordinated fashion. The original design of this system is preserved across many animals through evolution; thus, adaptive physiological and behavioral functions are similar across many animal species. Comparative study of physiological functioning in the nervous systems of different animals lend insights to their behavior and their mental processing and make it easier for us to understand the human brain and behavior. In addition, studying the development of the nervous system in a growing human provides a wealth of information about the change in its form and behaviors that result from this change. The nervous system is divided into central and peripheral nervous systems, and the two heavily interact with one another. The peripheral nervous system controls volitional (somatic nervous system) and nonvolitional (autonomic nervous system) behaviors using cranial and spinal nerves. The central nervous system is divided into forebrain, midbrain, and hindbrain, and each division performs a variety of tasks; for example, the cerebral cortex in the forebrain houses sensory, motor, and associative areas that gather sensory information, process information for perception and memory, and produce responses based on incoming and inherent information. To study the nervous system, a number of methods have evolved over time; these methods include examining brain lesions, microscopy, electrophysiology, electroencephalography, and many scanning technologies.

Learning Objectives

- Describe and understand the development of the nervous system.
- Learn and understand the two important parts of the nervous system.
- Explain the two systems in the peripheral nervous system and what you know about the different regions and areas of the central nervous system.
- Learn and describe different techniques of studying the nervous system. Understand which of these techniques are important for cognitive neuroscientists.
- Describe the reasons for studying different nervous systems in animals other than human beings. Explain what lessons we learn from the evolutionary history of this organ.

Evolution of the Nervous System

Many scientists and thinkers (Cajal, 1937; Crick & Koch, 1990; Edelman, 2004) believe that the human nervous system is the most complex machine known to man. Its complexity points to one undeniable fact—that it has evolved slowly over time from simpler forms. Evolution of the nervous system is intriguing not because we can marvel at this complicated biological structure, but it is fascinating because it inherits a lineage of a long history of many less complex nervous systems (Figure 1), and it documents a record of adaptive behaviors observed in life forms other than humans. Thus, evolutionary study of the nervous system is important, and it is the first step in understanding its design, its workings, and its functional interface with the environment.

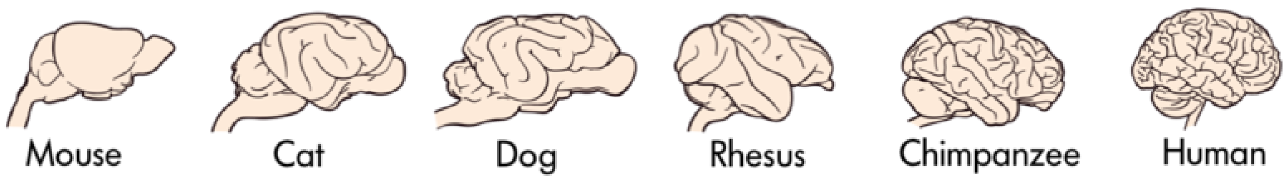


Figure 1 The brains of various animals

The brains of some animals, like apes, monkeys, and rodents, are structurally similar to humans (Figure 1), while others are not (e.g., invertebrates, single-celled organisms). Does anatomical similarity of these brains suggest that behaviors that emerge in these species are also similar? Indeed, many animals display behaviors that are similar to humans, e.g., apes use nonverbal communication signals with their hands and arms that resemble nonverbal forms of communication in humans (Gardner & Gardner, 1969; Goodall, 1986; Knapp & Hall, 2009). If we study very simple behaviors, like physiological responses made by individual neurons, then brain-based behaviors of invertebrates (Kandel & Schwartz, 1982) look very similar to humans, suggesting that from time immemorial such basic behaviors have been conserved in the brains of many simple animal forms and in fact are the foundation of more complex behaviors in animals that evolved later (Bullock, 1984).

Even at the micro-anatomical level, we note that individual neurons differ in complexity across animal species. Human neurons exhibit more intricate complexity than other animals; for example, neuronal processes (dendrites) in humans have many more branch points, branches, and spines.

Complexity in the structure of the nervous system, both at the macro- and micro-levels, give rise to complex behaviors. We can observe similar movements of the limbs, as in nonverbal communication, in apes and humans, but the variety and intricacy of nonverbal behaviors using hands in humans surpasses apes. Deaf individuals who use American Sign Language (ASL) express themselves in English nonverbally; they use this language with such fine gradation that many accents of ASL exist (Walker, 1987). Complexity of behavior with increasing complexity of the nervous system, especially the cerebral cortex, can be observed in the genus *Homo* (Figure 2). If we compare sophistication of material culture in **Homo habilis** (2 million years ago; brain volume ~650 cm3) and **Homo sapiens** (300,000 years to now; brain volume ~1400 cm3), the evidence shows that *Homo habilis* used crude stone tools compared with modern tools used by *Homo sapiens* to erect cities, develop written languages, embark on space travel, and study her own self. All of this is due to increasing complexity of the nervous system.

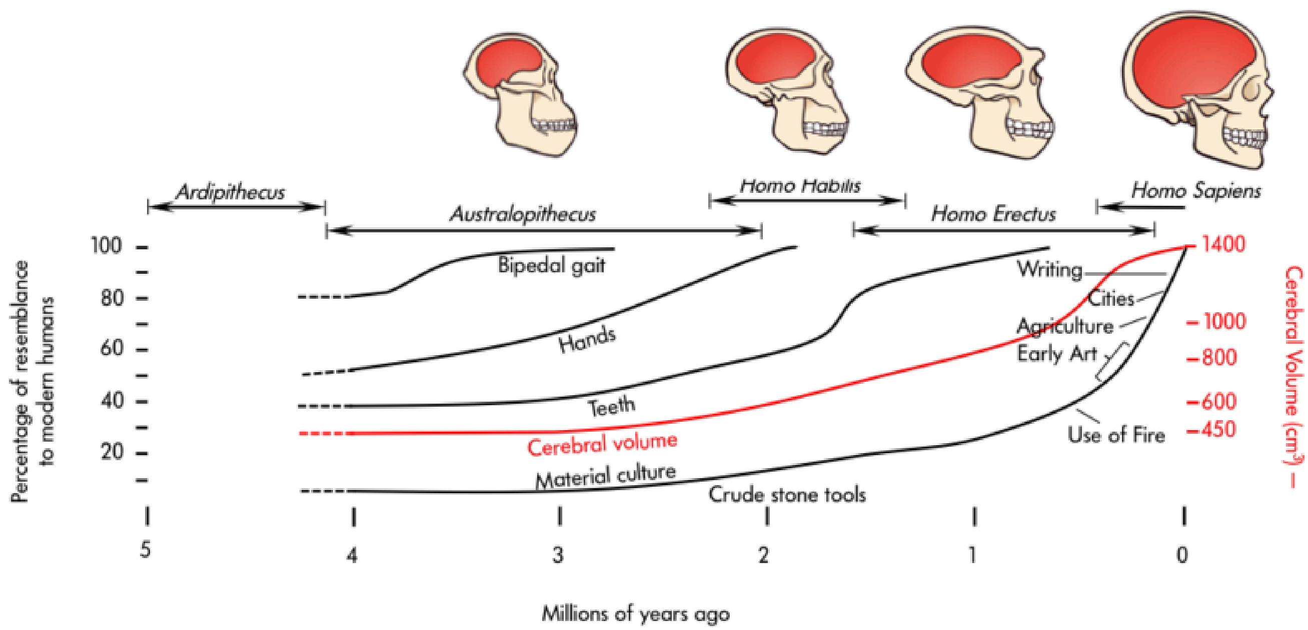


Figure 2 Changes in cerebral volume across evolution

What has led to the complexity of the brain and nervous system through evolution, to its behavioral and cognitive refinement? Darwin (1859, 1871) proposed two forces of natural and sexual selection as work engines behind this change. He prophesied, "psychology will be based on a new foundation, that of the necessary acquirement of each mental power and capacity by gradation" that is, psychology will be based on evolution (Rosenzweig, Breedlove, & Leiman, 2002).

Development of the Nervous System

Where the study of change in the nervous system over eons is immensely captivating, studying the change in a single brain during individual development is no less engaging. In many ways the ontogeny (development) of the nervous system in an individual mimics the evolutionary advancement of this structure observed across many animal species. During development, the nervous tissue emerges from the **ectoderm** (one of the three layers of the mammalian embryo) through the process of **neural induction**. This process causes the formation of the neural tube, which extends in a **rostrocaudal** (head-to-tail) plane. The tube, which is hollow, seams itself in the rostrocaudal direction. In some disease conditions, the neural tube does not close caudally and results in an abnormality called **spina bifida**. In this pathological condition, the lumbar and sacral segments of the spinal cord are disrupted.

As gestation progresses, the neural tube balloons up (cephalization) at the rostral end, and **forebrain**, midbrain, hindbrain, and the spinal cord can be visually delineated (day 40). About 50 days into gestation, six cephalic areas can be anatomically discerned (also see below for a more detailed description of these areas).

The progenitor cells (**neuroblasts**) that form the lining (**neuroepithelium)** of the neural tube generate all the neurons and glial cells of the central nervous system. During early stages of this development, neuroblasts rapidly divide and specialize into many varieties of neurons and glial cells, but this proliferation of cells is not uniform along the neural tube—that is why we see the forebrain and hindbrain expand into larger cephalic tissues than the midbrain. The neuroepithelium also generates a group of specialized cells that migrate outside the neural tube to form the **neural crest**. This structure gives rise to sensory and autonomic neurons in the peripheral nervous system.

The Structure of the Nervous System

The mammalian nervous system is divided into central and peripheral nervous systems.

The Peripheral Nervous System

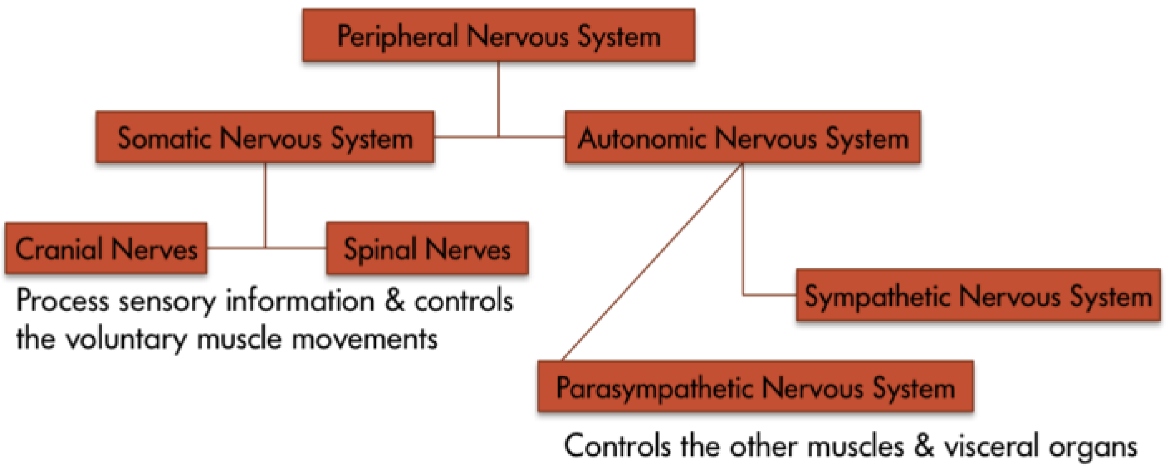


Figure 3 The various components of the peripheral nervous system

The peripheral nervous system is divided into somatic and **autonomic nervous systems** (Figure 3). Where the **somatic nervous system** consists of cranial nerves (12 pairs) and spinal nerves (31 pairs) and is under the volitional control of the individual in maneuvering bodily muscles, the autonomic nervous system also running through these nerves lets the individual have little control over muscles and glands. Main divisions of the autonomic nervous system that control visceral structures are the sympathetic and **parasympathetic nervous systems.**

At an appropriate cue (say a fear-inducing object like a snake), the sympathetic division generally energizes many muscles (e.g., heart) and glands (e.g., adrenals), causing activity and release of hormones that lead the individual to negotiate the fear-causing snake with fight- or-flight responses. Whether the individual decides to *fight* the snake or *run* away from it, either action requires energy; in short, the **sympathetic nervous system** says "go, go, go." The parasympathetic nervous system, on the other hand, curtails undue energy mobilization into muscles and glands and modulates the response by saying "stop, stop, stop." This push–pull tandem system regulates fight-or-flight responses in all of us.

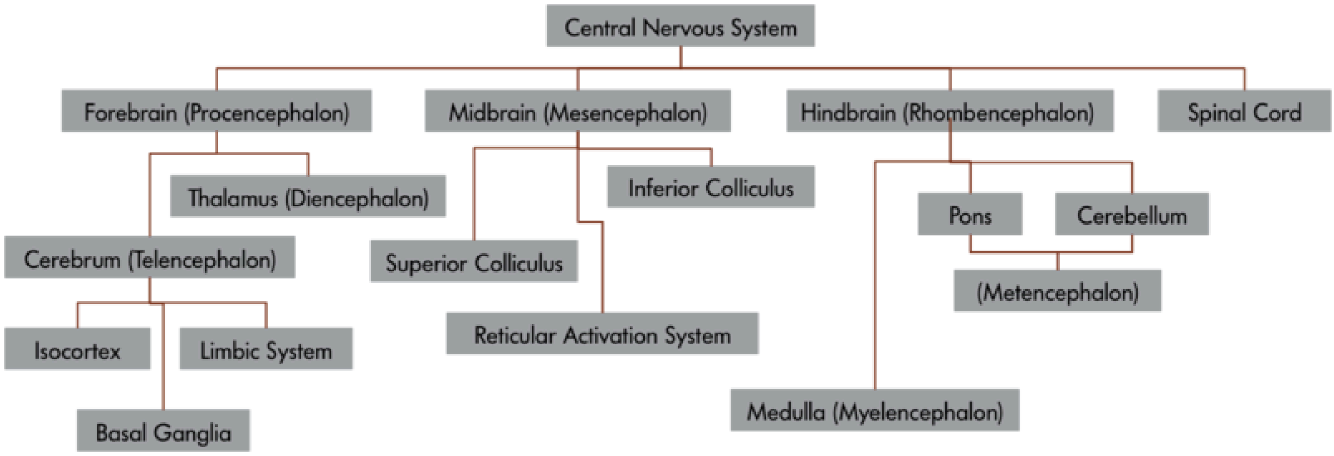


Figure 4 the central nervous system and its components

The Central Nervous System

The central nervous system is divided into a number of important parts (see Figure 4), including the spinal cord, each specialized to perform a set of specific functions. Telencephalon or **cerebrum** is a *newer* development in the evolution of the mammalian nervous system. In humans, it is about the size of a large napkin and when crumpled into the skull, it forms furrows called sulci (singular form, **sulcus**). The bulges between sulci are called gyri (singular form, **gyrus**). The cortex is divided into two hemispheres, and each hemisphere is further divided into four lobes (Figure 5a), which have specific functions. The division of these lobes is based on two delineating sulci: the **central sulcus** divides the hemisphere into frontal and parietal-occipital lobes and the **lateral sulcus** marks the **temporal lobe**, which lies below.

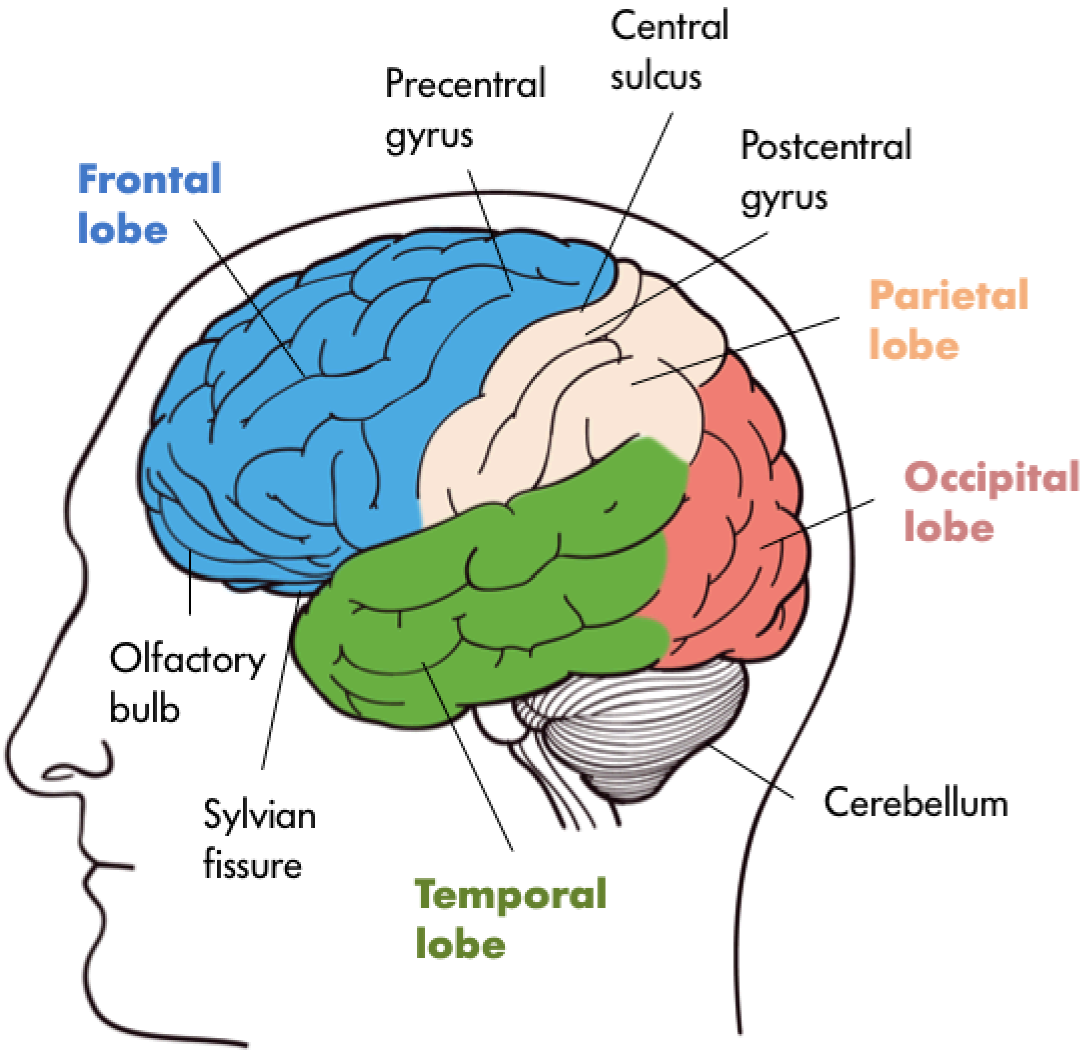


Figure 5a The lobes of the brain

Just in front of the central sulcus lies an area called the **primary motor cortex** (precentral gyrus), which connects to the muscles of the body, and on volitional command moves them. From mastication to movements in the genitalia, the body map is represented on this strip (Figure 5b).

Some body parts, like fingers, thumbs, and lips, occupy a greater representation on the strip than, say, the trunk. This disproportionate representation of the body on the primary motor cortex is called the **magnification factor** (Rolls & Cowey, 1970) and is seen in other motor and sensory areas. At the lower end of the central sulcus, close to the lateral sulcus, lies the **Broca's area** (Figure 6b) in the left **frontal lobe**, which is involved with language production. Damage to this part of the brain led Pierre Paul Broca, a French neuroscientist in 1861, to document many different forms of **aphasias**, in which his patients would lose the ability to speak or would retain partial speech impoverished in syntax and grammar (AAAS, 1880). It is no wonder that others have found subvocal rehearsal and central executive processes of **working memory** in this frontal lobe (Smith & Jonides, 1997, 1999).

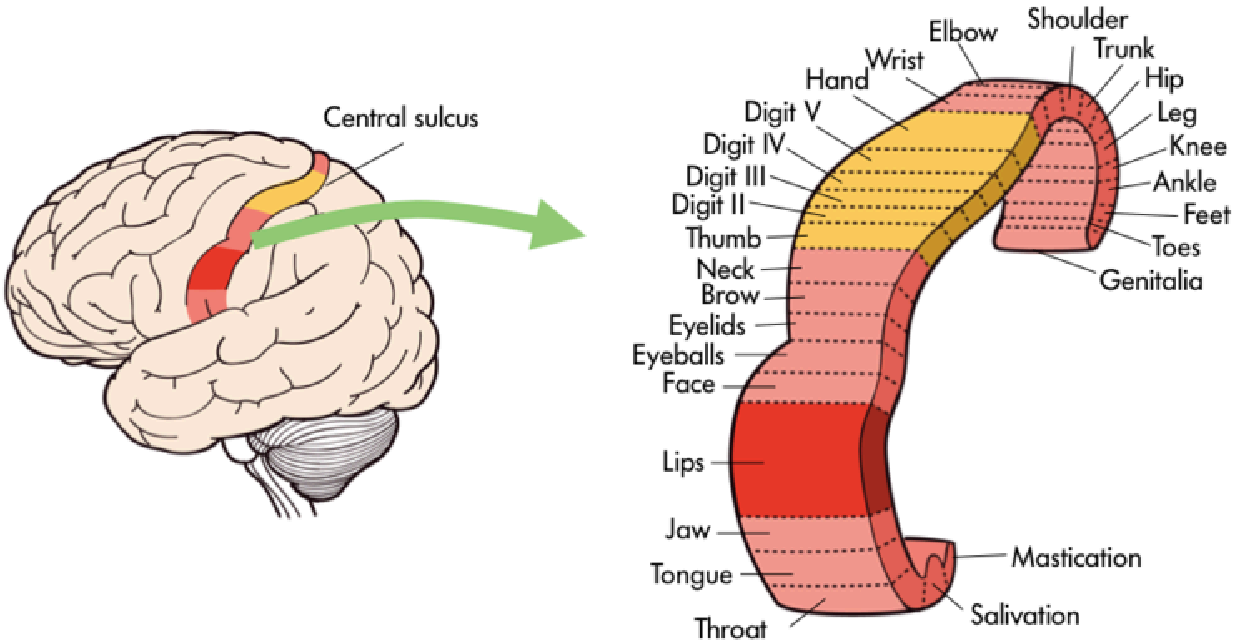


Figure 5b. Specific body parts like the tongue or fingers are mapped onto certain areas of the brain including the primary motor cortex.

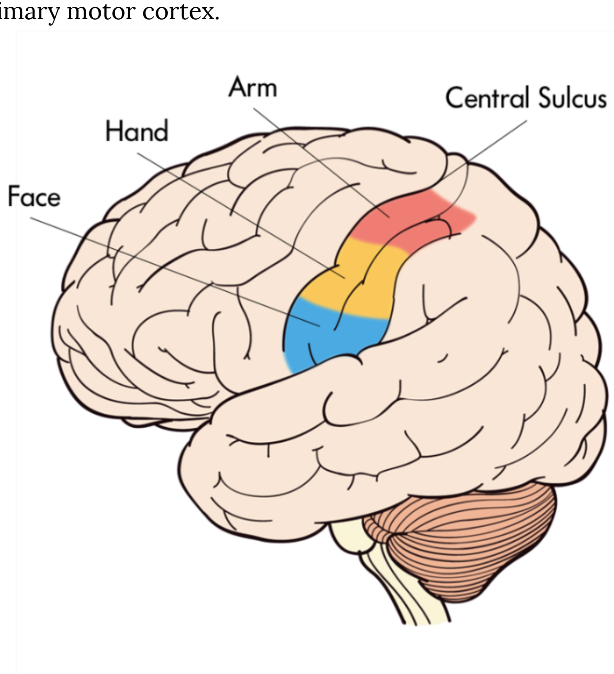


Figure 6a The Primary Somatosensory Cortex

Just behind the central gyrus, in the **parietal lobe**, lies the **primary somatosensory cortex** (Figure 6a) on the postcentral gyrus, which represents the whole body receiving inputs from the skin and muscles. The primary somatosensory cortex parallels, abuts, and connects heavily to the primary motor cortex and resembles it in terms of areas devoted to bodily representation. All spinal and some cranial nerves (e.g., the facial nerve) send sensory signals from skin (e.g., touch) and muscles to the primary somatosensory cortex. Close to the lower (ventral) end of this strip, curved inside the parietal lobe, is the taste area (secondary somatosensory cortex), which is involved with taste experiences that originate from the tongue, pharynx, epiglottis, and so forth.

Just below the parietal lobe, and under the caudal end of the lateral fissure, in the temporal lobe, lies the **Wernicke's area** (Demonet et al., 1992). This area is involved with language comprehension and is connected to the Broca's area through the **arcuate fasciculus**, nerve fibers that connect these two regions. Damage to the Wernicke's area (Figure 6b) results in many kinds of **agnosias**; agnosia is defined as an inability to know or understand language and speech-related behaviors. So an individual may show word deafness, which is an inability to recognize spoken language, or word blindness, which is an inability to recognize written or printed language. Close in proximity to the Wernicke's area is the primary auditory cortex, which is involved with audition, and finally the brain region devoted to smell (olfaction) is tucked away inside the primary olfactory cortex (prepyriform cortex).

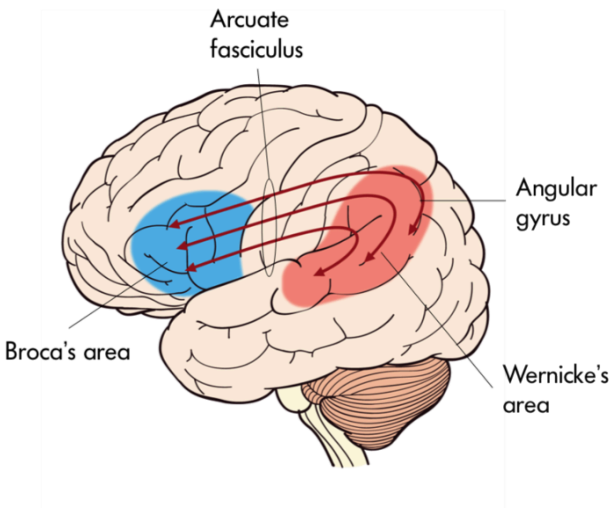


Figure 6b Wernicke's area

At the very back of the cerebral cortex lies the **occipital lobe** housing the primary visual cortex. Optic nerves travel all the way to the **thalamus** (**lateral geniculate nucleus, LGN**) and then to visual cortex, where images that are received on the retina are projected (Hubel, 1995).

In the past 50 to 60 years, visual sense and visual pathways have been studied extensively, and our understanding about them has increased manifold. We now understand that all objects that form images on the retina are transformed (**transduction**) in neural language handed down to the visual cortex for further processing. In the visual cortex, all attributes (features) of the image, such as the color, texture, and orientation, are decomposed and processed by different visual cortical modules (Van Essen, Anderson & Felleman, 1992) and then recombined to give rise to singular perception of the image in question.

If we cut the cerebral hemispheres in the middle, a new set of structures come into view. Many of these perform different functions vital to our being. For example, the **limbic system** contains a number of nuclei that process memory (**hippocampus** and **fornix**) and attention and emotions (**cingulate gyrus**); the **globus pallidus** is involved with motor movements and their coordination; the hypothalamus and thalamus are involved with drives, motivations, and trafficking of sensory and motor throughputs. The **hypothalamus** plays a key role in regulating endocrine hormones in conjunction with the pituitary gland that extends from the hypothalamus through a stalk (infundibulum).

As we descend down the thalamus, the midbrain comes into view with superior and inferior colliculi, which process visual and auditory information, as does the substantia nigra, which is involved with notorious Parkinson's disease, and the reticular formation regulating arousal, sleep, and temperature. A little lower, the hindbrain with the **pons** processes sensory and motor information employing the cranial nerves, works as a bridge that connects the cerebral cortex with the medulla, and reciprocally transfers information back and forth between the brain and the spinal cord.

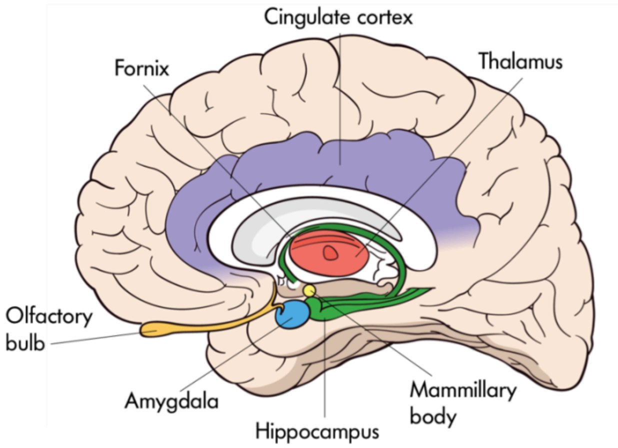


Figure 7 The interior of the brain

The **medulla oblongata** processes breathing, digestion, heart and blood vessel function, swallowing, and sneezing. The **cerebellum** controls motor movement coordination, balance, equilibrium, and muscle tone.

The midbrain and the hindbrain, which make up the brain stem, culminate in the spinal cord. Whereas inside the cerebral cortex, the **gray matter** (neuronal cell bodies) lies outside and **white matter** (myelinated axons) inside; in the spinal cord this arrangement reverses, as the gray matter resides inside and the white matter outside. Paired nerves (ganglia) exit the spinal cord, some closer in direction towards the back (dorsal) and others towards the front (ventral). The dorsal nerves (afferent) receive sensory information from skin and muscles, and ventral nerves (efferent) send signals to muscles and organs to respond.

Studying the Nervous System

The study of the nervous system involves anatomical and physiological techniques that have improved over the years in efficiency and caliber. Clearly, gross morphology of the nervous system requires an eye-level view of the brain and the spinal cord. However, to resolve minute components, optical and electron microscopic techniques are needed.

Light microscopes and, later, electron microscopes have changed our understanding of the intricate connections that exist among nerve cells. For example, modern staining procedures (**immunocytochemistry**) make it possible to see selected neurons that are of one type or another or are affected by growth. With better resolution of the electron microscopes, fine structures like the synaptic cleft between the pre- and post-synaptic neurons can be studied in detail.

Along with the neuroanatomical techniques, a number of other methodologies aid neuroscientists in studying the function and physiology of the nervous system. Early on, **lesion** **studies** in animals (and study of neurological damage in humans) provided information about the function of the nervous system, by ablating (removing) parts of the nervous system or using neurotoxins to destroy them and documenting the effects on behavior or mental processes. Later, more sophisticated microelectrode techniques were introduced, which led to recording from single neurons in the animal brains and investigating their physiological functions. Such studies led to formulating theories about how sensory and motor information are processed in the brain. To study many neurons (millions of them at a time) electroencephalographic (EEG) techniques were introduced. These methods are used to study how large ensembles of neurons, representing different parts of the nervous system, with (**event-related potentials**) or without stimulation function together. In addition, many scanning techniques that visualize the brain in conjunction with methods mentioned above are used to understand the details of the structure and function of the brain. These include **computerized axial tomography** (CAT), which uses X-rays to capture many pictures of the brain and sandwiches them into 3-D models to study it. The resolution of this method is inferior to **magnetic resonance imaging** (MRI), which is yet another way to capture brain images using large magnets that bobble (precession) hydrogen nuclei in the brain. Although the resolution of MRI scans is much better than CAT scans, they do not provide any functional information about the brain. **Positron Emission Tomography** (PET) involves the acquisition of physiologic (functional) images of the brain based on the detection of positrons. Radio- labeled isotopes of certain chemicals, such as an analog of glucose (fluorodeoxyglucose), enters the active nerve cells and emits positrons, which are captured and mapped into scans. Such scans show how the brain and its many modules become active (or not) when energized with entering glucose analog. Disadvantages of PET scans include being invasive and rendering poor spatial resolution. The latter is why modern PET machines are coupled with CAT scanners to gain better resolution of the functioning brain. Finally, to avoid the invasiveness of PET, functional MRI (fMRI) techniques were developed. Brain images based on fMRI technique visualize brain function by changes in the flow of fluids (blood) in brain areas that occur over time. These scans provide a wealth of functional information about the brain as the individual may engage in a task, which is why the last two methods of brain scanning are very popular among cognitive neuroscientists.

Understanding the nervous system has been a long journey of inquiry, spanning several hundreds of years of meticulous studies carried out by some of the most creative and versatile investigators in the fields of philosophy, evolution, biology, physiology, anatomy, neurology, neuroscience, cognitive sciences, and psychology. Despite our profound understanding of this organ, its mysteries continue to surprise us, and its intricacies make us marvel at this complex structure unmatched in the universe.

Outside Resources

Video: Pt. 1 video on the anatomy of the nervous system

http://www.youtube.com/watch?v=D1zkVBHPh5c

Video: Pt. 2 video on the anatomy of the nervous system

http://www.youtube.com/watch?v=8hC6NGQReL4

Video: To look at functions of the brain and neurons, watch

http://www.youtube.com/watch?v=9UukcdU258A

Web: To look at different kinds of brains, visit

http://brainmuseum.org/

Discussion Questions

1. Why is it important to study the nervous system in an evolutionary context?
2. How can we compare changes in the nervous system made through evolution to changes made during development?
3. What are the similarities and differences between the somatic and autonomic nervous systems?
4. Describe functions of the midbrain and hindbrain.
5. Describe the anatomy and functions of the forebrain.
6. Compare and contrast electroencephalograms to electrophysiological techniques.
7. Which brain scan methodologies are important for cognitive scientists? Why?

Vocabulary

Afferent nerves

Nerves that carry messages to the brain or spinal cord.

Agnosias

Due to damage of Wernicke's area. An inability to recognize objects, words, or faces.

Aphasia

Due to damage of the Broca's area. An inability to produce or understand words.

Arcuate fasciculus

A fiber tract that connects Wernicke's and Broca's speech areas.

Autonomic nervous system

A part of the peripheral nervous system that connects to glands and smooth muscles. Consists of sympathetic and parasympathetic divisions.

Broca's area

An area in the frontal lobe of the left hemisphere. Implicated in language production.

Central sulcus

The major fissure that divides the frontal and the parietal lobes.

Cerebellum

A nervous system structure behind and below the cerebrum. Controls motor movement coordination, balance, equilibrium, and muscle tone.

Cerebrum

Consists of left and right hemispheres that sit at the top of the nervous system and engages in a variety of higher-order functions.

Cingulate gyrus

A medial cortical portion of the nervous tissue that is a part of the limbic system.

Computerized axial tomography

A noninvasive brain-scanning procedure that uses X-ray absorption around the head.

Ectoderm

The outermost layer of a developing fetus.

Efferent nerves

Nerves that carry messages from the brain to glands and organs in the periphery.

Electroencephalography

A technique that is used to measure gross electrical activity of the brain by placing electrodes on the scalp.

Event-related potentials A physiological measure of large electrical change in the brain produced by sensory stimulation or motor responses.

Forebrain

A part of the nervous system that contains the cerebral hemispheres, thalamus, and hypothalamus.

Fornix

(plural form, fornices) A nerve fiber tract that connects the hippocampus to mammillary bodies.

Frontal lobe

The most forward region (close to forehead) of the cerebral hemispheres.

Functional magnetic resonance imaging

(or fMRI) A noninvasive brain-imaging technique that registers changes in blood flow in the brain during a given task (also see magnetic resonance imaging).

Globus pallidus

A nucleus of the basal ganglia.

Gray matter

Composes the bark or the cortex of the cerebrum and consists of the cell bodies of the neurons (see also white matter).

Gyrus

(plural form, gyri) A bulge that is raised between or among fissures of the convoluted brain.

Hippocampus

(plural form, hippocampi) A nucleus inside (medial) the temporal lobe implicated in learning and memory.

Homo habilis

A human ancestor, handy man, that lived two million years ago.

Homo sapiens

Modern man, the only surviving form of the genus Homo.

Hypothalamus

Part of the diencephalon. Regulates biological drives with pituitary gland.

Immunocytochemistry

A method of staining tissue including the brain, using antibodies.

Lateral geniculate nucleus

(or LGN) A nucleus in the thalamus that is innervated by the optic nerves and sends signals to the visual cortex in the occipital lobe.

Lateral sulcus

The major fissure that delineates the temporal lobe below the frontal and the parietal lobes.

Lesion studies

A surgical method in which a part of the animal brain is removed to study its effects on behavior or function.

Limbic system

A loosely defined network of nuclei in the brain involved with learning and emotion.

Magnetic resonance imaging

Or MRI is a brain imaging noninvasive technique that uses magnetic energy to generate brain images (also see fMRI).

Magnification factor

Cortical space projected by an area of sensory input (e.g., mm of cortex per degree of visual field).

Medulla oblongata

An area just above the spinal cord that processes breathing, digestion, heart and blood vessel function, swallowing, and sneezing.

Neural crest

A set of primordial neurons that migrate outside the neural tube and give rise to sensory and autonomic neurons in the peripheral nervous system.

Neural induction

A process that causes the formation of the neural tube.

Neuroblasts

Brain progenitor cells that asymmetrically divide into other neuroblasts or nerve cells.

Neuroepithelium

The lining of the neural tube.

Occipital lobe

The back part of the cerebrum, which houses the visual areas.

Parasympathetic nervous system

A division of the autonomic nervous system that is slower than its counterpart—that is, the sympathetic nervous system—and works in opposition to it. Generally engaged in “rest and digest” functions.

Parietal lobe

An area of the cerebrum just behind the central sulcus that is engaged with somatosensory and gustatory sensation.

Pons

A bridge that connects the cerebral cortex with the medulla, and reciprocally transfers information back and forth between the brain and the spinal cord.

Positron Emission Tomography

(or PET) An invasive procedure that captures brain images with positron emissions from the brain after the individual has been injected with radio-labeled isotopes.

Primary Motor Cortex

A strip of cortex just in front of the central sulcus that is involved with motor control.

Primary Somatosensory Cortex

A strip of cerebral tissue just behind the central sulcus engaged in sensory reception of bodily sensations.

Rostrocaudal

A front-back plane used to identify anatomical structures in the body and the brain.

Somatic nervous system

A part of the peripheral nervous system that uses cranial and spinal nerves in volitional actions.

Spina bifida

A developmental disease of the spinal cord, where the neural tube does not close caudally.

Sulcus

(plural form, sulci) The crevices or fissures formed by convolutions in the brain.

Sympathetic nervous system

A division of the autonomic nervous system, that is faster than its counterpart that is the parasympathetic nervous system and works in opposition to it. Generally engaged in “fight or flight” functions.

Temporal lobe

An area of the cerebrum that lies below the lateral sulcus; it contains auditory and olfactory (smell) projection regions.

Thalamus

A part of the diencephalon that works as a gateway for incoming and outgoing information.

Transduction

A process in which physical energy converts into neural energy.

Wernicke’s area

A language area in the temporal lobe where linguistic information is comprehended (Also see Broca’s area).

White matter

Regions of the nervous system that represent the axons of the nerve cells; whitish in color because of myelination of the nerve cells.

Working memory

Short transitory memory processed in the hippocampus.

References

American Association for the Advancement of Science (AAAS). (1880). Dr. Paul Broca. *Science*, 1(8), 93. http://www.jstor.org/stable/2900242

Bullock, T. H. (1984). Comparative neuroscience holds promise for quiet revolutions. *Science*, 225(4661), 473–478.

Crick, F., & Koch, C. (1990). Towards a neurobiological theory of consciousness. *Seminars in the Neurosciences*, 2, 263–275.

Darwin, C. (1871). *The descent of man, and the selection in relation to sex*. London: J. Murray.

Darwin, C. (1859). On the origins of species by means of natural selection, or, *The preservation of favoured races in the struggle for life*. London, UK: J. Murray.

Demonet, J. F., Chollet, F., Ramsay, S., Cardebat, D., Nespoulous, J. L., Wise, R., . . . Frackowiak,

R. (1992). The anatomy of phonological and semantic processing in normal subjects. *Brain*, 115(6), 1753–1768.

Edelman, G. (2004). *Wider than the sky: The phenomenal gift of consciousness*. New Haven, CT: Yale University Press.

Gardner, R. A., & Gardner, B. T. (1969). Teaching sign language to a chimpanzee. *Science*, 165 (3894), 664–672.

Goodall, J. (1986). *The chimpanzees of Gombe: Patterns of behavior*. Cambridge, MA: Harvard University Press.

Hubel, D. H. (1995). *Eye, brain, and vision*. Freeman & Co., NY: Scientific American Library/ Scientific American Books.

Kandel, E. R., & Schwartz, J. H. (1982). Molecular biology of learning: Modulation of transmitter release. *Science*, 218(4571), 433–443.

Knapp, M. L., & Hall, J. A. (2009). *Nonverbal communication in human interaction*. Boston, MA: Wadsworth Cengage Learning.

Ramón y Cahal, S. (1937). Recollections of my life. *Memoirs of the American Philosophical Society*, 8, 1901–1917.

Rolls, E. T., & Cowey, A. (1970). Topography of the retina and striate cortex and its relationship to visual acuity in rhesus monkeys and squirrel monkeys. *Experimental Brain Research*, 10 (3), 298–310.

Rosenzweig, M. R., Breedlove, S. M., & Leiman, A. L. (2002). *Biological psychology* (3rd ed.). Sunderland, MA: Sinauer Associates.

Smith, E. E., & Jonides, J. (1999). Storage and executive processes in the frontal lobes. *Science*, 283(5408), 1657–1661.

Smith, E. E., & Jonides, J. (1997). Working memory: A view from neuroimaging. *Cognitive psychology*, 33, 5–42.

Van Essen, D. C., Anderson, C. H., & Felleman, D. J. (1992). Information processing in the primate visual system: An integrated systems perspective. *Science*, 255(5043), 419–423.

Walker, L. A. (1987). *A loss for words: The story of deafness in a family*. New York, NY: Harper Perennial.

HUMAN SEXUAL ANATOMY AND PHYSIOLOGY

Don Lucas & Jennifer Fox

It's natural to be curious about anatomy and physiology. Being knowledgeable about anatomy and physiology increases our potential for pleasure, physical and psychological health, and life satisfaction. Beyond personal curiosity, thoughtful discussions about anatomy and physiology with sexual partners reduces the potential for miscommunication, unintended pregnancies, sexually transmitted infections, and sexual dysfunctions. Lastly, and most importantly, an appreciation of both the biological and psychological motivating forces behind sexual curiosity, desire, and the capacities of our brains can enhance the health of relationships.

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Learning Objectives

- Explain why people are curious about their own sexual anatomies and physiologies.
- List the sexual organs of the female and male.
- Describe the sexual response cycle.
- Distinguish between pleasure and reproduction as motives behind sexuality.
- Compare the central nervous system motivating sexual behaviors to the autonomic nervous system motivating sexual behaviors.
- Discuss the relationship between pregnancy and birth control.
- Analyze how sexually transmitted infections are associated with sexual behaviors.
- Understand the effects of sexual dysfunctions and their treatments on sexual behaviors.

Introduction

Most people are curious about sex. Google processes over 3.5 billion search queries per day (Google Search Statistics)—tens of millions of which, performed under the cloak of anonymity, are about sex. What are the most frequently asked questions concerning sex on Google? Are they about extramarital affairs? Kinky fantasies? Sexual positions? Surprisingly, no. Usually they are practical and straightforward, and tend to be about *sexual anatomy* (Stephens- Davidowitz, 2015)—for example, "How big should my penis be?" and, "Is it healthy for my vagina to smell like vinegar?" Further, Google reveals that people are much more concerned about their own sexual anatomies than the anatomies of others; for instance, men are 170 times more likely than women to pose questions about penises (Stephens-Davidowitz, 2015). The second most frequently asked questions about sex on Google are about *sexual physiology*—for example, "How can I make my boyfriend climax more quickly?" "Why is sex painful?" and, "What exactly is an orgasm?" These searches are clear indicators that people have a tremendous interest in very basic questions about sexual anatomy and physiology.

However, the accuracy of answers we get from friends, family, and even internet "authorities" to questions about sex is often unreliable (Fuxman et al., 2015; Simon & Daneback, 2013). For example, when Buhi and colleagues (2010) examined the content of 177 sexual-health websites, they found that nearly half contained inaccurate information. How about we—the authors of this module—make you a promise? If you learn this material, then we promise you won't need nearly as many clandestine Google excursions, because this module contains unbiased and scientifically-based answers to many of the questions you likely have about sexual anatomy and physiology.

Are you ready for a new twist on "sexually-explicit language"? Even though this module is about a fascinating topic–sex–it contains vocabulary that may be new or confusing to you. Learning this vocabulary may require extra effort, but if you understand these terms, you will understand sex and yourself better.

Masters and Johnson

Although people have always had sex, the scientific study of it has remained taboo until relatively recently. In fact, the study of sexual anatomy, physiology, and behavior wasn't formally undertaken until the late 19th century, and only began to be taken seriously as recently as the 1950's. Notably, William Masters (1915-2001) and Virginia Johnson (1925-2013) formed a research team in 1957 that expanded studies of sexuality from merely asking people about their sex lives to measuring people's anatomy and physiology while they were actually *having* sex. Masters was a former Navy lieutenant, married father of two, and trained gynecologist with an interest in studying prostitutes. Johnson was a former country music singer, single mother of two, three-time divorcee, and two-time college dropout with an interest in studying sociology. And yes, if it piques your curiosity, Masters and Johnson were lovers (when Masters was still married); they eventually married each other, but later divorced. Despite their colorful private lives they were dedicated researchers with an interest in understanding sex from a scientific perspective.

Masters and Johnson used primarily **plethysmography** (the measuring of changes in blood- or airflow to organs) to determine sexual responses in a wide range of body parts—breasts, skin, various muscle structures, bladder, rectum, external sex organs, and lungs—as well as measurements of people's pulse and blood pressure. They measured more than 10,000 orgasms in 700 individuals (18 to 89 years of age), during sex with partners or alone. Masters and Johnson's findings were initially published in two best-selling books: *Human Sexual Response*, 1966, and *Human Sexual Inadequacy*, 1970. Their initial experimental techniques and data form the bases of our contemporary understanding of sexual anatomy and physiology.

The Anatomy of Pleasure and Reproduction

Sexual anatomy is typically discussed only in terms of reproduction (see e.g., King, 2015). However, reproduction is only a (small) part of what drives us sexually (Lucas & Fox, 2018). Full discussions of sexual anatomy also include the concept of pleasure. Thus, we will explore the sexual anatomies of females (see Figures 1a and 1b) and males (see Figure 2) in terms of their capabilities for both reproduction and pleasure.

Female Anatomy

Many people find female sexual anatomy curious, confusing, and mysterious. This may be because so much of it is internal (inside the body), or because—historically—women have been expected to be modest and secretive regarding their bodies.

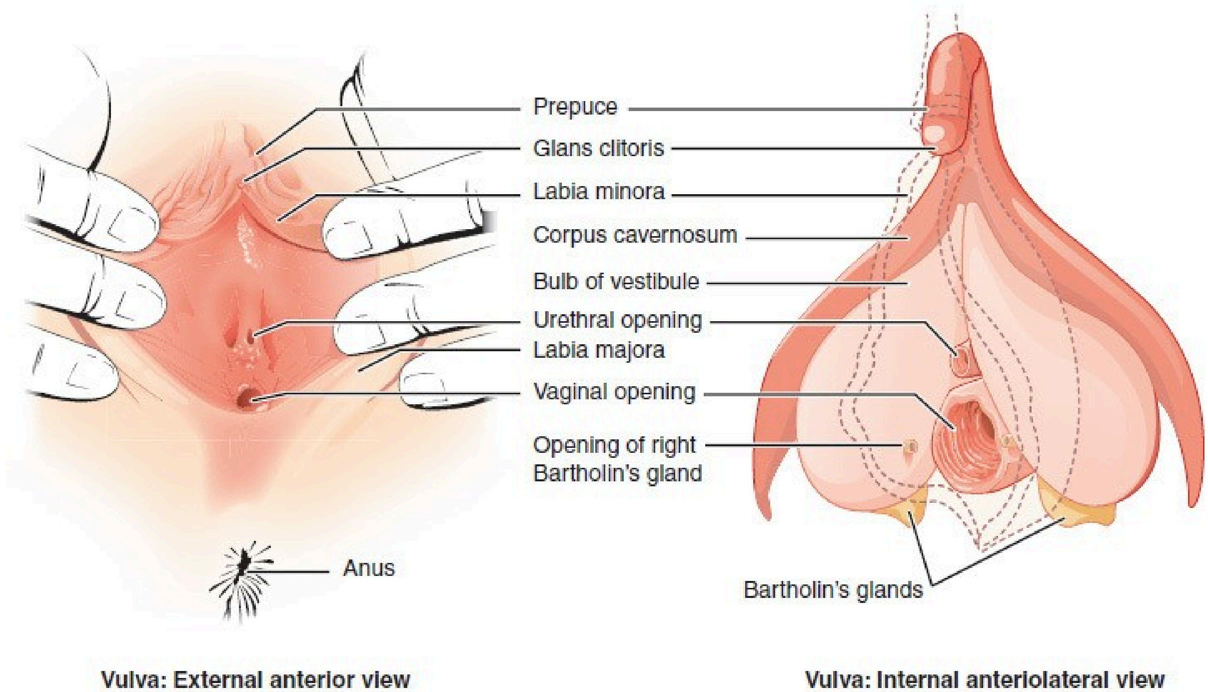


Figure 1a: The Female's External Sex Organs. [Image: Open Stax College, https://goo.gl/Hj59kX, CC BY 3.0, https://goo.gl/Dmg4Uu]

Perhaps the most visible structure of female sexual anatomy is the vulva. The primary functions of the vulva are pleasure and protection. The **vulva** is composed of the female's *externalsex organs* (see Figure 1a). It includes many parts:

the **labia majora**—the "large lips" enclosing and protecting the female's internal sex organs;

the **labia minora**—the"small lips" surrounding and defining the openings of the vagina and urethra; the minor and major **vestibular glands (VGs)**.

The minor VGs—also called **Skene's glands** (not pictured), are on the wall of the vagina and are associated with female ejaculation, and mythologically associated with the G-Spot (Kilchevsky et al., 2012; Wickman, 2017). The major

VGs—also called Bartholin's glands—are located just to the left and right of the vagina and produce lubrication to aid in sexual intercourse. Most females—especially postmenopausal females—at some time in their lives report inadequate lubrication, which, in turn, leads to discomfort or pain during sexual intercourse (Nappi & Lachowsky, 2009). Extending foreplay and using commercial water-, silicone-, or oil-based personal lubricants are simple solutions to this common problem.

The clitoris and vagina are considered parts of the vulva as well as internal sex organs (see Figure 1b). They are the most talked about organs in relation to their capacities for female pleasure (e.g., Jannini et al., 2012). Most of the **clitoris**, which is composed of 18 parts with an average overall excited length of about four inches, cannot be seen (Ginger & Yang, 2011; O'Connell et al., 2005). The visible parts—the glans and prepuce—are located above the urethra and join the labia minora at its pinnacle. The clitoris is highly sensitive, composed of more than 8,000 sensory-nerve endings, and is associated with initiating orgasms; 90% of females can orgasm by clitoral stimulation alone (O'Connell et al., 2005; Thompson, 2016).

The **vagina**, also called the "birth canal," is a muscular canal that spans from the cervix to the introitus. It has an average overall excited length of about four and a half inches (Masters & Johnson, 1966) and has two parts: First, there is the inner two-thirds (posterior wall)—formed during the first trimester of pregnancy. Second, there is the outer one-third of the vagina (anterior wall). It is formed during the second trimester of pregnancy and is generally more sensitive than the inner portion, but dramatically less sensitive than the clitoris (Hines, 2001). Only between 10% and 30% of females achieve orgasms by vaginal stimulation alone (Thompson, 2016). At each end of the vagina are the **cervix** (the lower portion of the uterus) and the **introitus** (the vaginal opening to the outside of the body). The vagina acts as a transport mechanism for sperm cells coming in, and menstrual fluid and babies going out. A healthy vagina has a pH level of about four, which is acidic. When the pH level changes, often due to normal circumstances (e.g., menstruation, using tampons, sexual intercourse), it facilitates the reproduction of microorganisms that often cause vaginal odor and pain (Anderson, Klink & Cohrssen, 2004). This potential problem can be solved with over-the-counter vaginal gels or oral probiotics to maintain normal vaginal pH levels (Tachedjiana et al., in press).

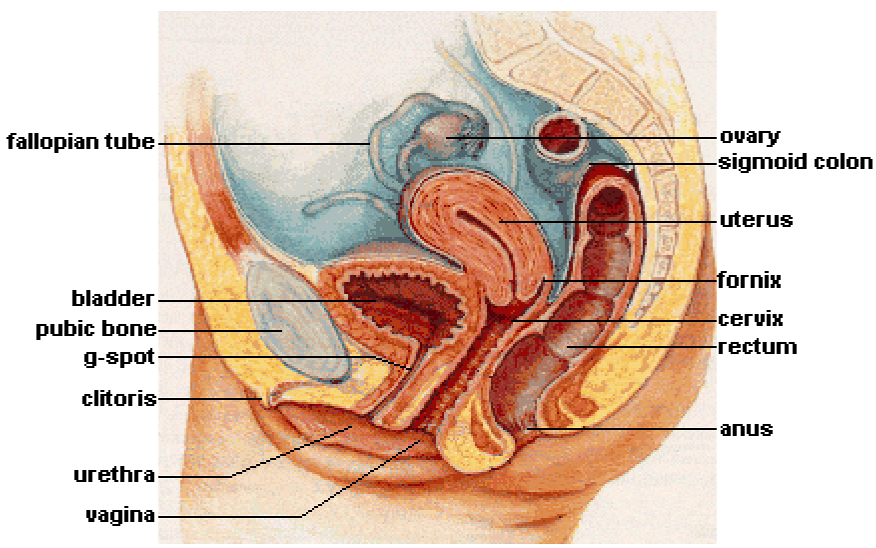


Figure 1b: The Female's Internal Sex Organs. [Image: unknown, https://goo.gl/5GMbCr, CC BY-SA 3.0, https://goo.gl/jidmcs]

The primary functions of the *internal sex organs* of the female are to store, transport, and keep ovum cells (eggs) healthy; and produce hormones (see Figure 1b). These organs include:

the **uterus** (or womb)—where human development occurs until birth;

the **ovaries**—the glands that house the ova (eggs; about two million; Faddy et al., 1992) and produce progesterone, estrogen, and small amounts of testosterone; the **fallopian tubes**—where fertilization is most likely to occur. These tubes allow for **ovulation** (about every 28 days), which is when ova travel from the ovaries to the uterus. If fertilization does not occur, **menstruation** begins. Menstruation, also known as a "period," is the discharge of ova along with the lining of the uterus through the vagina, usually taking several days to complete.

Male Anatomy

The most prominent *external sex organ* for the male is the **penis**. The penis's main functions are initiating orgasm, and transporting semen and urine from the body. On average, a flaccid penis is about three and a half inches in length, whereas an erect penis is about five inches (Veale et al., 2015; Wessells, Lue & McAninch, 1996).

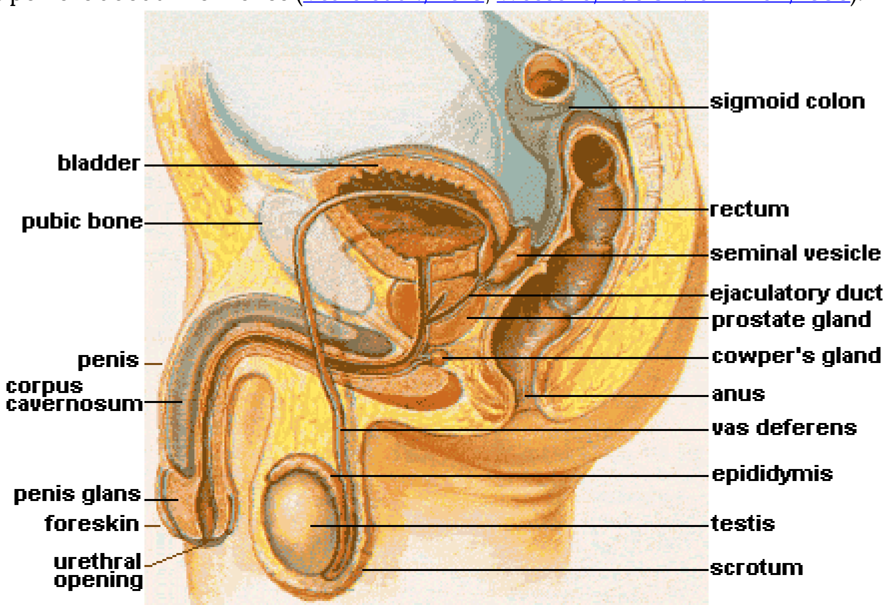


Figure 2: The Male's Internal and External Sex Organs. [Image: unknown, https://goo.gl/9kUDCN, CC BY-SA 3.0, https://goo.gl/jidmcs]

If you want to know the length of a particular male's erect penis, you'll have to actually see it—because there are *no* reliable correlations between the length of an erect penis and (a) the length of a flaccid penis, (b) the lengths of other body parts—including feet, hands, forearms, and overall height—or (c) race and ethnicity (Shah & Christopher, 2002; Siminoski & Bain, 1993; Veale et al., 2015; Wessells, Lue & McAninch, 1996). The penis has three parts: the root, shaft, and glans. **Foreskin** covers the glans, or head of the penis, except in circumcised males. The **glans penis** is highly sensitive, composed of more than 4,000 sensory-nerve endings, and associated with initiating orgasms (Halata, 1997). Lastly, it has the urethral opening that allows semen and urine to exit the body.

In addition to the penis, there are other male external sex organs that have two primary functions: producing hormones and sperm cells. The **scrotum** is the sac of skin behind and below the penis containing the testicles. The **testicles** (or testes) are the glands that produce testosterone, progesterone, small amounts of estrogen, and sperm cells.

Many people are surprised to learn that males also have *internal sex organs*. The primary functions of male internal sex organs are transporting sperm cells, keeping sperm cells healthy, and producing **semen**—the fluid in which sperm cells are transported. The male's internal sex organs include:

the **epididymis**, which is a twisted duct that matures, stores, and transports sperm cells into the vas deferens;

the **vas deferens**—a muscular tube that transports mature sperm to the urethra, except in males who have had a

vasectomy; the **seminal vesicles**–glands that provide energy for sperm cells to move. This energy is in the form of sugar (fructose) and it composes about 75% of the semen. Sperm cells only compose about 1% of the semen (Owen & Katz, 2005);

the **prostate gland**, which provides additional fluid to the semen that nourishes the sperm cells; and the **Cowper's glands**, which produce a fluid that lubricates the urethra and neutralizes any acidity due to urine; the **urethra**–the tube that carries urine and semen outside of the body.

Sex on the Brain

At first glance–or touch for that matter–the clitoris and penis are the parts of our anatomies that seem to bring the most pleasure. However, these two organs pale in comparison to our central nervous system's capacity for pleasure. Extensive regions of the brain and brainstem are activated when a person experiences pleasure, including: the insula, temporal cortex, limbic system, nucleus accumbens, basal ganglia, superior parietal cortex, dorsolateral prefrontal cortex, and cerebellum (see Figure 3, Ortigue et al., 2007). **Neuroimaging techniques** show that these regions of the brain are active when patients have spontaneous orgasms involving no direct stimulation of the skin (e.g., Fadul et al., 2005) and when experimental participants self-stimulate erogenous zones (e.g., Komisaruk et al., 2011). **Erogenous zones** are sensitive areas of skin that are connected, via the nervous system, to the somatosensory cortex in the brain.

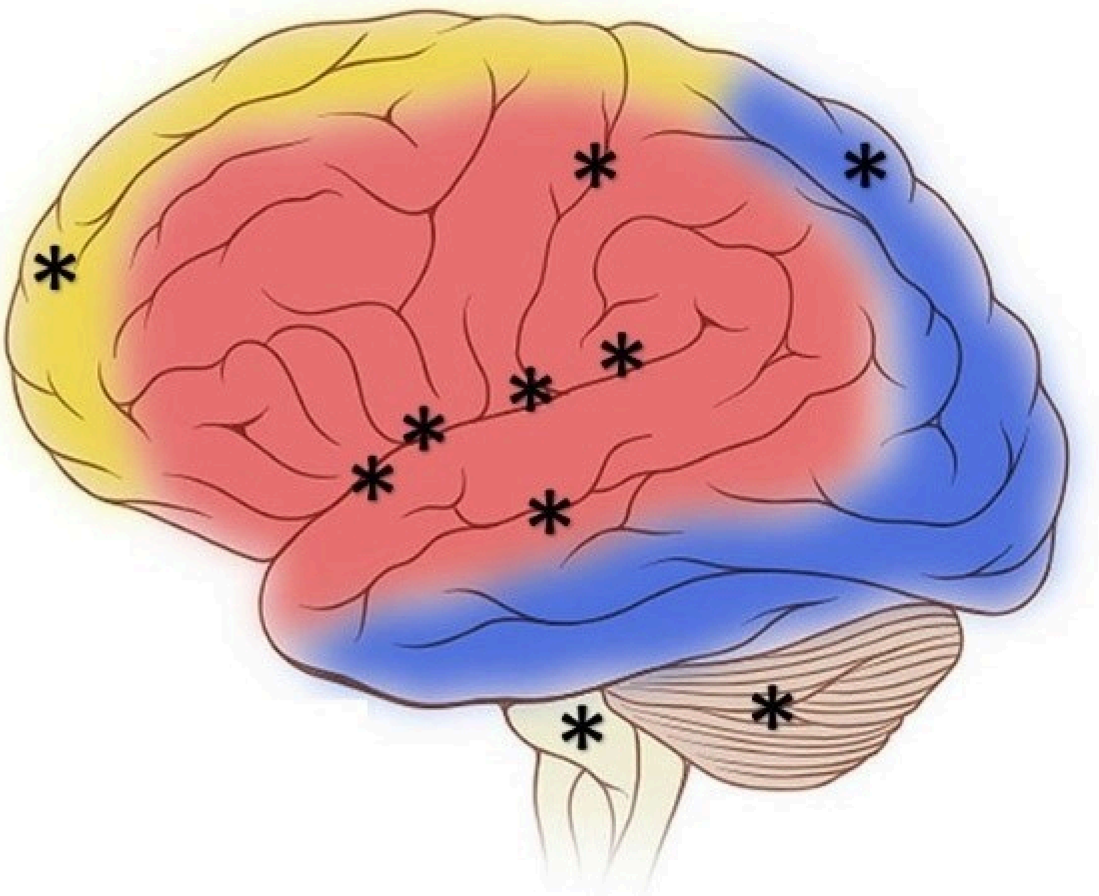


Figure 3: Some of the many regions of the brain and brainstem activated during pleasure experiences. [Image: Frank Gaillard, https://goo.gl/yCKuQ2, CC-BY-SA 3.0. Identifying marks added]

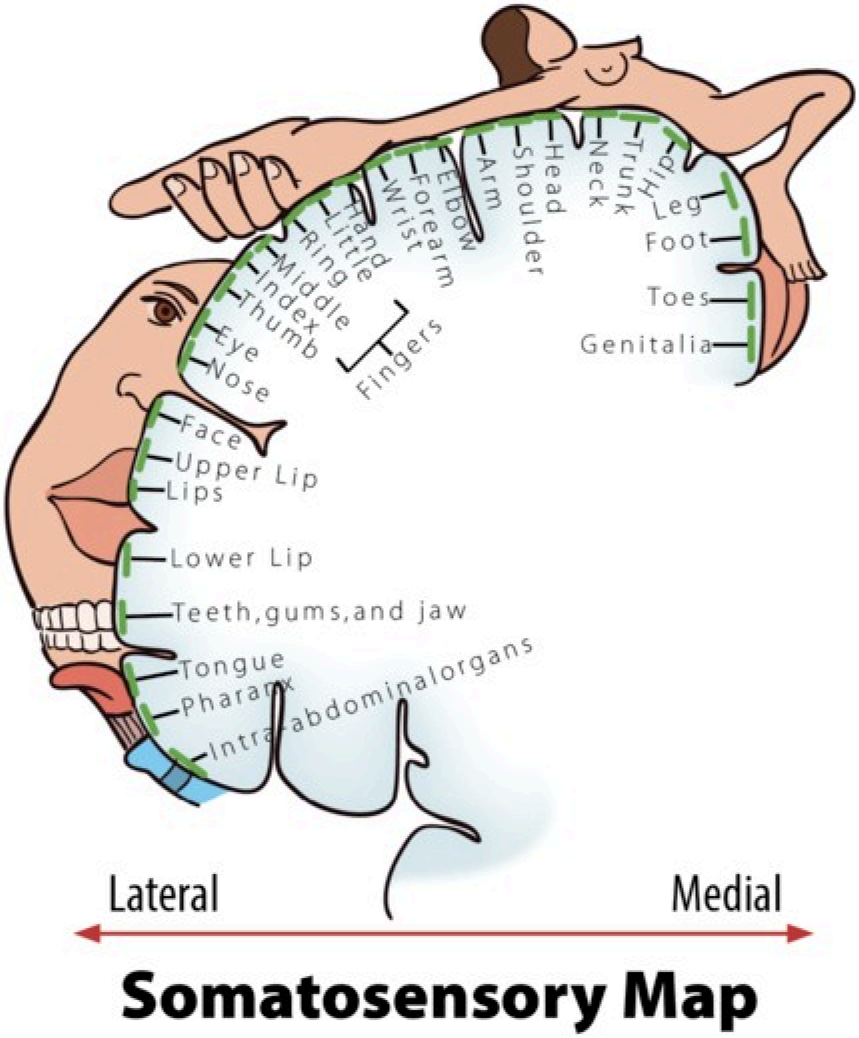


Figure 4: Erogenous Zones Mapped on the Somatosensory Cortex.

The **somatosensory cortex** (SC) is the part of the brain primarily responsible for processing sensory information from the skin. The more sensitive an area of your skin is (e.g., your lips), the larger the corresponding area of the SC will be; the less sensitive an area of your skin is (e.g., your trunk), the smaller the corresponding area of the SC will be (see Figure 4, Penfield & Boldrey, 1937). When a sensitive area of a person's body is touched, it is typically interpreted by the brain in one of three ways: "*That tickles!*" "*That hurts!*" or, "*That…you need to do again!*" Thus, the more sensitive areas of our bodies have greater potential to evoke pleasure. A study by Nummenmaa and his colleagues (2016) used a unique method to test this hypothesis. The Nummenmaa research team showed experimental participants images of same- and opposite-sex bodies.

They then asked the participants to color the regions of the body that, when touched, they or members of the opposite sex would experience as sexually arousing while masturbating or having sex with a partner. Nummenmaa found the expected "hotspot" erogenous zones around the external sex organs, breasts, and anus, but also reported areas of the skin beyond these hotspots: "[T]actile stimulation of practically all bodily regions trigger sexual arousal…." Moreover, he concluded, "[H]aving sex with a partner…"—beyond the hotspots—"…reflects the role of touching in the maintenance of…pair bonds."

Physiology and the Sexual Response Cycle

The brain and other sex organs respond to sexual stimuli in a universal fashion known as the **sexual response cycle** (SRC; Masters & Johnson, 1966). The SRC is composed of four phases:

Excitement: Activation of the sympathetic branch of the autonomic nervous system defines the *excitement phase*; heart rate and breathing accelerates, along with increased blood flow to the penis, vaginal walls, clitoris, and nipples. Involuntary muscular movements (**myotonia**), such as facial grimaces, also occur during this phase.

Plateau: Blood flow, heart rate, and breathing intensify during the *plateau phase*. During this phase, often referred to as "foreplay," females experience an **orgasmic platform**—the outer third of the vaginal walls tightening—and males experience a release of pre-seminal fluid containing healthy sperm cells (Killick et al., 2011). This early release of fluid makes penile withdrawal a relatively ineffective form of birth control (Aisch & Marsh, 2014). *(Question: What do you call a couple who use the withdrawal method of birth control? Answer: Parents.)*

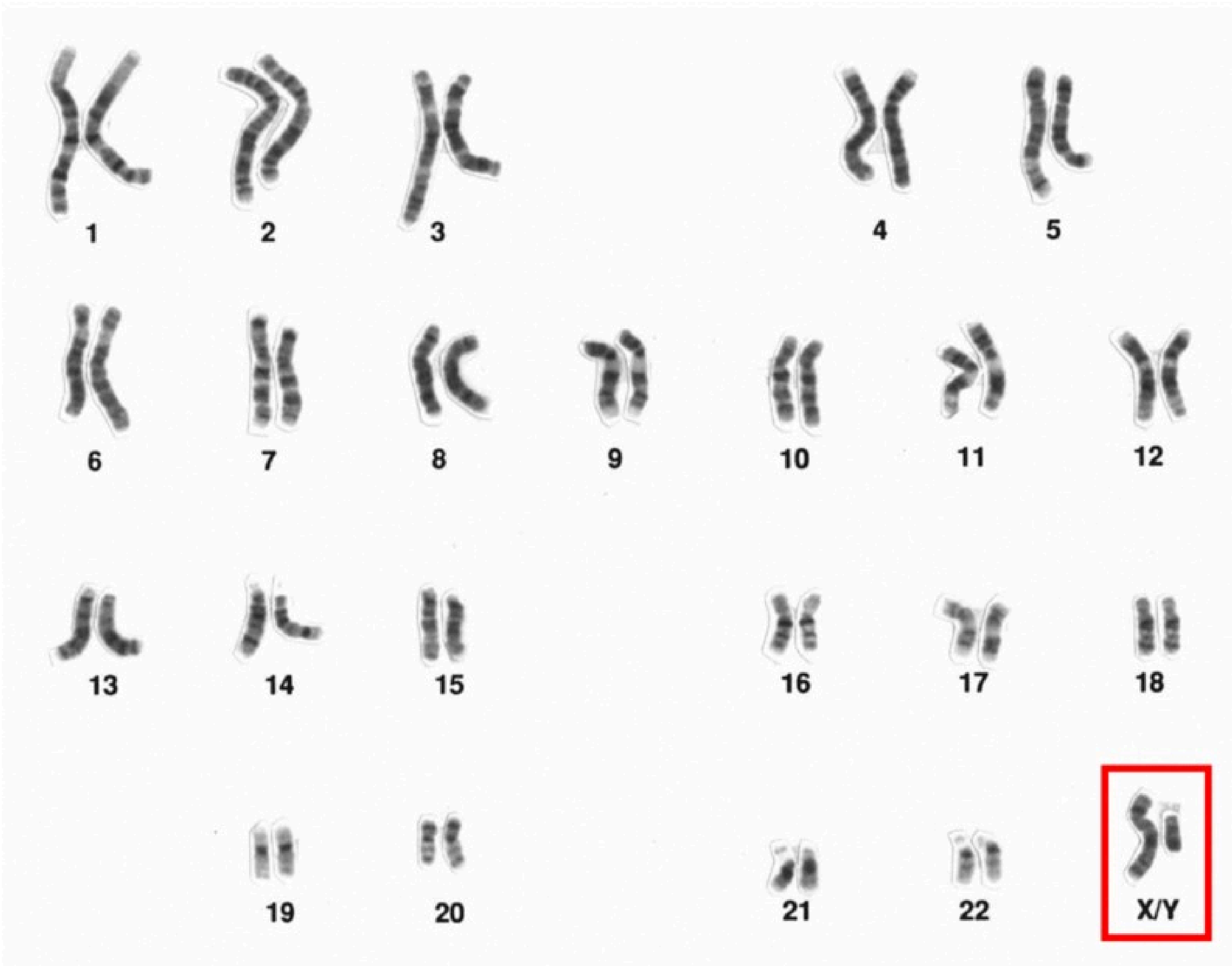
Orgasm: The shortest but most pleasurable phase is the *orgasm phase*. After reaching its climax, neuromuscular tension is released and the hormone **oxytocin** floods the bloodstream—facilitating emotional bonding. Although the rhythmic muscular contractions of an orgasm are temporally associated with ejaculation, this association is not necessary because orgasm and ejaculation are two separate physiological processes.

Resolution: The body returns to a pre-aroused state in the *resolution phase*. Males enter a **refractory period** of being unresponsive to sexual stimuli. The length of this period depends on age, frequency of recent sexual relations, level of intimacy with a partner, and novelty. Because females do not have a refractory period, they have a greater potential—physiologically—of having multiple orgasms. Ironically, females are also more likely to "fake" having orgasms (Opperman et al., 2014).

Of interest to note, the SRC occurs regardless of the type of sexual behavior—whether the behavior is masturbation; romantic kissing; or oral, vaginal, or anal sex (Masters & Johnson, 1966). Further, a partner or environmental object is sufficient, but not necessary, for the SRC to occur.

Pregnancy

One of the potential outcomes of the SRC is **pregnancy**—the time a female carries a developing human within her uterus. How does this happen?



Human male, sex chromosomes highlighted [Image: National Human Genome Research Institute, https://goo.gl/8UWQwa, Public Domain]

The process begins during vaginal intercourse when the male ejaculates, or releases semen. Each ejaculate contains about 300 million sperm cells. These sperm compete to make their way through the cervix and into the uterus. **Conception** typically occurs within a fallopian tube when a single sperm cell comes into contact with an ovum (egg). The sperm carries either an X- or Y- chromosome to fertilize the ovum– which, itself, usually carries an X- chromosome. These chromosomes, in combination with one another, are what determine a person's sex. The combination of two X chromosomes produces a female **zygote** (fertilized ovum). The combination of an X and Y chromosome produces a male zygote. XX- or XY-chromosomes form your 23rd set of chromosomes (most humans have a total of 46 chromosomes) commonly referred to as your **chromosomal sex** or genetic sex.

Interestingly, at least 1 in every 1,000 conceptions results in a variation of chromosomal sex beyond the typical XX or XY sets. Some of these variations include, XXX, XXY, XYY, or even a single X (Dreger, 1998). In some cases, people may have unusual physical characteristics, such as being taller than average, having a thick neck, or being sterile (unable to reproduce); but in many cases, these individuals have no cognitive, physical, or sexual issues (Wisniewski et al., 2000). Almost 15 out of every 1,000 births are multiple births (twins, triplets, quadruplets, etc.). These can occur in a couple of ways. Dizygotic (fraternal) births are the result of a female releasing multiple ova of which more than one is fertilized by sperm. Because sperm carry either X or Y chromosomes, fraternal births can be any combination of sexes (e.g., two girls or a boy and a girl). They develop together in the uterus and are usually born within minutes of one another. Monozygotic (identical) births result from a special circumstance in which a fertilized ovum splits into multiple identical embryos and they develop simultaneously. Identical twins are, therefore, the same sex.

Hours after conception, the zygote begins dividing into additional cells. It then starts traveling down the fallopian tube until it enters the uterus as a *blastocyst*. The blastocyst implants itself within the wall of the uterus to become an *embryo* (Moore, Persaud & Torchia, 2016). However, the percentage of successful implantations remains a mystery. Researchers believe the failure rate to be as high as 60% (Diedrich et al., 2007). Failed blastocysts are eliminated during menstruation, often without the female ever knowing conception occurred.

Mothers are pregnant for three **trimesters**, a term that begins with their last menstrual period and ends about 40 weeks later; each trimester is 13 weeks. During the first trimester, most of the body parts of the embryo are formed, although at this stage they are not in the same proportions as they will be at birth. The brain and head, for example, account for about half of the body at this point. During the fifth and sixth weeks of gestation, the **primitive gonads** are formed. They eventually develop into ovaries or testes. Until the seventh week, the developing embryo has the potential of having either male (**Wolffian ducts**) or female (**Mullerian ducts**) internal sex organs, regardless of chromosomal sex. In fact, there is an innate tendency for all embryos to have female internal sex organs, unless there is the presence of the SRY gene, located on the Y-chromosome (Grumbach & Conte, 1998; Wizemann & Pardue, 2001). The SRY gene causes XY-embryos to develop testes (dividing cells from the medulla). The testes emit testosterone which stimulates the development of male internal sex organs—the Wolffian ducts transforming into the epididymis, seminal vesicles, and vas deferens. The testes also emit a Mullerian inhibiting substance, a hormone that causes the Mullerian ducts to atrophy. If the SRY gene is not present or active—typical for chromosomal females (XX)—then XX-embryos develop ovaries (dividing cells from the cortex) and the Mullerian ducts transform into female internal sex organs, including the fallopian tubes, uterus, cervix, and inner two-thirds of the vagina (Carlson, 1986). Without a burst of testosterone from the testes, the Wolffian ducts naturally deteriorate (Grumbach & Conte, 1998; Wizemann & Pardue, 2001).

During the second trimester, expectant mothers can feel movement in their wombs. This is known as **quickening**. Inside the uterus, the embryo develops fine hair all over its body (called *lanugo*) as well as eyelashes and eyebrows. Major organs, such as the pancreas and liver, begin fully functioning. By the 20th week of gestation, the external sex organs are fully formed, which is why "sex determination" using ultrasound during this time is more accurate than in the first trimester (Igbinedion & Akhigbe, 2012; Odeh, Ophir & Bornstein, 2008). Formation of male external sex organs (e.g., the penis and scrotum) is dependent upon high levels of testosterone, whereas female external sex organs (e.g., the outer third of the vagina and the clitoris) form without hormonal influences (Carlson, 1986). Levels of sex hormones, such as estrogen, testosterone, and progesterone, begin affecting the brain during this trimester, impacting future emotions, behaviors, and thoughts related to gender identity and sexual orientation (Swaab, 2004). It's important to understand that the interactions of chromosomal sex, gonadal sex, sex hormones, internal sex organs, external sex organs, and brain differentiations during this developmental stage are too complex to readily conform to the familiar categories of sex, gender, and sexual orientation historically used to describe people (Herdt, 1996). Toward the end of the second trimester—at about the 26th week—is the **age of viability**, when survival outside of the uterus has a probability of more than 90% (Rysavy et al., 2015). Interestingly, technological advances and changes in hospital care have affected the age of viability such that viability is possible earlier in pregnancy (Rysavy et al., 2015).

During the third trimester, there is rapid development in the brain and rapid weight gain. Typically, by the 36th week, the fetus begins descending head-first into the uterine cavity. Getting ready for birth is not the only behavior exhibited during this last trimester. Erectile responses in male fetuses occur during this time (Haffner, 1999; Martinson, 1994; Parrot, 1994); and Giorgi and Siccardi (1996) reported ultrasonographic observations of a fetus performing self-exploration of her external sex organs. Most babies are born vaginally (through the vagina), though in the United States one-third are by Cesarean section (through the abdomen; Molina et al., 2015). A newborn's health is initially determined by his/her weight (normally ranging between 2,500 and 4,000 grams)—though birth weight significantly differs between ethnicities (Jannsen et al., 2007).

Potential outcomes of the Sexual Response Cycle are pregnancy and childbirth. [Image: Ernest F, https://goo.gl/TPu7g8, CC BY- SA 3.0, https://goo.gl/jidmcs]

Birth Control

Contraception, or birth control, reduces the probability of pregnancy resulting from sexual intercourse. There are various forms of birth control, including: hormonal, barrier, or natural. As shown in Table 1, the effectiveness of the different forms of birth control ranges widely, from 68% to 99.9% (optionsforsexualhealth.org).

Method	Effectiveness (Actual Use)	Effectiveness (Perfect Use)
Evra Patch	92%	99.7%
PILL - Combined	92%	99.7%
- Progestin	92%	99.7%
Nuvaring	92%	99.7%
IUD		
Copper T	99.2%	99.4%
Levonorgenestrel (Mirena)	99.9%	99.9%
Diaphragm & Spermicide	84%	94%
Spermicide & Male Condoms (1)	no confirmed data	99%
Female condom alone	79%	95%
Male condom alone	85%	98%
Spermicides (2)	71%	82%
Tubal ligation	99.5%	99.5%
Vasectomy	99.85%	99.9%
Cervical cap		
Woman has had children	68%	74%
Woman has not had children	84%	91%
Depo-Provera	97%	99.95%
Sponge		
Woman has had children	68%	80%
Woman has not had children	84%	91%
Fertility awareness method	75%	95-97%
Withdrawal	73%	96%
No method (Chance)	15%	15%
(1) separate spermicide in addition to condoms (2) foams, creams, gels, vaginal suppositories, and vaginal film		

Table 1. Forms of Birth Control and their Effectiveness – from https://www.optionsforsexualhealth.org/

Hormonal forms of birth control release synthetic estrogen or progestin, which prevents ovulation and thickens cervical mucus, making it difficult for sperm to reach ova (sexandu.ca/contraception). There are a variety of ways to introduce these hormones into the body, including: implantable rods, birth control pills, injections, transdermal patches, IUDs, and vaginal rings. For example, the vaginal ring is 92% effective, easily inserted into and taken out of the vagina by the user, and comprised of thin plastic containing a combination of hormones that are released during the time it is in the vagina–usually about three weeks.

Barrier forms of birth control prevent sperm from entering the uterus by creating a physical barrier or chemical barrier toxic to sperm. There are a variety of barrier methods, including:

vasectomies, tubal ligations, male and female condoms, spermicides, diaphragms, and cervical caps. The most popular barrier method is the condom, which is 79-85% effective. The male condom is placed over the penis, whereas the female condom is worn inside the vagina and fits around the cervix. Condoms prevent bodily fluids from being exchanged and reduce skin-to-skin contact. For this reason, condoms are also used to reduce the risk of some sexually transmitted infections (STIs). However, it is important to note that male and female condoms, or two male condoms, should not be worn simultaneously during penetration; the friction between multiple condoms creates microscopic tears, rendering them ineffective (Munoz, Davtyan & Brown, 2014).

Natural forms of birth control rely on knowledge of the menstrual cycle and awareness of the body. They include the Fertility Awareness Method (FAM), lactational amenorrhea method, and withdrawal. For example, the FAM is about 75% effective, and requires tracking the menstrual cycle, and avoiding sexual intercourse or using other forms of birth control during the female's fertile window. About 30% of females' fertile windows—the period when a female is most likely to conceive—are between days ten and seventeen of their menstrual cycle (Wilcox, Dunson & Baird, 2000). The remaining 70% of females experience irregular and less predictable fertile windows, reducing the efficacy of the FAM.

Other forms of birth control that do not fit into the above categories include: emergency contraceptive pills, the copper IUD, and abstinence. Emergency contraceptive pills (e.g., Plan B) delay the release of an ovum if taken prior to ovulation. **Emergency contraception** is a form of birth control typically used after unprotected sex, condom mishaps, or sexual assault. The most effective form of emergency contraception is the copper IUD. A medical professional inserts the IUD through the opening of the cervix and into the uterus. It is more than 99% effective and may be left within the uterus for over 10 years. It differs from typical IUDs because it is hormone-free and uses copper ions to create an inhospitable environment for sperm, thus significantly reducing the chances of fertilization. Additionally, the copper ions alter the lining of the uterus, which significantly reduces the probability of implantation. Lastly, **abstinence**—avoiding any sexual behaviors that may lead to conception—is the only form of birth control with a 100% effective rate.

There are many factors that determine the best birth control options for any particular person. Some factors are related to personality and habits. For example, if a woman is a forgetful person, "the pill" may not be her best option, since it requires being taken daily. Other factors that influence birth control choices include cost, age, education, religious beliefs, lifestyle, and sexual health.

Sexually Transmitted Infections

Unfortunately, a potential outcome of sexual activity is infection. **Sexually transmitted infections (STIs)** are like other transmittable infections, except STIs are primarily transmitted through social sexual behaviors. Social sexual behaviors include romantic kissing and oral, vaginal, and anal sex. Additionally, STIs can be transmitted through blood, and from mother to child during pregnancy and childbirth. STIs may lead to sexually transmitted diseases (STDs). Often, infections have no symptoms and do not lead to diseases. For example, the most common STI for men and women in the US is Human Papillomavirus (HPV). In most cases, HPV goes away on its own and has no symptoms. Only a fraction of HPV STIs develop into cervical, penile, mouth, or throat cancer (Centers for Disease Control and Prevention, CDCP, December 2016).

There are more than 30 different STIs. STIs differ in their primary methods of transmission, symptoms, treatments, and whether they are caused by viruses or bacteria. Worldwide, some of the most common STIs are: genital herpes (500 million), HPV (290 million), trichomoniasis (143 million), chlamydia (131 million), gonorrhoea (78 million), human immunodeficiency virus (HIV, 36 million), and syphilis (6 million; World Health Organization, 2016).

Sex education is a critical tool in the fight against sexually transmitted infections. [Image: turibamwe, https://goo.gl/iviJ3U, Public Domain]

Medical testing to determine whether someone has an STI is relatively simple and often free (gettested.cdc.gov). Further, there are vaccines or treatments for all STIs, and many STIs are curable (e.g., chlamydia, gonorrhea, and trichomoniasis). However, without seeking treatment, all STIs have potential negative health effects, including death from some. For example, if untreated, HIV often leads to the STD acquired immune deficiency syndrome (AIDS)—over one million people die every year from AIDs (aids.gov). Unfortunately, many, if not most, people with STIs never get tested or treated. For example, as many as 30% of those with HIV and 90% of those with genital herpes are unaware of having an STI (Fleming et al., 1997; Nguyen & Holodniy, 2008).

It is impossible to contract an STI from a person who does not have an STI. This may seem like an obvious statement, but a recent study asked 596 freshmen- and sophomore-level college students the following True/False question, "A person can get AIDS by having anal (rectal) intercourse even if neither partner is infected with the AIDS virus," and found that 33% of them answered "true" (Lucas et al., 2016). What *is* obvious, is that false stereotypes about anal sex causing AIDS continue to misinform our collective sexual knowledge. Only open, honest, and comprehensive education about human sexuality can fight these STI stereotypes. To be clear, anal sex is *associated* with STIs, but it cannot cause an STI. Specifically, anal sex, when compared to vaginal sex (the second most likely method of transmission), oral sex (third most likely), and romantic kissing (fourth most likely), is associated with the greatest risk of transmitting and contracting STIs, because the tissue lining of the rectum is relatively thin and apt to tear and bleed, thereby passing on the infection (CDCP, 2016).

A sexually active person's chance of getting an STI depends on a variety of factors. Two of these are age and access to sex education. Young people between the ages of 15 and 24 account for more than 50% of all new STIs, even though they account for only about 25% of the sexually active population (Satterwhite et al., 2013). Generally, young males and females are equally susceptible to getting an STI; however, females are much more likely to suffer long-term health consequences of an STI. For example, each year in the US, undiagnosed STDs cause about 24,000 females to become infertile (CDCP, October 2016; DiClemente, Salazar & Crosby, 2007).

Limited access to comprehensive sex education is also a major contributing factor toward the risk of contracting an STI. Unfortunately, some sex education is limited to the promotion of abstinence, and relies heavily on "virginity pledges." A virginity pledge is a commitment to refrain from sexual intercourse until heterosexual marriage. Although virginity pledges fit well with some cultural and religious worldviews, they are only effective if people, in fact, remain abstinent. Unfortunately, this is not always the case; research reveals many ways these types of strategies can backfire. Adolescents who take virginity pledges are significantly less likely than other adolescents to use contraception when they do become sexually active (Bearman & Brückner, 2001). Further, virginity pledgers are four to six times more likely than non- pledgers to engage in both oral and anal intercourse (Paik, Sanchagrin & Heimer, 2016), often assuming they're preserving their virgin status by simply avoiding vaginal sex. In fact, schools with students taking virginity pledges have significantly higher rates of STIs than other schools (Bearman & Brückner, 2001).

Interestingly, senior citizens are one of the fastest growing segments of the European and US populations being diagnosed with STIs. The Centers for Disease Control and Prevention report a steady increase in people over 65 being diagnosed with HIV; since 2007, incidence of syphilis among seniors is up by 52% and chlamydia is up by 32%; and from 2010 to 2014, there was a 38% increase in STI diagnoses in people between the ages of 50 and 70 (Forster, 2016; Weiss, 2014). Why is this happening? Bear in mind, seniors are not necessarily more sexually knowledgeable than adolescents; they may have no greater access to comprehensive sex education than younger people (Adams, Oye & Parker, 2003). Even so, medical advances allow seniors to continue to be sexually active at later points in their lifespan—and to make the same mistakes adolescents make about safer sex.

Safer Sex

STIs are 100% preventable: Simply don't engage in social sexual behaviors. But in the grand scheme of things, you may be surprised to hear, avoiding sex is detrimental to your physical and mental well-being—whereas, having sex can be widely beneficial (Charnetski & Brennan, 2004; Ditzen, Hoppmann & Klumb, 2008; Hall et al., 2010). Thus, we recommend **safer-sex practices**, such as communication, honesty, and barrier methods. Safer-sex practices always begin with communication. Before engaging in sexual behaviors with a partner, a clear, honest, and explicit understanding of your boundaries, as well as your partner's, should be established. Safer sex involves discussing and using barriers—male condoms, female condoms, or dental dams—relative to your specific sexual behaviors. Also, keep in mind: Although safer sex may use some of the same tools as birth control, safer sex is *not* birth control. Birth control focuses on reproduction; safer sex focuses on well-being.

Sex Fears with highest average rating by gender	
Men	**Women**
(1) Your partner has an **STI**	**(1)** Your partner won't want to wear a **condom**
(2) Your partner won't have an **orgasm** or be satisfied	**(2)** Your partner has an **STI**
(3) The condom will break/sex will result in **unintended pregnancy**	**(3)** The condom will break/sex will result in **unintended pregnancy**
(4) You'll **ejaculate prematurely**	**(4)** Your partner will find your **naked body unattractive**
(5) Your partner will find your **naked body unattractive**	**(5)** Your partner will not take **"no"** for an answer
(6) You **won't be able** to perform	**(6)** Your partner will want to do something you're **not comfortable** with
(7) You are **bad at sex**	**(7)** An **embarrassing bodily function** will occur during sex
(8) Your **penis** is **too small**	**(8)** Your partner won't have an **orgasm** or be satisfied
(9) Your partner will think you are **inexperienced**	**(9)** You won't have an **orgasm** or be satisfied
(10) It will be a**wkward** after sex	**(10)** You are **bad at sex**

Table 2: Top 10 Fears Men and Women Have During Sex

A proactive approach to behaving sexually may at first seem burdensome, but it can be easily reimagined as "foreplay," is associated with greater sexual satisfaction, increases the probability of orgasm, and addresses fears people have during sex (see Table 2; Jalili, 2016; Nuno, 2017).

Sexual Dysfunctions

Roughly 43% of women and 31% of men suffer from a clinically significant impairment to their ability to experience sexual pleasure or responsiveness as outlined by the SRC (Rosen, 2000). The *Diagnostic and Statistical Manualof Mental Disorders, 5th edition* (DSM) refers to these difficulties as **sexual dysfunctions**.

According to the DSM, there are four male-specific dysfunctions:

- delayed ejaculation
- erectile disorder (ED)
- male hypoactive sexual desire disorder
- premature ejaculation (PE)

There are three female-specific dysfunctions:

- female orgasmic disorder
- female sexual interest/arousal disorder
- genito-pelvic pain/penetration disorder

There is also one non-gender-specific sexual dysfunction: substance-/medication-induced sexual dysfunction (American Psychiatric Association, 2013). The most commonly reported male sexual dysfunctions are premature ejaculation (PE) and erectile dysfunction (ED), whereas females most frequently report dysfunctions involving desire and arousal. Females are also more likely to experience multiple sexual dysfunctions (McCabe et al., 2016).

PE is a pattern of early ejaculation that impairs sexual performance and causes personal distress. In severe cases, ejaculation may occur prior to the start of sexual activity or within 15 seconds of penetration (American Psychiatric Association, 2013). PE is a fairly common sexual dysfunction, with prevalence rates ranging from 20-30%. Relationship and intimacy difficulties, as well as anxiety, low self-confidence, and depression, are often associated with PE. Most males with PE do not seek treatment (Porst et al., 2007).

ED is the frequent difficulty to either obtain or maintain an erection, or a significant decrease in erectile firmness. Normal aging increases the prevalence and incidence rates of erectile difficulties, especially after the age of 50 (American Psychiatric Association, 2013). However, recent studies have found significant increases in the prevalence of ED in young men, less than 30 years of age (e.g., Capogrosso et al., 2013).

Female sexual interest/arousal disorder (FSIAD) is characterized by reduced or absent sexual interest or arousal. A person diagnosed with FSIAD has had an absence of at least three of the following emotions, behaviors, and thoughts for more than six months:

interest in sexual activity
sexual or erotic thoughts and fantasies
initiation of sexual activity
sexual excitement or pleasure during sexual activity
sexual interest/arousal in response to sexual or erotic cues
genital or non-genital sensations during sexual activity

FSIAD is not diagnosed if the presenting symptoms are a result of insufficient stimulation or lack of sexual knowledge—such as the erroneous expectation that penile-vaginal intercourse always results in orgasm (American Psychiatric Association, 2013).

Treatments

When it comes to treating sexual dysfunctions, there's some good news and there's some bad news. The good news is that most sexual dysfunctions have treatments—however, most people don't seek them out (Gott & Hinchliff, 2003). So, the further good news is that—once you have the knowledge (say, from this module)—if you experience such difficulties, getting treatment is just a matter of making the choice to seek it out. Unfortunately, the bad news is that most treatments for sexual dysfunctions don't address the psychological and sociocultural underpinnings of the problems, but instead focus *exclusively* on the physiological roots. For example, Montague et al. (2007, pg. 1-7) make this point perfectly clear in *The American Urological Association's* treatment options for ED: "The currently available therapies…for the treatment of erectile dysfunction include the following: oral phosphodiesterase type 5 inhibitors, intra-urethral alprostadil, intracavernous vasoactive drug injection, vacuum constriction devices, and penile prosthesis implantation."

Treatments that focus solely on managing symptoms with biological fixes neglect the fundamental issue of sexual dysfunctions being grounded in psychological, relational, and social contexts.

Relationship issues like frequent disagreement and conflict can lead to sexual dysfunction. [Image: Ed Yourdon, https://goo. gl/9e8YU5, CC BY-NC-SA 2.0, https://goo.gl/3QMoxH]

For example, a female seeking treatment for inadequate lubrication during intercourse is most likely to be prescribed a supplemental lubricant to alleviate her symptoms. The next time she is sexually intimate, the lubricant may solve her vaginal dryness, but her lack of natural arousal and lubrication due to partner abuse, is completely overlooked (Kleinplatz, 2012).

There are numerous factors associated with sexual dysfunctions, including: relationship issues; adverse sexual attitudes and beliefs; medical issues; sexually-oppressive cultural attitudes, codes, or laws; and a general lack of knowledge. Thus, treatments for sexual dysfunctions should address the physiological, psychological, and sociocultural roots of the problem.

Conclusion

We hope the information in this module has a positive impact on your physical, psychological, and relational health. As we initially promised, your clandestine Google searches should decrease now that you've acquired a scientifically-based foundation in sexual anatomy and physiology. What we neglected to mention earlier is that this foundation may dramatically increase your *overt* Google searches about sexuality! Exploring human sexuality is a limitless enterprise. And, by embracing your innate curiosity and sexual knowledge, we predict your sexual-literacy journeys are just beginning.

Outside Resources

Journal: The Journal of Sex Research

http://www.sexscience.org/journal_of_sex_research/

Journal: The Journal of Sexual Medicine

http://www.jsm.jsexmed.org/

Organization: Advocates for Youth partners with youth leaders, adult allies, and youth- serving organizations to advocate for policies and champion programs that recognize young people's rights to honest sexual health information; accessible, confidential, and affordable sexual health services; and the resources and opportunities necessary to create sexual health equity for all youth.

http://www.advocatesforyouth.org/

Organization: SIECUS – the Sexuality Information and Education Council of the United States

– was founded in 1964 to provide education and information about sexuality and sexual and reproductive health. http://www.siecus.org/

Organization: The Guttmacher Institute is a leading research and policy organization committed to advancing sexual and reproductive health and rights in the United States and globally.

https://www.guttmacher.org/

Video: 5MIweekly—YouTube channel with weekly videos that playfully and scientifically examine human sexuality.

https://www.youtube.com/channel/UCQFQ0vPPNPS-LYhlbKOzpFw

Video: Sexplanations—YouTube channel with shame-free educational videos on everything sex.

https://www.youtube.com/user/sexplanations

Video: YouTube – AsapSCIENCE

https://www.youtube.com/user/AsapSCIENCE

Web: Kinsey Confidential—Podcast with empirically-based answers about sexual questions.

http://kinseyconfidential.org/

Web: Sex & Psychology Web: Sex & Psychology—Blog about the science of sex, love, and relationships.

http://www.lehmiller.com/

Vocabulary

Abstinence

Avoiding any sexual behaviors that may lead to conception.

Age of viability

The age at which a fetus can survive outside of the uterus.

Barrier forms of birth control

Methods in which sperm is prevented from entering the uterus, either through physical or chemical barriers.

Cervix

The lower portion of the uterus that connects to the vagina.

Chromosomal sex

Also known as genetic sex; defined by the 23rd set of chromosomes.

Clitoris

A sensitive and erectile part of the vulva; its main function is to initiate orgasms.

Conception

Occurs typically within the fallopian tube, when a single sperm fertilizes an ovum cell.

Cowper's glands

Glands that produce a fluid that lubricates the urethra and neutralizes any acidity due to urine.

Emergency contraception

A form of birth control used in a variety of circumstances, such as after unprotected sex, condom mishaps, or sexual assault.

Epididymis

A twisted duct that matures, stores, and transports sperm cells into the vas deferens.

Erogenous zones

Highly sensitive areas of the body.

Excitement phase

The activation of the sympathetic branch of the autonomic nervous system defines this phase of the sexual response cycle; heart rate and breathing accelerate, along with increased blood flow to the penis, vaginal walls, clitoris, and nipples.

Fallopian tubes

The female's internal sex organ where fertilization is most likely to occur.

Foreskin

The skin covering the glans or head of the penis.

Glans penis

The highly sensitive head of the penis, associated with initiating orgasms.

Hormonal forms of birth control

Methods by which synthetic estrogen or progesterone are released to prevent ovulation and thicken cervical mucus.

Introitus

The vaginal opening to the outside of the body.

Labia majora

The "large lips" enclosing and protecting the female internal sex organs.

Labia minora

The "small lips" surrounding and defining the openings of the vagina and urethra.

Menstruation

The process by which ova as well as the lining of the uterus are discharged from the vagina after fertilization does not occur.

Mullerian ducts

Primitive female internal sex organs.

Myotonia

Involuntary muscular movements, such as facial grimaces, that occur during the excitement phase of the sexual response cycle.

Natural forms of birth control

Methods that rely on knowledge of the menstrual cycle and awareness of the body.

Neuroimaging techniques

Seeing and measuring live and active brains by such techniques as electroencephalography (EEG), computerized axial tomography (CAT), and functional magnetic resonance imaging (fMRI).

Orgasm phase

The shortest, but most pleasurable, phase of the sexual response cycle.

Orgasmic platform

The tightening of the outer third of the vaginal walls during the plateau phase of the sexual response cycle.

Ovaries

The glands housing the ova and producing progesterone, estrogen, and small amounts of testosterone.

Ovulation

When ova travel from the ovaries to the uterus.

Oxytocin

A neurotransmitter that regulates bonding and sexual reproduction.

Penis

The most prominent external sex organ in males; it has three main functions: initiating orgasm, and transporting semen and urine outside of the body.

Plateau phase

The phase of the sexual response cycle in which blood flow, heart rate, and breathing intensify.

Plethysmography

The measuring of changes in blood – or airflow – to organs.

Pregnancy

The time in which a female carries a developing human within her uterus.

Primitive gonads

Reproductive structures in embryos that will eventually develop into ovaries or testes.

Prostate gland

A male gland that releases prostatic fluid to nourish sperm cells.

Quickening

The feeling of fetal movement.

Refractory period

Time following male ejaculation in which he is unresponsive to sexual stimuli.

Resolution phase

The phase of the sexual response cycle in which the body returns to a pre-aroused state.

Safer-sex practices

Doing anything that may decrease the probability of sexual assault, sexually transmitted infections, or unwanted pregnancy; these may include using condoms, honesty, and communication.

Scrotum

The sac of skin behind and below the penis, containing the testicles.

Semen

The fluid that sperm cells are transported within.

Seminal vesicles

Glands that provide sperm cells the energy that allows them to move.

Sexual dysfunctions

A range of clinically significant impairments in a person's ability to experience pleasure or respond sexually as outlined by the sexual response cycle.

Sexual response cycle

Excitement, Plateau, Orgasm, and Resolution.

Sexually transmitted infections (STIs)

Infections primarily transmitted through social sexual behaviors.

Skene's glands

Also called minor vestibular glands, these glands are on the anterior wall of the vagina and are associated with female ejaculation.

Somatosensory cortex

A portion of the parietal cortex that processes sensory information from the skin.

Testicles

Also called testes—the glands producing testosterone, progesterone, small amounts of estrogen, and sperm cells.

Trimesters

Phases of gestation, beginning with the last menstrual period and ending about 40 weeks later; each trimester is roughly 13 weeks in length.

Urethra

The tube that carries urine and semen outside of the body.

Uterus

Also called the womb—the female's internal sex organ where offspring develop until birth.

Vagina

Also called the birth canal—a muscular canal that spans from the cervix to the introitus, it acts as a transport mechanism for sperm cells coming in, and menstrual fluid and babies going out.

Vas deferens

A muscular tube that transports mature sperm to the urethra.

Vasectomy

A surgical form of birth control in males, in which the vas deferens is intentionally damaged.

Vestibular glands (VGs)

Also called major vestibular glands, these glands are located just to the left and right of the vagina, and produce lubrication to aid in sexual intercourse.

Vulva

The female's external sex organs.

Wolffian ducts

Primitive male internal sex organs.

Zygote

Fertilized ovum.

Discussion Questions

1. Consider your own source(s) of sexual anatomy and physiology information previous to this module. Discuss at least three of your own prior sexual beliefs challenged by the content of this module.
2. Pretend you are tasked with teaching a group of adolescents about sexual anatomy, but with a twist: You must teach through the lens of pleasure instead of reproduction. What would your talking points be? Be sure to incorporate the role of the brain in evoking sexual pleasure.
3. Given how universal and similar the sexual response cycle is for both males and females, why do you think males enter a refractory period during the resolution phase and females do not? Consider potential evolutionary reasons for why this occurs.
4. Imagine yourself as a developing human being from conception to birth. Using a first- person point of view, create a commentary that addresses the significant milestones achieved in each trimester.
5. Pretend your hypothetical adolescent daughter has expressed interest in birth control. During her appointment with a health care provider, what are some factors that should be considered prior to selecting the best birth control method for her?
6. Describe at least three ways you can reduce your chances of contracting a sexually transmitted infection.
7. How can practicing safer sex enhance your well-being?
8. As discussed within the module, numerous influences contribute to the development and maintenance of a sexual dysfunction, such as, adverse sexual attitudes and beliefs. Which influences, if any, can you relate to? How do you plan on addressing those influences to achieve optimal sexual health?

References

Adams, M., S., Oye, J., & Parker, T. S. (2003). Sexuality of older adults and the Internet: From sex education to cybersex. *Sexual and Relationship Therapy*, 18, 405-415.

Aisch, G., & Marsh, B. (2014). How Likely Is It That Birth Control Could Let You Down? https://www.nytimes.com/interactive/2014/09/14/sunday-review/unplanned-pregnancies.html. Retrieved on March 23, 2017.

American Psychiatric Association. (2013). *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.). Washington, DC: Author.

Anderson, M. R., Klink, K., & Cohrssen, A. (2004). Evaluation of vaginal complaints. *Journal of The American Medical Association*, 291, 1368-1379.

Bearman, P. S., & Brückner, H. (2001). Promising the future: Virginity pledges and first intercourse. *American Journal of Sociology*, 106, 859-912.

Buhi, E.R., Daley, E.M., Oberne, A., Smith, S.A., Schneider, T., Fuhrmann, H.J.(2010). Quality and accuracy of sexual health information web sites visited by young people. *Journal of Adolescent Health*, Volume 47, Issue 2 , 206 – 208.

Capogrosso, P., Colicchia, M., Ventimiglia, E., Castagna, G., Clementi, M. C., Suardi, N., Castiglione, F., Briganti, A., Cantiello, F., Damiano, R., Montorsi, F., & Salonia, A. (2013). One patient out of four with newly diagnosed erectile dysfunction is a young man—worrisome picture from the everyday clinical practice. *Journal of Sexual Medicine*, 10, 1833-1841.

Carlson, N. R. (1986). *Physiology of behavior*. Boston: Allyn and Bacon.

Centers for Disease Control and Prevention (2016). Anal sex and HIV risk. https://www.cdc.gov/hiv/risk/analsex.html Retrieved on March 21, 2017.

Centers for Disease Control and Prevention (December 2016). What is HPV? https://www.cdc.gov/hpv/parents/whatishpv.html Retrieved on May 6, 2017.

Centers for Disease Control and Prevention (October 2016). Sexually transmitted disease surveillance, 2015. https://www.cdc.gov/std/stats15/std-surveillance-2015-print.pdf Retrieved on May 6, 2017. Centers for Disease Control, National HIV, STD, and Hepatitis Testing.

Charnetski, C. J., & Brennan, F. X. (2004). Sexual frequency and salivary Immunoglobulin A (IgA). *Psychological Reports*, 94, 839-844.

DiClemente, R. J., Salazar, L. F., & Crosby, R. A. (2007). A review of STD/HIV preventive interventions for adolescents: Sustaining effects using an ecological approach. *Journal of Pediatric Psychology*, 32, 888-906.

Diedrich, K., Fauser, B. C. J. M., Devroey, P., & Griesinger, G. (2007). The role of the endometrium and embryo in human implantation. *Human Reproduction Update*, 13, 365-377.

Ditzen, B., Hoppmann, C., & Klumb, P. (2008). Positive couple interactions and daily cortisol: On the stress-protecting role of intimacy. *Psychosomatic Medicine*, 70, 883-889.

Dreger, A. (1998). Ambiguous sex—or ambivalent medicine? Ethical issues in the treatment of intersexuality. *Hastings Center Report*, 28, 24-35.

Faddy, M.J., Gosden, R. G., Gougeon, A., Richardson, S. J., & Nelson, J. F. (1992). Accelerated disappearance of ovarian follicles in mid-life: Implications for forecasting menopause. Human Reproduction, 7, 1342–1346.

Fadul, C. E., Stommel, E. W., Dragnev, K. H., Eskey, C. J., & Dalmau, J. O. (2005). Focal paraneoplastic limbic encephalitis presenting as orgasmic epilepsy. *Journal of Neuro Oncology*, 72, 195–198.

Fleming, D. T., et al. (1997). Herpes simplex virus type 2 in the United States, 1976–1994. *New England Journal of Medicine*, 337, 1105–1111.

Forster, K. (December 8, 2016). STIs in people aged 50 to 70 have risen by more than a third over the last decade.

Independent. http://www.independent.co.uk/life-style/health-and-fa milies/health-news/older-people-stis-sexually-transmitted-infections-50-to-70-chief-med ical-officer-report-dame-sally-a7463861.html Retrieved on May 9, 2017.

Fuxman, S., De Los Santos, S., Finkelstein, D., Landon, M. K., & O'Donnell, L. (2015). Sources of information on sex and antecedents of early sexual initiation among urban Latino youth. *American Journal of Sexuality Education*, 10, 333-350.

Ginger, V. A. T., & Yang, C. C. (2011). Functional anatomy of the female sex organs. In Mulhall, J. P., Incrocci, L., Goldstein, I., & Rosen, R. (eds). *Cancer and sexual health*. Springer Publishing.

Giorgi, G., & Siccardi, M. (1996). Ultrasonographic observation of a female fetus sexual behavior in utero [Letter to the editors]. *American Journal of Obstetrics and Gynecology*, 175,(3, Part 1). Google Search Statistics, http://www.internetlivestats.com/google-search-statistics/ Retrieved on May 5, 2017.

Gott, M., & Hinchliff, S. (2003). Barriers to seeking treatment for sexual problems in primary care: A qualitative study with older people. *Family Practice*, 20, 690-695.

Grumbach, M. M., & Conte, F. A. (1998). Disorders of sex differentiation. In: Wilson, J. D., Foster, W., Kronenborg, H. M., & Larsen, P. R. (Eds.) *Williams Textbook of Endocrinology*, Ed:9th. (pps. 1303-1425). Philadelphia: WB Saunders.

Haffner, D. W. (1999). *From diapers to dating: A parent\'s guide to raising sexually healthy children*. New York, NY: Newmarket Press.

Halata, Z., & Spaethe, A. (1997). Sensory innervation of the human penis. *Advanced Experimental Medical Biology*, 424, 265–266.

Hall, S. A., Shackelton, R., Rosen, R. C., & Araujo, A. B. (2010). Sexual activity, erectile dysfunction, and incident cardiovascular events. *American Journal of Cardiology*, 105, 192-197.

Herdt, G. (1996). *Third sex, third gender–Beyond sexual dimorphism in culture and history*. Cambridge: MIT Press.

Hines, T. (2001). The G-Spot: A modern gynecologic myth. *American Journal of Obstetrics and Gynecology*, 185, 359–362.

Igbinedion, B. O. E., & Akhigbe, T. O. (2012). The accuracy of 2D ultrasound prenatal sex determination. *Nigerian Medical Journal: Journal of the Nigeria Medical Association*, 53, 71–75.

Jalili, C. (2016). Here's what 2,000 men and women fear the most about sex. *Elite Daily*. http://elitedaily.com/dating/fears-sex-study/ Retrieved on May 10, 2017.

Jannini, E. A., Rubio-Casillas, A., Whipple, B., Buisson, O., Komisaruk, B. R., & Brody, S. (2012). Female orgasm(s): One, two, several. *Journal of Sexual Medicine*, 9, 956–965.

Janssen, P. A., Thiessen, P., Klein, M. C., Whitfield, M. F., MacNab, Y. C., & Cullis-Kuhl, S. C. (2007). Standards for the measurement of birth weight, length and head circumference at term in neonates of European, Chinese and South Asian ancestry. *Open Medicine*, *1*, e74–e88.

Kilchevsky, A., Vardi, Y., Lowenstein, L., & Gruenwald, I. (2012). Is the female G-Spot truly a distinct anatomic entity? *Sexual Medicine*, 9, 719-726.

Killick, S. R., Leary, C., Trussell, J., & Guthrie, K. A. (2011). Sperm content of pre-ejaculatory fluid. *Human Fertility*, 14, 48-52.

King, B. M. (2015). *Human Sexuality Today* (7th ed.). Upper Saddle River, NJ: Prentice Hall. Kleinplatz, P. J. (2012). *New directions in sex therapy: Innovations and alternatives*. New York: Routledge.

Komisaruk, B. R., Wise, N., Frangos, E., Liu, W., Allen, K., & Brody, S. (2011). Women\'s clitoris, vagina and cervix mapped on the sensory cortex: fMRI evidence. *Journal of Sexual Medicine*, 10, 822–830.

Lucas, D. R., & Fox, J. (2018). *The psychology of human sexuality*. In R. Biswas-Diener & E. Diener (Eds), Noba textbook series: Psychology. Champaign, IL: DEF publishers. DOI: nobaproject.com).

Lucas, D. R., Roberts, C., Nylander, G., & Higdon, M. (2016). Do Americans know more about sex today than they did 25 years ago? Paper presented at the annual meeting of the Southwestern Psychological Association, Dallas, Texas.

Martinson, F. M. (1994). *The sexual life of children*. Westport, CT: Bergin & Garvey.

Masters, W. H., & Johnson, V. E. (1966). *Human Sexual Response*. Boston: Little, Brown.

McCabe, M.P., Sharlip, I.D., Lewis, R., Atalla, E., Balon, R., Fisher, A.D., Laumann, E., Lee, S.W., & Segraves, R.T. (2016).

Incidence and prevalence of sexual dysfunction in women and men: A consensus statement from the fourth international consultation on sexual medicine 2015. *The Journal of Sexual Medicine*, 13, 144 -152.
Molina G., Weiser, T.G., Lipsitz, S. R., Esquivel, M. M., Uribe-Leitz, T., Azad, T., Shah, N., Semrau, K., Berry, W. R., Gawande, A. A., & Haynes, A. B. Relationship between Cesarean delivery rate and maternal and neonatal mortality. *Journal of the American Medical Association*, 314, 2263-2270.
Montague, D. K., Jarow, J. P., Broderick, G. A., et al. (2007). The management of erectile dysfunction: An update. *The American Urological Association. Journal of Urology, June*.
Moore, K.T., Persaud, T.V.N., & Torchia, M.G. (2016). *The developing human: Clinically oriented embryology*. Philadelphia, PA: Elsevier, Inc.
Munoz, K., Davtyan, M., & Brown, B. (2014). Revisiting the condom riddle: Solutions and implications. *Electronic Journal of Human Sexuality*, 17.
Nappi, R. E., & Lachowsky, M. (2009). Menopause and sexuality: Prevalence of symptoms and impact on quality of life. *Maturitas*, 63, 138-141.
Nguyen, N., & Holodniy, M. (2008). HIV infection in the elderly. *Clinical Interventions in Aging*, 3, 453–472.
Nummenmaa, L., Suvilehto, J.T., Glerean, E., Santtila, P., & Hietanen, J. K. (2016). Topography of human erogenous zones. *Archives of Sexual Behavior*, 45, 1207-1216.
Nuno, S. M. (2017). Let's talk about sex: The importance of open communication about sexuality before and during Relationships. In N. R. Stilton (Ed.), *Family Dynamics and Romantic Relationships in a Changing Society* (pp. 47-61). IGI Global.
O'Connell, H.E., Sanjeevan, K.V., & Hutson, J. M. (2005). Anatomy of the clitoris. *Journal of Urology*, 174, 1189-1195.
Odeh M., Ophir E., & Bornstein J. (2008). Hypospadias mimicking female genitalia on early second trimester sonographic examination. *Journal of Clinical Ultrasound*, 36, 581–583.
Opperman, E., Braun, V., Clarke, V., & Rogers, C. (2014). It feels so good it almost hurts: Young adults experiences of orgasm and sexual pleasure. *The Journal of Sex Research*, 51, 503-515. Options for Sexual Health. Retrieved on July 2, 2017.
Ortigue, S., Grafton, S. T., & Bianchi-Demicheli, F. (2007). Correlation between insula activation and self-reported quality of orgasm in women. *Neuroimage*, 37, 551-560.
Owen, D. H., & Katz, D. F. (2005). A review of the physical and chemical properties of human semen and the formulation of a semen simulant. *Journal of Andrology*, 26, 459–469.
Paik, A., Sanchagrin, K. J., & Heimer, K. (2016). Broken promises: Abstinence pledging and sexual and reproductive health. *Journal of Marriage and Family*, 78, 546-561.
Parrot, A. (1994). Incest, infertility, infant sexuality. In Bullough, V. & Bullough, B. (Eds.), *Human Sexuality Encyclopedia* (pp. 289-310). New York, NY: Garland.
Penfield, W., & Boldrey, E. (1937). Somatic motor and sensory representation in the cerebral cortex of man as studied by electrical stimulation. *Brain*, 60, 389-443.
Porst, H., Montorsi, F., Rosen, R.C., Gaynor, L., Grupe, S., & Alexander, J. (2007). The Premature Ejaculation Prevalence and Attitudes (PEPA) survey: Prevalence, comorbidities, and professional help-seeking. *European Urology*, 51, 816–824.
Rosen, R. C. (2000). Prevalence and risk factors of sexual dysfunction in men and women. *Current Psychiatry Reports*, 3,189-195.
Rysavy, M. A., Li, L., Bell, E. F., Das, A., Hintz, S. R., Stoll, B. J., et al. (2015). Between-hospital variation in treatment and outcomes in extremely preterm infants. *New England Journal of Medicine*, 372, 1801–1811.
Satterwhite, C. L., Torrone, E., Meites, E., Dunne, E. F., Mahajan, R., Ocfemia, M. C., Su, J., Xu, F., & Weinstock, H. (2013). Sexually transmitted infections among U.S. women and men: Prevalence and incidence estimates, 2008. *Sexually Transmitted Diseases*, 40, 187-193.
Shah, J., & Christopher, N. (2002). Can shoe size predict penile length? *British Journal of Urology International*, 90, 586–587.

Siminoski, K., & Bain, J. (1993). The relationships among height, penile length, and foot size. *Annals of Sex Research*, 6, 231-235.
Simon, L., & Daneback, K. (2013). Adolescents' use of the Internet for sex education: A thematic and critical review of the literature. *International Journal of Sexual Health*, 25, 305-319.
Stephens-Davidowitz, S. (2015). Searching for sex. *Sunday Review, New York Times*, https://www.nytimes.com/2015/01/25/opinion/sunday/seth-stephens-davidowitz-search ing-for-sex.html. Retrieved on May 5, 2017.
Swaab, D. F. (2004). Sexual differentiation of the human brain: Relevance for gender identity, transsexualism and sexual orientation. *Gynecological Endocrinology*, 19, 301-312.
Tachedjiana, G., Aldunatea, M., Bradshawe, C. S., & Coneg, R. A. (in press). The role of lactic acid production by probiotic Lactobacillus species in vaginal health. *Research in Microbiology*
The Society of Obstetricians and Gynaecologists of Canada. Retrieved on July 2, 2017. Thompson, D. (2016). Anatomy may be key to female orgasm. https://consumer.healthday.com/sexual-health-information-32/orgasm-health-news-510/anatomy-may-be-key-to-female-orgasm-709934.html. Retrieved on March 25, 2017.
Veale, D., Miles, S., Bramley, S., Muir, G. & Hodsoll, J. (2015). Am I normal? A systematic review and construction of nomograms for flaccid and erect penis length and circumference in up to 15,521 men. *British Journal of Urology International*, 115, 978–986.
Weiss, R. (2014). Baby Boomers Gone Wild! Seniors and STDs. *Psychology Today*. https://www.psychologytoday.com/blog/love-and-sex-in-the-digital-age/201403/baby-boo mers-gone-wild-seniors-and-stds Retrieved on May 6, 2017.
Wessells, H., Lue, T.F., & McAninch, J. W. (1996). Penile length in the flaccid and erect states: Guidelines for penile augmentation. *Journal of Urology*, 156, 995-997.
Wickman, D. (2017). Plasticity of the Skene\'s gland in women who report fluid ejaculation with orgasm. *The Journal of Sexual Medicine*, 14, S67.
Wilcox, A. J., Dunson, D., & Baird, D. D. (2000). The timing of the "fertile window" in the menstrual cycle: Day specific estimates from a prospective study. *British Medical Journal*, 321, 1259-1262.
Wisniewski, A. B., Migeon, C J., Meyer-Bahlburg, H. F., Gearhart, J. P., Berkovitz, G. D., Brown, T. R., & Money, J. (2000). Complete androgen insensitivity syndrome: Long-term medical, surgical, and psychosexual outcome. *Journal of Clinical Endocrinology and Metabolism*, 85, 2664–2669.
Wizemann , T. M., & Pardue, M. L. (2001). Sex begins in the womb. In T. M. Wizemann & M. L. Pardue (Eds.), *Exploring the Biological Contributions to Human Health: Does Sex Matter*? Washington (DC): National Academies Press (US).
World Health Organization (August 2016). Sexually transmitted infections (STIs). http://www.who.int/mediacentre/factsheets/fs110/en/ Retrieved May 6, 2017.

THE NATURE-NURTURE QUESTION

Eric Turkheimer

People have a deep intuition about what has been called the "nature–nurture question." Some aspects of our behavior feel as though they originate in our genetic makeup, while others feel like the result of our upbringing or our own hard work. The scientific field of behavior genetics attempts to study these differences empirically, either by examining similarities among family members with different degrees of genetic relatedness, or, more recently, by studying differences in the DNA of people with different behavioral traits. The scientific methods that have been developed are ingenious, but often inconclusive. Many of the difficulties encountered in the empirical science of behavior genetics turn out to be conceptual, and our intuitions about nature and nurture get more complicated the harder we think about them. In the end, it is an oversimplification to ask how "genetic" some particular behavior is. Genes and environments always combine to produce behavior, and the real science is in the discovery of how they combine for a given behavior.

Learning Objectives

- Understand what the nature–nurture debate is and why the problem fascinates us.
- Understand why nature–nurture questions are difficult to study empirically.
- Know the major research designs that can be used to study nature–nurture questions.
- Appreciate the complexities of nature–nurture and why questions that seem simple turn out not to have simple answers.

Introduction

There are three related problems at the intersection of philosophy and science that are fundamental to our understanding of our relationship to the natural world: the mind–body problem, the free will problem, and the nature–nurture problem. These great questions have a lot in common. Everyone, even those without much knowledge of science or philosophy, has opinions about the answers to these questions that come simply from observing the world we live in. Our feelings about our relationship with the physical and biological world often seem incomplete. We are in control of our actions in some ways, but at the mercy of our bodies in others; it feels obvious that our consciousness is some kind of creation of our physical brains, at the same time we sense that our awareness must go beyond just the physical. This incomplete knowledge of our relationship with nature leaves us fascinated and a little obsessed, like a cat that climbs into a paper bag and then out again, over and over, mystified every time by a relationship between inner and outer that it can see but can't quite understand.

It may seem obvious that we are born with certain characteristics while others are acquired, and yet of the three great questions about humans' relationship with the natural world, only nature–nurture gets referred to as a "debate." In the history of psychology, no other question has caused so much controversy and offense: We are so concerned with nature–nurture because our very sense of moral character seems to depend on it. While we may admire the athletic skills of a great basketball player, we think of his height as simply a gift, a payoff in the "genetic lottery." For the same reason, no one blames a short person for his height or someone's congenital disability on poor decisions: To state the obvious, it's "not their fault." But we do praise the concert violinist (and perhaps her parents and teachers as well) for her dedication, just as we condemn cheaters, slackers, and bullies for their bad behavior.

The problem is, most human characteristics aren't usually as clear-cut as height or instrument- mastery, affirming our nature–nurture expectations strongly one way or the other. In fact, even the great violinist might have some inborn qualities—perfect pitch, or long, nimble fingers—that support and reward her hard work. And the basketball player might have eaten a diet while growing up that promoted his genetic tendency for being tall. When we think about our own qualities, they seem under our control in some respects, yet beyond our control in others. And often the traits that don't seem to have an obvious cause are the ones that concern us the most and are far more personally significant. What about how much we drink or worry? What about our honesty, or religiosity, or sexual orientation? They all come from that uncertain zone, neither fixed by nature nor totally under our own control.

One major problem with answering nature-nurture questions about people is, how do you set up an experiment? In nonhuman animals, there are relatively straightforward experiments for tackling nature–nurture questions.

Researchers have learned a great deal about the nature-nurture dynamic by working with animals. But of course many of the techniques used to study animals cannot be applied to people. Separating these two influences in human subjects is a greater research challenge. [Image: Sebastián Dario, https://goo.gl/OPiIWd, CC BY-NC 2.0, https://goo.gl/FIlc2e]

Say, for example, you are interested in aggressiveness in dogs. You want to test for the more important determinant of aggression: being born to aggressive dogs or being raised by them. You could mate two aggressive dogs—angry Chihuahuas— together, and mate two nonaggressive dogs—happy beagles—together, then switch half the puppies from each litter between the different sets of parents to raise. You would then have puppies born to aggressive parents (the Chihuahuas) but being raised by nonaggressive parents (the Beagles), and vice versa, in litters that mirror each other in puppy distribution. The big questions are: Would the Chihuahua parents raise aggressive beagle puppies? Would the beagle parents raise *non*aggressive Chihuahua puppies? Would the puppies' *nature* win out, regardless of who raised them? Or... would the result be a combination of nature *and* nurture? Much of the most significant nature–nurture research has been done in this way (Scott & Fuller, 1998), and animal breeders have been doing it successfully for thousands of years. In fact, it is fairly easy to breed animals for behavioral traits.

With people, however, we can't assign babies to parents at random, or select parents with certain behavioral characteristics to mate, merely in the interest of science (though history does include horrific examples of such practices, in misguided attempts at "eugenics," the shaping of human characteristics through intentional breeding). In typical human families, children's biological parents raise them, so it is very difficult to know whether children act like their parents due to genetic (nature) or environmental (nurture) reasons. Nevertheless, despite our restrictions on setting up human-based experiments, we do see real-world examples of nature-nurture at work in the human sphere—though they only provide partial answers to our many questions.

The science of how genes and environments work together to influence behavior is called **behavioral genetics**. The easiest opportunity we have to observe this is the **adoption study**. When children are put up for adoption, the parents who give birth to them are no longer the parents who raise them. This setup isn't quite the same as the experiments with dogs (children aren't assigned to random adoptive parents in order to suit the particular interests of a scientist) but adoption still tells us some interesting things, or at least confirms some basic expectations. For instance, if the biological child of tall parents were adopted into a family of short people, do you suppose the child's growth would be affected? What about the biological child of a Spanish-speaking family adopted at birth into an English-speaking family? What language would you expect the child to speak? And what might these outcomes tell you about the difference between height and language in terms of nature-nurture?

Another option for observing nature- nurture in humans involves **twin studies**. There are two types of twins: monozygotic (MZ) and dizygotic (DZ). Monozygotic twins, also called "identical" twins, result from a single zygote (fertilized egg) and have the same DNA. They are essentially clones. Dizygotic twins, also known as "fraternal" twins, develop from two zygotes and share 50% of their DNA. Fraternal twins are ordinary siblings who happen to have been born at the same time. To analyze nature– nurture using twins, we compare the similarity of MZ and DZ pairs. Sticking with the features of height and spoken language, let's take a look at how nature and nurture apply: Identical twins, unsurprisingly, are almost perfectly similar for height.

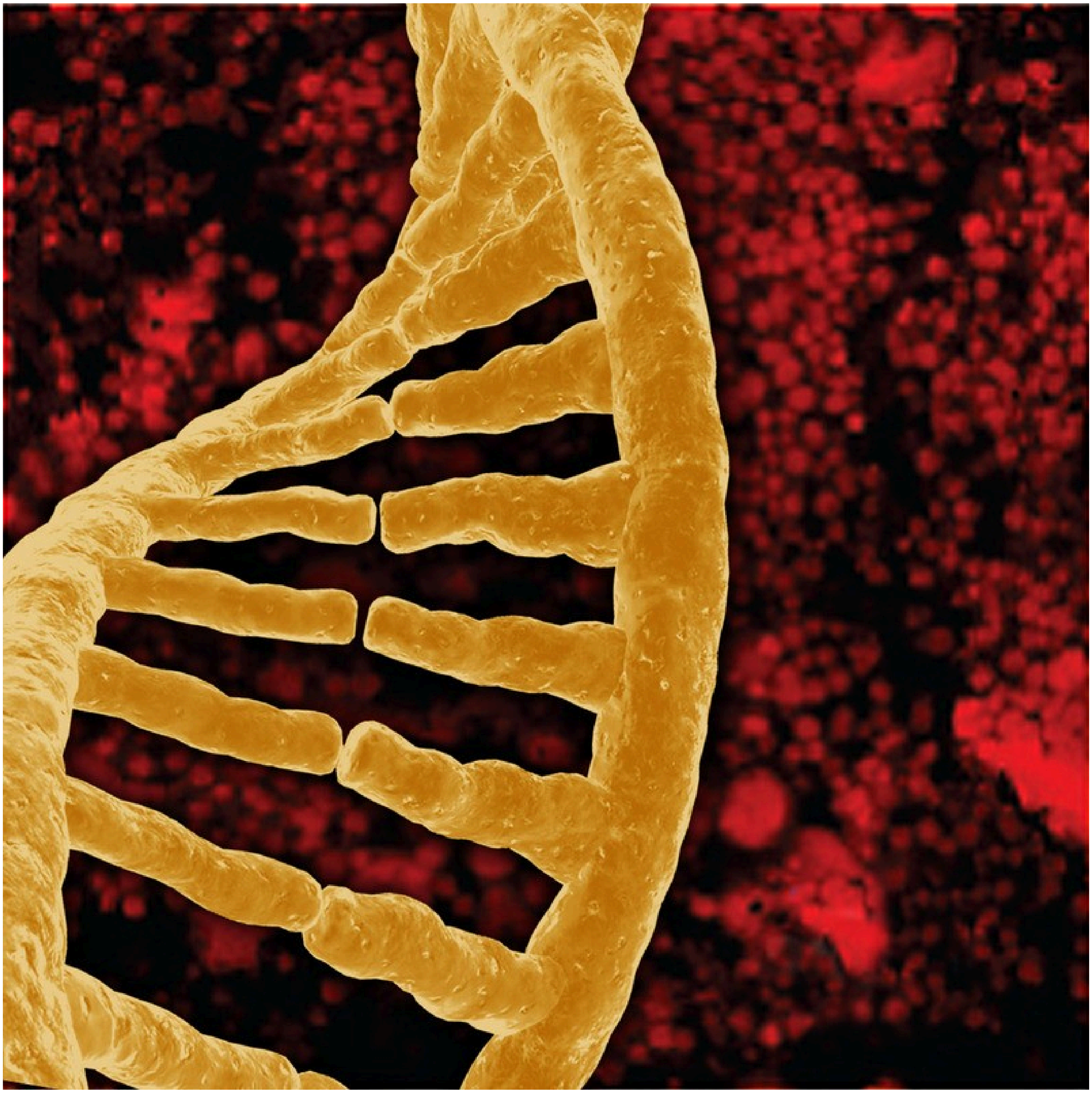
Studies focused on twins have led to important insights about the biological origins of many personality characteristics.

The heights of fraternal twins, however, are like any other sibling pairs: more similar to each other than to people from other families, but hardly identical. This contrast between twin types gives us a clue about the role genetics plays in determining height. Now consider spoken language. If one identical twin speaks Spanish at home, the co-twin with whom she is raised almost certainly does too. But the same would be true for a pair of fraternal twins raised together. In terms of spoken language, fraternal twins are just as similar as identical twins, so it appears that the genetic match of identical twins doesn't make much difference.

Twin and adoption studies are two instances of a much broader class of methods for observing nature-nurture called **quantitative genetics**, the scientific discipline in which similarities among individuals are analyzed based on how biologically related they are. We can do these studies with siblings and half-siblings, cousins, twins who have been separated at birth and raised separately (Bouchard, Lykken, McGue, & Segal, 1990; such twins are very rare and play a smaller role than is commonly believed in the science of nature–nurture), or with entire extended families (see Plomin, DeFries, Knopik, & Neiderhiser, 2012, for a complete introduction to research methods relevant to nature–nurture).

For better or for worse, contentions about nature–nurture have intensified because quantitative genetics produces a number called a **heritability coefficient**, varying from 0 to 1, that is meant to provide a single measure of genetics' influence of a trait. In a general way, a heritability coefficient measures how strongly differences among individuals are related to differences among their genes. But beware: Heritability coefficients, although simple to compute, are deceptively difficult to interpret. Nevertheless, numbers that provide simple answers to complicated questions tend to have a strong influence on the human imagination, and a great deal of time has been spent discussing whether the heritability of intelligence or personality or depression is equal to one number or another.

One reason nature–nurture continues to fascinate us so much is that we live in an era of great scientific discovery in genetics, comparable to the times of Copernicus, Galileo, and Newton, with regard to astronomy and physics. Every day, it seems, new discoveries are made, new possibilities proposed. When Francis Galton first started thinking about nature–nurture in the late-19th century he was very influenced by his cousin, Charles Darwin, but genetics *per se* was unknown. Mendel's famous work with peas, conducted at about the same time, went undiscovered for 20 years; quantitative genetics was developed in the 1920s; DNA was discovered by Watson and Crick in the 1950s; the human genome was completely sequenced at the turn of the 21st century; and we are now on the verge of being able to obtain the specific DNA sequence of anyone at a relatively low cost.



Quantitative genetics uses statistical methods to study the effects that both heredity and environment have on test subjects. These methods have provided us with the heritability coefficient which measures how strongly differences among individuals for a trait are related to differences among their genes. [Image: EMSL, https://goo.gl/IRfn9g, CC BY-NC-SA 2.0, https://goo.gl/fbv27n]

No one knows what this new genetic knowledge will mean for the study of nature–nurture, but as we will see in the next section, answers to nature–nurture questions have turned out to be far more difficult and mysterious than anyone imagined.

Outside Resources

Web: Institute for Behavioral Genetics

http://www.colorado.edu/ibg/

Discussion Questions

1. Is your personality more like one of your parents than the other? If you have a sibling, is his or her personality like yours? In your family, how did these similarities and differences develop? What do you think caused them?
2. Can you think of a human characteristic for which genetic differences would play almost no role? Defend your choice.
3. Do you think the time will come when we will be able to predict almost everything about someone by examining their DNA on the day they are born?
4. Identical twins are more similar than fraternal twins for the trait of aggressiveness, as well as for criminal behavior. Do these facts have implications for the courtroom? If it can be shown that a violent criminal had violent parents, should it make a difference in culpability or sentencing?

Vocabulary

Adoption study

A behavior genetic research method that involves comparison of adopted children to their adoptive and biological parents.

Behavioral genetics

The empirical science of how genes and environments combine to generate behavior.

Heritability coefficient

An easily misinterpreted statistical construct that purports to measure the role of genetics in the explanation of differences among individuals.

Quantitative genetics

Scientific and mathematical methods for inferring genetic and environmental processes based on the degree of genetic and environmental similarity among organisms.

Twin studies

A behavior genetic research method that involves comparison of the similarity of identical (monozygotic; MZ) and fraternal (dizygotic; DZ) twins.

References

Bouchard, T. J., Lykken, D. T., McGue, M., & Segal, N. L. (1990). Sources of human psychological differences: The Minnesota study of twins reared apart. Science, 250(4978), 223–228.

Caspi, A., McClay, J., Moffitt, T. E., Mill, J., Martin, J., Craig, I. W., Taylor, A. & Poulton, R. (2002). Role of genotype in the cycle of violence in maltreated children. Science, 297(5582), 851– 854.

McGue, M., & Lykken, D. T. (1992). Genetic influence on risk of divorce. Psychological Science, 3(6), 368–373.

Plomin, R., Corley, R., DeFries, J. C., & Fulker, D. W. (1990). Individual differences in television viewing in early childhood: Nature as well as nurture. Psychological Science, 1(6), 371–377.

Plomin, R., DeFries, J. C., Knopik, V. S., & Neiderhiser, J. M. (2012). Behavioral genetics. New York, NY: Worth Publishers.

Scott, J. P., & Fuller, J. L. (1998). Genetics and the social behavior of the dog. Chicago, IL: University of Chicago Press.

Turkheimer, E. (2000). Three laws of behavior genetics and what they mean. Current Directions in Psychological Science, 9(5), 160–164.

SENSATION AND PERCEPTION

The topics of sensation and perception are among the oldest and most important in all of psychology. People are equipped with senses such as sight, hearing and taste that help us to take in the world around us. Amazingly, our senses have the ability to convert real-world information into electrical information that can be processed by the brain. The way we interpret this information– our perceptions– is what leads to our experiences of the world. In this module, you will learn about the biological processes of sensation and how these can be combined to create perceptions.

Learning Objectives

- Differentiate the processes of sensation and perception.
- Explain the basic principles of sensation and perception.
- Describe the function of each of our senses.
- Outline the anatomy of the sense organs and their projections to the nervous system.
- Apply knowledge of sensation and perception to real world examples.
- Explain the consequences of multimodal perception.

Introduction

> *"Once I was hiking at Cape Lookout State Park in Tillamook, Oregon. After passing through a vibrantly colored, pleasantly scented, temperate rainforest, I arrived at a cliff overlooking the Pacific Ocean. I grabbed the cold metal railing near the edge and looked out at the sea. Below me, I could see a pod of sea lions swimming in the deep blue water. All around me I could smell the salt from the sea and the scent of wet, fallen leaves."*

This description of a single memory highlights the way a person's senses are so important to our experience of the world around us.

Before discussing each of our extraordinary senses individually, it is necessary to cover some basic concepts that apply to all of them. It is probably best to start with one very important distinction that can often be confusing: the difference between sensation and perception. The *physical* process during which our sensory organs—those involved with hearing and taste, for example— respond to external stimuli is called **sensation**. Sensation happens when you eat noodles or feel the wind on your face or hear a car horn honking in the distance. During sensation, our sense organs are engaging in **transduction**, the conversion of one form of energy into another. Physical energy such as light or a sound wave is converted into a form of energy the brain can understand: electrical stimulation. After our brain receives the electrical signals, we make sense of all this stimulation and begin to appreciate the complex world around us. This *psychological* process—making sense of the stimuli—is called **perception**. It is during this process that you are able to *identify* a gas leak in your home or a song that reminds you of a specific afternoon spent with friends.

Our senses combine to create our perceptions of the world. [Image: Adam John Privitera, CC BY-NC-SA 4.0, https://goo.gl/H2QaA8]

Regardless of whether we are talking about sight or taste or any of the individual senses, there are a number of basic principles that influence the way our sense organs work. The first of these influences is our ability to detect an external stimulus. Each sense organ—our eyes or tongue, for instance—requires a minimal amount of stimulation in order to detect a stimulus. This **absolute threshold** explains why you don't smell the perfume someone is wearing in a classroom unless they are somewhat close to you. Because absolute threshold changes throughout the day and based on what other stimuli you have recently experienced, researchers define absolute threshold as the minimum about of stimulation needed to detect a stimulus 50% of the time.

The way we measure absolute thresholds is by using a method called **signal detection**. This process involves presenting stimuli of varying intensities to a research participant in order to determine the level at which he or she can reliably detect stimulation in a given sense. During one type of hearing test, for example, a person listens to increasingly louder tones (starting from silence). This type of test is called *the method of limits*, and it is an effort to determine the point, or threshold, at which a person begins to hear a stimulus (see Additional Resources for a video demonstration). In the example of louder tones, the method of limits test is using *ascending trials*. Some method of limits tests use *descending trials*, such as making a light grow dimmer until a person can no longer see it. Correctly indicating that a sound was heard is called a hit; failing to do so is called a miss. Additionally, indicating that a sound was heard when one wasn't played is called a *false alarm*, and correctly identifying when a sound wasn't played is a *correct rejection*.

Through these and other studies, we have been able to gain an understanding of just how remarkable our senses are. For example, the human eye is capable of detecting candlelight from 30 miles away in the dark. We are also capable of hearing the ticking of a watch in a quiet environment from 20 feet away. If you think that's amazing, I encourage you to read more about the extreme sensory capabilities of nonhuman animals; many animals possess what we would consider super-human abilities.

A similar principle to the absolute threshold discussed above underlies our ability to detect the difference between two stimuli of different intensities. The **differential threshold** (or difference threshold) or **just noticeable difference (JND)**, for each sense has been studied using similar methods to signal detection. To illustrate, find a friend and a few objects of known weight (you'll need objects that weigh 1, 2, 10 and 11 lbs.—or in metric terms: 1, 2, 5 and 5.5 kg). Have your friend hold the lightest object (1 lb. or 1 kg). Then, replace this object with the next heaviest and ask him or her to tell you which one weighs more. Reliably, your friend will say the second object every single time. It's extremely easy to tell the difference when something weighs double what another weighs! However, it is not so easy when the difference is a smaller percentage of the overall weight. It will be much harder for your friend to reliably tell the difference between 10 and 11 lbs. (or 5 versus 5.5 kg) than it is for 1 and 2 lbs. This is phenomenon is called **Weber's Law**, and it is the idea that bigger stimuli require larger differences to be noticed. As with the absolute threshold, your ability to notice differences varies throughout the day and based on what other stimuli you have recently experienced so the difference threshold is defined as the smallest difference detectable 50% of the time.

Crossing into the world of perception, it is clear that our experience influences how our brain processes things. You have tasted food that you like and food that you don't like. There are some bands you enjoy and others you can't stand. However, during the time you first eat something or hear a band, you process those stimuli using **bottom-up processing**. This is when we build up to perception from the individual pieces. Sometimes, though, stimuli we've experienced in our past will influence how we process new ones. This is called **top-down processing**. The best way to illustrate these two concepts is with our ability to read. Read the following quote out loud:

Figure 1. An example of stimuli processing.

Notice anything odd while you were reading the text in the triangle? Did you notice the second "the"? If not, it's likely because you were reading this from a top-down approach. Having a second "the" doesn't make sense. We know this. Our brain knows this and doesn't *expect* there to be a second one, so we have a tendency to skip right over it. In other words, your past experience has changed the way you perceive the writing in the triangle! A beginning reader—one who is using a bottom-up approach by carefully attending to each piece—would be less likely to make this error.

Finally, it should be noted that when we experience a sensory stimulus that doesn't change, we stop paying attention to it. This is why we don't feel the weight of our clothing, hear the hum of a projector in a lecture hall, or see all the tiny scratches on the lenses of our glasses. When a stimulus is constant and unchanging, we experience **sensory adaptation**. This occurs because if a stimulus does not change, our receptors quit responding to it. A great example of this occurs when we leave the radio on in our car after we park it at home for the night. When we listen to the radio on the way home from work the volume seems reasonable. However, the next morning when we start the car, we might be startled by how loud the radio. We don't remember it being that loud last night. What happened? We adapted to the constant stimulus (the radio volume) over the course of the previous day and increased the volume at various times.

Now that we have introduced some basic sensory principles, let us take on each one of our fascinating senses individually.

Vision

How vision works

Vision is a tricky matter. When we see a pizza, a feather, or a hammer, we are actually seeing light bounce off that object and into our eye. Light enters the eye through the pupil, a tiny opening behind the cornea. The pupil regulates the amount of light entering the eye by contracting (getting smaller) in bright light and dilating (getting larger) in dimmer light. Once past the pupil, light passes through the lens, which focuses an image on a thin layer of cells in the back of the eye, called the **retina**.

Because we have two eyes in different locations, the image focused on each retina is from a slightly different angle (**binocular disparity**), providing us with our perception of 3D space (**binocular vision**). You can appreciate this by holding a pen in your hand, extending your arm in front of your face, and looking at the pen while closing each eye in turn. Pay attention to the apparent position of the pen relative to objects in the background. Depending on which eye is open, the pen appears to jump back and forth! This is how video game manufacturers create the perception of 3D without special glasses; two slightly different images are presented on top of one another.

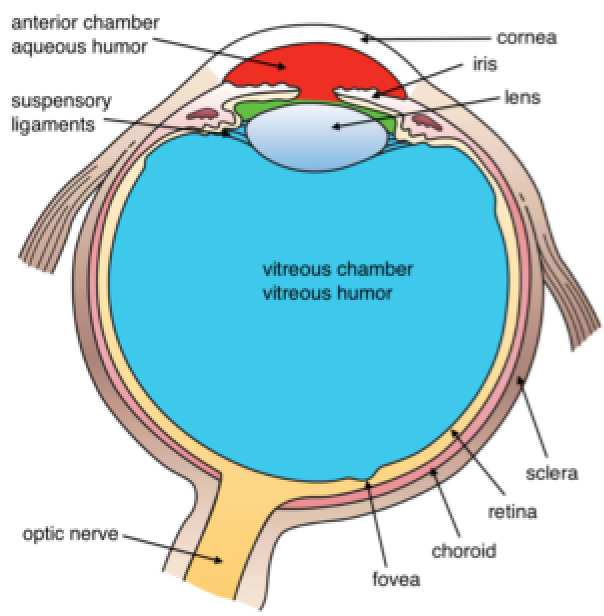


Figure 2. Diagram of the human eye. Notice the Retina, labeled here: this is the location of the Cones and Rods in the eye. [Image: Holly Fischer, https://goo.gl/ozuG0Q, CC BY 3.0, https://goo.gl/TSIsIq]

It is in the retina that light is transduced, or converted into electrical signals, by specialized cells called photoreceptors. The retina contains two main kinds of photoreceptors: **rods**and **cones**. Rods are primarily responsible for our ability to see in dim light conditions, such as during the night. Cones, on the other hand, provide us with the ability to see color and fine detail when the light is brighter. Rods and cones differ in their distribution across the retina, with the highest concentration of cones found in the fovea (the central region of focus), and rods dominating the periphery (see Figure 2). The difference in distribution can explain why looking directly at a dim star in the sky makes it seem to disappear; there aren't enough rods to process the dim light!Next, the electrical signal is sent through a layer of cells in the retina, eventually traveling down the optic nerve. After passing through the thalamus, this signal makes it to the **primary visual cortex**, where information about light orientation and movement begin to come together (Hubel & Wiesel, 1962). Information is then sent to a variety of different areas of the cortex for more complex processing. Some of these cortical regions are fairly specialized—for example, for processing faces (fusiform face area) and body parts (extrastriate body area). Damage to these areas of the cortex can potentially result in a specific kind of **agnosia**, whereby a person loses the ability to perceive visual stimuli. A great example of this is illustrated in the writing of famous neurologist Dr. Oliver Sacks; he experienced *prosopagnosia*, the inability to recognize faces. These specialized regions for visual recognition comprise the **ventral pathway** (also called the "what" pathway). Other areas involved in processing location and movement make up the **dorsal pathway** (also called the "where" pathway). Together, these pathways process a large amount of information about visual stimuli (Goodale & Milner, 1992). Phenomena we often refer to as optical illusions provide misleading information to these "higher" areas of visual processing (see Additional Resources for websites containing amazing optical illusions).

Dark and light adaptation

Humans have the ability to adapt to changes in light conditions. As mentioned before, rods are primarily involved in our ability to see in dim light. They are the photoreceptors responsible for allowing us to see in a dark room. You might notice that this night vision ability takes around 10 minutes to turn on, a process called **darkadaptation**. This is because our rods become bleached in normal light conditions and require time to recover. We experience the opposite effect when we leave a dark movie theatre and head out into the afternoon sun. During **lightadaptation**, a large number of rods and cones are bleached at once, causing us to be blinded for a few seconds. Light adaptation happens almost instantly compared with dark adaptation. Interestingly, some people think pirates wore a patch over one eye in order to keep it adapted to the dark while the other was adapted to the light. If you want to turn on a light without losing your night vision, don't worry about wearing an eye patch, just use a red light; this wavelength doesn't bleach your rods.

Color vision

Figure 3. Stare at the center of the Canadian flag for fifteen seconds. Then, shift your eyes away to a white wall or blank piece of paper. You should see an "after image" in a different color scheme.

Our cones allow us to see details in normal light conditions, as well as color. We have cones that respond *preferentially*, not exclusively, for red, green and blue (Svaetichin, 1955). This **trichromatic theory** is not new; it dates back to the early 19th century (Young, 1802; Von Helmholtz, 1867). This theory, however, does not explain the odd effect that occurs when we look at a white wall after staring at a picture for around 30 seconds. Try this: stare at the image of the flag in Figure 3 for 30 seconds and then immediately look at a sheet of white paper or a wall. According to the trichromatic theory of color vision, you should see white when you do that. Is that what you experienced? As you can see, the trichromatic theory doesn't explain the *afterimage* you just witnessed. This is where the **opponent-process theory** comes in (Hering, 1920). This theory states that our cones send information to *retinal ganglion cells* that respond to *pairs* of colors (red-green, blue-yellow, black-white). These specialized cells take information from the cones and compute the difference between the two colors—a process that explains why we cannot see reddish-green or bluish-yellow, as well as why we see afterimages. Color deficient vision can result from issues with the cones or retinal ganglion cells involved in color vision.

Hearing (Audition)

Some of the most well-known celebrities and top earners in the world are musicians. Our worship of musicians may seem silly when you consider that all they are doing is vibrating the air a certain way to create **sound waves**, the physical stimulus for **audition**.

People are capable of getting a large amount of information from the basic qualities of sound waves. The *amplitude* (or intensity) of a sound wave codes for the loudness of a stimulus; higher amplitude sound waves result in louder sounds. The *pitch* of a stimulus is coded in the *frequency* of a sound wave; higher frequency sounds are higher pitched. We can also gauge the quality, or *timbre*, of a sound by the complexity of the sound wave. This allows us to tell the difference between bright and dull sounds as well as natural and synthesized instruments (Välimäki & Takala, 1996).

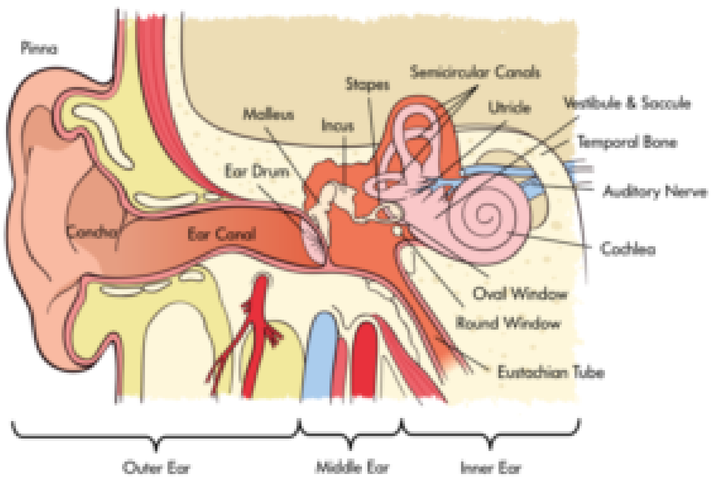


Figure 4. Diagram of the human ear. Notice the Cochlea labeled here: it is the location of the auditory Hair Cells that are tonotopically organized.

In order for us to sense sound waves from our environment they must reach our inner ear. Lucky for us, we have evolved tools that allow those waves to be funneled and amplified during this journey. Initially, sound waves are funneled by your **pinna** (the external part of your ear that you can actually see) into your **auditory canal** (the hole you stick Q-tips into despite the box advising against it). During their journey, sound waves eventually reach a thin, stretched membrane called the **tympanic membrane** (eardrum), which vibrates against the three smallest bones in the body—the malleus (hammer), the incus (anvil), and the stapes (stirrup)—collectively called the **ossicles**. Both the tympanic membrane and the ossicles amplify the sound waves before they enter the fluid-filled **cochlea**, a snail-shell-like bone structure containing **auditory hair cells** arranged on the basilar membrane (see Figure 4) according to the frequency they respond to (called tonotopic organization). Depending on age, humans can normally detect sounds between 20 Hz and 20 kHz. It is inside the cochlea that sound waves are converted into an electrical message.

Because we have an ear on each side of our head, we are capable of localizing sound in 3D space pretty well (in the same way that having two eyes produces 3D vision). Have you ever dropped something on the floor without seeing where it went? Did you notice that you were somewhat capable of locating this object based on the sound it made when it hit the ground? We can reliably locate something based on which ear receives the sound first. What about the height of a sound?

If both ears receive a sound at the same time, how are we capable of localizing sound vertically? Research in cats (Populin & Yin, 1998) and humans (Middlebrooks & Green, 1991) has pointed to differences in the quality of sound waves depending on vertical positioning.

After being processed by auditory hair cells, electrical signals are sent through the *cochlear nerve* (a division of the vestibulocochlear nerve) to the thalamus, and then the **primary auditory cortex** of the temporal lobe. Interestingly, the tonotopic organization of the cochlea is maintained in this area of the cortex (Merzenich, Knight, & Roth, 1975; Romani, Williamson, & Kaufman, 1982). However, the role of the primary auditory cortex in processing the wide range of features of sound is still being explored (Walker, Bizley, & Schnupp, 2011).

Balance and the vestibular system

The inner ear isn't only involved in hearing; it's also associated with our ability to balance and detect where we are in space. The **vestibular system** is comprised of three semicircular canals—fluid-filled bone structures containing cells that respond to changes in the head's orientation in space. Information from the vestibular system is sent through the vestibular nerve (the other division of the vestibulocochlear nerve) to muscles involved in the movement of our eyes, neck, and other parts of our body. This information allows us to maintain our gaze on an object while we are in motion. Disturbances in the vestibular system can result in issues with balance, including vertigo.

Touch

Who doesn't love the softness of an old t-shirt or the smoothness of a clean shave? Who actually enjoys having sand in their swimsuit? Our skin, the body's largest organ, provides us with all sorts of information, such as whether something is smooth or bumpy, hot or cold, or even if it's painful. **Somatosensation**–which includes our ability to sense touch, temperature and pain–transduces physical stimuli, such as fuzzy velvet or scalding water, into electrical potentials that can be processed by the brain.

Tactile sensation

Tactile stimuli–those that are associated with texture–are transduced by special receptors in the skin called **mechanoreceptors**. Just like photoreceptors in the eye and auditory hair cells in the ear, these allow for the conversion of one kind of energy into a form the brain can understand.

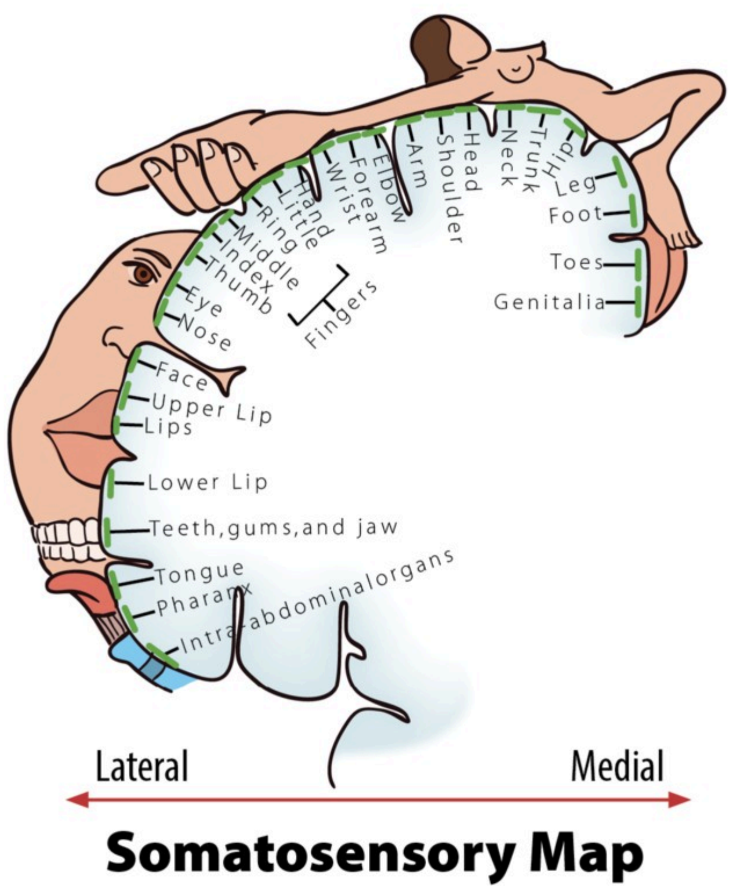


Figure 5. A drawing of the somatosensory cortex in the brain and the areas in the human body that correspond to it – they are drawn in proportion to the most sensitive or the most innervated parts of the body.

After tactile stimuli are converted by mechanoreceptors, information is sent through the thalamus to the **primary somatosensory cortex**for further processing. This region of the cortex is organized in a **somatotopic map** where different regions are sized based on the sensitivity of specific parts on the opposite side of the body (Penfield & Rasmussen, 1950). Put simply, various areas of the skin, such as lips and fingertips, are more sensitive than others, such as shoulders or ankles. This sensitivity can be represented with the distorted proportions of the human body shown in Figure 5.

Pain

Most people, if asked, would love to get rid of pain (**nociception**), because the sensation is very unpleasant and doesn't appear to have obvious value. But the perception of pain is our body's way of sending us a signal that something is wrong and needs our attention. Without pain, how would we know when we are accidentally touching a hot stove, or that we should rest a strained arm after a hard workout?

Phantom limbs

Records of people experiencing **phantom limbs** after amputations have been around for centuries (Mitchell, 1871). As the name suggests, people with a phantom limb have the sensations such as itching seemingly coming from their missing limb. A phantom limb can also involve **phantom limb pain**, sometimes described as the muscles of the missing limb uncomfortably clenching. While the mechanisms underlying these phenomena are not fully understood, there is evidence to support that the damaged nerves from the amputation site are still sending information to the brain (Weinstein, 1998) and that the brain is reacting to this information (Ramachandran & Rogers-Ramachandran, 2000). There is an interesting treatment for the alleviation of phantom limb pain that works by tricking the brain, using a special mirror box to create a visual representation of the missing limb. The technique allows the patient to manipulate this representation into a more comfortable position (Ramachandran & Rogers-Ramachandran, 1996).

Smell and Taste: The Chemical Senses

The two most underappreciated senses can be lumped into the broad category of **chemical senses**. Both **olfaction** (smell) and **gustation** (taste) require the transduction of chemical stimuli into electrical potentials. I say these senses are underappreciated because most people would give up either one of these if they were forced to give up a sense. While this may not shock a lot of readers, take into consideration how much money people spend on the perfume industry annually ($29 billion US Dollars). Many of us pay a lot more for a favorite brand of food because we prefer the taste. Clearly, we humans care about our chemical senses.

Unlike any of the other senses discussed so far, the receptors involved in our perception of both smell and taste bind directly with the stimuli they transduce. **Odorants**in our environment, very often mixtures of them, bind with olfactory receptors found in the **olfactory epithelium**. The binding of odorants to receptors is thought to be similar to how a lock and key operates, with different odorants binding to different specialized receptors based on their shape. However, the **shape theory of olfaction** isn't universally accepted and alternative theories exist, including one that argues that the vibrations of odorant molecules correspond to their subjective smells (Turin, 1996). Regardless of how odorants bind with receptors, the result is a pattern of neural activity. It is thought that our memories of these patterns of activity underlie our subjective experience of smell (Shepherd, 2005). Interestingly, because olfactory receptors send projections to the brain through the *cribriform plate* of the skull, head trauma has the potential to cause **anosmia**, due to the severing of these connections. If you are in a line of work where you constantly experience head trauma (e.g. professional boxer) and you develop anosmia, don't worry—your sense of smell will probably come back (Sumner, 1964).

Olfaction (smell)

Unlike any of the other senses discussed so far, the receptors involved in our perception of both smell and taste bind directly with the stimuli they transduce. **Odorants** in our environment, very often mixtures of them, bind with olfactory receptors found in the **olfactory epithelium**. The binding of odorants to receptors is thought to be similar to how a lock and key operates, with different odorants binding to different specialized receptors based on their shape. However, the **shape theory of olfaction** isn't universally accepted and alternative theories exist, including one that argues that the vibrations of odorant molecules correspond to their subjective smells (Turin, 1996). Regardless of how odorants bind with receptors, the result is a pattern of neural activity. It is thought that our memories of these patterns of activity underlie our subjective experience of smell (Shepherd, 2005). Interestingly, because olfactory receptors send projections to the brain through the *cribriform plate* of the skull, head trauma has the potential to cause **anosmia**, due to the severing of these connections. If you are in a line of work where you constantly experience head trauma (e.g. professional boxer) and you develop anosmia, don't worry—your sense of smell will probably come back (Sumner, 1964).

Gustation (taste)

Taste works in a similar fashion to smell, only with receptors found in the taste buds of the tongue, called **taste receptor cells**. To clarify a common misconception, taste buds are not the bumps on your tongue (papillae), but are located in small divots around these bumps.

Ghost Pepper, also known as Bhut Jolokia is one of the hottest peppers in the world, it's 10 times hotter than a habanero, and 400 times hotter than tabasco sauce. What do you think would happen to your taste receptor cells if you took a bite out of this little guy? [Image: Richard Elzey, https://goo.gl/suJHNg, CC BY 2.0, https://goo.gl/9uSnqN]

These receptors also respond to chemicals from the outside environment, except these chemicals, called **tastants**, are contained in the foods we eat. The binding of these chemicals with taste receptor cells results in our perception of the five basic tastes: sweet, sour, bitter, salty and umami (savory)– although some scientists argue that there are more (Stewart et al., 2010). Researchers used to think these tastes formed the basis for a map- like the organization of the tongue; there was even a clever rationale for the concept, about how the back of the tongue sensed bitter so we would know to spit out poisons, and the front of the tongue sensed sweet so we could identify high-energy foods. However, we now know that all areas of the tongue with taste receptor cells are capable of responding to every taste (Chandrashekar, Hoon, Ryba, & Zuker, 2006).

During the process of eating we are not limited to our sense of taste alone. While we are chewing, food odorants are forced back up to areas that contain olfactory receptors. This combination of taste and smell gives us the perception of **flavor**. If you have doubts about the interaction between these two senses, I encourage you to think back to consider how the flavors of your favorite foods are impacted when you have a cold; everything is pretty bland and boring, right?

Putting it all Together: Multimodal Perception

Though we have spent the majority of this module covering the senses individually, our real-world experience is most often multimodal, involving combinations of our senses into one perceptual experience. This should be clear after reading the description of walking through the forest at the beginning of the module; it was the combination of senses that allowed for that experience. It shouldn't shock you to find out that at some point information from each of our senses becomes integrated. Information from one sense has the potential to influence how we perceive information from another, a process called **multimodal perception**.

Interestingly, we actually respond more strongly to multimodal stimuli compared to the sum of each single modality together, an effect called the **super additive effect of multisensory integration**. This can explain how you're still able to understand what friends are saying to you at a loud concert, as long as you are able to get visual cues from watching them speak. If you were having a quiet conversation at a café, you likely wouldn't need these additional cues. In fact, the **principle of inverse effectiveness** states that you are *less* likely to benefit from additional cues from other modalities if the initial unimodal stimulus is strong enough (Stein & Meredith, 1993).

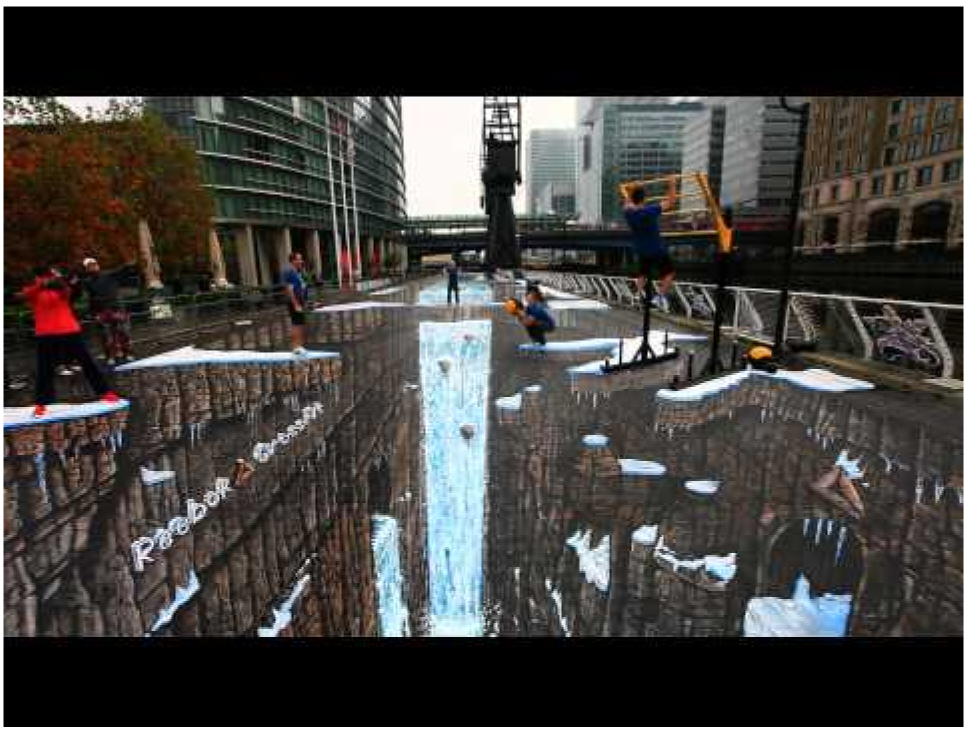
Because we are able to process multimodal sensory stimuli, and the results of those processes are qualitatively different from those of unimodal stimuli, it's a fair assumption that the brain is doing something qualitatively different when they're being processed. There has been a growing body of evidence since the mid-90's on the neural correlates of multimodal perception. For example, neurons that respond to both visual and auditory stimuli have been identified in the *superior temporal sulcus* (Calvert, Hansen, Iversen, & Brammer, 2001). Additionally, multimodal "what" and "where" pathways have been proposed for auditory and tactile stimuli (Renier et al., 2009). We aren't limited to reading about these regions of the brain and what they do; we can experience them with a few interesting examples (see Additional Resources for the "McGurk Effect," the "Double Flash Illusion," and the "Rubber Hand Illusion").

Conclusion

Our impressive sensory abilities allow us to experience the most enjoyable and most miserable experiences, as well as everything in between. Our eyes, ears, nose, tongue and skin provide an interface for the brain to interact with the world around us. While there is simplicity in covering each sensory modality independently, we are organisms that have evolved the ability to process multiple modalities as a unified experience.

Outside Resources

Audio: Auditory Demonstrations from Richard Warren's lab at the University of Wisconsin, Milwaukee
http://www4.uwm.edu/APL/demonstrations.html
Audio: Auditory Demonstrations. CD published by the Acoustical Society of America (ASA).
You can listen to the demonstrations here
http://www.feilding.net/sfuad/musi3012-01/demos/audio/
Book: Ackerman, D. (1990). A natural history of the senses. Vintage.
http://www.dianeackerman.com/a-natural-history-of-the-senses-by-diane-ackerman
Book: Sacks, O. (1998). The man who mistook his wife for a hat: And other clinical tales. Simon and Schuster.
http://www.oliversacks.com/books-by-oliver-sacks/man-mistook-wife-hat/
Video: Acquired knowledge and its impact on our three-dimensional interpretation of the world – 3D Street Art



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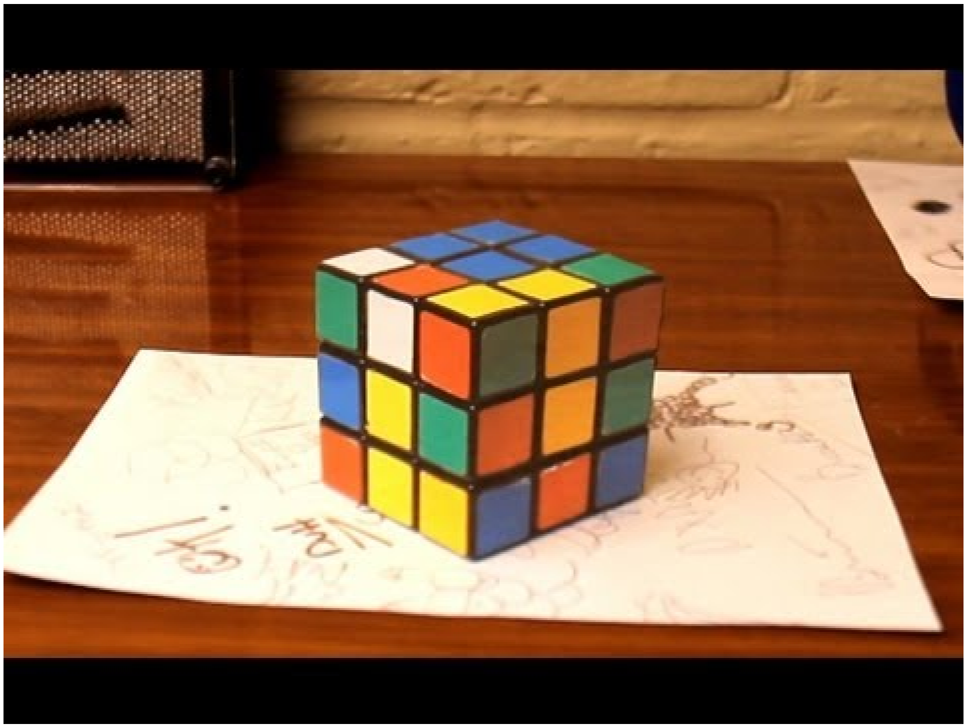
Video: Acquired knowledge and its impact on our three-dimensional interpretation of the world – Anamorphic Illusions



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Video: Cybersenses
https://www.youtube.com/watch?v=_8rPD6xLB4A
Video: Seeing Sound, Tasting Color
https://www.youtube.com/watch?v=FTr1VnXKr4A
Video: The Phantom Limb Phenomenon
https://www.youtube.com/watch?v=1mHIv5ToMTM
Web: A regularly updated website covering some of the amazing sensory capabilities of non-human animals.
http://phenomena.nationalgeographic.com/category/animal-senses/
Web: A special ringtone that is only audible to younger people.
https://www.youtube.com/watch?v=IrewnzQYrPI
Web: Amazing library with visual phenomena and optical illusions, explained
http://michaelbach.de/ot/index.html
Web: An article on the discoveries in echolocation: the use of sound in locating people and things
http://www.psychologicalscience.org/index.php/publications/observer/2015/december-15/using-sound-to-get-around.html
Web: An optical illusion demonstration the opponent-process theory of color vision.
https://www.youtube.com/watch?v=qA2brNUo7WA
Web: Anatomy of the eye
http://www.eyecareamerica.org/eyecare/anatomy/
Web: Animation showing tonotopic organization of the basilar membrane.

https://www.youtube.com/watch?v=dyenMluFaUw
Web: Best Illusion of the Year Contest website
http://illusionoftheyear.com/
Web: Demonstration of contrast gain adaptation
http://www.michaelbach.de/ot/lum_contrast-adapt/
Web: Demonstration of illusory contours and lateral inhibition. Mach bands
http://michaelbach.de/ot/lum-MachBands/index.html
Web: Demonstration of illusory contrast and lateral inhibition. The Hermann grid
http://michaelbach.de/ot/lum_herGrid/
Web: Demonstrations and illustrations of cochlear mechanics can be found here
http://lab.rockefeller.edu/hudspeth/graphicalSimulations
Web: Double Flash Illusion

A Vimeo element has been excluded from this version of the text. You can view it online here: *https://pressbooks.library.upei.ca/upeiintropsychology/?p=1096*

Web: Further information regarding what and where/how pathways
http://www.scholarpedia.org/article/What_and_where_pathways
Web: Great website with a large collection of optical illusions
http://www.michaelbach.de/ot/
Web: McGurk Effect Video
https://www.youtube.com/watch?v=G-lN8vWm3m0
Web: More demonstrations and illustrations of cochlear mechanics
http://www.neurophys.wisc.edu/animations/
Web: Scientific American Frontiers: Cybersenses
http://www.pbs.org/saf/1509/
Web: The Genetics of Taste
http://www.smithsonianmag.com/arts-culture/the-genetics-of-taste-88797110/?no-ist
Web: The Monell Chemical Sense Center website
http://www.monell.org/
Web: The Rubber Hand Illusion
https://www.youtube.com/watch?v=sxwn1w7MJvk
Web: The Tongue Map: Tasteless Myth Debunked
http://www.livescience.com/7113-tongue-map-tasteless-myth-debunked.html

Discussion Questions

1. There are a number of myths that exist about the sensory capabilities of infants. How would you design a study to determine what the true sensory capabilities of infants are?
2. A well-documented phenomenon experienced by millennials is the phantom vibration of a cell phone when no actual text message has been received. How can we use signal detection theory to explain this?
3. What physical features would an organism need in order to be really good at localizing sound in 3D space? Are there any organisms that currently excel in localizing sound? What features allow them to do this?
4. What issues would exist with visual recognition of an object if a research participant had his/her corpus callosum severed? What would you need to do in order to observe these deficits?

Vocabulary

Absolute threshold
The smallest amount of stimulation needed for detection by a sense.
Agnosia
Loss of the ability to perceive stimuli.
Anosmia
Loss of the ability to smell.
Audition
Ability to process auditory stimuli. Also called hearing.
Auditory canal
Tube running from the outer ear to the middle ear.
Auditory hair cells
Receptors in the cochlea that transduce sound into electrical potentials.
Binocular disparity
Difference is images processed by the left and right eyes.
Binocular vision
Our ability to perceive 3D and depth because of the difference between the images on each of our retinas.
Bottom-up processing
Building up to perceptual experience from individual pieces.
Chemical senses
Our ability to process the environmental stimuli of smell and taste.
Cochlea
Spiral bone structure in the inner ear containing auditory hair cells.
Cones
Photoreceptors of the retina sensitive to color. Located primarily in the fovea.
Dark adaptation
Adjustment of eye to low levels of light.
Differential threshold (or difference threshold)
The smallest difference needed in order to differentiate two stimuli. (See Just Noticeable Difference (JND))
Dorsal pathway
Pathway of visual processing. The "where" pathway.
Flavor
The combination of smell and taste.
Gustation
Ability to process gustatory stimuli. Also called taste.
Just noticeable difference (JND)
The smallest difference needed in order to differentiate two stimuli. (see Differential Threshold)
Light adaptation
Adjustment of eye to high levels of light.
Mechanoreceptors
Mechanical sensory receptors in the skin that response to tactile stimulation.
Multimodal perception

The effects that concurrent stimulation in more than one sensory modality has on the perception of events and objects in the world.

Nociception

Our ability to sense pain.

Odorants

Chemicals transduced by olfactory receptors.

Olfaction

Ability to process olfactory stimuli. Also called smell.

Olfactory epithelium

Organ containing olfactory receptors.

Opponent-process theory

Theory proposing color vision as influenced by cells responsive to pairs of colors.

Ossicles

A collection of three small bones in the middle ear that vibrate against the tympanic membrane.

Perception

The psychological process of interpreting sensory information.

Phantom limb

The perception that a missing limb still exists.

Phantom limb pain

Pain in a limb that no longer exists.

Pinna

Outermost portion of the ear.

Primary auditory cortex

Area of the cortex involved in processing auditory stimuli.

Primary somatosensory cortex

Area of the cortex involved in processing somatosensory stimuli.

Primary visual cortex

Area of the cortex involved in processing visual stimuli.

Principle of inverse effectiveness

The finding that, in general, for a multimodal stimulus, if the response to each unimodal component (on its own) is weak, then the opportunity for multisensory enhancement is very large. However, if one component—by itself—is sufficient to evoke a strong response, then the effect on the response gained by simultaneously processing the other components of the stimulus will be relatively small.

Retina

Cell layer in the back of the eye containing photoreceptors.

Rods

Photoreceptors of the retina sensitive to low levels of light. Located around the fovea.

Sensation

The physical processing of environmental stimuli by the sense organs.

Sensory adaptation

Decrease in sensitivity of a receptor to a stimulus after constant stimulation.

Shape theory of olfaction

Theory proposing that odorants of different size and shape correspond to different smells.

Signal detection

Method for studying the ability to correctly identify sensory stimuli.

Somatosensation

Ability to sense touch, pain and temperature.

Somatotopic map

Organization of the primary somatosensory cortex maintaining a representation of the arrangement of the body.

Sound waves

Changes in air pressure. The physical stimulus for audition.

Superadditive effect of multisensory integration

The finding that responses to multimodal stimuli are typically greater than the sum of the independent responses to each unimodal component if it were presented on its own.

Tastants

Chemicals transduced by taste receptor cells.

Taste receptor cells

Receptors that transduce gustatory information.

Top-down processing

Experience influencing the perception of stimuli.

Transduction

The conversion of one form of energy into another.

Trichromatic theory

Theory proposing color vision as influenced by three different cones responding preferentially to red, green and blue.

Tympanic membrane

Thin, stretched membrane in the middle ear that vibrates in response to sound. Also called the eardrum.

Ventral pathway

Pathway of visual processing. The “what” pathway.

Vestibular system

Parts of the inner ear involved in balance.

Weber’s law

States that just noticeable difference is proportional to the magnitude of the initial stimulus.

References

Calvert, G. A., Hansen, P. C., Iversen, S. D., & Brammer, M. J. (2001). Detection of audio-visual integration sites in humans by application of electrophysiological criteria to the BOLD effect. *Neuroimage*, 14(2), 427-438.

Chandrashekar, J., Hoon, M. A., Ryba, N. J., & Zuker, C. S. (2006). The receptors and cells for mammalian taste. *Nature*, 444(7117), 288-294.

Goodale, M. A., & Milner, A. D. (1992). Separate visual pathways for perception and action. *Trends in Neurosciences*, 15(1), 20-25.

Hering, E. (1920). *Grundzüge der Lehre vom Lichtsinn*. J.Springer.

Hubel, D. H., & Wiesel, T. N. (1962). Receptive fields, binocular interaction and functional architecture in the cat's visual cortex. *The Journal of Physiology*,160(1), 106.

Merzenich, M. M., Knight, P. L., & Roth, G. L. (1975). Representation of cochlea within primary auditory cortex in the cat. *Journal of Neurophysiology*, 38(2), 231-249.

Middlebrooks, J. C., & Green, D. M. (1991). Sound localization by human listeners. *Annual Review of Psychology*, 42(1), 135-159.

Mitchell, S. W. (1871). Phantom limbs. Lippincott's Magazine of Popular *Literature and Science*, 8, 563-569.

Penfield, W., & Rasmussen, T. (1950). *The cerebral cortex of man; a clinical study of localization of function*. Oxford: England

Populin, L. C., & Yin, T. C. (1998). Behavioral studies of sound localization in the cat. *The Journal of Neuroscience*, 18(6), 2147-2160.

Ramachandran, V. S., & Rogers-Ramachandran, D. (2000). Phantom limbs and neural plasticity. *Archives of Neurology*, 57(3), 317-320.

Ramachandran, V. S., & Rogers-Ramachandran, D. (1996). Synaesthesia in phantom limbs induced with mirrors. *Proceedings of the Royal Society of London B: Biological Sciences*, 263 (1369), 377-386.

Renier, L. A., Anurova, I., De Volder, A. G., Carlson, S., VanMeter, J., & Rauschecker, J. P. (2009). Multisensory integration of sounds and vibrotactile stimuli in processing streams for "what" and "where". *The Journal of Neuroscience*, 29(35), 10950-10960.

Romani, G. L., Williamson, S. J., & Kaufman, L. (1982). Tonotopic organization of the human auditory cortex. *Science*, 216(4552), 1339-1340.

Shepherd, G. M. (2005). Outline of a theory of olfactory processing and its relevance to humans. *Chemical Senses*, 30(suppl 1), i3-i5.

Stein, B. E., & Meredith, M. A. (1993). *The merging of the senses*. The MIT Press.

Stewart, J. E., Feinle-Bisset, C., Golding, M., Delahunty, C., Clifton, P. M., & Keast, R. S. (2010). Oral sensitivity to fatty acids, food consumption and BMI in human subjects. *British Journal of Nutrition*, 104(01), 145-152.

Sumner, D. (1964). Post Traumatic Anosmia. *Brain*, 87(1), 107-120.

Svaetichin, G. (1955). Spectral response curves from single cones. Acta physiologica Scandinavica. *Supplementum*, 39(134), 17-46.

Turin, L. (1996). A spectroscopic mechanism for primary olfactory reception. *Chemical Senses*, 21(6), 773-791.

Von Helmholtz, H. (1867). *Handbuch der physiologischen Optik* (Vol. 9). Voss.

Välimäki, V., & Takala, T. (1996). Virtual musical instruments—natural sound using physical models. *Organised Sound*, 1(02), 75-86.

Walker, K. M., Bizley, J. K., King, A. J., & Schnupp, J. W. (2011). Multiplexed and robust representations of sound features in auditory cortex. *The Journal of Neuroscience*, 31(41), 14565-14576.

Weinstein, S. M. (1998). Phantom limb pain and related disorders. *Neurologic Clinics*, 16(4), 919-935.

Young, T. (1802). The Bakerian lecture: On the theory of light and colours. *Philosophical transactions of the Royal Society of London*, 12–48.

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R. Biswas-Diener & E. Diener (Eds), Noba Textbook Series: Psychology. Champaign, IL: DEF Publishers. Retrieved from **http://noba.to/xgk3ajhy**

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THE UNCONSCIOUS

Learning Objectives

- Understand the logic underlying the assumption that unconscious processes are important.
- Obtain a basic understanding of some important historical thoughts about unconscious processes.
- Learn about some of the important psychological experiments on the unconscious.
- Appreciate the distinction between consciousness and attention.

Have you ever grabbed a candy bar, chewing gum or a magazine as you purchased your groceries? These well-known “impulse buys” raise an intriguing question: what is *really* driving your decisions? While, on the one hand, you might argue that it is your conscious mind that decides what you buy, what you eat and what you read. On the other hand you’d probably have to admit that those celebrity magazines and salted chocolates weren’t actually on your shopping list with the eggs and the bread. So where did the desire to purchase them come from? As we will see in this module, there are a number of forces that operate on your thinking and decisions that you might not even be aware of; all of them being processed by the unconscious.

A Little Bit of History

Although the term "**unconscious**" was only introduced fairly recently (in the 18th century by the German philosopher Platner, the German term being "Unbewusstsein"), the relative "unconsciousness" of human nature has evoked both marvel and frustration for more than two millennia. Socrates (490–399 BC) argued that free will is limited, or at least so it seems, after he noticed that people often do things they really do not want to do. He called this *akrasia*, which can best be translated as "the lack of control over oneself." A few centuries later, the Roman thinker Plotinus (AD 205–270) was presumably the first to allude to the possibility of unconscious psychological processes in writing: "The absence of a conscious perception is no proof of the absence of mental activity."

As far back as the Ancient Greeks people have been interested in the puzzle of the seeming lack of control that we exhibit in our decision-making. What would Socrates have thought if he could see how modern people navigate a typical supermarket? [Image: Mtaylor848, https://goo.gl/GhuC6L, CC BY-SA 3.0, https://goo.gl/eLCn2O]

These two ideas, first verbalized by Socrates and Plotinus respectively, were– and still are–hotly debated in psychology, philosophy, and neuroscience. That is, scientists still investigate the extent to which human behavior is (and/or seems) voluntary or involuntary, and scientists still investigate the relative importance of unconscious versus conscious psychological processes, or mental activity in general. And, perhaps not surprisingly, both issues are still controversial.

During the scientific revolution in Europe, our unconscious was taken away from us, so to speak, by the French philosopher Descartes (1596–1650). Descartes's dualism entailed a strict distinction between body and mind. According to Descartes, the mind produces psychological processes and everything going on in our minds is by definition conscious. Some psychologists have called this idea, in which mental processes taking place outside conscious awareness were rendered impossible, the **Cartesian catastrophe**. It took well over two centuries for science to fully recover from the impoverishment dictated by Descartes.

This is not say that contemporaries of Descartes and later thinkers all agreed with Descartes's dualism. In fact, many of them disagreed and kept on theorizing about unconscious psychological processes. For instance, the British philosopher John Norris (1657–1711) said: "We may have ideas of which we are not conscious. . . . There are infinitely more ideas impressed on our minds than we can possibly attend to or perceive." Immanuel Kant (1724– 1804) agreed:

"The field of our sense-perceptions and sensations, of which we are not conscious . . .is immeasurable." Norris and Kant used a logical argument that many proponents of the importance of unconscious psychological processes still like to point at today: *There is so much going on in our brains, and the capacity of consciousness is so small, that there must be much more than just consciousness.*

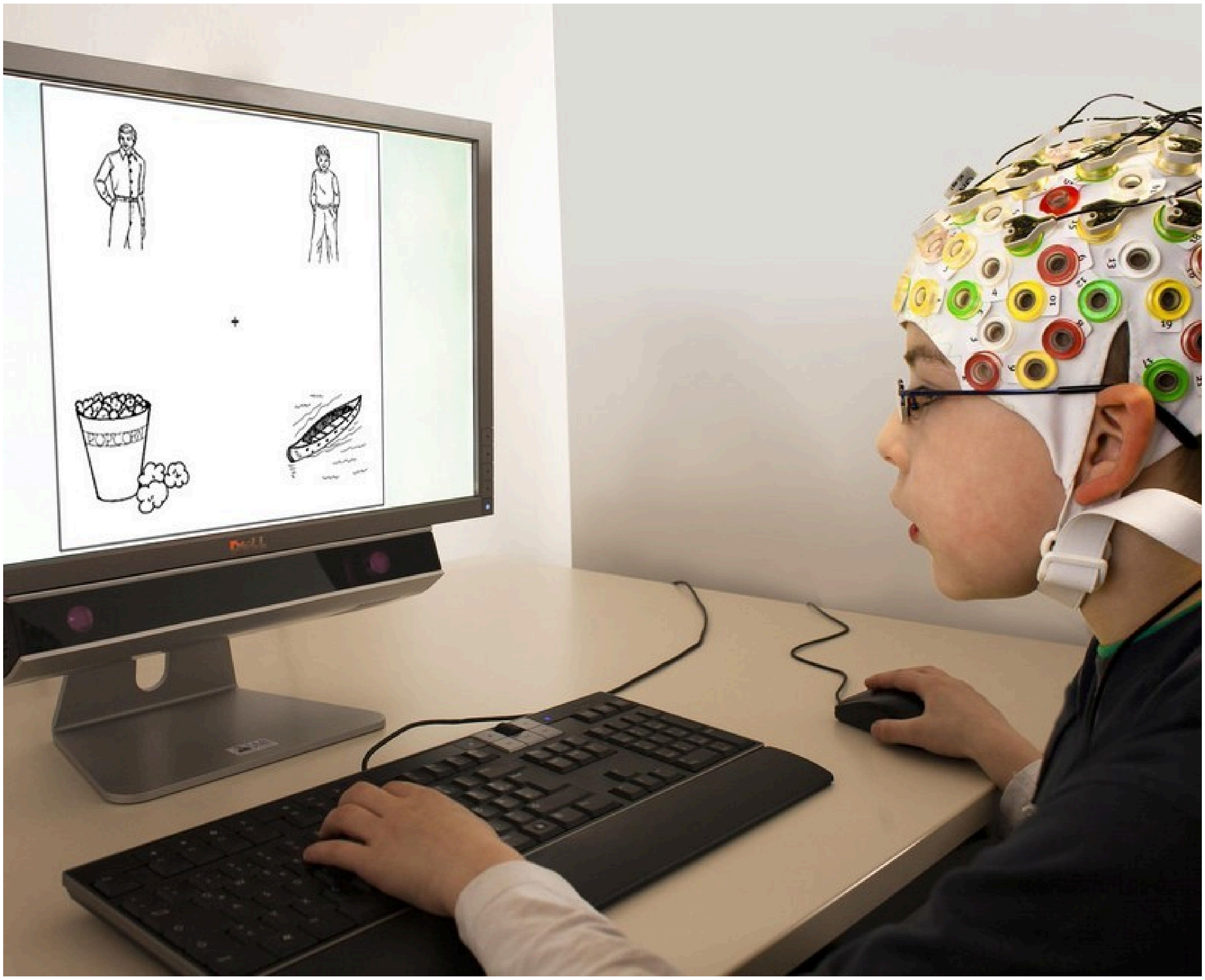
The most famous advocate of the importance of unconscious processes arrived at the scene in the late 19th century: the Austrian neurologist Sigmund Freud. Most people associate Freud with psychoanalysis, with his theory on id, ego, and superego, and with his ideas on repression, hidden desires, and dreams. Such associations are fully justified, but Freud also published lesser-known general theoretical work (e.g., Freud, 1915/1963). This theoretical work sounds, in contrast to his psychoanalytic work, very fresh and contemporary. For instance, Freud already argued that human behavior never starts with a conscious process (compare this to the Libet experiment discussed below).

Freud, and also Wilhelm Wundt, pointed at another logical argument for the necessity of unconscious psychological processes. Wundt put it like this: "Our mind is so fortunately equipped, that it brings us the most important bases for our thoughts without our having the least knowledge of this work of elaboration. Only the results of it become conscious. This unconscious mind is for us like an unknown being who creates and produces for us, and finally throws the ripe fruits in our lap." In other words, we may become consciously aware of many different things—the taste of a glass of Burgundy, the beauty of the Taj Mahal, or the sharp pain in our toe after a collision with a bed—but these experiences do not hover in the air before they reach us. They are prepared, somehow and somewhere. *Unless you believe consciousness is causally disconnected from other bodily and mental processes (for instance if one assumes it is guided by the gods), conscious experiences must be prepared by other processes in the brain of which we are not conscious.*

The German psychologist Watt (1905), in an appealing experiment, showed that we are only consciously aware of the results of mental processes. His participants were repeatedly presented with nouns (e.g., "oak") and had to respond with an associated word as quickly as they could. On some occasions participants were requested to name a superordinate word ("oak"-"tree"), while on other occasions they were asked to come up with a part ("oak"-"acorn") or a subordinate ("oak"-"beam") word. Hence, participants' thinking was divided into four stages: the instructions (e.g., superordinate), the presentation of the noun (e.g., "oak"), the search for an appropriate association, and the verbalization of the reply (e.g., "tree"). Participants were asked to carefully introspect on all four stages to shed light on the role of consciousness during each stage. The third stage (searching for an association) is the stage during which the actual thinking takes place and hence this was considered the most interesting stage. However, unlike the other stages, this stage was, as psychologists call it, introspectively blank: Participants could not report anything. The thinking itself was unconscious, and participants were only conscious of the answer that surfaced.

Where Action Originates

The idea that we unconsciously prepare an action before we are conscious of this action was tested in one of psychology's most famous experiments. Quite some time ago, Kornhuber and Deecke (1965) did experiments in which they asked their participants to perform a simple action, in this case flexing a finger. They also measured **EEG** to investigate when the brain starts to prepare the action. Their results showed that the first sign of unconscious preparation preceded an action by about 800 milliseconds. This is a serious amount of time, and it led Benjamin Libet to wonder whether conscious awareness of the decision to act appears just as long or even longer in advance as well.



Using EEG in the psychology lab, experimenters have been able to show that unconscious preparation precedes conscious decision-making. [Image: SMI Eye Tracking, https://goo.gl/xFMw5I, CC BY 2.0, https://goo.gl/BRvSA7]

Libet (1985) replicated the Kornhuber and Deecke experiments while adding another measure: conscious awareness of the decision to act. He showed that conscious decisions *follow* unconscious preparation and only precede the actual execution of the action by about 200 milliseconds. In other words, the unconscious decides to act, we then become consciously aware of wanting to execute the action, and finally we act.

The experiment by Libet caused quite a stir, and some people tried to save the day for the decisive role of consciousness by criticizing the experiment. Some of this criticism made sense, such as the notion that the action sequence in the Libet experiments does not start with the EEG signals in the brain, but instead before that, with the instruction of the experimenter to flex a finger. And this instruction is consciously perceived. The dust surrounding the precise meaning of this experiment has still not completely settled, and recently Soon and colleagues (Soon, Brass, Heinze, & Haynes, 2008) reported an intriguing experiment in which they circumvented an important limitation of the Libet experiment. Participants had to repeatedly make a dichotomous choice (they were to press one of two buttons) and they could freely choose which one. The experimenters measured participants' brain activity. After the participants made their simple choice many times, the experimenters could, by looking at the difference in brain activity for the two different choices in earlier trials, predict which button a participant was going to press next up to ten seconds in advance—indeed, long before a participant had consciously "decided" what button to press next.

The Unconscious in Social Psychological Processes

These days, most scientific research on unconscious processes is aimed at showing that people do not need consciousness for certain psychological processes or behaviors. One such example is attitude formation. The most basic process of attitude formation is through mere exposure (Zajonc, 1968). Merely perceiving a stimulus repeatedly, such as a brand on a billboard one passes every day or a song that is played on the radio frequently, renders it more positive. Interestingly, mere exposure does not require conscious awareness of the object of an attitude. In fact, **mere-exposure effects** occur even when novel stimuli are presented subliminally for extremely brief durations (e.g., Kunst-Wilson & Zajonc, 1980). Intriguingly, in such subliminal mere-exposure experiments, participants indicate a preference for, or a positive attitude towards, stimuli they do not consciously remember being exposed to.

The research on unconscious processes also greatly improved our understanding of prejudice. People automatically categorize other people according to their race, and Patricia Devine (1989) demonstrated that categorization unconsciously leads to the activation of associated cultural stereotypes. Importantly, Devine also showed that stereotype activation was not moderated by people's level of explicit prejudice. The conclusion of this work was bleak: We unconsciously activate cultural stereotypes, and this is true for all of us, even for people who are not explicitly prejudiced, or, in other words, for people who do not want to stereotype.

Unconscious Processing and the Role of Attention

Insight into unconscious processes has also contributed to our ideas about creativity. Creativity is usually seen as the result of a three-stage process. It begins with attending to a problem consciously. You think and read about a problem and discuss matters with others. This stage allows the necessary information to be gathered and organized, but during this stage a truly creative idea is rarely produced. The second stage is unconscious; it is the incubation stage during which people think unconsciously. The problem is put aside for a while, and conscious attention is directed elsewhere. The process of unconscious thought sometimes leads to a "**Eureka experience**" whereby the creative product enters consciousness.

The “Eureka experience” is that moment when an idea enters conscious awareness. [Image: Bart, https://goo.gl/ZMnGFr, CC BY-NC 2.0, https://goo.gl/VnKlK8]

This third stage is one where conscious attention again plays a role. The creative product needs to be verbalized and communicated. For example, a scientific discovery needs detailed proof before it can be communicated to others.

The idea that people think unconsciously has also been applied to decision making (Dijksterhuis & Nordgren, 2006). In a recent set of experiments (Bos, Dijksterhuis, & van Baaren, 2008), participants were presented with information about various alternatives (such as cars or roommates) differing in attractiveness. Subsequently, participants engaged in a **distractor task** before they made a decision. That is, they consciously thought about something else; in this case, they solved anagrams. However, one group was told, prior to the distractor task, that they would be later asked questions about the decision problem. A second group was instead told that they were done with the decision problem and would not be asked anything later on. In other words, the first group had the goal to further process the information, whereas the second group had no such goal. Results showed that the first group made better decisions than the latter. Although they did the exact same thing consciously—again, solving anagrams—the first group made better decisions than the second group because the first thought unconsciously. Recently, researchers reported neuroscientific evidence for such unconscious thought processes, indeed showing that recently encoded information is further processed unconsciously when people have the goal to do so (Creswell, Bursley, & Satpute, in press).

People are sometimes surprised to learn that we can do so much, and so many sophisticated things, unconsciously. However, it is important to realize that there is no one-to-one relation between attention and consciousness (see e.g., Dijksterhuis & Aarts, 2010). Our behavior is largely guided by goals and motives, and these goals determine what we pay attention to— that is, how many resources our brain spends on something—but not necessarily what we become consciously aware of. We can be conscious of things that we hardly pay attention to (such as fleeting daydreams), and we can be paying a lot of attention to something we are temporarily unaware of (such as a problem we want to solve or a big decision we are facing). Part of the confusion arises because attention and consciousness are correlated. When one pays more attention to an incoming stimulus, the probability that one becomes consciously aware of it increases. However, attention and consciousness are distinct. And to understand why we can do so many things unconsciously, attention is the key. We need attention, but for quite a number of things, we do not need conscious awareness.

These days, most researchers agree that the most sensible approach to learn about unconscious and conscious processes is to consider (higher) cognitive operations as unconscious, and test what (if anything) consciousness adds (Dijksterhuis & Aarts 2010; van Gaal, Lamme, Fahrenfort, & Ridderinkhof, 2011; for an exception, see Newell & Shanks, in press). However, researchers still widely disagree about the relative importance or contribution of conscious and unconscious processes. Some theorists maintain the causal role of consciousness is limited or virtually nonexistent; others still believe that consciousness plays a crucial role in almost all human behavior of any consequence.

Note: The historical overview of the way people thought about the unconscious is largely based on Koestler (1964).

Outside Resources

Book: A wonderful book about how little we know about ourselves: Wilson, T. D. (2002). Strangers to ourselves. Cambridge, MA: Harvard University Press.

Book: Another wonderful book about free will—or its absence?: Wegner, D. M. (2002). The illusion of conscious will. Cambridge, MA: MIT Press.

Video: An interesting video on attention

http://www.dansimons.com/videos.html

Discussion Questions

1. Assess both the strengths and weaknesses of the famous Libet study.
2. Assuming that attention and consciousness are orthogonal, can you name examples of conscious processes that hardly require attention or of unconscious processes that require a lot of attention?
3. Do you think some of the priming experiments can also be explained purely by conscious processes?
4. What do you think could be the main function of consciousness?
5. Some people, scientists included, have a strong aversion to the idea that human behavior is largely guided by unconscious processes. Do you know why?

Vocabulary

Cartesian catastrophe

The idea that mental processes taking place outside conscious awareness are impossible.

Conscious

Having knowledge of something external or internal to oneself; being aware of and responding to one's surroundings.

Distractor task

A task that is designed to make a person think about something unrelated to an impending decision.

EEG

(Electroencephalography) The recording of the brain's electrical activity over a period of time by placing electrodes on the scalp.

Eureka experience

When a creative product enters consciousness.

Mere-exposure effects

The result of developing a more positive attitude towards a stimulus after repeated instances of mere exposure to it.

Unconscious

Not conscious; the part of the mind that affects behavior though it is inaccessible to the conscious mind.

References

Bos, M. W., Dijksterhuis, A. & van Baaren, R. B. (2008). On the goal-dependency of unconscious thought. *Journal of Experimental Psychology*, 44, 1114–20.

Creswell, D., Bursley, J. & Satpute, A. (in press). Neural reactivation links unconscious thought to decision making performance. *Social Cognitive and Affective Neuroscience*.

Devine, P. G. (1989). Stereotypes and prejudice: Their automatic and controlled components. *Journal of Personality and Social Psychology*, 56, 5–18.

Dijksterhuis, A., & Aarts, H. (2010). Goals, attention, and (un)consciousness. *Annual Review of Psychology*, 61, 467–490.

Dijksterhuis, A., & Nordgren, L. F. (2006). A theory of unconscious thought. *Perspectives on Psychological Science*, 1, 95–109.

Freud, S. (1963). *General Psychological Theory*. New York: Simon & Schuster. (Original work published 1915.)

Koestler, A. (1964). *The act of creation*. London: Penguin.

Kornhuber, H. H., & Deecke, L. (1965). Hirnpotentialanderungen bei Wilkurbewegungen und passiv Bewegungen des Menschen: Berietschaftpotential und reafferente Potentiale. *Pflugers Archiv fur Gesamte Psychologie*, 284, 1–17.

Kunst-Wilson, W., & Zajonc, R. (1980). Affective discrimination of stimuli that cannot be recognized. *Science*, 207, 557–558.

Libet, B., (1985). Unconscious cerebral initiative and the role of conscious will in voluntary action. *Behavioral and Brain Sciences*, 8, 529–39.

Newell, B. R., & Shanks, D. R. (in press). Unconscious influences on decision making: A critical review. *Behavioral and Brain Sciences*.

Soon, C. S., Brass, M., Heinze, H. J. & Haynes, J. D. (2008). Unconscious determinants of free decisions in the human brain. *Nature Neuroscience* 11, 543–45.

Watt, H. J. (1905). Experimentelle Beitrage zur einer Theorie des Denkens. *Archiv für die Geschichte der Psychologie*, 4, 289–436.

Zajonc, R. B. (1968). Attitudinal effects of mere exposure. *Journal of Personality and Social Psychology*, 9, 1–27.

van Gaal, S., Lamme, V. A. F., Fahrenfort, J. J., & Ridderinkhof, K. R. (2011). Dissociable brain mechanisms underlying the conscious and unconscious control of behavior. *Journal of Cognitive Neuroscience 23(1)*, 91–105.

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- To provide instructors with a platform to customize educational content to better suit their curriculum
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The Diener Education Fund is co-founded by Drs. Ed and Carol Diener. Ed is the Joseph Smiley Distinguished Professor of Psychology (Emeritus) at the University of Illinois. Carol Diener is the former director of the Mental Health Worker and the Juvenile Justice Programs at the University of Illinois. Both Ed and Carol are award- winning university teachers.

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R. Biswas-Diener & E. Diener (Eds), Noba Textbook Series: Psychology. Champaign, IL: DEF Publishers. Retrieved from **http://noba.to/46hrvmab**

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Dijksterhuis, A. (2020). The unconscious. In R. Biswas-Diener & E. Diener (Eds), Noba textbook series: Psychology. Champaign, IL: DEF publishers. Retrieved from http://noba.to/46hrvmab

CONSCIOUSNESS

Authors: Ken Paller & Satoru Suzuki

Consciousness is the ultimate mystery. What is it and why do we have it? These questions are difficult to answer, even though consciousness is so fundamental to our existence. Perhaps the natural world could exist largely as it is without human consciousness; but taking away consciousness would essentially take away our humanity. Psychological science has addressed questions about consciousness in part by distinguishing neurocognitive functions allied with conscious experience from those that transpire without conscious experience. The continuing investigation of these sorts of distinctions is yielding an empirical basis for new hypotheses about the precursors of conscious experience. Richer conceptualizations are thus being built, combining first-person and third-person perspectives to provide new clues to the mystery of consciousness

Learning Objectives

Understand scientific approaches to comprehending consciousness.

Be familiar with evidence about human vision, memory, body awareness, and decision making relevant to the study of consciousness.

Appreciate some contemporary theories about consciousness.

Conscious Experiences

Contemplate the unique experience of being you at this moment! You, and only you, have direct knowledge of your own conscious experiences. At the same time, you cannot know consciousness from anyone else's inside view. How can we begin to understand this fantastic ability to have private, conscious experiences?

At the most basic level all of conscious experience is unique to each individual. [Image: Étienne Ljóni Poisson, https://goo.gl/ mbo5VJ, CC BY-NC-SA 2.0, https://goo.gl/Toc0ZF]

In a sense, everything you know is from your own vantage point, with your own consciousness at the center. Yet the scientific study of consciousness confronts the challenge of producing general understanding that goes beyond what can be known from one individual's perspective.

To delve into this topic, some terminology must first be considered. The term *consciousness* can denote the ability of a person to generate a series of conscious experiences one after another. Here we include experiences of feeling and understanding sensory input, of a temporal sequence of autobiographical events, of imagination, of emotions and moods, of ideas, of memories—the whole range of mental contents open to an individual.

Consciousness can also refer to the state of an individual, as in a sharp or dull state of consciousness, a drug-induced state such as euphoria, or a diminished state due to drowsiness, sleep, neurological abnormality, or coma. In this module, we focus not on states of consciousness or on self-consciousness, but rather on the process that unfolds in the course of a **conscious experience**—a moment of **awareness**—the essential ingredient of consciousness.

Other Minds

You have probably experienced the sense of knowing exactly what a friend is thinking. Various signs can guide our inferences about consciousness in others. We can try to infer what's going on in someone else's mind by relying on the assumption that they feel what we imagine we would feel in the same situation. We might account for someone's actions or emotional expressions through our knowledge of that individual and our careful observations of their behavior. In this way, we often display substantial insight into what they are thinking. Other times we are completely wrong.

By measuring brain activity using various neuroscientific technologies, we can acquire additional information useful for deciphering another person's state of mind. In special circumstances such inferences can be highly accurate, but limitations on mind reading remain, highlighting the difficulty of understanding exactly how conscious experiences arise.

A Science of Consciousness

Attempts to understand consciousness have been pervasive throughout human history, mostly dominated by philosophical analyses focused on the **first-person perspective**. Now we have a wider set of approaches that includes philosophy, psychology, neuroscience, cognitive science, and **contemplative science** (Blackmore, 2006; Koch, 2012; Zelazo, Moscovitch, & Thompson, 2007; Zeman, 2002).

Consciousness is a topic that has been addressed by religious scholars, philosophers, psychologists, and neuroscientists. [Image: CC0 Public Domain, https://goo.gl/m25gce]

The challenge for this combination of approaches is to give a comprehensive explanation of consciousness. That explanation would include describing the benefits of consciousness, particularly for behavioral capabilities that conscious experiences allow, that trump automatic behaviors. Subjective experiences also need to be described in a way that logically shows how they result from precursor events in the human brain. Moreover, a full account would describe how consciousness depends on biological, environmental, social, cultural, and developmental factors.

At the outset, a central question is how to conceive of consciousness relative to other things we know. Objects in our environment have a physical basis and are understood to be composed of constituents, such that they can be broken down into molecules, elements, atoms, particles, and so on. Yet we can also understand things relationally and conceptually. Sometimes a phenomenon can best be conceived as a process rather than a physical entity (e.g., digestion is a process whereby food is broken down). What, then, is the relationship between our conscious thoughts and the physical universe, and in particular, our brains?

Rene Descartes' position, *dualism*, was that mental and physical are, in essence, different substances. This view can be contrasted with *reductionist views* that mental phenomena can be explained via descriptions of physical phenomena. Although the dualism/reductionism debate continues, there are many ways in which mind can be shown to depend on brain.

A prominent orientation to the scientific study of consciousness is to seek understanding of these dependencies—to see how much light they can shed on consciousness. Significant advances in our knowledge about consciousness have thus been gained, as seen in the following examples.

Conscious Experiences of Visual Perception

Suppose you meet your friend at a crowded train station. You may notice a subtle smile on her face. At that moment you are probably unaware of many other things happening within your view. What makes you aware of some things but not others? You probably have your own intuitions about this, but experiments have proven wrong many common intuitions about what generates visual awareness.

Are you really aware of everything that is going on around you? In the context of a crowded train station you may be visually aware of certain things while essentially being blind to many others that are right in front of you. [Image: Diego Torres Silvestre, https://goo.gl/ZkCWEC, CC BY 2.0, https://goo.gl/BRvSA7]

For instance, you may think that if you attentively look at a bright spot, you must be aware of it. Not so. In a phenomenon known as motion-induced blindness, bright discs completely vanish from your awareness in full attention. To experience this for yourself, see this module's Outside Resource section for a demonstration of motion-induced blindness.

You may think that if you deeply analyze an image, decoding its meaning and making a decision about it, you must be aware of the image. Not necessarily. When a number is briefly flashed and rapidly replaced by a random pattern, you may have no awareness of it, despite the fact that your brain allows you to determine that the number is greater than 5, and then prepare your right hand for a key press if that is what you were instructed to do (Dehaene et al., 1998).

Thus, neither the brightness of an image, paying full attention to it, nor deeply analyzing it guarantees that you will be aware of it. What, then, is the crucial ingredient of visual awareness?

A contemporary answer is that our awareness of a visual feature depends on a certain type of reciprocal exchange of information across multiple brain areas, particularly in the cerebral cortex. In support of this idea, directly activating your visual motion area (known as V5) with an externally applied magnetic field (*transcranial magnetic stimulation*) will make you see moving dots. This is not surprising. What is surprising is that activating your visual motion area alone does not let you see motion. You will not see moving dots if the feedback signal from V5 to the primary visual cortex is disrupted by a further transcranial magnetic stimulation pulse (Pascual-Leone & Walsh, 2001). The reverberating reciprocal exchange of information between higher-level visual areas and primary visual cortex appears to be essential for generating visual awareness.

This idea can also explain why people with certain types of brain damage lack visual awareness. Consider a patient with brain damage limited to primary visual cortex who claims not to see anything – a problem termed *cortical blindness*. Other areas of visual cortex may still receive visual input through projections from brain structures such as the thalamus and superior colliculus, and these networks may mediate some preserved visual abilities that take place without awareness. For example, a patient with cortical blindness might detect moving stimuli via V5 activation but still have no conscious experiences of the stimuli, because the reverberating reciprocal exchange of information cannot take place between V5 and the damaged primary visual cortex. The preserved ability to detect motion might be evident only when a guess is required ("guess whether something moved to the left or right")—otherwise the answer would be "I didn't see anything." This phenomenon of blindsight refers to blindness due to a neurological cause that preserves abilities to analyze and respond to visual stimuli that are not consciously experienced (Lamme, 2001).

If exchanges of information across brain areas are crucial for generating visual awareness, neural synchronization must play an important role because it promotes neural communication. A neuron's excitability varies over time. Communication among neural populations is enhanced when their oscillatory cycles of excitability are synchronized. In this way, information transmitted from one population in its excitable phase is received by the target population when it is also in its excitable phase. Indeed, oscillatory neural synchronization in the beta- and gamma-band frequencies (identified according to the number of oscillations per second, 13–30 Hz and 30–100 Hz, respectively) appears to be closely associated with visual awareness. This idea is highlighted in the *Global Neuronal WorkspaceTheory of Consciousness* (Dehaene & Changeux, 2011), in which sharing of information among prefrontal, inferior parietal, and occipital regions of the cerebral cortex is postulated to be especially important for generating awareness.

A related view, the *Information Integration Theory of Consciousness*, is that shared information itself constitutes consciousness (Tononi, 2004). An organism would have minimal consciousness if the structure of shared information is simple, whereas it would have rich conscious experiences if the structure of shared information is complex. Roughly speaking, complexity is defined as the number of intricately interrelated informational units or ideas generated by a web of local and global sharing of information. The degree of consciousness in an organism (or a machine) would be high if numerous and diversely interrelated ideas arise, low if only a few ideas arise or if there are numerous ideas but they are random and unassociated. Computational analyses provide additional perspectives on such proposals. In particular, if every neuron is connected to every other neuron, all neurons would tend to activate together, generating few distinctive ideas. With a very low level of neuronal connectivity at the other extreme, all neurons would tend to activate independently, generating numerous but unassociated ideas. To promote a rich level of consciousness, then, a suitable mixture of short-, medium-, and long-range neural connections would be needed. The human cerebral cortex may indeed have such an optimum structure of neural connectivity. Given how consciousness is conceptualized in this theory as graded rather than all-or-none, a quantitative approach (e.g., Casali et al., 2013; Monti et al., 2013) could conceivably be used to estimate the level of consciousness in nonhuman species and artificial beings.

Conscious Experiences of Memory

The pinnacle of conscious human memory functions is known as episodic recollection because it allows one to reexperience the past, to virtually relive an earlier event. People who suffer from amnesia due to neurological damage to certain critical brain areas have poor memory for events and facts. Their memory deficit disrupts the type of memory termed *declarative memory* and makes it difficult to consciously remember. However, amnesic insults typically spare a set of memory functions that do not involve conscious remembering. These other types of memory, which include various habits, motor skills, cognitive skills, and procedures, can be demonstrated when an individual executes various actions as a function of prior learning, but in these cases a conscious experience of remembering is not necessarily included.

Research on amnesia has thus supported the proposal that conscious remembering requires a specific set of brain operations that depend on networks of neurons in the cerebral cortex.

Memory is one basis for conscious awareness. [Image: CC0 Public Domain, https://goo.gl/m25gce]

Some of the other types of memory involve only subcortical brain regions, but there are also notable exceptions. In particular, *perceptual priming* is a type of memory that does not entail the conscious experience of remembering and that is typically preserved in amnesia. Perceptual priming is thought to reflect a fluency of processing produced by a prior experience, even when the individual cannot remember that prior experience. For example, a word or face might be perceived more efficiently if it had been viewed minutes earlier than if it hadn't. Whereas a person with amnesia can demonstrate this item-specific fluency due to changes in corresponding cortical areas, they nevertheless would be impaired if asked to recognize the words or faces they previously experienced. A reasonable conclusion on the basis of this evidence is that remembering an episode is a conscious experience not merely due to the involvement of one portion of the cerebral cortex, but rather due to the specific configuration of cortical activity involved in the sharing or integration of information.

Further neuroscientific studies of memory retrieval have shed additional light on the necessary steps for conscious recollection. For example, storing memories for the events we experience each day appears to depend on connections among multiple cortical regions as well as on a brain structure known as the hippocampus. Memory storage becomes more secure due to interactions between the hippocampus and cerebral cortex that can transpire over extended time periods following the initial registration of information. Conscious retrieval thus depends on the activity of elaborate sets of networks in the cortex. Memory retrieval that does not include conscious recollection depends either on restricted portions of the cortex or on brain regions separate from the cortex.

The ways in which memory expressions that include the awareness of remembering differ from those that do not thus highlight the special nature of conscious memory experiences (Paller, Voss, & Westerberg, 2009; Voss, Lucas, & Paller, 2012). Indeed, memory storage in the brain can be very complex for many different types of memory, but there are specific physiological prerequisites for the type of memory that coincides with conscious recollection.

Conscious Experiences of Body Awareness

The brain can generate body awareness by registering coincident sensations. For example, when you rub your arm, you see your hand rubbing your arm and simultaneously feel the rubbing sensation in both your hand and your arm. This simultaneity tells you that it is *your* hand and *your* arm. Infants use the same type of coincident sensations to initially develop the self/nonself distinction that is fundamental to our construal of the world.

The fact that your brain constructs body awareness in this way can be experienced via the rubber-hand illusion (see Outside Resource on this). If you see a rubber hand being rubbed and simultaneously feel the corresponding rubbing sensation on your own body out of view, you will momentarily feel a bizarre sensation—that the rubber hand is your own.

The construction of our body awareness appears to be mediated by specific brain mechanisms involving a region of the cortex known as the temporoparietal junction. Damage to this brain region can generate distorted body awareness, such as feeling a substantially elongated torso. Altered neural activity in this region through artificial stimulation can also produce an out-of- body experience (see this module's Outside Resources section), in which you feel like your body is in another location and you have a novel perspective on your body and the world, such as from the ceiling of the room.

Remarkably, comparable brain mechanisms may also generate the normal awareness of the sense of self and the sensation of being inside a body. In the context of *virtual reality* this sensation is known as *presence* (the compelling experience of actually being there). Our normal localization of the self may be equally artificial, in that it is not a given aspect of life but is constructed through a special brain mechanism.

A *Social Neuroscience Theory of Consciousness* (Graziano & Kastner, 2011) ascribes an important role to our ability to localize our own sense of self. The main premise of the theory is that you fare better in a social environment to the extent that you can predict what people are going to do. So, the human brain has developed mechanisms to construct models of other people's attention and intention, and to localize those models in the corresponding people's heads to keep track of them. The proposal is that the same brain mechanism was adapted to construct a model of one's own attention and intention, which is then localized in one's own head and perceived as consciousness. If so, then the primary function of consciousness is to allow us to predict our own behavior. Research is needed to test the major predictions of this new theory, such as whether changes in consciousness (e.g., due to normal fluctuations, psychiatric disease, brain damage) are closely associated with changes in the brain mechanisms that allow us to model other people's attention and intention.

Conscious Experiences of Decision Making

Choosing among multiple possible actions, the sense of *volition*, is closely associated with our subjective feeling of consciousness. When we make a lot of decisions, we may feel especially conscious and then feel exhausted, as if our mental energy has been drained.

We make decisions in two distinct ways. Sometimes we carefully analyze and weigh different factors to reach a decision, taking full advantage of the brain's conscious mode of information processing. Other times we make a *gut decision*, trusting the unconscious mode of information processing (although it still depends on the brain). The unconscious mode is adept at simultaneously considering numerous factors in parallel, which can yield an overall impression of the sum total of evidence. In this case, we have no awareness of the individual considerations. In the conscious mode, in contrast, we can carefully scrutinize each factor—although the act of focusing on a specific factor can interfere with weighing in other factors.

When making a decision you might carefully consider your choices or simply "go with your gut". [Image: Daniel Lee, https:// goo.gl/aJi3jx, CC BY-NC-SA 2.0, https://goo.gl/Toc0ZF]

One might try to optimize decision making by taking into account these two strategies. A careful conscious decision should be effective when there are only a few known factors to consider. A gut decision should be effective when a large number of factors should be considered simultaneously. Gut decisions can indeed be accurate on occasion (e.g., guessing which of many teams will win a close competition), but only if you are well versed in the relevant domain (Dane, Rockmann, & Pratt, 2012).

As we learn from our experiences, some of this gradual knowledge accrual is unconscious; we don't know we have it and we can use it without knowing it. On the other hand, consciously acquired information can be uniquely beneficial by allowing additional stages of control (de Lange, van Gaal, Lamme, & Dehaene, 2011). It is often helpful to control which new knowledge we acquire and which stored information we retrieve in accordance with our conscious goals and beliefs.

Whether you choose to trust your gut or to carefully analyze the relevant factors, you feel that you freely reach your own decision. Is this feeling of free choice real? Contemporary experimental techniques fall short of answering this existential question. However, it is likely that at least the sense of immediacy of our decisions is an illusion.

In one experiment, people were asked to freely consider whether to press the right button or the left button, and to press it when they made the decision (Soon, Brass, Heinze, & Haynes, 2008). Although they indicated that they made the decision immediately before pressing the button, their brain activity, measured using functional magnetic resonance imaging, predicted their decision as much as 10 seconds before they said they freely made the decision. In the same way, each conscious experience is likely preceded by precursor brain events that on their own do not entail consciousness but that culminate in a conscious experience.

In many situations, people generate a reason for an action that has nothing to do with the actual basis of the decision to act in a particular way. We all have a propensity to retrospectively produce a reasonable explanation for our behavior, yet our behavior is often the result of unconscious mental processing, not conscious volition.

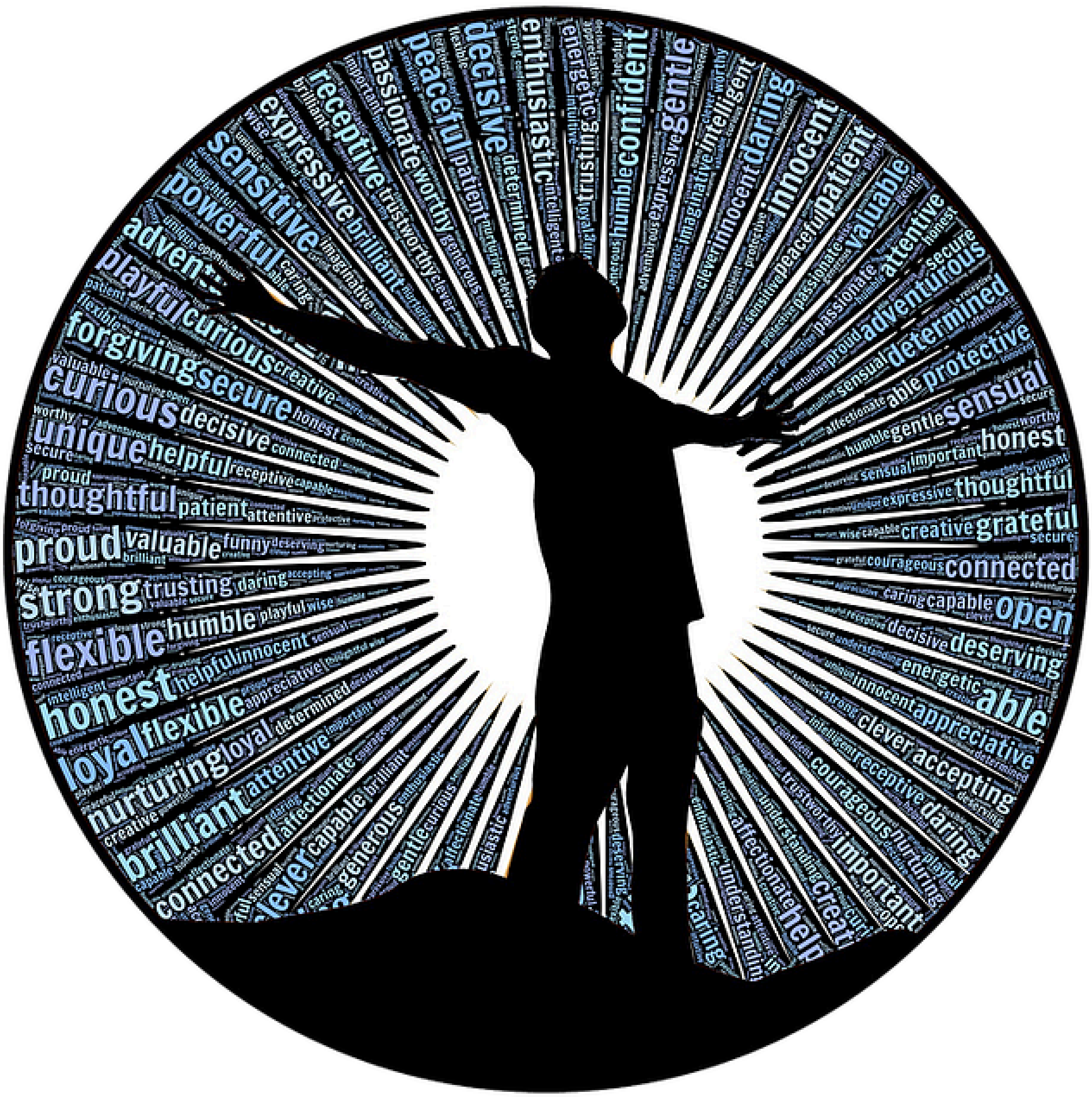
Why do we feel that each of our actions is immediately preceded by our own decision to act? This illusion may help us distinguish our own actions from those of other agents. For example, while walking hand-in-hand with a friend, if you felt you made a decision to turn left immediately before you both turned left, then you know that you initiated the turn; otherwise, you would know that your friend did.

Even if some aspects of the decision-making process are illusory, to what extent are our decisions determined by prior conditions? It certainly seems that we can have full control of some decisions, such as when we create a conscious intention that leads to a specific action: You can decide to go left or go right. To evaluate such impressions, further research must develop a better understanding of the neurocognitive basis of volition, which is a tricky undertaking, given that decisions are conceivably influenced by unconscious processing, neural noise, and the unpredictability of a vast interactive network of neurons in the brain.

Yet belief in free choice has been shown to promote moral behavior, and it is the basis of human notions of justice. The sense of free choice may be a beneficial trait that became prevalent because it helped us flourish as social beings.

Understanding Consciousness

Our human consciousness unavoidably colors all of our observations and our attempts to gain understanding. Nonetheless, scientific inquiries have provided useful perspectives on consciousness. The advances described above should engender optimism about the various research strategies applied to date and about the prospects for further insight into consciousness in the future.



Because conscious experiences are inherently private, they have sometimes been taken to be outside the realm of scientific inquiry. This view idealizes science as an endeavor involving only observations that can be verified by multiple observers, relying entirely on the **third-person perspective**, or the view from nowhere (from no particular perspective). Yet conducting science is a human activity that depends, like other human activities, on individuals and their subjective experiences. A rational scientific account of the world cannot avoid the fact that people have subjective experiences.

Subjectivity thus has a place in science. Conscious experiences can be subjected to systematic analysis and empirical tests to yield progressive understanding. Many further questions remain to be addressed by scientists of the future. Is the first-person perspective of a conscious experience basically the same for all human beings, or do individuals differ fundamentally in their introspective experiences and capabilities? Should psychological science focus only on ordinary experiences of consciousness, or are extraordinary experiences also relevant? Can training in introspection lead to a specific sort of expertise with respect to conscious experience? An individual with training, such as through extensive meditation practice, might be able to describe their experiences in a more precise manner, which could then support improved characterizations of consciousness. Such a person might be able to understand subtleties of experience that other individuals fail to notice, and thereby move our understanding of consciousness significantly forward. These and other possibilities await future scientific inquiries into consciousness.

Outside Resources

Video: Demonstration of motion-induced blindness – Look steadily at the blue moving pattern. One or more of the yellow spots may disappear.
http://www.youtube.com/watch?v=4Aye9FWgxUg

Web: Learn more about motion-induced blindness on Michael Bach's website

http://www.michaelbach.de/ot/mot-mib/index.html

Video: Clip showing a patient with blindsight, from the documentary "Phantoms in the Brain."

http://youtu.be/Cy8FSffrNDI

Video: Clip on the rubber hand illusion, from the BBC science series "Horizon."

http://www.youtube.com/watch?v=Qsmkgi7FgEo

Video: Clip on out-of-body experiences induced using virtual reality.

http://www.youtube.com/watch?v=4PQAc_Z2OfQ

App: Visual illusions for the iPad.

http://www.exploratorium.edu/explore/apps/color-uncovered

Web: Definitions of Consciousness

http://www.consciousentities.com/definitions.htm

Video: The mind-body problem – An interview with Ned Block

http://vimeo.com/58254376

Video: Imaging the Brain, Reading the Mind – A talk by Marsel Mesulam.

https://www.youtube.com/watch?v=Xp_LXwZns6Q&feature=youtu.be

Video: Ted Talk – Simon Lewis: Don't take consciousness for granted

http://www.ted.com/talks/simon_lewis_don_t_take_consciousness_for_granted.html

Discussion Questions

1. Why has consciousness evolved? Presumably it provides some beneficial capabilities for an organism beyond behaviors that are based only on automatic triggers or unconscious processing. What are the likely benefits of consciousness?
2. How would you explain to a congenitally blind person the experience of seeing red? Detailed explanations of the physics of light and neurobiology of color processing in the brain would describe the mechanisms that give rise to the experience of seeing red, but would not convey the experience. What would be the best way to communicate the subjective experience itself?
3. Our visual experiences seem to be a direct readout of information from the world that comes into our eyes, and we usually believe that our mental representations give us an accurate and exact re-creation of the world. Is it possible that what we consciously perceive is not veridical, but is a limited and distorted view, in large part a function of the specific sensory and information-processing abilities that the brain affords?
4. When are you most conscious—while you're calm, angry, happy, or moved; while absorbed in a movie, video game, or athletic activity; while engaged in a spirited conversation, making decisions, meditating, reflecting, trying to solve a difficult problem, day dreaming, or feeling creative? How do these considerations shed light on what consciousness is?
5. Consciousness may be a natural biological phenomenon and a chief function of a brain, but consider the many ways in which it is also contingent on (i) a body linked with a brain, (ii) an outside world, (iii) a social environment, and (iv) a developmental trajectory. How do these considerations enrich our understanding of consciousness?
6. Conscious experiences may not be limited to human beings. However, the difficulty of inferring consciousness in other beings highlights the limitations of our current understanding of consciousness. Many nonhuman animals may have conscious experiences; pet owners often have no doubt about what their pets are thinking. Computers with sufficient complexity might at some point be conscious—but how would we know?

Vocabulary

Awareness

A conscious experience or the capability of having conscious experiences, which is distinct from self-awareness, the conscious understanding of one's own existence and individuality.

Conscious experience

The first-person perspective of a mental event, such as feeling some sensory input, a memory, an idea, an emotion, a mood, or a continuous temporal sequence of happenings.

Contemplative science

A research area concerned with understanding how contemplative practices such as meditation can affect individuals, including changes in their behavior, their emotional reactivity, their cognitive abilities, and their brains. Contemplative science also seeks insights into conscious experience that can be gained from first-person observations by individuals who have gained extraordinary expertise in introspection.

First-person perspective

Observations made by individuals about their own conscious experiences, also known as introspection or a subjective point of view. Phenomenology refers to the description and investigation of such observations.

Third-person perspective

Observations made by individuals in a way that can be independently confirmed by other individuals so as to lead to general, objective understanding. With respect to consciousness, third-person perspectives make use of behavioral and neural measures related to conscious experiences.

References

Blackmore, S. (2006). Conversations on consciousness: What the best minds think about the brain, free will, and what it means to be human. Oxford: Oxford University Press.

Casali, A. G., Gosseries, O., Rosanova, M., Boly, M. Sarasso, S., Casali, K. R., Casarotto, S., Bruno, M.-A., Laureys, S., Tononi, G., & Massimini, M. (2013). A theoretically based index of consciousness independent of sensory processing and behavior. Science Translational Medicine, 5, 198ra105

Dane, E., Rockmann, K. W., & Pratt, M. G. (2012). When should I trust my gut? Linking domain expertise to intuitive decision-making effectiveness. Organizational Behavior and Human Decision Processes, 119, 187–194.

Dehaene, S., & Changeux, J.-P. (2011). Experimental and theoretical approaches to conscious processing. Neuron, 70, 200–227.

Dehaene, S., Naccache, L., Le Clec'H, G., Koechlin, E., Mueller, M., Dehaene-Lambertz, G., van de Moortele, P.-F., & Le Bihan, D. (1998). Imaging unconscious semantic priming. Nature, 395, 597–600.

Graziano, M. S. A., & Kastner, S. (2011). Human consciousness and its relationship to social neuroscience: A novel hypothesis. Cognitive Neuroscience, 2, 98–113.Koch, C. (2012). Consciousness: Confessions of a romantic reductionist. Cambridge, MA: MIT Press.

Lamme, V. A. F. (2001). Blindsight: The role of feedforward and feedback corticocortical connections. Acta Psychologica, 107, 209–228.

Monti, M. M., Lutkenhoff, E. S., Rubinov, M., Boveroux, P., Vanhaudenhuyse, A., Gosseries O., Bruno, M. A., Noirhomme, Q., Boly, M., & Laureys S. (2013) Dynamic change of global and local information processing in propofol-induced loss and recovery of consciousness. PLoS Comput Biol 9(10): e1003271. doi:10.1371/journal.pcbi.1003271

Paller, K. A., Voss, J. L., & Westerberg, C. E. (2009). Investigating the awareness of remembering.Perspectives on Psychological Science, 4, 185–199.Pascual-Leone, A., & Walsh, V. (2001). Fast back projections from the motion to the primary visual area necessary for visual awareness. Science, 292, 510–512.

Soon, C. S., Brass, M., Heinze, H.-J., & Haynes, J.-D. (2008). Unconscious determinants of free decision in the human brain. Nature Neuroscience, 11, 543–545.Tononi, G. (2004). An information integration theory of consciousness. BMCNeuroscience, 5(42), 1–22. Retrieved from http://www.biomedcentral.com/1471-2202/5/42/

Voss, J. L., Lucas, H. D., & Paller, K. A. (2012). More than a feeling: Pervasive influences of memory processing without awareness of retrieval. Cognitive Neuroscience, 3, 193–207.

Zelazo, P. D., Moscovitch, M., & Thompson, E. (2007). The Cambridge Handbook of Consciousness.Cambridge, UK: Cambridge University Press.Zeman, A. (2002). A user's guide to consciousness. New Haven, CT: Yale University Press.

STATES OF CONSCIOUSNESS

Introduction

Have you ever had a fellow motorist stopped beside you at a red light, singing his brains out, or picking his nose, or otherwise behaving in ways he might not normally do in public? There is something about being alone in a car that encourages people to zone out and forget that others can see them. Although these little lapses of attention are amusing for the rest of us, they are also instructive when it comes to the topic of consciousness.

This guy is singing his heart out in his one-man mobile music studio. Have you ever done this? [Image: Joshua Ommen, https://goo.gl/ Za97c3, CC BY-NC-SA 2.0, https://goo.gl/Toc0ZF]

Consciousness is a term meant to indicate awareness. It includes awareness of the self, of bodily sensations, of thoughts and of the environment. In English, we use the opposite word "unconscious" to indicate senselessness or a barrier to awareness, as in the case of "Theresa fell off the ladder and hit her head, knocking herself unconscious." And yet, psychological theory and research suggest that consciousness and unconsciousness are more complicated than falling off a ladder. That is, consciousness is more than just being "on" or "off." For instance, Sigmund Freud (1856 – 1939)—a psychological theorist—understood that even while we are awake, many things lay outside the realm of our conscious awareness (like being in the car and forgetting the rest of the world can see into your windows). In response to this notion, Freud introduced the concept of the "subconscious" (Freud, 2001) and proposed that some of our memories and even our basic motivations are not always accessible to our conscious minds.

Upon reflection, it is easy to see how slippery a topic consciousness is. For example, are people conscious when they are daydreaming? What about when they are drunk? In this module, we will describe several levels of consciousness and then discuss altered states of consciousness such as hypnosis and sleep.

Levels of Awareness

In 1957, a marketing researcher inserted the words "Eat Popcorn" onto one frame of a film being shown all across the United States. And although that frame was only projected onto the movie screen for 1/24th of a second—a speed too fast to be perceived by conscious awareness—the researcher reported an increase in popcorn sales by nearly 60%. Almost immediately, all forms of "subliminal messaging" were regulated in the US and banned in countries such as Australia and the United Kingdom. Even though it was later shown that the researcher had made up the data (he hadn't even inserted the words into the film), this fear about influences on our subconscious persists. At its heart, this issue pits various levels of awareness against one another. On the one hand, we have the "low awareness" of subtle, even subliminal influences. On the other hand, there is you—the conscious thinking, feeling you which includes all that you are currently aware of, even reading this sentence. However, when we consider these different levels of awareness separately, we can better understand how they operate.

Low Awareness

You are constantly receiving and evaluating sensory information. Although each moment has too many sights, smells, and sounds for them all to be consciously considered, our brains are nonetheless processing all that information. For example, have you ever been at a party, overwhelmed by all the people and conversation, when out of nowhere you hear your name called? Even though you have no idea what else the person is saying, you are somehow conscious of your name (for more on this, "the cocktail party effect," see Noba's Module on Attention). So, even though you may not be *aware* of various stimuli in your environment, your brain is paying closer attention than you think.

Similar to a reflex (like jumping when startled), some **cues**, or significant sensory information, will automatically elicit a response from us even though we never consciously perceive it. For example, Öhman and Soares (1994) measured subtle variations in sweating of participants with a fear of snakes. The researchers flashed pictures of different objects (e.g., mushrooms, flowers, and most importantly, snakes) on a screen in front of them, but did so at speeds that left the participant clueless as to what he or she had actually seen. However, when snake pictures were flashed, these participants started sweating more (i.e., a sign of fear), even though they had no idea what they'd just viewed!

Although our brains perceive some stimuli without our conscious awareness, do they really affect our subsequent thoughts and behaviors? In a landmark study, Bargh, Chen, and Burrows (1996) had participants solve a word search puzzle where the answers pertained to words about the elderly (e.g., "old," "grandma") or something random (e.g., "notebook," "tomato"). Afterward, the researchers secretly measured how fast the participants walked down the hallway exiting the experiment. And although none of the participants were aware of a theme to the answers, those who had solved a puzzle with elderly words (vs. those with other types of words) walked more slowly down the hallway!

This effect is called **priming** (i.e., readily "activating" certain concepts and associations from one's memory) has been found in a number of other studies. For example, priming people by having them drink from a warm glass (vs. a cold one) resulted in behaving more "warmly" toward others (Williams & Bargh, 2008). Although all of these influences occur beneath one's conscious awareness, they still have a significant effect on one's subsequent thoughts and behaviors.

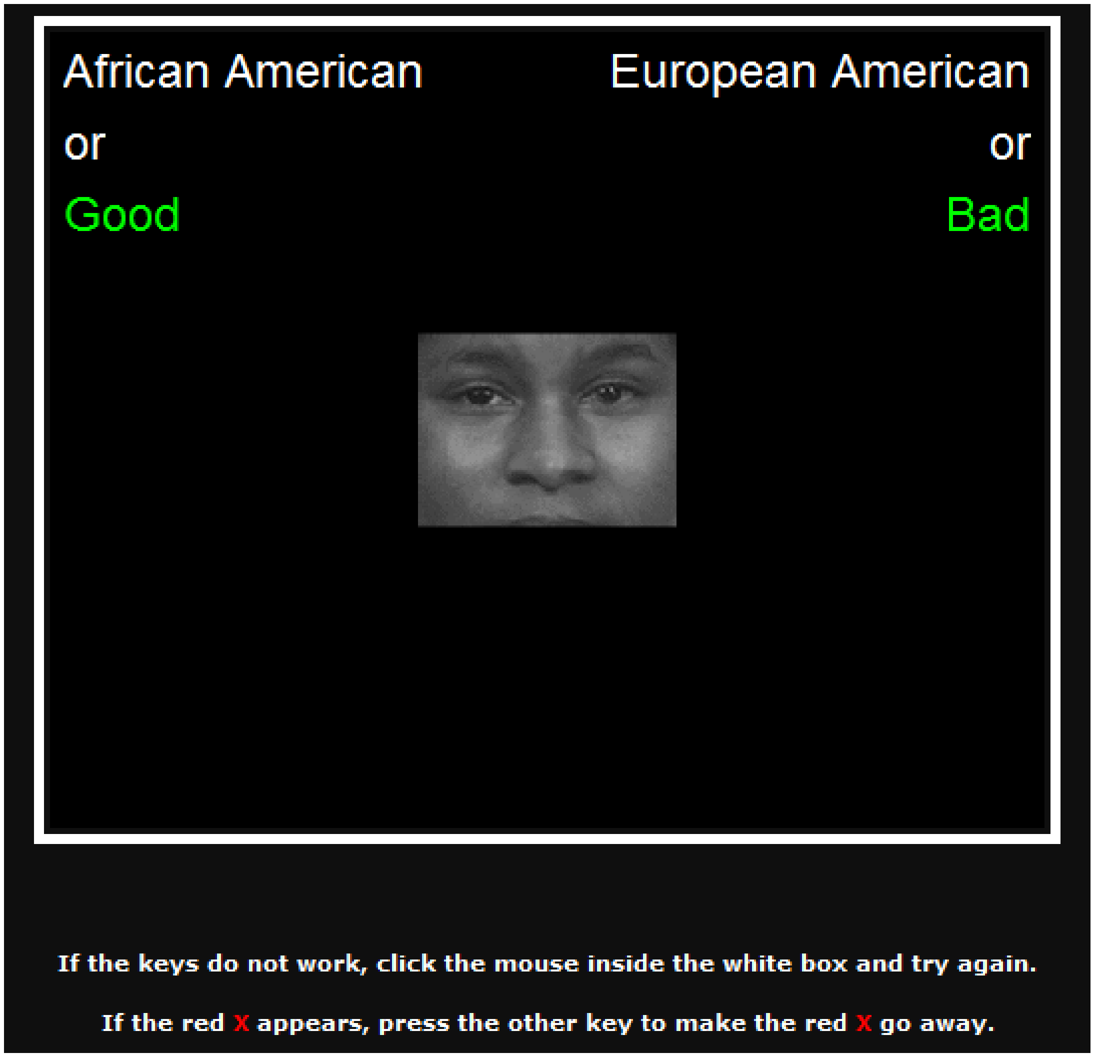
Priming Studies and Replication

If the results of priming studies sound too fantastic to be believed, you are not alone in your skepticism. Recently, many studies in psychology—including many priming studies—have come under scrutiny because they do not "replicate." This means that when later researchers have attempted to recreate certain studies, they have not always gotten the same—or even similar—results. Non-replication does not suggest that the original researchers "faked" the results, but that there may have been flaws in the original sampling or research methods. Fortunately, researchers are very aware of the problem of non-replication and have taken steps to address the issue. For an in-depth exploration of the so-called "replication crisis" in psychology, please see the Noba module on that topic.

In the last two decades, researchers have made advances in studying aspects of psychology that exist beyond conscious awareness. As you can understand, it is difficult to use self-reports and surveys to ask people about motives or beliefs that they, themselves, might not even be aware of! One way of side-stepping this difficulty can be found in the **implicit associations test**, or IAT (Greenwald, McGhee & Schwartz, 1998). This research method uses computers to assess people's reaction times to various stimuli and is a very difficult test to fake because it records automatic reactions that occur in milliseconds. For instance, to shed light on deeply held biases, the IAT might present photographs of Caucasian faces and Asian faces while asking research participants to click buttons indicating either "good" or "bad" as quickly as possible. Even if the participant clicks "good" for every face shown, the IAT can still pick up tiny delays in responding. Delays are associated with more mental effort needed to process information. When information is processed quickly—as in the example of white faces being judged as "good"—it can be contrasted with slower processing—as in the example of Asian faces being judged as "good"—and the difference in processing speed is reflective of bias. In this regard, the IAT has been used for investigating stereotypes (Nosek, Banaji & Greenwald, 2002) as well as self-esteem (Greenwald & Farnam, 2000). This method can help uncover non-conscious biases as well as those that we are motivated to suppress.

High Awareness

Just because we may be influenced by these "invisible" factors, it doesn't mean we are helplessly controlled by them. The other side of the awareness continuum is known as "high awareness." This includes effortful attention and careful decision making. For example, when you listen to a funny story on a date, or consider which class schedule would be preferable, or complete a complex math problem, you are engaging a state of consciousness that allows you to be highly aware of and focused on particular details in your environment.



An actual screenshot from an IAT (Implicit Association Test) that a person might take to test their own mental representations of various cognitive constructs. In this particular case, this is an item testing an individual's unconscious reaction towards members of various ethnic groups. [Image: Courtesy of Anthony Greenwald from Project Implicit]

Mindfulness is a state of higher consciousness that includes an awareness of the thoughts passing through one's head. For example, have you ever snapped at someone in frustration, only to take a moment and reflect on why you responded so aggressively? This more effortful consideration of your thoughts could be described as an expansion of your conscious awareness as you take the time to consider the possible influences on your thoughts. Research has shown that when you engage in this more deliberate consideration, you are less persuaded by irrelevant yet biasing influences, like the presence of a celebrity in an advertisement (Petty & Cacioppo, 1986). Higher awareness is also associated with recognizing when you're using a stereotype, rather than fairly evaluating another person (Gilbert & Hixon, 1991).

Humans alternate between low and high thinking states. That is, we shift between focused attention and a less attentive default sate, and we have neural networks for both (Raichle, 2015). Interestingly, the the less we're paying attention, the more likely we are to be influenced by non-conscious stimuli (Chaiken, 1980). Although these subtle influences may affect us, we can use our higher conscious awareness to protect against external influences. In what's known as the **Flexible Correction Model** (Wegener & Petty, 1997), people who are aware that their thoughts or behavior are being influenced by an undue, outside source, can correct their attitude against the bias. For example, you might be aware that you are influenced by mention of specific political parties. If you were motivated to consider a government policy you can take your own biases into account to attempt to consider the policy in a fair way (on its own merits rather than being attached to a certain party).

To help make the relationship between lower and higher consciousness clearer, imagine the brain is like a journey down a river. In low awareness, you simply float on a small rubber raft and let the currents push you. It's not very difficult to just drift along but you also don't have total control. Higher states of consciousness are more like traveling in a canoe.

Meditation has been practiced for centuries in religious contexts. In the past 50 years it has become increasingly popular as a secular practice. Scientific studies have linked meditation to lower stress and higher well-being. [Image: Indrek Torilo, https://goo.gl/Bc5Iwm, CC BY-NC 2.0, https://goo.gl/FIlc2e]

In this scenario, you have a paddle and can steer, but it requires more effort. This analogy applies to many states of consciousness, but not all. What about other states such as like sleeping, daydreaming, or hypnosis? How are these related to our conscious awareness?

	Costs	Benefits
Low Awareness	*Influenced by subtle factors*	*Saves mental effort*
High Awareness	*Uses mental effort*	*Can overcome some biases*

Table 1: States of Consciousness

Other States of Consciousness

Hypnosis

If you've ever watched a stage hypnotist perform, it may paint a misleading portrait of this state of consciousness. The hypnotized people on stage, for example, appear to be in a state similar to sleep. However, as the hypnotist continues with the show, you would recognize some profound differences between sleep and hypnosis. Namely, when you're asleep, hearing the word "strawberry" doesn't make you flap your arms like a chicken. In stage performances, the hypnotized participants appear to be highly suggestible, to the point that they are seemingly under the hypnotist's control. Such performances are entertaining but have a way of sensationalizing the true nature of hypnotic states.

People being hypnotized on stage. [Image: New Media Expo, https:// goo.gl/FWgBqs, CC BY-NC-SA 2.0, https://goo.gl/FIlc2e]

Hypnosis is an actual, documented phenomenon—one that has been studied and debated for over 200 years (Pekala et al., 2010). Franz Mesmer (1734 – 1815) is often credited as among the first people to "discover" hypnosis, which he used to treat members of elite society who were experiencing psychological distress. It is from Mesmer's name that we get the English word, "mesmerize" meaning "to entrance or transfix a person's attention." Mesmer attributed the effect of hypnosis to "animal magnetism," a supposed universal force (similar to gravity) that operates through all human bodies. Even at the time, such an account of hypnosis was not scientifically supported, and Mesmer himself was frequently the center of controversy.

Over the years, researchers have proposed that **hypnosis** is a mental state characterized by reduced peripheral awareness and increased focus on a singular stimulus, which results in an enhanced susceptibility to suggestion (Kihlstrom, 2003). For example, the hypnotist will usually induce hypnosis by getting the person to pay attention only to the hypnotist's voice. As the individual focuses more and more on that, s/he begins to forget the context of the setting and responds to the hypnotist's suggestions as if they were his or her own. Some people are naturally more suggestible, and therefore more "hypnotizable" than are others, and this is especially true for those who score high in empathy (Wickramasekera II & Szlyk, 2003). One common "trick" of stage hypnotists is to discard volunteers who are less suggestible than others.

Dissociation is the separation of one's awareness from everything besides what one is centrally focused on. For example, if you've ever been daydreaming in class, you were likely so caught up in the fantasy that you didn't hear a word the teacher said. During hypnosis, this dissociation becomes even more extreme. That is, a person concentrates so much on the words of the hypnotist that s/he loses perspective of the rest of the world around them. As a consequence of dissociation, a person is less effortful, and less self-conscious in consideration of his or her own thoughts and behaviors. Similar to low awareness states, where one often acts on the first thought that comes to mind, so, too, in hypnosis does the individual simply follow the first thought that comes to mind, i.e., the hypnotist's suggestion. Still, just because one is more susceptible to suggestion under hypnosis, it doesn't mean s/he will do anything that's ordered. To be hypnotized, you must first *want* to be hypnotized (i.e., you can't be hypnotized against your will; Lynn & Kirsh, 2006), and once you are hypnotized, you won't do anything you wouldn't also do while in a more natural state of consciousness (Lynn, Rhue, & Weekes, 1990).

Today, **hypnotherapy** is still used in a variety of formats, and it has evolved from Mesmer's early tinkering with the concept. Modern hypnotherapy often uses a combination of relaxation, suggestion, motivation and expectancies to create a desired mental or behavioral state. Although there is mixed evidence on whether hypnotherapy can help with addiction reduction (e.g., quitting smoking; Abbot et al., 1998) there is some evidence that it can be successful in treating sufferers of acute and chronic pain (Ewin, 1978; Syrjala et al., 1992). For example, one study examined the treatment of burn patients with either hypnotherapy, pseudo-hypnosis (i.e., a placebo condition), or no treatment at all. Afterward, even though people in the placebo condition experienced a 16% decrease in pain, those in the actual hypnosis condition experienced a reduction of nearly 50% (Patterson et al., 1996). Thus, even though hypnosis may be sensationalized for television and movies, its ability to disassociate a person from their environment (or their pain) in conjunction with increased suggestibility to a clinician's recommendations (e.g., "you will feel less anxiety about your chronic pain") is a documented practice with actual medical benefits.

Now, similar to hypnotic states, **trance states** also involve a dissociation of the self; however, people in a trance state are said to have less voluntary control over their behaviors and actions. Trance states often occur in religious ceremonies, where the person believes he or she is "possessed" by an otherworldly being or force. While in trance, people report anecdotal accounts of a "higher consciousness" or communion with a greater power. However, the body of research investigating this phenomenon tends to reject the claim that these experiences constitute an "altered state of consciousness."

Most researchers today describe both hypnosis and trance states as "subjective" alterations of consciousness, not an actually distinct or evolved form (Kirsch & Lynn, 1995). Just like you feel different when you're in a state of deep relaxation, so, too, are hypnotic and trance states simply shifts from the standard conscious experience. Researchers contend that even though both hypnotic and trance states appear and feel wildly different than the normal human experience, they can be explained by standard socio-cognitive factors like imagination, expectation, and the interpretation of the situation.

Sleep

You may have experienced the sensation– as you are falling asleep– of falling and then found yourself physically jerking forward and grabbing out as if you were really falling. Sleep is a unique state of consciousness; it lacks full awareness but the brain is still active. People generally follow a "biological clock" that impacts when they naturally become drowsy, when they fall asleep, and the time they naturally awaken. The hormone **melatonin** increases at night and is associated with becoming sleepy. Your natural daily rhythm, or **Circadian Rhythm**, can be influenced by the amount of daylight to which you are exposed as well as your work and activity schedule. Changing your location, such as flying from Canada to England, can disrupt your natural sleep rhythms, and we call this **jet lag**.

Sleep is necessary in order for people to function well. [Image: jaci XIII, https://goo.gl/pog6Fr, CC BY-NC 2.0, https://goo.gl/ FIlc2e]

You can overcome jet lag by synchronizing yourself to the local schedule by exposing yourself to daylight and forcing yourself to stay awake even though you are naturally sleepy.

Interestingly, sleep itself is more than shutting off for the night (or for a nap). Instead of turning off like a light with a flick of a switch, your shift in consciousness is reflected in your brain's electrical activity. While you are awake and alert your brain activity is marked by *beta* waves. Beta waves are characterized by being high in frequency but low in intensity. In addition, they are the most inconsistent brain wave and this reflects the wide variation in sensory input that a person processes during the day. As you begin to relax these change to *alpha* waves. These waves reflect brain activity that is less frequent, more consistent and more intense. As you slip into actual sleep you transition through many stages. Scholars differ on how they characterize sleep stages with some experts arguing that there are four distinct stages (Manoach et al., 2010), while others recognize five (Šušmáková, & Krakovská, 2008) but they all distinguish between those that include rapid eye movement (REM) and those that are non- rapid eye movement (NREM). In addition, each stage is typically characterized by its own unique pattern of brain activity:

Stage 1 (called NREM 1, or N1) is the "falling asleep" stage and is marked by theta waves.

Stage 2 (called NREM 2, or N2) is considered a light sleep. Here, there are occasional "sleep spindles," or very high intensity brain waves. These are thought to be associated with the processing of memories. NREM 2 makes up about 55% of all sleep.

Stage 3 (called NREM 3, or N3) makes up between 20-25% of all sleep and is marked by greater muscle relaxation and the appearance of delta waves.

Finally, REM sleep is marked by rapid eye movement (REM). Interestingly, this stage—in terms of brain activity—is similar to wakefulness. That is, the brain waves occur less intensely than in other stages of sleep. REM sleep accounts for about 20% of all sleep and is associated with dreaming.

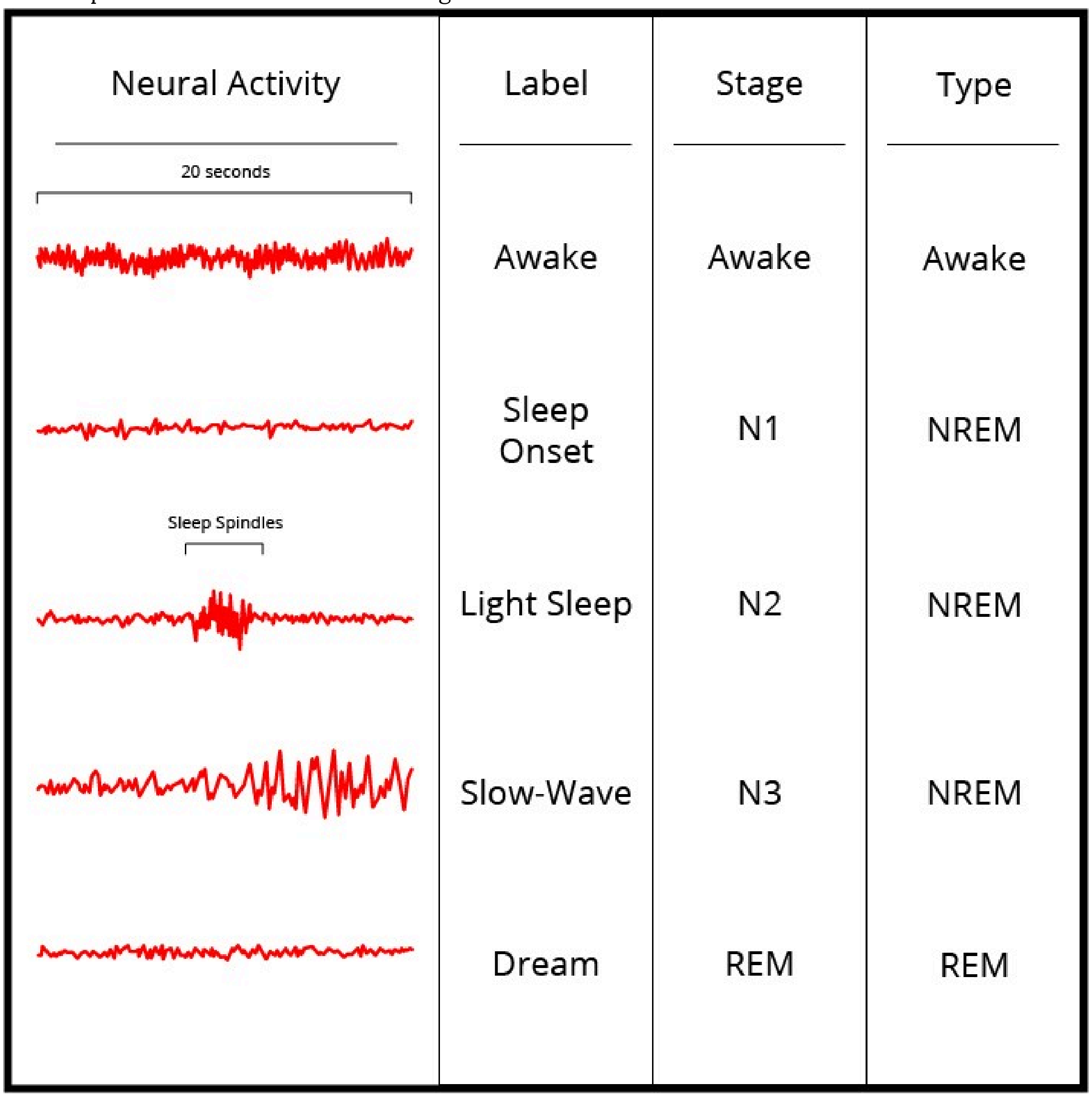


Figure 1. Changes in brain activity or brainwaves across different stages of

consciousness – from being awake and throughout various stages of sleep. [Image: Noba]

Dreams are, arguably, the most interesting aspect of sleep. Throughout history dreams have been given special importance because of their unique, almost mystical nature. They have been thought to be predictions of the future, hints of hidden aspects of the self, important lessons about how to live life, or opportunities to engage in impossible deeds like flying. There are several competing theories of why humans dream. One is that it is our nonconscious attempt to make sense of our daily experiences and learning. Another, popularized by Freud, is that dreams represent taboo or troublesome wishes or desires. Regardless of the specific reason we know a few facts about dreams: all humans dream, we dream at every stage of sleep, but dreams during REM sleep are especially vivid. One under-explored area of dream research is the possible social functions of dreams: we often share our dreams with others and use them for entertainment value.

Sleep serves many functions, one of which is to give us a period of mental and physical restoration. Children generally need more sleep than adults since they are developing. It is so vital, in fact, that a lack of sleep is associated with a wide range of problems. People who do not receive adequate sleep are more irritable, have slower reaction time, have more difficulty sustaining attention, and make poorer decisions. Interestingly, this is an issue relevant to the lives of college students. In one highly cited study researchers found that 1 in 5 students took more than 30 minutes to fall asleep at night, 1 in 10 occasionally took sleep medications, and more than half reported being "mostly tired" in the mornings (Buboltz, et al, 2001).

Psychoactive Drugs

On April 16, 1943, Albert Hoffman—a Swiss chemist working in a pharmaceutical company— accidentally ingested a newly synthesized drug. The drug—lysergic acid diethylimide (LSD)— turned out to be a powerful hallucinogen. Hoffman went home and later reported the effects of the drug, describing them as seeing the world through a "warped mirror" and experiencing visions of "extraordinary shapes with intense, kaleidoscopic play of colors." Hoffman had discovered what members of many traditional cultures around the world already knew: there are substances that, when ingested, can have a powerful effect on perception and on consciousness.

Drugs operate on human physiology in a variety of ways and researchers and medical doctors tend to classify drugs according to their effects. Here we will briefly cover 3 categories of drugs: hallucinogens, depressants, and stimulants.

Hallucinogens

It is possible that hallucinogens are the substance that have, historically, been used the most widely. Traditional societies have used plant-based hallucinogens such as peyote, ebene, and psilocybin mushrooms in a wide range of religious ceremonies. **Hallucinogens** are substances that alter a person's perceptions, often by creating visions or hallucinations that are not real. There are a wide range of hallucinogens and many are used as recreational substances in industrialized societies. Common examples include marijuana, LSD, and MDMA (also known as "ecstasy"). Marijuana is the dried flowers of the hemp plant and is often smoked to produce **euphoria**. The active ingredient in marijuana is called THC and can produce distortions in the perception of time, can create a sense of rambling, unrelated thoughts, and is sometimes associated with increased hunger or excessive laughter. The use and possession of marijuana is illegal in most places but this appears to be a trend that is changing. Uruguay, Bangladesh, and several of the United States, have recently legalized marijuana. This may be due, in part, to changing public attitudes or to the fact that marijuana is increasingly used for medical purposes such as the management of nausea or treating glaucoma.

Depressants

Depressants are substances that, as their name suggests, slow down the body's physiology and mental processes. Alcohol is the most widely used depressant. Alcohol's effects include the reduction of inhibition, meaning that intoxicated people are more likely to act in ways they would otherwise be reluctant to. Alcohol's psychological effects are the result of it increasing the neurotransmitter GABA. There are also physical effects, such as loss of balance and coordination, and these stem from the way that alcohol interferes with the coordination of the visual and motor systems of the brain. Despite the fact that alcohol is so widely accepted in many cultures it is also associated with a variety of dangers. First, alcohol is toxic, meaning that it acts like a poison because it is possible to drink more alcohol than the body can effectively remove from the bloodstream. When a person's **blood alcohol content (BAC)** reaches .3 to .4% there is a serious risk of death. Second, the lack of judgment and physical control associated with alcohol is associated with more risk taking behavior or dangerous behavior such as drunk driving. Finally, alcohol is addictive and heavy drinkers often experience significant interference with their ability to work effectively or in their close relationships.

Other common depressants include opiates (also called "narcotics"), which are substances synthesized from the poppy flower. Opiates stimulate endorphin production in the brain and because of this they are often used as pain killers by medical professionals. Unfortunately, because opiates such as Oxycontin so reliably produce euphoria they are increasingly used—illegally—as recreational substances. Opiates are highly addictive.

Stimulants

Stimulants are substances that "speed up" the body's physiological and mental processes. Two commonly used stimulants are caffeine—the drug found in coffee and tea—and nicotine, the active drug in cigarettes and other tobacco products. These substances are both legal and relatively inexpensive, leading to their widespread use. Many people are attracted to stimulants because they feel more alert when under the influence of these drugs. As with any drug there are health risks associated with consumption. For example, excessive consumption of these types of stimulants can result in anxiety, headaches, and insomnia. Similarly, smoking cigarettes— the most common means of ingesting nicotine—is associated with higher risks of cancer.

Caffeine is the most widely consumed stimulant in the world. Be honest, how many cups of coffee, tea, or energy drinks have you had today? [Image: Personeelsnet, https://goo.gl/h0GQ3R, CC BY-SA 2.0, https://goo.gl/iZlxAE]

For instance, among heavy smokers 90% of lung cancer is directly attributable to smoking (Stewart & Kleihues, 2003).

There are other stimulants such as cocaine and methamphetamine (also known as “crystal meth” or “ice”) that are illegal substances that are commonly used. These substances act by blocking “re-uptake” of dopamine in the brain. This means that the brain does not naturally clear out the dopamine and that it builds up in the synapse, creating euphoria and alertness. As the effects wear off it stimulates strong cravings for more of the drug. Because of this these powerful stimulants are highly addictive.

Conclusion

When you think about your daily life it is easy to get lulled into the belief that there is one “setting” for your conscious thought. That is, you likely believe that you hold the same opinions, values, and memories across the day and throughout the week. But “you” are like a dimmer switch on a light that can be turned from full darkness increasingly on up to full brightness. This switch is consciousness. At your brightest setting you are fully alert and aware; at dimmer settings you are day dreaming; and sleep or being knocked unconscious represent dimmer settings still. The degree to which you are in high, medium, or low states of conscious awareness affect how susceptible you are to persuasion, how clear your judgment is, and how much detail you can recall. Understanding levels of awareness, then, is at the heart of understanding how we learn, decide, remember and many other vital psychological processes.

Outside Resources

App: Visual illusions for the iPad.

http://www.exploratorium.edu/explore/apps/color-uncovered

Book: A wonderful book about how little we know about ourselves: Wilson, T. D. (2004). Strangers to ourselves. Cambridge, MA: Harvard University Press. http://www.hup.harvard.edu/catalog.php?isbn=9780674013827

Book: Another wonderful book about free will—or its absence?: Wegner, D. M. (2002). The illusion of conscious will. Cambridge, MA: MIT Press. https://mitpress.mit.edu/books/illusion-conscious-will

Information on alcoholism, alcohol abuse, and treatment:

http://www.niaaa.nih.gov/alcohol-health/support-treatment

The American Psychological Association has information on getting a good night's sleep as well as on sleep disorders

http://www.apa.org/helpcenter/sleep-disorders.aspx

The LSD simulator: This simulator uses optical illusions to simulate the halluginogenic experience of LSD. Simply follow the instructions in this two minute video. After looking away you may see the world around you in a warped or pulsating way similar to the effects of LSD. The effect is temporary and will disappear in about a minute. https://youtu.be/fVaLddnlafc

The National Sleep Foundation is a non-profit with videos on insomnia, sleep training in children, and other topics

https://sleepfoundation.org/video-library

Video: An artist who periodically took LSD and drew self-portraits: http://www.openculture.com/2013/10/artist-draws-nine-portraits-on-lsd-during-1950s-resea rch-experiment.html

Video: An interesting video on attention:

http://www.dansimons.com/videos.html

Video: Clip on out-of-body experiences induced using virtual reality.

A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.library.upei.ca/upeiintropsychology/?p=940

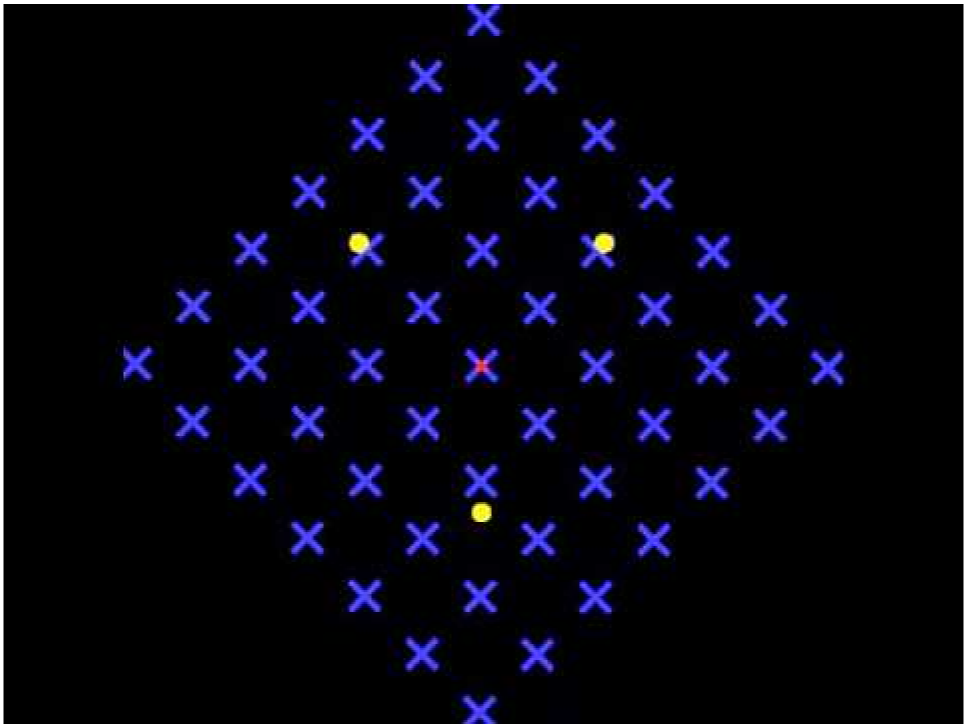
Video: Clip on the rubber hand illusion, from the BBC science series \\\\\\\"Horizon.\\\\\\\"

A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.library.upei.ca/upeiintropsychology/?p=940

Video: Clip showing a patient with blindsight, from the documentary \\\\\\\"Phantoms in the Brain.\\\\\\\"

A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.library.upei.ca/upeiintropsychology/?p=940

Video: Demonstration of motion-induced blindness – Look steadily at the blue moving pattern. One or more of the yellow spots may disappear:



A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.library.upei.ca/upeiintropsychology/?p=940

Video: Howie Mandel from America\\\'s Got Talent being hypnotized into shaking hands with people:

A YouTube element has been excluded from this version of the text. You can view it online here: *https://pressbooks.library.upei.ca/upeiintropsychology/?p=940*

Video: Imaging the Brain, Reading the Mind – A talk by Marsel Mesulam.

http://video.at.northwestern.edu/lores/SO_marsel.m4v

Video: Lucas Handwerker – a stage hypnotist discusses the therapeutic aspects of hypnosis:

https://www.youtube.com/watch?v=zepp_H6K5wY

Video: Ted Talk – Simon Lewis: Don\\\\\\\'t take consciousness for granted

http://www.ted.com/talks/simon_lewis_don_t_take_consciousness_for_granted.html

Video: TED Talk on Dream Research:

https://www.youtube.com/watch?v=y9ArPNAOHCo

Video: The mind-body problem – An interview with Ned Block:

A Vimeo element has been excluded from this version of the text. You can view it online here: https://pressbooks.library.upei.ca/upeiintropsychology/?p=940

Want a quick demonstration of priming? (Want a quick demonstration of how powerful these effects can be? Check out:

A YouTube element has been excluded from this version of the text. You can view it online here: https://pressbooks.library.upei.ca/upeiintropsychology/?p=940

Web: A good overview of priming:

http://en.wikipedia.org/wiki/Priming_(psychology)

Web: Definitions of Consciousness:

http://www.consciousentities.com/definitions.htm

Web: Learn more about motion-induced blindness on Michael Bach's website:

http://www.michaelbach.de/ot/mot-mib/index.html

Discussion Questions

1. If someone were in a coma after an accident, and you wanted to better understand how "conscious" or aware s/he were, how might you go about it?
2. What are some of the factors in daily life that interfere with people's ability to get adequate sleep? What interferes with your sleep?
3. How frequently do you remember your dreams? Do you have recurring images or themes in your dreams? Why do you think that is?
4. Consider times when you fantasize or let your mind wander? Describe these times: are you more likely to be alone or with others? Are there certain activities you engage in that seem particularly prone to daydreaming?
5. A number of traditional societies use consciousness altering substances in ceremonies. Why do you think they do this?
6. Do you think attitudes toward drug use are changing over time? If so, how? Why do you think these changes occur?
7. Students in high school and college are increasingly using stimulants such as Adderol as study aids and "performance enhancers." What is your opinion of this trend?

Vocabulary

Blood Alcohol Content (BAC)

a measure of the percentage of alcohol found in a person's blood. This measure is typically the standard used to determine the extent to which a person is intoxicated, as in the case of being too impaired to drive a vehicle.

Circadian Rhythm

The physiological sleep-wake cycle. It is influenced by exposure to sunlight as well as daily schedule and activity. Biologically, it includes changes in body temperature, blood pressure and blood sugar.

Consciousness

the awareness or deliberate perception of a stimulus

Cues

a stimulus that has a particular significance to the perceiver (e.g., a sight or a sound that has special relevance to the person who saw or heard it)

Depressants

a class of drugs that slow down the body's physiological and mental processes.

Dissociation

the heightened focus on one stimulus or thought such that many other things around you are ignored; a disconnect between one's awareness of their environment and the one object the person is focusing on

Euphoria

an intense feeling of pleasure, excitement or happiness.

Flexible Correction Model

the ability for people to correct or change their beliefs and evaluations if they believe these judgments have been biased (e.g., if someone realizes they only thought their day was great because it was sunny, they may revise their evaluation of the day to account for this "biasing" influence of the weather)

Hallucinogens

substances that, when ingested, alter a person's perceptions, often by creating hallucinations that are not real or distorting their perceptions of time.

Hypnosis

the state of consciousness whereby a person is highly responsive to the suggestions of another; this state usually involves a dissociation with one's environment and an intense focus on a single stimulus, which is usually accompanied by a sense of relaxation

Hypnotherapy

The use of hypnotic techniques such as relaxation and suggestion to help engineer desirable change such as lower pain or quitting smoking.

Implicit Associations Test

A computer reaction time test that measures a person's automatic associations with concepts. For instance, the IAT could be used to measure how quickly a person makes positive or negative evaluations of members of various ethnic groups.

Jet Lag

The state of being fatigued and/or having difficulty adjusting to a new time zone after traveling a long distance (across multiple time zones).

Melatonin

A hormone associated with increased drowsiness and sleep.

Mindfulness

a state of heightened focus on the thoughts passing through one's head, as well as a more controlled evaluation of those thoughts (e.g., do you reject or support the thoughts you're having?)

Priming

the activation of certain thoughts or feelings that make them easier to think of and act upon

Stimulants

a class of drugs that speed up the body's physiological and mental processes.

Trance States

Trance: a state of consciousness characterized by the experience of "out-of-body possession," or an acute dissociation between one's self and the current, physical environment surrounding them.

References

Abbot, N. C., Stead, L. F., White, A. R., Barnes, J., & Ernst, E. (1998). Hypnotherapy for smoking cessation. *Cochrane Database of Systematic Reviews*, 2.

Bargh, J. A., Chen, M., & Burrows, L. (1996). Automaticity of social behavior: Direct effects of trait construct and stereotype activation on action. *Journal of Personality and Social Psychology*, 71(2), 230.

Buboltz, W., Brown, F. & Soper, B. (2001). Sleep habits and patterns of college students: A preliminary study. *Journal of American College Health*, 50, 131-135.

Chaiken, S. (1980). Heuristic versus systematic information processing and the use of source versus message cues in persuasion. *Journal of Personality and Social Psychology*, 39(5), 752.

Ewin, D. M. (1978). *Clinical use of hypnosis for attenuation of burn depth. Hypnosis at its Bicentennial-Selected Papers from the Seventh International Congress of Hypnosis and Psychosomatic Medicine*. New York: Plenum Press.

Freud, S. (2001). *The Standard Edition of the Complete Psychological Works of Sigmund Freud: The Interpretation of Dreams* (First Part) (Vol. 4). Random House.

Gilbert, D. T., & Hixon, J. G. (1991). The trouble of thinking: activation and application of stereotypic beliefs. *Journal of Personality and Social Psychology*, 60(4), 509.

Greenwald, A. G., & Farnham, S. D. (2000). Using the Implicit Association Test to measure self- esteem and self-concept. *Journal of Personality and Social Psychology*, 79, 1022-1038.

Greenwald, A. G., McGhee, D. E., & Schwartz, J. K. L. (1998). Measuring individual differences in implicit cognition: The Implicit Association Test. *Journal of Personality and Social Psychology*, 74, 1464-1480.

Kihlstrom, J.F. (2003). Hypnosis and memory. In J.F. Byrne (Ed.), *Learning and memory*, 2nd ed. (pp. 240-242). Farmington Hills, Mi.: Macmillan Reference

Kirsch, I., & Lynn, S. J. (1995). Altered state of hypnosis: Changes in the theoretical landscape. *American Psychologist*, 50(10), 846.

Lynn S. J., and Kirsch I. (2006). *Essentials of clinical hypnosis*. Washington, DC: American Psychological Association.

Lynn, S. J., Rhue, J. W., & Weekes, J. R. (1990). Hypnotic involuntariness: A social-cognitive analysis. *Psychological Review*, 97, 169–184.

Manoach, D. S., Thakkar, K. N., Stroynowski, E., Ely, A., McKinley, S. K., Wamsley, E., … & Stickgold, R. (2010). Reduced overnight consolidation of procedural learning in chronic medicated schizophrenia is related to specific sleep stages. *Journal of Psychiatric Research*, 44(2),112-120.

Nosek, B. A., Banaji, M. R., & Greenwald, A. G. (2002). Harvesting implicit group attitudes and beliefs from a demonstration website. *Group Dynamics*, 6(1), 101-115.

Patterson, D. R., Everett, J. J., Burns, G. L., & Marvin, J. A. (1992). Hypnosis for the treatment of burn pain. *Journal of Consulting and Clinical Psychology*, 60, 713-17

Pekala, R. J., Kumar, V. K., Maurer, R., Elliott-Carter, N., Moon, E., & Mullen, K. (2010). Suggestibility, expectancy, trance state effects, and hypnotic depth: I. Implications for understanding hypnotism. *American Journal of Clinical Hypnosis*, 52(4), 275-290.

Petty, R. E., & Cacioppo, J. T. (1986). The Elaboration Likelihood Model of persuasion. In L. Berkowitz (Ed.), *Advances in Experimental Social Psychology* (Vol. 19, pp. 123-205). New York: Academic Press.

Raichle, M. E. (2015). The brain's default mode network. *Annual Review of Neuroscience*, 38, 433-447.

Stewart, B. & Kleinhues, P. (2003). *World cancer report*. World Health Organization.

Syrjala, K. L., Cummings, C., & Donaldson, G. W. (1992). Hypnosis or cognitive behavioral training for the reduction of pain and nausea during cancer treatment: A controlled clinical trial. *Pain*, 48, 137-46.

Wegener, D. T., & Petty, R. E. (1997). The flexible correction model: The role of naive theories of bias in bias correction. *Advances in Experimental Social Psychology*, 29, 142-208.

Wickramasekera II, I. E., & Szlyk, J. (2003). Could empathy be a predictor of hypnotic ability? *International Journal of Clinical and Experimental Hypnosis*, *51*(4), 390–399.

Williams, L. E., & Bargh, J. A. (2008). Experiencing physical warmth promotes interpersonal warmth. *Science*, *322*(5901), 606-607.

Öhman, A., & Soares, J. J. (1994). \"Unconscious anxiety\": phobic responses to masked stimuli. *Journal of Abnormal Psychology*, *103*(2), 231.

Šušmáková, K., & Krakovská, A. (2008). Discrimination ability of individual measures used in sleep stages classification. *Artificial Intelligence in Medicine*, *44*(3), 261-277.

LANGUAGE AND LANGUAGE USE

Language and Language Use

Yoshihisa Kashima

Humans have the capacity to use complex language, far more than any other species on Earth. We cooperate with each other to use language for communication; language is often used to communicate about and even construct and maintain our social world. Language use and human sociality are inseparable parts of Homo sapiens as a biological species.

Learning Objectives

Define basic terms used to describe language use.

Describe the process by which people can share new information by using language.

Characterize the typical content of conversation and its social implications.

Characterize psychological consequences of language use and give an example.

Introduction

Imagine two men of 30-something age, Adam and Ben, walking down the corridor. Judging from their clothing, they are young businessmen, taking a break from work. They then have this exchange.

Adam: "You know, Gary bought a ring."

Ben: "Oh yeah? For Mary, isn't it?" (Adam nods.)

If you are watching this scene and hearing their conversation, what can you guess from this? First of all, you'd guess that Gary bought a ring for Mary, whoever Gary and Mary might be. Perhaps you would infer that Gary is getting married to Mary. What else can you guess? Perhaps that Adam and Ben are fairly close colleagues, and both of them know Gary and Mary reasonably well. In other words, you can guess the social relationships surrounding the people who are engaging in the conversation and the people whom they are talking about.

Language is used in our everyday lives. If psychology is a science of behavior, scientific investigation of language *use* must be one of the most central topics– this is because language use is ubiquitous. Every human group has a language; human infants (except those who have unfortunate disabilities) learn at least one language without being taught explicitly. Even when children who don't have much language to begin with are brought together, they can begin to develop and use their own language. There is at least one known instance where children who had had little language were brought together and developed their own language spontaneously with minimum input from adults.

Language is an essential tool that enables us to live the kind of lives we do. Much of contemporary human civilization wouldn't have been possible without it. [Image: Marc Wathieu, https://goo.gl/jNSzTC, CC BY-NC 2.0, https://goo.gl/VnKlK8]

In Nicaragua in the 1980s, deaf children who were separately raised in various locations were brought together to schools for the first time. Teachers tried to teach them Spanish with little success. However, they began to notice that the children were using their hands and gestures, apparently to communicate with each other. Linguists were brought in to find out what was happening—it turned out the children had developed their own sign language by themselves. That was the birth of a new language, Nicaraguan Sign Language (Kegl, Senghas, & Coppola, 1999). Language is ubiquitous, and we humans are born to use it.

How Do We Use Language?

If language is so ubiquitous, how do we actually use it? To be sure, some of us use it to write diaries and poetry, but the primary form of language use is interpersonal. That's how we learn language, and that's how we use it. Just like Adam and Ben, we exchange words and utterances to communicate with each other. Let's consider the simplest case of two people, Adam and Ben, talking with each other. According to Clark (1996), in order for them to carry out a conversation, they must keep track of **common ground**. Common ground is a set of knowledge that the speaker and listener share and they think, assume, or otherwise take for granted that they share. So, when Adam says, "Gary bought a ring," he takes for granted that Ben knows the meaning of the words he is using, whom Gary is, and what buying a ring means. When Ben says, "For Mary, isn't it?" he takes for granted that Adam knows the meaning of these words, who Mary is, and what buying a ring for someone means. All these are part of their common ground.

The “common ground” in a conversation helps people coordinate their language use. And as conversations progress common ground shifts and changes as the participants add new information and cooperate to help one another understand. [Image: Converse College, https://goo.gl/UhbMQH, CC BY-NC 2.0, https://goo.gl/VnKlK8]

Note that, when Adam presents the information about Gary’s purchase of a ring, Ben responds by presenting his inference about who the recipient of the ring might be, namely, Mary. In conversational terms, Ben’s utterance acts as evidence for his comprehension of Adam’s utterance– “Yes, I understood that Gary bought a ring”—and Adam’s nod acts as evidence that he now has understood what Ben has said too —“Yes, I understood that you understood that Gary has bought a ring for Mary.” This new information is now added to the initial common ground. Thus, the pair of utterances by Adam and Ben (called an adjacency pair) together with Adam’s affirmative nod jointly completes one proposition, "Gary bought a ring for Mary," and adds this information to their common ground. This way, common ground changes as we talk, gathering new information that we agree on and have evidence that we share. It evolves as people take turns to assume the roles of speaker and listener, and actively engage in the exchange of meaning.

Common ground helps people coordinate their language use. For instance, when a speaker says something to a listener, he or she takes into account their common ground, that is, what the speaker thinks the listener knows. Adam said what he did because he knew Ben would know who Gary was. He'd have said, "A friend of mine is getting married," to another colleague who wouldn't know Gary. This is called **audience design** (Fussell & Krauss, 1992); speakers design their utterances for their audiences by taking into account the audiences' knowledge. If their audiences are seen to be knowledgeable about an object (such as Ben about Gary), they tend to use a brief label of the object (i.e., Gary); for a less knowledgeable audience, they use more descriptive words (e.g., "a friend of mine") to help the audience understand their utterances (Box 1).

Box 1. Coordinating Language Use by Audience Design

In systematic research on audience design, Fussell and Krauss (1992) found that, when communicating about public figures, speakers included more descriptive information (e.g., physical appearances, occupation) about lesser known and less identifiable people (e.g., Kevin Kline, Carl Icahn) than better known ones (e.g., Woody Allen, Clint Eastwood), so that their listeners can identify whom they are talking about. Likewise, Isaacs and Clark (1987) showed that people who were familiar with New York City could gauge their audience's familiarity with NYC soon after they began conversation and adjusted their descriptions of NYC landmarks to help the audience identify such landmarks as the Brooklyn Bridge and Yankee Stadium more easily. More generally, Grice (1975) suggested that speakers often follow certain rules, which he calls conversational maxims, by trying to be informative (maxim of quantity), truthful (maxim of quality), relevant (maxim of relation), and clear and unambiguous (maxim of manner).

So, language use is a cooperative activity, but how do we coordinate our language use in a conversational setting? To be sure, we have a conversation in small groups. The number of people engaging in a conversation at a time is rarely more than four. By some counts (e.g., Dunbar, Duncan, & Nettle, 1995; James, 1953), more than 90 percent of conversations happen in a group of four individuals or less. Certainly, coordinating conversation among four is not as difficult as coordinating conversation among 10. But, even among only four people, if you think about it, everyday conversation is an almost miraculous achievement. We typically have a conversation by rapidly exchanging words and utterances in real time in a noisy environment. Think about your conversation at home in the morning, at a bus stop, in a shopping mall. How can we keep track of our common ground under such circumstances?

Pickering and Garrod (2004) argue that we achieve our conversational coordination by virtue of our ability to interactively align each other's actions at different levels of language use: **lexicon** (i.e., words and expressions), **syntax** (i.e., grammatical rules for arranging words and expressions together), as well as speech rate and accent. For instance, when one person uses a certain expression to refer to an object in a conversation, others tend to use the same expression (e.g., Clark & Wilkes-Gibbs, 1986). Furthermore, if someone says "the cowboy offered a banana to the robber," rather than "the cowboy offered the robber a banana," others are more likely to use the same syntactic structure (e.g., "the girl gave a book to the boy" rather than "the girl gave the boy a book") even if different words are involved (Branigan, Pickering, & Cleland, 2000). Finally, people in conversation tend to exhibit similar accents and rates of speech, and they are often associated with people's social identity (Giles, Coupland, & Coupland, 1991). So, if you have lived in different places where people have somewhat different accents (e.g., United States and United Kingdom), you might have noticed that you speak with Americans with an American accent, but speak with Britons with a British accent.

Pickering and Garrod (2004) suggest that these interpersonal alignments at different levels of language use can activate similar **situation models** in the minds of those who are engaged in a conversation. Situation models are representations about the topic of a conversation. So, if you are talking about Gary and Mary with your friends, you might have a situation model of Gary giving Mary a ring in your mind. Pickering and Garrod's theory is that as you describe this situation using language, others in the conversation begin to use similar words and grammar, and many other aspects of language use converge. As you all do so, similar situation models begin to be built in everyone's mind through the mechanism known as **priming**. Priming occurs when your thinking about one concept (e.g., "ring") reminds you about other related concepts (e.g., "marriage", "wedding ceremony"). So, if everyone in the conversation knows about Gary, Mary, and the usual course of events associated with a ring—engagement, wedding, marriage, etc.—everyone is likely to construct a shared situation model about Gary and Mary.

Thus, making use of our highly developed interpersonal ability to imitate (i.e., executing the same action as another person) and cognitive ability to infer (i.e., one idea leading to other ideas), we humans coordinate our common ground, share situation models, and communicate with each other.

What Do We Talk About?

What are humans doing when we are talking? Surely, we can communicate about mundane things such as what to have for dinner, but also more complex and abstract things such as the meaning of life and death, liberty, equality, and fraternity, and many other philosophical thoughts.

Studies show that people love to gossip. By gossiping, humans can communicate and share their representations about their social world—who their friends and enemies are, what the right thing to do is under what circumstances, and so on. [Image: aqua. mech, https://goo.gl/Q7Ap4b, CC BY 2.0, https://goo.gl/T4qgSp]

Well, when naturally occurring conversations were actually observed (Dunbar, Marriott, & Duncan, 1997), a staggering 60%–70% of everyday conversation, for both men and women, turned out to be gossip—people talk about themselves and others whom they know. Just like Adam and Ben, more often than not, people use language to communicate about their social world.

Gossip may sound trivial and seem to belittle our noble ability for language—surely one of the most remarkable human abilities of all that distinguish us from other animals. *Au contraire*, some have argued that gossip—activities to think and communicate about our social world—is one of the most critical uses to which language has been put. Dunbar (1996) conjectured that gossiping is the human equivalent of grooming, monkeys and primates attending and tending to each other by cleaning each other's fur. He argues that it is an act of socializing, signaling the importance of one's partner. Furthermore, by gossiping, humans can communicate and share their representations about their social world—who their friends and enemies are, what the right thing to do is under what circumstances, and so on. In so doing, they can regulate their social world—making more friends and enlarging one's own group (often called the **ingroup**, the group to which one belongs) against other groups (**outgroups**) that are more likely to be one's enemies. Dunbar has argued that it is these social effects that have given humans an evolutionary advantage and larger brains, which, in turn, help humans to think more complex and abstract thoughts and, more important, maintain larger ingroups. Dunbar (1993) estimated an equation that predicts average group size of nonhuman primate genera from their average neocortex size (the part of the brain that supports higher order cognition). In line with his **social brain hypothesis**, Dunbar showed that those primate genera that have larger brains tend to live in larger groups. Furthermore, using the same equation, he was able to estimate the group size that human brains can support, which turned out to be about 150—approximately the size of modern hunter- gatherer communities. Dunbar's argument is that language, brain, and human group living have co-evolved—language and human sociality are inseparable.

Dunbar's hypothesis is controversial. Nonetheless, whether or not he is right, our everyday language use often *ends up* maintaining the existing structure of intergroup relationships. Language use can have implications for how we construe our social world. For one thing, there are subtle cues that people use to convey the extent to which someone's action is just a special case in a particular context or a pattern that occurs across many contexts and more like a character trait of the person. According to Semin and Fiedler (1988), someone's action can be described by an action verb that describes a concrete action (e.g., he runs), a state verb that describes the actor's psychological state (e.g., he likes running), an adjective that describes the actor's personality (e.g., he is athletic), or a noun that describes the actor's role (e.g., he is an athlete). Depending on whether a verb or an adjective (or noun) is used, speakers can convey the permanency and stability of an actor's tendency to act in a certain way—verbs convey particularity, whereas adjectives convey permanency. Intriguingly, people tend to describe positive actions of their ingroup members using adjectives (e.g., he is generous) rather than verbs (e.g., he gave a blind man some change), and negative actions of outgroup members using adjectives (e.g., he is cruel) rather than verbs (e.g., he kicked a dog). Maass, Salvi, Arcuri, and Semin (1989) called this a **linguistic intergroup bias**, which can produce and reproduce the representation of intergroup relationships by painting a picture favoring the ingroup. That is, ingroup members are typically good, and if they do anything bad, that's more an exception in special circumstances; in contrast, outgroup members are typically bad, and if they do anything good, that's more an exception.

Box 2. Emotion & Talk

People tend to tell stories that evoke strong emotions (Rimé, Mesquita, Philippot, & Boca, 1991). Such emotive stories can then spread far and wide through people's social networks. When a group of 33 psychology students visited a city morgue (no doubt an emotive experience for many), they told their experience to about six people on average; each of these people who heard about it told one person, who in turn told another person on average. By this third retelling of the morgue visit, 881 people had heard about this in their community within 10 days. If everyone in society is connected with one another by six degrees of separation (Travers & Milgram, 1969) and if a chain letter can travel hundreds of steps via the Internet (Liben-Nowell & Klein, 2008), the possibility of emotive gossip traveling through a vast social network is not a fantasy. Indeed, urban legends that evoke strong feelings of disgust tend to spread in cyberspace and become more prevalent on the Internet (Heath, Bell, & Sternberg, 2001).

In addition, when people exchange their gossip, it can spread through broader **social networks**. If gossip is transmitted from one person to another, the second person can transmit it to a third person, who then in turn transmits it to a fourth, and so on through a chain of communication. This often happens for emotive stories (Box 2). If gossip is repeatedly transmitted and spread, it can reach a large number of people. When stories travel through communication chains, they tend to become conventionalized (Bartlett, 1932). A Native American tale of the "War of the Ghosts" recounts a warrior's encounter with ghosts traveling in canoes and his involvement with their ghostly battle. He is shot by an arrow but doesn't die, returning

home to tell the tale. After his narration, however, he becomes still, a black thing comes out of his mouth, and he eventually dies. When it was told to a student in England in the 1920s and retold from memory to another person, who, in turn, retold it to another and so on in a communication chain, the mythic tale became a story of a young warrior going to a battlefield, in which canoes became boats, and the black thing that came out of his mouth became simply his spirit (Bartlett, 1932). In other words, information transmitted multiple times was transformed to something that was easily understood by many, that is, information was assimilated into the common ground shared by most people in the linguistic community. Morerecently, Kashima (2000) conducted a similar experiment using a story that contained a sequence of events that described a young couple's interaction that included both stereotypical and counter-stereotypical actions (e.g., a man watching sports on TV on Sunday vs. a man vacuuming the house). After the retelling of this story, much of the counter- stereotypical information was dropped, and stereotypical information was more likely to be retained. Because stereotypes are part of the common ground shared by the community, this finding too suggests that conversational retellings are likely to reproduce conventional content.

Psychological Consequences of Language Use

What are the psychological consequences of language use? When people use language to describe an experience, their thoughts and feelings are profoundly shaped by the linguistic representation that they have produced rather than the original experience per se (Holtgraves & Kashima, 2008). For example, Halberstadt (2003) showed a picture of a person displaying an ambiguous emotion and examined how people evaluated the displayed emotion. When people verbally explained why the target person was expressing a particular emotion, they tended to remember the person as feeling that emotion more intensely than when they simply labeled the emotion.

Thus, constructing a linguistic representation of another person's emotion apparently biased the speaker's memory of that person's emotion. Furthermore, linguistically labeling one's own emotional experience appears to alter the speaker's neural processes. When people linguistically labeled negative images, the amygdala—a brain structure that is critically involved in the processing of negative emotions such as fear—was activated less than when they were not given a chance to label them (Lieberman et al., 2007). Potentially because of these effects of verbalizing emotional experiences, linguistic reconstructions of negative life events can have some therapeutic effects on those who suffer from the traumatic experiences (Pennebaker & Seagal, 1999).

By verbalizing our own emotional experiences – such as in a conversation with a close friend – we can improve our psychological well-being. [Image: Drew Herron, https://goo.gl/lKMAv1, CC BY-NC-SA 2.0, https://goo.gl/Toc0ZF]

Lyubomirsky, Sousa, and Dickerhoof (2006) found that writing and talking about negative past life events improved people's psychological well-being, but just thinking about them worsened it. There are many other examples of effects of language use on memory and decision making (Holtgraves & Kashima, 2008).

Box 3. Sapir-Whorf Hypothesis

An example of evidence for Sapir-Whorf hypothesis comes from a comparison between English and Mandarin Chinese speakers (Boroditsky, 2000). In English, time is often metaphorically described in horizontal terms. For instance, good times are ahead of us, or hardship can be left behind us. We can move a meeting forward or backward. Mandarin Chinese speakers use similar horizontal metaphors too, but also use vertical metaphors. So, for instance, the last month is called shang ge yue or "above month," and the next month, xia ge yue or "below month." To put it differently, the arrow of time flies horizontally in English, but it can fly both horizontally and vertically in Chinese. Does this difference in language use affect English and Chinese speakers' comprehension of language?

This is what Boroditsky (2000) found. First, English and Chinese speakers' understanding of sentences that use a horizontal (e.g., "June comes before August") did not differ very much. When they were first presented with a picture that implies a horizontal positioning (e.g., the black worm is ahead of the white worm), they could read and understand them faster than when they were presented with a picture that implies a vertical positioning (e.g., the black ball is above the white ball). This implies that thinking about the horizontal positioning (ahead or behind) equally primed (i.e., reminded) both English and Chinese speakers of the horizontal metaphor used in the sentence about time. However, English and Chinese speakers' comprehension differed for statements that do not use a spatial metaphor such as "August is later than June." When primed with the vertical spatial positioning, Chinese speakers comprehended these statements faster, but English speakers more slowly, than when they were primed with the horizontal spatial positioning. Apparently, English speakers were not used to thinking about months in terms of the vertical line, above or below. Indeed, when they were trained to do so, their comprehension was similar to Chinese speakers' (see Boroditsky, Furman, & McCormick, 2011, for recent review of related research).

Furthermore, if a certain type of language use (linguistic practice) (Holtgraves & Kashima, 2008) is repeated by a large number of people in a community, it can potentially have a significant effect on their thoughts and action. This notion is often called **Sapir-Whorf hypothesis** (Sapir, 1921; Whorf, 1956; Box 3). For instance, if you are given a description of a man, Steven, as having greater than average experience of the world (e.g., well- traveled, varied job experience), a strong family orientation, and well- developed social skills, how do you describe Steven? Do you think you can remember Steven's personality five days later? It will probably be difficult. But if you know Chinese and are reading about Steven in Chinese, as Hoffman, Lau, and Johnson (1986) showed, the chances are that you can remember him well. This is because English does not have a word to describe this kind of personality, whereas Chinese does (*shì gù*). This way, the language you use can influence your cognition. In its strong form, it has been argued that language *determines* thought, but this is probably wrong. Language does not completely determine our thoughts—our thoughts are far too flexible for that—but habitual uses of language can influence our habit of thought and action.

For instance, some linguistic practice seems to be associated even with cultural values and social institution. Pronoun drop is the case in point. Pronouns such as "I" and "you" are used to represent the speaker and listener of a speech in English. In an English sentence, these pronouns cannot be dropped if they are used as the subject of a sentence. So, for instance, "I went to the movie last night" is fine, but "Went to the movie last night" is not in standard English. However, in other languages such as Japanese, pronouns can be, and in fact often are, dropped from sentences. It turned out that people living in those countries where pronoun drop languages are spoken tend to have more collectivistic values (e.g., employees having greater loyalty toward their employers) than those who use non–pronoun drop languages such as English (Kashima & Kashima, 1998). It was argued that the explicit reference to "you" and "I" may remind speakers the distinction between the self and other, and the differentiation between individuals. Such a linguistic practice may act as a constant reminder of the cultural value, which, in turn, may encourage people to perform the linguistic practice.

Conclusion

Language and language use constitute a central ingredient of human psychology. Language is an essential tool that enables us to live the kind of life we do. Can you imagine a world in which machines are built, farms are cultivated, and goods and services are transported to our household without language? Is it possible for us to make laws and regulations, negotiate contracts, and enforce agreements and settle disputes without talking? Much of contemporary human civilization wouldn't have been possible without the human ability to develop and use language. Like the Tower of Babel, language can divide humanity, and yet, the core of humanity includes the innate ability for language use. Whether we can use it wisely is a task before us in this globalized world.

Discussion Questions

1. In what sense is language use innate and learned?
2. Is language a tool for thought or a tool for communication?
3. What sorts of unintended consequences can language use bring to your psychological processes?

Vocabulary

Audience design

Constructing utterances to suit the audience's knowledge.

Common ground

Information that is shared by people who engage in a conversation.

Ingroup

Group to which a person belongs.

Lexicon

Words and expressions.

Linguistic intergroup bias

A tendency for people to characterize positive things about their ingroup using more abstract expressions, but negative things about their outgroups using more abstract expressions.

Outgroup

Group to which a person does not belong.

Priming

A stimulus presented to a person reminds him or her about other ideas associated with the stimulus.

Sapir-Whorf hypothesis

The hypothesis that the language that people use determines their thoughts.

Situation model

A mental representation of an event, object, or situation constructed at the time of comprehending a linguistic description.

Social brain hypothesis

The hypothesis that the human brain has evolved, so that humans can maintain larger ingroups.

Social networks

Networks of social relationships among individuals through which information can travel.

Syntax

Rules by which words are strung together to form sentences.

References

Bartlett, F. C. (1932). *Remembering: A study in experimental and social psychology*. Cambridge, UK: Cambridge University Press.

Branigan, H. P., Pickering, M. J., & Cleland, A. A. (2000). Syntactic co-ordination in dialogue. *Cognition*, 75, B13–25.

Clark, H. H. (1996). *Using language*. Cambridge, UK: Cambridge University Press.

Clark, H. H., & Wilkes-Gibbs, D. (1986). Referring as a collaborative process. *Cognition*, 22, 1–39. Dunbar, R. (1996). *Grooming, gossip, and the evolution of language*. Boston, MA: Harvard University Press.

Dunbar, R. I. M. (1993). Coevolution of neorcortical size, group size and language in humans. *Behavioral and Brain Sciences*, 16, 681–735.

Dunbar, R. I. M., Duncan, N. D. C., & Nettle, D. (1995). Size and structure of freely forming conversational groups. *Human Nature*, 6, 67–78.

Dunbar, R. I. M., Marriott, A., & Duncan, N. D. C. (1997). Human conversational behaviour. *Human Nature*, 8, 231–246.

Fussell, S. R., & Krauss, R. M. (1992). Coordination of knowledge in communication: Effects of speakers' assumptions about what others know. *Journal of Personality and Social Psychology*, 62, 378–391.

Giles, H., Coupland, N., & Coupland, J. (1991) Accommodation theory: Communication, context, and consequence. In H. Giles, J. Coupland, & N. Coupland (Eds.), *Contexts of accommodation: Developments in applied sociolinguistics* (pp. 1–68). Cambridge, UK: Cambridge University Press.

Halberstadt, J. (2003). The paradox of emotion attribution: Explanation biases perceptual memory for emotional expressions. *Current Directions in Psychological Science*, 12, 197–201.

Hoffman, C., Lau, I., & Johnson, D. R. (1986). The linguistic relativity of person cognition: An English-Chinese comparison. *Journal of Personality and Social Psychology*, 51, 1097–1105.

Holtgraves, T. M., & Kashima, Y. (2008). Language, meaning, and social cognition. *Personality and Social Psychology Review*, 12, 73–94.

James, J. (1953). The distribution of free-forming small group size. *American Sociological Review*, 18, 569–570.

Kashima, E., & Kashima, Y. (1998). Culture and language: The case of cultural dimensions and personal pronoun use. *Journal of Cross-Cultural Psychology*, 29, 461–486.

Kashima, Y. (2000). Maintaining cultural stereotypes in the serial reproduction of narratives. *Personality and Social Psychology Bulletin*, 26, 594–604.

Kegl, J., Senghas, A., & Coppola, M. (1999). Creation through contact: Sign language emergence and sign language change in Nicaragua. In M. DeGraff (Ed.), *Language creation and language change Creolization, diachrony, and development* (pp. 179–237). Cambridge, MA: The MIT Press.

Lieberman, M., Eisenberger, N. I., Crockett, M. J., Tom, S. M., Pfeifer, J. H., & Way, B. W. (2007). Putting feelings into words. *Psychological Science*, 18, 421–428.

Lyubomirsky, S., Sousa, L., & Dickerhoof, R. (2006). The costs and benefits of writing, talking, and thinking about life's triumphs and defeats. *Journal of Personality and Social Psychology*, 90, 692–708.

Maass, A., Salvi, D., Arcuri, L., & Semin, G. (1989). Language use in intergroup contexts: The linguistic intergroup bias. *Journal of Personality and Social Psychology*, 57, 981–993.

Pennebaker, J. W., & Seagal, J. (1999). Forming a story: The health benefits of narrative. *Journal of Clinical Psychology*, 55, 1243–1254.

Pickering, M. J., & Garrod, S. (2004). Toward a mechanistic psychology of dialogue. *Behavioral and Brain Sciences*, 27, 169–226.

Sapir, E. (1921). *Language: An introduction to the study of speech*. New York, NY: Harcourt Brace.

Semin, G., & Fiedler, K. (1988). The cognitive functions of linguistic categories in describing persons: Social cognition and language. *Journal of Personality and Social Psychology*, 54, 558– 568.

Whorf, B. L. (1956). *Language, thought, and reality* (J. B. Carroll, Ed.). Cambridge, MA: MIT Press.

CATEGORIES AND CONCEPTS

Introduction

Consider the following set of objects: some dust, papers, a computer monitor, two pens, a cup, and an orange.

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]

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

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.

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]

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.

Furniture	Fruit
chair	orange
table	banana
desk	pear
bookcase	plum
lamp	strawberry
cushion	pineapple
rug	lemon
stove	honeydew
picture	date
vase	tomato

Table 1. Examples of two categories, with members ordered by typicality (from Rosch & Mervis, 1975)

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.

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).

Text Box 1

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.

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.

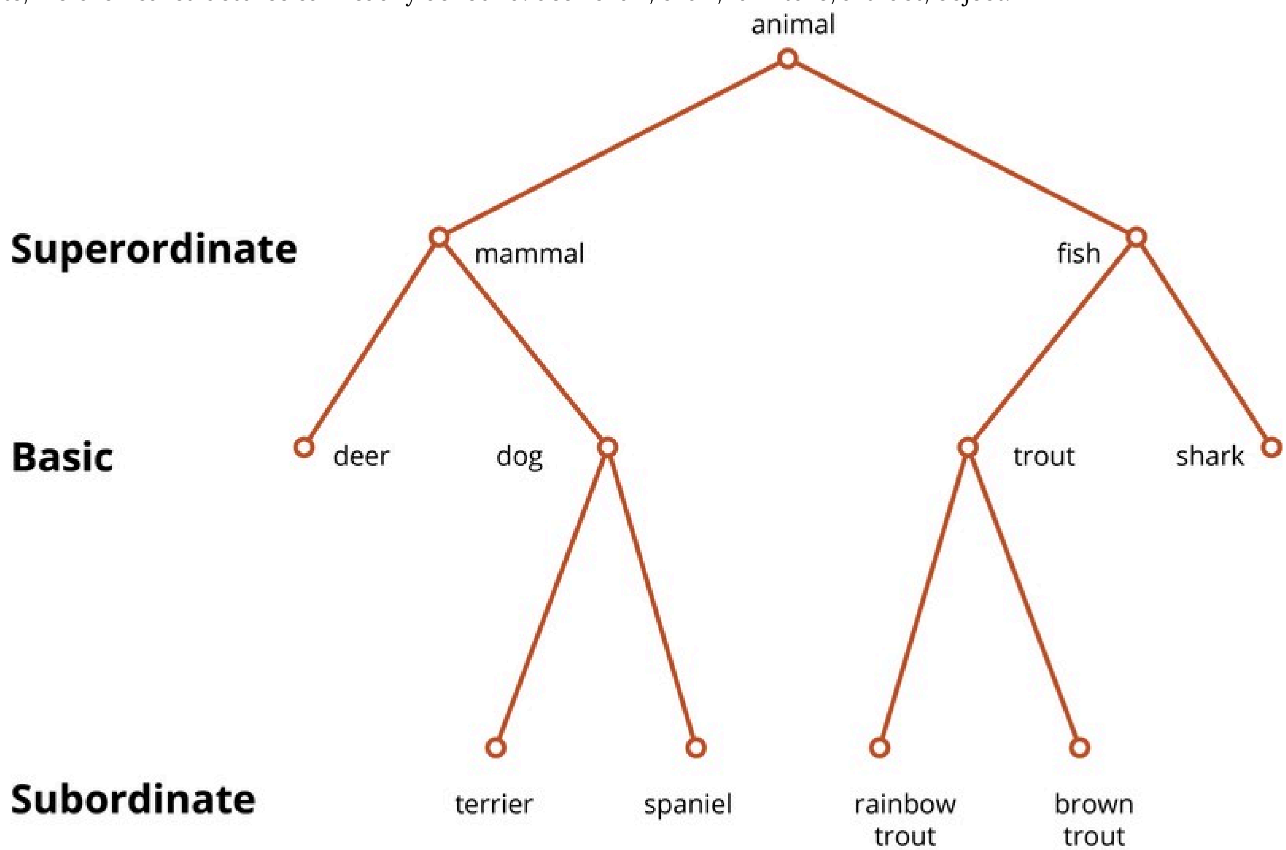


Figure 1. This is a highly simplified illustration of hierarchically organized categories, with the superordinate, basic, and subordinate levels labeled. Keep in mind that there may be even more specific subordinates (e.g., wire-haired terriers) and more general superordinates (e.g., living thing)

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).

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.**[1]** 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.

[1] 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.

Theories of Concept Representation

Now that we know these facts about the psychology of concepts, the question arises of how concepts are mentally represented. There have been two main answers. The first, somewhat confusingly called the *prototype theory* suggests that people have a *summary representation* of the category, a mental description that is meant to apply to the category as a whole. (The significance of *summary* will become apparent when the next theory is described.) This description can be represented as a set of *weightedfeatures* (Smith & Medin, 1981). The features are weighted by their frequency in the category. For the category of birds, having wings and feathers would have a very high weight; eating worms would have a lower weight; living in Antarctica would have a lower weight still, but not zero, as some birds do live there.

The idea behind prototype theory is that when you learn a category, you learn a general description that applies to the category as a whole: Birds have wings and usually fly; some eat worms; some swim underwater to catch fish. People can state these generalizations, and sometimes we learn about categories by reading or hearing such statements ("The kimodo dragon can grow to be 10 feet long").

When you try to classify an item, you see how well it matches that weighted list of features. For example, if you saw something with wings and feathers fly onto your front lawn and eat a worm, you could (unconsciously) consult your concepts and see which ones contained the features you observed. This example possesses many of the highly weighted bird features, and so it should be easy to identify as a bird.

This theory readily explains the phenomena we discussed earlier. Typical category members have more, higher-weighted features. Therefore, it is easier to match them to your conceptual representation. Less typical items have fewer or lower- weighted features (and they may have features of other concepts).

If you were asked, "What kind of animal is this?" according to prototype theory, you would consult your summary representations of different categories and then select the one that is most similar to this image—probably a lizard! [Image: Adhi Rachdian, https://goo.gl/dQyUwf, CC BY 2.0, https://goo.gl/BRvSA7]

Therefore, they don't match your representation as well. This makes people less certain in classifying such items. Borderline items may have features in common with multiple categories or not be very close to any of them. For example, edible seaweed does not have many of the common features of vegetables but also is not close to any other food concept (meat, fish, fruit, etc.), making it hard to know what kind of food it is.

A very different account of concept representation is the *exemplar theory* (**exemplar** being a fancy name for an example; Medin & Schaffer, 1978). This theory denies that there is a summary representation. Instead, the theory claims that your concept of vegetables is remembered examples of vegetables you have seen. This could of course be hundreds or thousands of exemplars over the course of your life, though we don't know for sure how many exemplars you actually remember.

How does this theory explain classification? When you see an object, you (unconsciously) compare it to the exemplars in your memory, and you judge how similar it is to exemplars in different categories. For example, if you see some object on your plate and want to identify it, it will probably activate memories of vegetables, meats, fruit, and so on. In order to categorize this object, you calculate how similar it is to each exemplar in your memory. These similarity scores are added up for each category. Perhaps the object is very similar to a large number of vegetable exemplars, moderately similar to a few fruit, and only minimally similar to some exemplars of meat you remember. These similarity scores are compared, and the category with the highest score is chosen.[2]

Why would someone propose such a theory of concepts? One answer is that in many experiments studying concepts, people learn concepts by seeing exemplars over and over again until they learn to classify them correctly. Under such conditions, it seems likely that people eventually memorize the exemplars (Smith & Minda, 1998). There is also evidence that *close similarity* to well-remembered objects has a large effect on classification. Allen and Brooks (1991) taught people to classify items by following a rule. However, they also had their subjects study the items, which were richly detailed. In a later test, the experimenters gave people new items that were very similar to one of the old items but were in a different category. That is, they changed one property so that the item no longer followed the rule. They discovered that people were often fooled by such items. Rather than following the category rule they had been taught, they seemed to recognize the new item as being very similar to an old one and so put it, incorrectly, into the same category.

Many experiments have been done to compare the prototype and exemplar theories. Overall, the exemplar theory seems to have won most of these comparisons. However, the experiments are somewhat limited in that they usually involve a small number of exemplars that people view over and over again. It is not so clear that exemplar theory can explain real- world classification in which people do not spend much time learning individual items (how much time do you spend studying squirrels? or chairs?). Also, given that some part of our knowledge of categories is learned through general statements we read or hear, it seems that there must be room for a summary description separate from exemplar memory.

Many researchers would now acknowledge that concepts are represented through multiple cognitive systems. For example, your knowledge of dogs may be in part through general descriptions such as “dogs have four legs.” But you probably also have strong memories of some exemplars (your family dog, Lassie) that influence your categorization. Furthermore, some categories also involve rules (e.g., a strike in baseball). How these systems work together is the subject of current study.

[2] Actually, the decision of which category is chosen is more complex than this, but the details are beyond this discussion.

Knowledge

The final topic has to do with how concepts fit with our broader knowledge of the world. We have been talking very generally about people learning the features of concepts. For example, they see a number of birds and then learn that birds generally have wings, or perhaps they remember bird exemplars. From this perspective, it makes no difference what those exemplars or features are—people just learn them. But consider two possible concepts of buildings and their features in Table 2.

Donker	Blegdav
has thick windows	has steel windows
is red	is purple
divers live there	farmers live there
is under water	is in the desert
get there by submarine	get there by submarine
has fish as pets	has polar bears as pets

Table 2. Examples of two fictional concepts

Imagine you had to learn these two concepts by seeing exemplars of them, each exemplar having some of the features listed for the concept (as well as some idiosyncratic features). Learning the donker concept would be pretty easy. It seems to be a kind of underwater building, perhaps for deep-sea explorers. Its features seem to go together. In contrast, the blegdav doesn't really make sense. If it's in the desert, how can you get there by submarine, and why do they have polar bears as pets? Why would farmers live in the desert or use submarines? What good would steel windows do in such a building? This concept seems peculiar. In fact, if people are asked to learn new concepts that make sense, such as donkers, they learn them quite a bit faster than concepts such as blegdavs that don't make sense (Murphy & Allopenna, 1994). Furthermore, the features that seem connected to one another (such as being underwater and getting there by submarine) are learned better than features that don't seem related to the others (such as being red).

Such effects demonstrate that when we learn new concepts, we try to connect them to the knowledge we already have about the world. If you were to learn about a new animal that doesn't seem to eat or reproduce, you would be very puzzled and think that you must have gotten something wrong. By themselves, the prototype and exemplar theories don't predict this. They simply say that you learn descriptions or exemplars, and they don't put any constraints on what those descriptions or exemplars are. However, the *knowledge approach* to concepts emphasizes that concepts are meant to tell us about real things in the world, and so our knowledge of the world is used in learning and thinking about concepts.

We can see this effect of knowledge when we learn about new pieces of technology. For example, most people could easily learn about tablet computers (such as iPads) when they were first introduced by drawing on their knowledge of laptops, cell phones, and related technology. Of course, this reliance on past knowledge can also lead to errors, as when people don't learn about features of their new tablet that weren't present in their cell phone or expect the tablet to be able to do something it can't.

One important aspect of people's knowledge about categories is called **psychological essentialism** (Gelman, 2003; Medin & Ortony, 1989). People tend to believe that some categories—most notably natural kinds such as animals, plants, or minerals—have an underlying property that is found only in that category and that causes its other features. Most categories don't actually have essences, but this is sometimes a firmly held belief. For example, many people will state that there is something about dogs, perhaps some specific gene or set of genes, that all dogs have and that makes them bark, have fur, and look the way they do. Therefore, decisions about whether something is a dog do not depend only on features that you can easily see but also on the assumed presence of this cause.

Although it may seem natural that different species have an unchangeable "essence," consider evolution and everything's development from common ancestors. [Image: Marc Dragiewicz, https://goo.gl/E9v4eR, CC BY-NC-SA 2.0, https://goo.gl/Toc0ZF]

Belief in an essence can be revealed through experiments describing fictional objects. Keil (1989) described to adults and children a fiendish operation in which someone took a raccoon, dyed its hair black with a white stripe down the middle, and implanted a "sac of super-smelly yucky stuff" under its tail. The subjects were shown a picture of a skunk and told that this is now what the animal looks like. What is it? Adults and children over the age of 4 all agreed that the animal is still a raccoon. It may look and even act like a skunk, but a raccoon cannot change its stripes (or whatever!)—it will always be a raccoon.

Importantly, the same effect was not found when Keil described a coffeepot that was operated on to look like and function as a bird feeder. Subjects agreed that it was now a bird feeder. Artifacts don't have an essence.

Signs of essentialism include (a) objects are believed to be either in or out of the category, with no in-between; (b) resistance to change of category membership or of properties connected to the essence; and (c) for living things, the essence is passed on to progeny.

Essentialism is probably helpful in dealing with much of the natural world, but it may be less helpful when it is applied to humans. Considerable evidence suggests that people think of gender, racial, and ethnic groups as having essences, which serves to emphasize the difference between groups and even justify discrimination (Hirschfeld, 1996). Historically, group differences were described by inheriting the blood of one's family or group. "Bad blood" was not just an expression but a belief that negative properties were inherited and could not be changed. After all, if it is in the nature of "those people" to be dishonest (or clannish or athletic…), then that could hardly be changed, any more than a raccoon can change into a skunk.

Research on categories of people is an exciting ongoing enterprise, and we still do not know as much as we would like to about how concepts of different kinds of people are learned in childhood and how they may (or may not) change in adulthood. Essentialism doesn't apply only to person categories, but it is one important factor in how we think of groups.

Conclusion

Concepts are central to our everyday thought. When we are planning for the future or thinking about our past, we think about specific events and objects in terms of their categories. If you're visiting a friend with a new baby, you have some expectations about what the baby will do, what gifts would be appropriate, how you should behave toward it, and so on. Knowing about the category of babies helps you to effectively plan and behave when you encounter this child you've never seen before.

Learning about those categories is a complex process that involves seeing exemplars (babies), hearing or reading general descriptions ("Babies like black-and-white pictures"), general knowledge (babies have kidneys), and learning the occasional rule (all babies have a rooting reflex). Current research is focusing on how these different processes take place in the brain. It seems likely that these different aspects of concepts are accomplished by different neural structures (Maddox & Ashby, 2004).

Another interesting topic is how concepts differ across cultures. As different cultures have different interests and different kinds of interactions with the world, it seems clear that their concepts will somehow reflect those differences. On the other hand, the structure of categories in the world also imposes a strong constraint on what kinds of categories are actually useful. Some researchers have suggested that differences between Eastern and Western modes of thought have led to qualitatively different kinds of concepts (e.g., Norenzayan, Smith, Kim, & Nisbett, 2002). Although such differences are intriguing, we should also remember that different cultures seem to share common categories such as chairs, dogs, parties, and jars, so the differences may not be as great as suggested by experiments designed to detect cultural effects. The interplay of culture, the environment, and basic cognitive processes in establishing concepts has yet to be fully investigated.

Outside Resources

Debate: The debate about Pluto and the definition of planet is an interesting one, as it illustrates the difficulty of arriving at definitions even in science. The Planetary Science Institute's website has a series of press releases about the Pluto debate, including reactions from astronomers, while it happened.

http://www.psi.edu

Image Search: It can be interesting to get a pictorial summary of how much diversity there is among category members. If you do an image search for familiar categories such as houses, dogs, weddings, telephones, fruit, or whatever, you can get a visual display on a single page of the category structure. Of course, the results are probably biased, as people do not just randomly upload pictures of dogs or fruit, but it nonetheless will likely reveal the typicality structure, as most of the pictures will be of typical exemplars, and the atypical ones will stand out. (This activity will also demonstrate the phenomenon of ambiguity in language, as a search for "house" will yield some pictures of the TV character House, M.D. However, that is a lesson for a different module.)

https://www.google.com/

Self-test: If you would like to run your own category-learning experiment, you can do so by following the link below. It works either in-browser or by download. When downloaded, users can put in their own stimuli to categorize.

http://cognitrn.psych.indiana.edu/CogSciSoftware/Categorization/index.html

Software: Self-test Categorization Applet – This software allows you to conduct your own categorization experiment.

http://cognitrn.psych.indiana.edu/CogSciSoftware/Categorization/index.html

Web: A Compendium of Category and Concept Activities and Worksheets – This website contains all types of printable worksheets and activities on how to categorize concepts. It includes word searches, picture sorts, and more.

Categories – word lists, activities, worksheets, and more

Web: An interesting article at Space.com argues (I believe correctly) that the term planet will not and should not be defined.

http://www.space.com/3142-planets-defined.html

Web: Most familiar categories have simple labels such as planet or dog. However, more complex categories can be made up for a particular purpose. Barsalou (1983) studied categories such as things to carry out of a burning house or ways to avoid being killed by the Mob. Interestingly, someone has published a book consisting of people's photographs of things they would carry out of a burning house, and there is also a website showing such collections. Try to analyze what is common to the category members. What is the category's prototype?

http://theburninghouse.com/

Discussion Questions

1. Pick a couple of familiar categories and try to come up with definitions for them. When you evaluate each proposal (a) is it in fact accurate as a definition, and (b) is it a definition that people might actually use in identifying category members?
2. For the same categories, can you identify members that seem to be "better" and "worse" members? What about these items makes them typical and atypical?
3. Going around the room, point to some common objects (including things people are wearing or brought with them) and identify what the basic-level category is for that item. What are superordinate and subordinate categories for the same items?
4. List some features of a common category such as tables. The knowledge view suggests that you know reasons for why these particular features occur together. Can you articulate some of those reasons? Do the same thing for an animal category.
5. Choose three common categories: a natural kind, a human artifact, and a social event. Discuss with class members from other countries or cultures whether the corresponding categories in their cultures differ. Can you make a hypothesis about when such categories are likely to differ and when they are not?

Vocabulary

Basic-level category

The neutral, preferred category for a given object, at an intermediate level of specificity.

Category

A set of entities that are equivalent in some way. Usually the items are similar to one another.

Concept

The mental representation of a category.

Exemplar

An example in memory that is labeled as being in a particular category.

Psychological essentialism

The belief that members of a category have an unseen property that causes them to be in the category and to have the properties associated with it.

Typicality

The difference in “goodness” of category members, ranging from the most typical (the prototype) to borderline members.

References

Allen, S. W., & Brooks, L. R. (1991). Specializing the operation of an explicit rule. *Journal of Experimental Psychology: General*, 120, 3–19.

Anglin, J. M. (1977). *Word, object, and conceptual development*. New York, NY: W. W. Norton.

Berlin, B. (1992). *Ethnobiological classification: Principles of categorization of plants and animals in traditional societies*. Princeton, NJ: Princeton University Press.

Brown, R. (1958). How shall a thing be called? *Psychological Review*, 65, 14–21.

Gelman, S. A. (2003). *The essential child: Origins of essentialism in everyday thought*. Oxford, UK: Oxford University Press.

Hampton, J. A. (1979). Polymorphous concepts in semantic memory. *Journal of Verbal Learning and Verbal Behavior*, 18, 441–461.

Hirschfeld, L. A. (1996). *Race in the making: Cognition, culture, and the child's construction of human kinds*. Cambridge, MA: MIT Press.

Horton, M. S., & Markman, E. M. (1980). Developmental differences in the acquisition of basic and superordinate categories. *Child Development*, 51, 708–719.

Keil, F. C. (1989). *Concepts, kinds, and cognitive development*. Cambridge, MA: MIT Press.

Maddox, W. T., & Ashby, F. G. (2004). Dissociating explicit and procedural-based systems of perceptual category learning. *Behavioural Processes*, 66, 309–332.

Mandler, J. M. (2004). *The foundations of mind: Origins of conceptual thought*. Oxford, UK: Oxford University Press.

Mareschal, D., Quinn, P. C., & Lea, S. E. G. (Eds.) (2010). *The making of human concepts*. Oxford, UK: Oxford University Press.

McCloskey, M. E., & Glucksberg, S. (1978). Natural categories: Well defined or fuzzy sets? *Memory & Cognition*, 6, 462–472.

Medin, D. L., & Ortony, A. (1989). Psychological essentialism. In S. Vosniadou & A. Ortony (Eds.), *Similarity and analogical reasoning* (pp. 179–195). Cambridge, UK: Cambridge University Press.

Medin, D. L., & Schaffer, M. M. (1978). Context theory of classification learning. *Psychological Review*, 85, 207–238.

Mervis, C. B. (1987). Child-basic object categories and early lexical development. In U. Neisser (Ed.), *Conceptsandconceptualdevelopment: Ecologicaland intellectual factors in categorization* (pp. 201–233). Cambridge, UK: Cambridge University Press.

Murphy, G. L., & Allopenna, P. D. (1994). The locus of knowledge effects in concept learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 20, 904–919.

Murphy, G. L., & Brownell, H. H. (1985). Category differentiation in object recognition: Typicality constraints on the basic category advantage. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 11, 70–84.

Norenzayan, A., Smith, E. E., Kim, B. J., & Nisbett, R. E. (2002). Cultural preferences for formal versus intuitive reasoning. *Cognitive Science*, 26, 653–684.

Rosch, E., & Mervis, C. B. (1975). Family resemblance: Studies in the internal structure of categories. *Cognitive Psychology*, 7, 573–605.

Rosch, E., Mervis, C. B., Gray, W., Johnson, D., & Boyes-Braem, P. (1976). *Basic objects in natural categories. Cognitive Psychology*, 8, 382–439.

Rosch, E., Simpson, C., & Miller, R. S. (1976). Structural bases of typicality effects. *Journal of Experimental Psychology: Human Perception and Performance*, 2, 491–502.

Rosch, E. H. (1973). On the internal structure of perceptual and semantic categories. In T. E. Moore (Ed.), *Cognitive development and the acquisition of language* (pp. 111–144). New York, NY: Academic Press.

Smith, E. E., & Medin, D. L. (1981). *Categories and concepts*. Cambridge, MA: Harvard University Press.

Smith, J. D., & Minda, J. P. (1998). Prototypes in the mist: The early epochs of category learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 24, 1411–1436.

Tanaka, J. W., & Taylor, M. E. (1991). Object categories and expertise: Is the basic level in the eye of the beholder? *Cognitive Psychology*, 15, 121–149.

Wisniewski, E. J., & Murphy, G. L. (1989). Superordinate and basic category names in discourse: A textual analysis. *Discourse Processes*, 12, 245–261.

JUDGMENT AND DECISION MAKING (REAL)

Introduction

Every day you have the opportunity to make countless decisions: should you eat dessert, cheat on a test, or attend a sports event with your friends. If you reflect on your own history of choices you will realize that they vary in quality; some are rational and some are not. This module provides an overview of decision making and includes discussion of many of the common biases involved in this process.

In his Nobel Prize–winning work, psychologist Herbert Simon (1957; March & Simon, 1958) argued that our decisions are bounded in their rationality. According to the **bounded rationality** framework, human beings try to make rational decisions (such as weighing the costs and benefits of a choice) but our cognitive limitations prevent us from being fully rational. Time and cost constraints limit the quantity and quality of the information that is available to us. Moreover, we only retain a relatively small amount of information in our usable memory. And limitations on intelligence and perceptions constrain the ability of even very bright decision makers to accurately make the best choice based on the information that is available.

About 15 years after the publication of Simon's seminal work, Tversky and Kahneman (1973, 1974; Kahneman & Tversky, 1979) produced their own Nobel Prize–winning research, which provided critical information about specific systematic and predictable **biases**, or mistakes, that influence judgment (Kahneman received the prize after Tversky's death). The work of Simon, Tversky, and Kahneman paved the way to our modern understanding of judgment and decision making. And their two Nobel prizes signaled the broad acceptance of the field of behavioral decision research as a mature area of intellectual study.

What Would a Rational Decision Look Like?

People often have to use incomplete information and intuition to make even the most important of decisions. A fully rational decision requires a careful, systematic process. [Image: CC0 Public Domain, https://goo.gl/m25gce]

Imagine that during your senior year in college, you apply to a number of doctoral programs, law schools, or business schools (or another set of programs in whatever field most interests you). The good news is that you receive many acceptance letters. So, how should you decide where to go? Bazerman and Moore (2013) outline the following six steps that you should take to make a rational decision: (1) define the problem (i.e., selecting the right graduate program), (2) identify the criteria necessary to judge the multiple options (location, prestige, faculty, etc.), (3) weight the criteria (rank them in terms of importance to you), (4) generate alternatives (the schools that admitted you), (5) rate each alternative on each criterion (rate each school on each criteria that you identified, and (6) compute the optimal decision. Acting rationally would require that you follow these six steps in a fully rational manner.

I strongly advise people to think through important decisions such as this in a manner similar to this process. Unfortunately, we often don't. Many of us rely on our intuitions far more than we should. And when we do try to think systematically, the way we enter data into such formal decision-making processes is often biased.

Fortunately, psychologists have learned a great deal about the biases that affect our thinking. This knowledge about the systematic and predictable mistakes that even the best and the brightest make can help you identify flaws in your thought processes and reach better decisions.

Biases in Our Decision Process

Simon's concept of bounded rationality taught us that judgment deviates from rationality, but it did not tell us *how* judgment is biased. Tversky and Kahneman's (1974) research helped to diagnose the specific systematic, directional biases that affect human judgment. These biases are created by the tendency to short-circuit a rational decision process by relying on a number of simplifying strategies, or rules of thumb, known as **heuristics**. Heuristics allow us to cope with the complex environment surrounding our decisions. Unfortunately, they also lead to systematic and predictable biases.

To highlight some of these biases please answer the following three quiz items:

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

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.

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.

Program A: If Program A is adopted, 200 people will be saved.

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?

Overconfidence

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:

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)

536 people (as of 2013)

$6.007 billion

8. 70.3 years (as of 2012)
9. 4,321
10. 52

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/IYzbDV, CC BY 2.0, https://goo.gl/BRvSA7]

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.

Anchoring

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

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:

Program C: If Program C is adopted, 400 people will die.

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 apriori 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).

Contemporary Developments

The concept of bounded willpower may explain why many of us are better shoppers than savers. [Image: CC0 Public Domain, https://goo.gl/m25gce]

Bounded rationality served as the integrating concept of the field of behavioral decision research for 40 years. Then, in 2000, Thaler (2000) suggested that decision making is bounded in two ways not precisely captured by the concept of bounded rationality. First, he argued that our **willpower is bounded** and that, as a consequence, we give greater weight to present concerns than to future concerns. Our immediate motivations are often inconsistent with our long-term interests in a variety of ways, such as the common failure to save adequately for retirement or the difficulty many people have staying on a diet. Second, Thaler suggested that our **self-interest is bounded** such that we care about the outcomes of others. Sometimes we positively value the outcomes of others—giving them more of a commodity than is necessary out of a desire to be fair, for example. And, in unfortunate contexts, we sometimes are willing to forgo our own benefits out of a desire to harm others.

My colleagues and I have recently added two other important bounds to the list. Chugh, Banaji, and Bazerman (2005) and Banaji and Bhaskar (2000) introduced the concept of **bounded ethicality**, which refers to the notion that our ethics are limited in ways we are not even aware of ourselves. Second, Chugh and Bazerman (2007) developed the concept of **bounded awareness** to refer to the broad array of focusing failures that affect our judgment, specifically the many ways in which we fail to notice obvious and important information that is available to us.

A final development is the application of judgment and decision-making research to the areas of behavioral economics, behavioral finance, and behavioral marketing, among others. In each case, these fields have been transformed by applying and extending research from the judgment and decision-making literature.

Fixing Our Decisions

Ample evidence documents that even smart people are routinely impaired by biases. Early research demonstrated, unfortunately, that awareness of these problems does little to reduce bias (Fischhoff, 1982). The good news is that more recent research documents interventions that do help us overcome our faulty thinking (Bazerman & Moore, 2013).

One critical path to fixing our biases is provided in Stanovich and West's (2000) distinction between **System 1** and **System 2** decision making. System 1 processing is our intuitive system, which is typically fast, automatic, effortless, implicit, and emotional. System 2 refers to decision making that is slower, conscious, effortful, explicit, and logical. The six logical steps of decision making outlined earlier describe a System 2 process.

Clearly, a complete System 2 process is not required for every decision we make. In most situations, our System 1 thinking is quite sufficient; it would be impractical, for example, to logically reason through every choice we make while shopping for groceries. But, preferably, System 2 logic should influence our most important decisions. Nonetheless, we use our System 1 processes for most decisions in life, relying on it even when making important decisions.

The key to reducing the effects of bias and improving our decisions is to transition from trusting our intuitive System 1 thinking toward engaging more in deliberative System 2 thought. Unfortunately, the busier and more rushed people are, the more they have on their minds, and the more likely they are to rely on System 1 thinking (Chugh, 2004). The frantic pace of professional life suggests that executives often rely on System 1 thinking (Chugh, 2004).

Fortunately, it is possible to identify conditions where we rely on intuition at our peril and substitute more deliberative thought. One fascinating example of this substitution comes from journalist Michael Lewis' (2003) account of how Billy Beane, the general manager of the Oakland Athletics, improved the outcomes of the failing baseball team after recognizing that the intuition of baseball executives was limited and systematically biased and that their intuitions had been incorporated into important decisions in ways that created enormous mistakes. Lewis (2003) documents that baseball professionals tend to overgeneralize from their personal experiences, be overly influenced by players' very recent performances, and overweigh what they see with their own eyes, despite the fact that players' multiyear records provide far better data. By substituting valid predictors of future performance (System 2 thinking), the Athletics were able to outperform expectations given their very limited payroll.

Another important direction for improving decisions comes from Thaler and Sunstein's (2008) book *Nudge: Improving Decisions about Health, Wealth, and Happiness*. Rather than setting out to debias human judgment, Thaler and Sunstein outline a strategy for how "decision architects" can change environments in ways that account for human bias and trigger better decisions as a result. For example, Beshears, Choi, Laibson, and Madrian (2008) have shown that simple changes to defaults can dramatically improve people's decisions. They tackle the failure of many people to save for retirement and show that a simple change can significantly influence enrollment in 401(k) programs. In most companies, when you start your job, you need to proactively sign up to join the company's retirement savings plan.

Nudges can be used to help people make better decisions about saving for retirement. [Image: Tax Credits, https://goo.gl/YLuyth, CC BY 2.0, https://goo.gl/BRvSA7]

Many people take years before getting around to doing so. When, instead, companies automatically enroll their employees in 401(k) programs and give them the opportunity to "opt out," the net enrollment rate rises significantly. By changing defaults, we can counteract the human tendency to live with the status quo.

Similarly, Johnson and Goldstein's (2003) cross-European organ donation study reveals that countries that have opt-in organ donation policies, where the default is not to harvest people's organs without their prior consent, sacrifice thousands of lives in comparison to opt-out policies, where the default is to harvest organs. The United States and too many other countries require that citizens opt in to organ donation through a proactive effort; as a consequence, consent rates range between 4.25%–44% across these countries. In contrast, changing the decision architecture to an opt-out policy improves consent rates to 85.9% to 99.98%. Designing the donation system with knowledge of the power of defaults can dramatically change donation rates without changing the options available to citizens. In contrast, a more intuitive strategy, such as the one in place in the United States, inspires defaults that result in many unnecessary deaths.

Concluding Thoughts

Our days are filled with decisions ranging from the small (what should I wear today?) to the important (should we get married?). Many have real world consequences on our health, finances and relationships. Simon, Kahneman, and Tversky created a field that highlights the surprising and predictable deficiencies of the human mind when making decisions. As we understand more about our own biases and thinking shortcomings we can begin to take them into account or to avoid them. Only now have we reached the frontier of using this knowledge to help people make better decisions.

Outside Resources

Book: Bazerman, M. H., & Moore, D. (2013). Judgment in managerial decision making (8th ed.). John Wiley & Sons Inc.

Book: Kahneman, D. (2011) Thinking, Fast and Slow. New York, NY: Farrar, Straus and Giroux.

Book: Thaler, R. H., & Sunstein, C. R. (2008). Nudge: Improving Decisions about Health, Wealth, and Happiness. New Haven, CT: Yale University Press.

Discussion Questions

1. Are the biases in this module a problem in the real world?
2. How would you use this module to be a better decision maker?
3. Can you see any biases in today's newspaper?

Vocabulary

Anchoring

The bias to be affected by an initial anchor, even if the anchor is arbitrary, and to insufficiently adjust our judgments away from that anchor.

Biases

The systematic and predictable mistakes that influence the judgment of even very talented human beings.

Bounded awareness

The systematic ways in which we fail to notice obvious and important information that is available to us.

Bounded ethicality

The systematic ways in which our ethics are limited in ways we are not even aware of ourselves.

Bounded rationality

Model of human behavior that suggests that humans try to make rational decisions but are bounded due to cognitive limitations.

Bounded self-interest

The systematic and predictable ways in which we care about the outcomes of others.

Bounded willpower

The tendency to place greater weight on present concerns rather than future concerns.

Framing

The bias to be systematically affected by the way in which information is presented, while holding the objective information constant.

Heuristics

cognitive (or thinking) strategies that simplify decision making by using mental short-cuts

Overconfident

The bias to have greater confidence in your judgment than is warranted based on a rational assessment.

System 1

Our intuitive decision-making system, which is typically fast, automatic, effortless, implicit, and emotional.

System 2

Our more deliberative decision-making system, which is slower, conscious, effortful, explicit, and logical.

References

Alpert, M., & Raiffa, H. (1969). A progress report on the training of probability assessors. Unpublished Report.

Banaji, M. R., & Bhaskar, R. (2000). Implicit stereotypes and memory: The bounded rationality of social beliefs. In D. L. Schacter & E. Scarry (Eds.), *Memory, brain, and belief* (pp. 139–175). Cambridge, MA: Harvard University Press.

Bazerman, M. H., & Moore, D. (2013). *Judgment in managerial decision making* (8th ed.). John Wiley & Sons Inc.

Beshears, J., Choi, J. J., Laibson, D., & Madrian, B. C. (2008). The importance of default options for retirement saving outcomes: Evidence from the United States. In S. J. Kay & T. Sinha (Eds.), *Lessons from pension reform in the Americas* (pp. 59–87). Oxford: Oxford University Press.

Chugh, D. (2004). Societal and managerial implications of implicit social cognition: Why milliseconds matter. *Social Justice Research*, 17(2), 203–222.

Chugh, D., & Bazerman, M. H. (2007). Bounded awareness: What you fail to see can hurt you. *Mind & Society*, 6(1), 1–18.

Chugh, D., Banaji, M. R., & Bazerman, M. H. (2005). Bounded ethicality as a psychological barrier to recognizing conflicts of interest. In D. Moore, D. M. Cain, G. Loewenstein, & M. H. Bazerman (Eds.), *Conflicts of Interest* (pp. 74–95). New York, NY: Cambridge University Press.

Fischhoff, B. (1982). Debiasing. In D. Kahneman, P. Slovic, & A. Tversky (Eds.), *Judgment under uncertainty: Heuristics and biases* (pp. 422–444). New York, NY: Cambridge University Press.

Johnson, E. J., & Goldstein, D. (2003). Do defaults save lives? *Science* 302(5649), 1338–1339. Joyce, E. J., & Biddle, G. C. (1981). Are auditors' judgments sufficiently regressive? *Journal of Accounting Research*, 19(2), 323–349.

Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica*, 47(2), 263–292.

Lewis, M. (2003). *Moneyball: The art of winning an unfair game*. New York, NY: W.W. Norton & Company Ltd.

March, J. G., & Simon, H. A. (1958). *Organizations*. Oxford: Wiley.

Simon, H. A. (1957). *Models of man, social and rational: Mathematical essays on rational human behavior in a social setting*. New York, NY: John Wiley & Sons.

Stanovich, K. E., & West, R. F. (2000). Individual differences in reasoning: Implications for the rationality debate? *Behavioral and Brain Sciences*, 23, 645–726.

Thaler, R. H. (2000). From homo economicus to homo sapiens. *Journal of Economics Perspectives*, 14, 133–141.

Thaler, R. H., & Sunstein, C. R. (2008). *Nudge: Improving decisions about health, wealth, and happiness.* New Haven, CT: Yale University Press.

Tversky, A., & Kahneman, D. (1981). The framing of decisions and the psychology of choice. *Science, New Series*, *211*(4481), 453–458.

Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science, New Series*, 185(4157), 1124–1131.

Tversky, A., & Kahneman, D. (1973). Availability: A heuristic for judging frequency and probability. *Cognitive Psychology*, 5(2), 207–232.