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About Noba

The Diener Education Fund (DEF) is a non-profit organization founded with the mission of re-inventing higher education to serve the changing needs of students and professors. The initial focus of the DEF is on making information, especially of the type found in textbooks, widely available to people of all backgrounds. This mission is embodied in the Noba project.

Noba is an open and free online platform that provides high-quality, flexibly structured textbooks and educational materials. The goals of Noba are three-fold:

- To reduce financial burden on students by providing access to free educational content
- To provide instructors with a platform to customize educational content to better suit their curriculum
- To present material written by a collection of experts and authorities in the field

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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Foundations in Psychological Science
This module provides an introduction and overview of the historical development of the science and practice of psychology in America. Ever-increasing specialization within the field often makes it difficult to discern the common roots from which the field of psychology has evolved. By exploring this shared past, students will be better able to understand how psychology has developed into the discipline we know today.

Learning Objectives

• Describe the precursors to the establishment of the science of psychology.
• Identify key individuals and events in the history of American psychology.
• Describe the rise of professional psychology in America.
• Develop a basic understanding of the processes of scientific development and change.
• Recognize the role of women and people of color in the history of American psychology.

Introduction

It is always a difficult question to ask, where to begin to tell the story of the history of psychology. Some would start with ancient Greece; others would look to a demarcation in the late 19th century when the science of psychology was formally proposed and instituted. These two perspectives, and all that is in between, are appropriate for describing a history of psychology. The interested student will have no trouble finding an abundance of resources on all of these time frames and perspectives (Goodwin, 2011; Leahey, 2012; Schultz & Schultz,
For the purposes of this module, we will examine the development of psychology in America and use the mid-19th century as our starting point. For the sake of convenience, we refer to this as a history of modern psychology.

Psychology is an exciting field and the history of psychology offers the opportunity to make sense of how it has grown and developed. The history of psychology also provides perspective. Rather than a dry collection of names and dates, the history of psychology tells us about the important intersection of time and place that defines who we are. Consider what happens when you meet someone for the first time. The conversation usually begins with a series of questions such as, “Where did you grow up?” “How long have you lived here?” “Where did you go to school?” The importance of history in defining who we are cannot be understated. Whether you are seeing a physician, talking with a counselor, or applying for a job, everything begins with a history. The same is true for studying the history of psychology; getting a history of the field helps to make sense of where we are and how we got here.

**A Prehistory of Psychology**

Precursors to American psychology can be found in philosophy and physiology. Philosophers such as John Locke (1632–1704) and Thomas Reid (1710–1796) promoted empiricism, the idea that all knowledge comes from experience. The work of Locke, Reid, and others emphasized the role of the human observer and the primacy of the senses in defining how the mind comes to acquire knowledge. In American colleges and universities in the early 1800s, these principles were taught as courses on mental and moral philosophy. Most often these courses taught about the mind based on the faculties of intellect, will, and the senses (Fuchs, 2000).

**Physiology and Psychophysics**

Philosophical questions about the nature of mind and knowledge were matched in the 19th century by physiological investigations of the sensory systems of the human observer. German
physiologist Hermann von Helmholtz (1821–1894) measured the speed of the neural impulse and explored the physiology of hearing and vision. His work indicated that our senses can deceive us and are not a mirror of the external world. Such work showed that even though the human senses were fallible, the mind could be measured using the methods of science. In all, it suggested that a science of psychology was feasible.

An important implication of Helmholtz’s work was that there is a psychological reality and a physical reality and that the two are not identical. This was not a new idea; philosophers like John Locke had written extensively on the topic, and in the 19th century, philosophical speculation about the nature of mind became subject to the rigors of science.

The question of the relationship between the mental (experiences of the senses) and the material (external reality) was investigated by a number of German researchers including Ernst Weber and Gustav Fechner. Their work was called psychophysics, and it introduced methods for measuring the relationship between physical stimuli and human perception that would serve as the basis for the new science of psychology (Fancher & Rutherford, 2011).

The formal development of modern psychology is usually credited to the work of German physician, physiologist, and philosopher Wilhelm Wundt (1832–1920). Wundt helped to establish the field of experimental psychology by serving as a strong promoter of the idea that psychology could be an experimental field and by providing classes, textbooks, and a laboratory for training students. In 1875, he joined the faculty at the University of Leipzig and quickly began to make plans for the creation of a program of experimental psychology. In 1879, he complemented his lectures on experimental psychology with a laboratory experience: an event that has served as the popular date for the establishment of the science of psychology.

The response to the new science was immediate and global. Wundt attracted students from around the world to study the new experimental psychology and work in his lab. Students were trained to offer detailed self-reports of their reactions to various stimuli, a procedure known as introspection. The goal was to identify the elements of consciousness. In addition to the study of sensation and perception, research was done on mental chronometry, more commonly known as reaction time. The work of Wundt and his students demonstrated that the mind could be measured and the nature of consciousness could be revealed through scientific means. It was an exciting proposition, and one that found great interest in America. After the opening of Wundt’s lab in 1879, it took just four years for the first psychology laboratory to open in the United States (Benjamin, 2007).

Scientific Psychology Comes to the United States
Wundt's version of psychology arrived in America most visibly through the work of Edward Bradford Titchener (1867–1927). A student of Wundt's, Titchener brought to America a brand of experimental psychology referred to as “structuralism.” Structuralists were interested in the contents of the mind—what the mind is. For Titchener, the general adult mind was the proper focus for the new psychology, and he excluded from study those with mental deficiencies, children, and animals (Evans, 1972; Titchener, 1909).

Experimental psychology spread rather rapidly throughout North America. By 1900, there were more than 40 laboratories in the United States and Canada (Benjamin, 2000). Psychology in America also organized early with the establishment of the American Psychological Association (APA) in 1892. Titchener felt that this new organization did not adequately represent the interests of experimental psychology, so, in 1904, he organized a group of colleagues to create what is now known as the Society of Experimental Psychologists (Goodwin, 1985). The group met annually to discuss research in experimental psychology. Reflecting the times, women researchers were not invited (or welcome). It is interesting to note that Titchener's first doctoral student was a woman, Margaret Floy Washburn (1871–1939). Despite many barriers, in 1894, Washburn became the first woman in America to earn a Ph.D. in psychology and, in 1921, only the second woman to be elected president of the American Psychological Association (Scarborough & Furumoto, 1987).

Striking a balance between the science and practice of psychology continues to this day. In 1988, the American Psychological Society (now known as the Association for Psychological Science) was founded with the central mission of advancing psychological science.

**Toward a Functional Psychology**

While Titchener and his followers adhered to a structural psychology, others in America were pursuing different approaches. William James, G. Stanley Hall, and James McKeen Cattell were among a group that became identified with “functionalism.” Influenced by Darwin's evolutionary theory, functionalists were interested in the activities of the mind—what the mind does. An interest in functionalism opened the way for the study of a wide range of approaches, including animal and comparative psychology (Benjamin, 2007).

William James (1842–1910) is regarded as writing perhaps the most influential and important book in the field of psychology, *Principles of Psychology*, published in 1890. Opposed to the reductionist ideas of Titchener, James proposed that consciousness is ongoing and continuous; it cannot be isolated and reduced to elements. For James, consciousness helped us adapt to our environment in such ways as allowing us to make choices and have personal
responsibility over those choices.

At Harvard, James occupied a position of authority and respect in psychology and philosophy. Through his teaching and writing, he influenced psychology for generations. One of his students, Mary Whiton Calkins (1863–1930), faced many of the challenges that confronted Margaret Floy Washburn and other women interested in pursuing graduate education in psychology. With much persistence, Calkins was able to study with James at Harvard. She eventually completed all the requirements for the doctoral degree, but Harvard refused to grant her a diploma because she was a woman. Despite these challenges, Calkins went on to become an accomplished researcher and the first woman elected president of the American Psychological Association in 1905 (Scarborough & Furumoto, 1987).

G. Stanley Hall (1844–1924) made substantial and lasting contributions to the establishment of psychology in the United States. At Johns Hopkins University, he founded the first psychological laboratory in America in 1883. In 1887, he created the first journal of psychology in America, American Journal of Psychology. In 1892, he founded the American Psychological Association (APA); in 1909, he invited and hosted Freud at Clark University (the only time Freud visited America). Influenced by evolutionary theory, Hall was interested in the process of adaptation and human development. Using surveys and questionnaires to study children, Hall wrote extensively on child development and education. While graduate education in psychology was restricted for women in Hall's time, it was all but non-existent for African Americans. In another first, Hall mentored Francis Cecil Sumner (1895–1954) who, in 1920, became the first African American to earn a Ph.D. in psychology in America (Guthrie, 2003).

James McKeen Cattell (1860–1944) received his Ph.D. with Wundt but quickly turned his interests to the assessment of individual differences. Influenced by the work of Darwin's cousin, Frances Galton, Cattell believed that mental abilities such as intelligence were inherited and could be measured using mental tests. Like Galton, he believed society was better served by identifying those with superior intelligence and supported efforts to encourage them to reproduce. Such beliefs were associated with eugenics (the promotion of selective breeding) and fueled early debates about the contributions of heredity and environment in defining who we are. At Columbia University, Cattell developed a department of psychology that became world famous also promoting psychological science through advocacy and as a publisher of scientific journals and reference works (Fancher, 1987; Sokal, 1980).

**The Growth of Psychology**

Throughout the first half of the 20th century, psychology continued to grow and flourish in
America. It was large enough to accommodate varying points of view on the nature of mind and behavior. Gestalt psychology is a good example. The Gestalt movement began in Germany with the work of Max Wertheimer (1880–1943). Opposed to the reductionist approach of Wundt's laboratory psychology, Wertheimer and his colleagues Kurt Koffka (1886–1941), Wolfgang Kohler (1887–1967), and Kurt Lewin (1890–1947) believed that studying the whole of any experience was richer than studying individual aspects of that experience. The saying “the whole is greater than the sum of its parts” is a Gestalt perspective. Consider that a melody is an additional element beyond the collection of notes that comprise it. The Gestalt psychologists proposed that the mind often processes information simultaneously rather than sequentially. For instance, when you look at a photograph, you see a whole image, not just a collection of pixels of color. Using Gestalt principles, Wertheimer and his colleagues also explored the nature of learning and thinking. Most of the German Gestalt psychologists were Jewish and were forced to flee the Nazi regime due to the threats posed on both academic and personal freedoms. In America, they were able to introduce a new audience to the Gestalt perspective, demonstrating how it could be applied to perception and learning (Wertheimer, 1938). In many ways, the work of the Gestalt psychologists served as a precursor to the rise of cognitive psychology in America (Benjamin, 2007).

Behaviorism emerged early in the 20th century and became a major force in American psychology. Championed by psychologists such as John B. Watson (1878–1958) and B. F. Skinner (1904–1990), behaviorism rejected any reference to mind and viewed overt and observable behavior as the proper subject matter of psychology. Through the scientific study of behavior, it was hoped that laws of learning could be derived that would promote the prediction and control of behavior. Russian physiologist Ivan Pavlov (1849–1936) influenced early behaviorism in America. His work on conditioned learning, popularly referred to as classical conditioning, provided support for the notion that learning and behavior were controlled by events in the environment and could be explained with no reference to mind or consciousness (Fancher, 1987).

For decades, behaviorism dominated American psychology. By the 1960s, psychologists began to recognize that behaviorism was unable to fully explain human behavior because it neglected mental processes. The turn toward a cognitive psychology was not new. In the 1930s, British psychologist Frederic C. Bartlett (1886–1969) explored the idea of the constructive mind, recognizing that people use their past experiences to construct frameworks in which to understand new experiences. Some of the major pioneers in American cognitive psychology include Jerome Bruner (1915–), Roger Brown (1925–1997), and George Miller (1920–2012). In the 1950s, Bruner conducted pioneering studies on cognitive aspects of sensation and perception. Brown conducted original research on language and memory, coined the term “flashbulb memory,” and figured out how to study the tip-of-the-tongue phenomenon.
Miller’s research on working memory is legendary. His 1956 paper “The Magic Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information” is one of the most highly cited papers in psychology. A popular interpretation of Miller’s research was that the number of bits of information an average human can hold in working memory is 7 ± 2. Around the same time, the study of computer science was growing and was used as an analogy to explore and understand how the mind works. The work of Miller and others in the 1950s and 1960s has inspired tremendous interest in cognition and neuroscience, both of which dominate much of contemporary American psychology.

Applied Psychology in America

In America, there has always been an interest in the application of psychology to everyday life. Mental testing is an important example. Modern intelligence tests were developed by the French psychologist Alfred Binet (1857–1911). His goal was to develop a test that would identify schoolchildren in need of educational support. His test, which included tasks of reasoning and problem solving, was introduced in the United States by Henry Goddard (1866–1957) and later standardized by Lewis Terman (1877–1956) at Stanford University. The assessment and meaning of intelligence has fueled debates in American psychology and society for nearly 100 years. Much of this is captured in the nature-nurture debate that raises questions about the relative contributions of heredity and environment in determining intelligence (Fancher, 1987).

Applied psychology was not limited to mental testing. What psychologists were learning in their laboratories was applied in many settings including the military, business, industry, and education. The early 20th century was witness to rapid advances in applied psychology. Hugo Munsterberg (1863–1916) of Harvard University made contributions to such areas as employee selection, eyewitness testimony, and psychotherapy. Walter D. Scott (1869–1955) and Harry Hollingworth (1880–1956) produced original work on the psychology of advertising and marketing. Lillian Gilbreth (1878–1972) was a pioneer in industrial psychology and engineering psychology. Working with her husband, Frank, they promoted the use of time and motion studies to improve efficiency in industry. Lillian also brought the efficiency movement to the home, designing kitchens and appliances including the pop-up trashcan and refrigerator door shelving. Their psychology of efficiency also found plenty of applications at home with their 12 children. The experience served as the inspiration for the movie Cheaper by the Dozen (Benjamin, 2007).

Clinical psychology was also an early application of experimental psychology in America. Lightner Witmer (1867–1956) received his Ph.D. in experimental psychology with Wilhelm Wundt and returned to the University of Pennsylvania, where he opened a psychological clinic
in 1896. Witmer believed that because psychology dealt with the study of sensation and perception, it should be of value in treating children with learning and behavioral problems. He is credited as the founder of both clinical and school psychology (Benjamin & Baker, 2004).

**Psychology as a Profession**

As the roles of psychologists and the needs of the public continued to change, it was necessary for psychology to begin to define itself as a profession. Without standards for training and practice, anyone could use the title psychologist and offer services to the public. As early as 1917, applied psychologists organized to create standards for education, training, and licensure. By the 1930s, these efforts led to the creation of the American Association for Applied Psychology (AAAP). While the American Psychological Association (APA) represented the interests of academic psychologists, AAAP served those in education, industry, consulting, and clinical work.

The advent of WWII changed everything. The psychiatric casualties of war were staggering, and there were simply not enough mental health professionals to meet the need. Recognizing the shortage, the federal government urged the AAAP and APA to work together to meet the mental health needs of the nation. The result was the merging of the AAAP and the APA and a focus on the training of professional psychologists. Through the provisions of National Mental Health Act of 1946, funding was made available that allowed the APA, the Veterans Administration, and the Public Health Service to work together to develop training programs that would produce clinical psychologists. These efforts led to the convening of the Boulder Conference on Graduate Education in Clinical Psychology in 1949 in Boulder, Colorado. The meeting launched doctoral training in psychology and gave us the scientist-practitioner model of training. Similar meetings also helped launch doctoral training programs in counseling and school psychology. Throughout the second half of the 20th century, alternatives to Boulder have been debated. In 1973, the Vail Conference on Professional Training in Psychology proposed the scholar-practitioner model and the Psy.D. degree (Doctor of Psychology). It is a training model that emphasizes clinical training and practice that has become more common (Cautin & Baker, in press).

**Psychology and Society**

Given that psychology deals with the human condition, it is not surprising that psychologists would involve themselves in social issues. For more than a century, psychology and psychologists have been agents of social action and change. Using the methods and tools of science, psychologists have challenged assumptions, stereotypes, and stigma. Founded in
1936, the Society for the Psychological Study of Social Issues (SPSSI) has supported research and action on a wide range of social issues. Individually, there have been many psychologists whose efforts have promoted social change. Helen Thompson Woolley (1874–1947) and Leta S. Hollingworth (1886–1939) were pioneers in research on the psychology of sex differences. Working in the early 20th century, when women's rights were marginalized, Thompson examined the assumption that women were overemotional compared to men and found that emotion did not influence women's decisions any more than it did men's. Hollingworth found that menstruation did not negatively impact women's cognitive or motor abilities. Such work combatted harmful stereotypes and showed that psychological research could contribute to social change (Scarborough & Furumoto, 1987).

Among the first generation of African American psychologists, Mamie Phipps Clark (1917–1983) and her husband Kenneth Clark (1914–2005) studied the psychology of race and demonstrated the ways in which school segregation negatively impacted the self-esteem of African American children. Their research was influential in the 1954 Supreme Court ruling in the case of Brown v. Board of Education, which ended school segregation (Guthrie, 2003). In psychology, greater advocacy for issues impacting the African American community were advanced by the creation of the Association of Black Psychologists (ABPsi) in 1968.

In 1957, psychologist Evelyn Hooker (1907–1996) published the paper “The Adjustment of the Male Overt Homosexual,” reporting on her research that showed no significant differences in psychological adjustment between homosexual and heterosexual men. Her research helped to de-pathologize homosexuality and contributed to the decision by the American Psychiatric Association to remove homosexuality from the Diagnostic and Statistical Manual of Mental Disorders in 1973 (Garnets & Kimmel, 2003).

**Conclusion**

Growth and expansion have been a constant in American psychology. In the latter part of the 20th century, areas such as social, developmental, and personality psychology made major contributions to our understanding of what it means to be human. Today neuroscience is enjoying tremendous interest and growth.

As mentioned at the beginning of the module, it is a challenge to cover all the history of psychology in such a short space. Errors of omission and commission are likely in such a selective review. The history of psychology helps to set a stage upon which the story of psychology can be told. This brief summary provides some glimpse into the depth and rich content offered by the history of psychology. The modules in this e-book are all elaborations
on the foundation created by our shared past. It is hoped that you will be able to see these connections and have a greater understanding and appreciation for both the unity and diversity of the field of psychology.

**Timeline**

1600s – Rise of empiricism emphasizing centrality of human observer in acquiring knowledge

1850s - Helmholtz measures neural impulse / Psychophysics studied by Weber & Fechner

1859 - Publication of Darwin's *Origin of Species*

1879 - Wundt opens lab for experimental psychology

1883 - First psychology lab opens in the United States

1887 – First American psychology journal is published: *American Journal of Psychology*

1890 – James publishes *Principles of Psychology*

1892 – APA established

1894 – Margaret Floy Washburn is first U.S. woman to earn Ph.D. in psychology

1904 - Founding of Titchener's experimentalists

1905 - Mary Whiton Calkins is first woman president of APA

1909 – Freud's only visit to the United States

1913 - John Watson calls for a psychology of behavior

1920 – Francis Cecil Sumner is first African American to earn Ph.D. in psychology

1921 – Margaret Floy Washburn is second woman president of APA

1930s – Creation and growth of the American Association for Applied Psychology (AAAP) / Gestalt psychology comes to America
1936- Founding of The Society for the Psychological Study of Social Issues

1940s – Behaviorism dominates American psychology

1946 – National Mental Health Act

1949 – Boulder Conference on Graduate Education in Clinical Psychology

1950s – Cognitive psychology gains popularity

1954 – Brown v. Board of Education

1957 – Evelyn Hooker publishes The Adjustment of the Male Overt Homosexual

1968 – Founding of the Association of Black Psychologists

1973 – Psy.D. proposed at the Vail Conference on Professional Training in Psychology

1988 – Founding of the American Psychological Society (now known as the Association for Psychological Science)
Outside Resources

Podcast: History of Psychology Podcast Series
http://www.yorku.ca/christo/podcasts/

Web: Advances in the History of Psychology
http://ahp.apps01.yorku.ca/

Web: Center for the History of Psychology
http://www.uakron.edu/chp

Web: Classics in the History of Psychology
http://psychclassics.yorku.ca/

Web: Psychology’s Feminist Voices
http://www.feministvoices.com/

Web: This Week in the History of Psychology
http://www.yorku.ca/christo/podcasts/

Discussion Questions

1. Why was psychophysics important to the development of psychology as a science?
2. How have psychologists participated in the advancement of social issues?
3. Name some ways in which psychology began to be applied to the general public and everyday problems.
4. Describe functionalism and structuralism and their influences on behaviorism and cognitive psychology.
Vocabulary

Behaviorism
The study of behavior.

Cognitive psychology
The study of mental processes.

Consciousness
Awareness of ourselves and our environment.

Empiricism
The belief that knowledge comes from experience.

Eugenics
The practice of selective breeding to promote desired traits.

Flashbulb memory
A highly detailed and vivid memory of an emotionally significant event.

Functionalism
A school of American psychology that focused on the utility of consciousness.

Gestalt psychology
An attempt to study the unity of experience.

Individual differences
Ways in which people differ in terms of their behavior, emotion, cognition, and development.

Introspection
A method of focusing on internal processes.

Neural impulse
An electro-chemical signal that enables neurons to communicate.

Practitioner-Scholar Model
A model of training of professional psychologists that emphasizes clinical practice.
Psychophysics
Study of the relationships between physical stimuli and the perception of those stimuli.

Realism
A point of view that emphasizes the importance of the senses in providing knowledge of the external world.

Scientist-practitioner model
A model of training of professional psychologists that emphasizes the development of both research and clinical skills.

Structuralism
A school of American psychology that sought to describe the elements of conscious experience.

Tip-of-the-tongue phenomenon
The inability to pull a word from memory even though there is the sensation that that word is available.
References


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**

- Understand 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.
- Understand what a longitudinal study is.
- Understand the strengths and weaknesses of different 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.

**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
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.

Research Designs

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.

**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.

![Scatterplot of the association between happiness and ratings of the past month](image)

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. 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.

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.

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.

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.

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.

**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.

**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!
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!

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.

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.
Outside Resources

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

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/

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

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 related 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


The brain is the most complex part of the human body. It is the center of consciousness and also controls all voluntary and involuntary movement and bodily functions. It communicates with each part of the body through the nervous system, a network of channels that carry electrochemical signals.

**Learning Objectives**

- Name the various parts of the nervous system and their respective functions
- Explain how neurons communicate with each other
- Identify the location and function of the limbic system
- Articulate how the “motor strip” is an example of brain region specialization
- Name at least three neuroimaging techniques and describe how they work

In the 1800s a German scientist by the name of Ernst Weber conducted several experiments meant to investigate how people perceive the world via their own bodies. It is obvious that we use our sensory organs—our eyes, ears, and nose—to take in and understand the world around us. Weber was particularly interested in the sense of touch. Using a drafting compass he placed the two points far apart and set them on the skin of a volunteer. When the points were far apart the research participants could easily distinguish between them. As Weber repeated the process with ever closer points, however, most people lost the ability to tell the difference between them. Weber discovered that the ability to recognize these “just noticeable differences” depended on where on the body the compass was positioned. Your
back, for example, is far less sensitive to touch than is the skin on your face. Similarly, the tip of your tongue is extremely sensitive! In this way, Weber began to shed light on the way that nerves, the nervous system, and the brain form the biological foundation of psychological processes.

In this module we will explore the biological side of psychology by paying particular attention to the brain and to the nervous system. Understanding the nervous system is vital to understanding psychology in general. It is through the nervous system that we experience pleasure and pain, feel emotions, learn and use language, and plan goals, just to name a few examples. In the pages that follow we will begin by examining how the human nervous system develops and then we will learn about the parts of the brain and how they function. We will conclude with a section on how modern psychologists study the brain.

It is worth mentioning here, at the start, that an introduction to the biological aspects of psychology can be both the most interesting and most frustrating of all topics for new students of psychology. This is, in large part, due to the fact that there is so much new information to learn and new vocabulary associated with all the various parts of the brain and nervous system. In fact, there are 30 key vocabulary words presented in this module! We encourage you not to get bogged down in difficult words. Instead, pay attention to the broader concepts, perhaps even skipping over the vocabulary on your first reading. It is helpful to pass back through with a second reading, once you are already familiar with the topic, with attention to learning the vocabulary.

**Nervous System development across the human lifespan**

As a species, humans have evolved a complex nervous system and brain over millions of years. Comparisons of our nervous systems with those of other animals, such as chimpanzees, show some similarities. Researchers can also use fossils to study the relationship between brain
volume and human behavior over the course of evolutionary history. *Homo habilis*, for instance, a human ancestor living about 2 million years ago shows a larger brain volume than its own ancestors but far less than modern *homo sapiens*. The main difference between humans and other animals—in terms of brain development—is that humans have a much more developed frontal cortex (the front part of the brain associated with planning).

Interestingly, a person’s unique nervous system develops over the course of their lifespan in a way that resembles the evolution of nervous systems in animals across vast stretches of time. For example, the human nervous system begins developing even before a person is born. It begins as a simple bundle of tissue that forms into a tube and extends along the head-to-tail plane becoming the spinal cord and brain. By day 40 of gestation (40 days after fertilization of the egg) the spinal cord, hindbrain, midbrain and forebrain are all visibly distinct. What, exactly, is this nervous system that is developing and what does it do?

The nervous system can be thought of as the body’s communication network that consists of all nerve cells. There are many ways in which we can divide the nervous system to understand it more clearly. One common way to do so is by parsing it into the central nervous system and the peripheral nervous system. Each of these can be sub-divided, in turn. Let’s take a closer, more in-depth look at each. And, don’t worry, the nervous system is complicated with many parts and many new vocabulary words. It might seem overwhelming at first but through the figures and a little study you can get it.

### The Central Nervous System (CNS): The Neurons inside the Brain

The Central Nervous System, or CNS for short, is made up of the brain and spinal cord (see Figure 1). The CNS is the portion of the nervous system that is encased in bone (the brain is protected by the skull and the spinal cord is protected by the spinal column). It is referred to as “central” because it is the brain and spinal cord that are primarily responsible for processing sensory information—touching a hot stove or seeing a rainbow, for example—and sending signals to the peripheral nervous system for action. It communicates largely by sending electrical signals through individual nerve cells that make up the fundamental building blocks of the nervous system, called neurons. There are approximately 100 billion...
neurons in the human brain and each has many contacts with other neurons, called synapses.

If we were able to magnify a view of individual neurons we would see that they are cells made from distinct parts (see Figure 2). The three main components of a neuron are the dendrites, the soma, and the axon. Neurons communicate with one another by receiving information through the dendrites, which act as an antenna. When the dendrites channel this information to the soma, or cell body, it builds up as an electro-chemical signal. This electrical part of the signal, called an action potential, shoots down the axon, a long tail that leads away from the soma and toward the next neuron. When people talk about “nerves” in the nervous system, it typically refers to bundles of axons that form long neural wires along which electrical signals can travel. Cell-to-cell communication is helped by the fact that the soma is covered by a myelin sheath—a layer of fatty cells that allow the signal to travel very rapidly from neuron to neuron.

If we were to zoom in still further we could take a closer look at the synapse, the space between neurons (see Figure 3). Here, we would see that there is a space between neurons, called the synaptic gap. To give you a sense of scale we can compare the synaptic gap to the thickness of a dime, the thinnest of all American coins (about 1.35 mm). You could stack approximately 70,000 synaptic gaps in the thickness of a single coin!

As the action potential, the electrical signal reaches the end of the axon, tiny packets of chemicals, called neurotransmitters, are released. This is the chemical part of the electro-chemical signal. These neurotransmitters are the chemical signals that travel from one neuron to another, enabling them to communicate with one another. There are many different types
of neurotransmitters and each has a specialized function. For example, serotonin affects sleep, hunger and mood. Dopamine is associated with attention, learning and pleasure.

It is amazing to realize that when you think—when you reach out to grab a glass of water, when you realize that your best friend is happy, when you try to remember the name of the parts of a neuron—what you are experiencing is actually electro-chemical impulses shooting between nerves!

The Central Nervous System: Looking at the Brain as a Whole

If we were to zoom back out and look at the central nervous system again we would see that the brain is the largest single part of the central nervous system. The brain is the headquarters of the entire nervous system and it is here that most of your sensing, perception, thinking, awareness, emotions, and planning take place. For many people the brain is so important that there is a sense that it is there—inside the brain—that a person's sense of self is located (as opposed to being primarily in your toes, by contrast). The brain is so important, in fact, that it consumes 20% of the total oxygen and calories we consume even though it is only, on average, about 2% of our overall weight.

It is helpful to examine the various parts of the brain and to understand their unique functions to get a better sense of the role the brain plays. We will start by looking at very general areas of the brain and then we will zoom in and look at more specific parts. Anatomists and neuroscientists often divide the brain into portions based on the location and function of various brain parts. Among the simplest ways to organize the brain is to describe it as having three basic portions: the hindbrain, midbrain and forebrain. Another way to look at the brain is to consider the brain stem, the Cerebelum, and the Cerebrum. There is another part, called the Limbic System that is less well defined. It is made up of a number of structures that are “sub-cortical” (existing in the hindbrain) as well as regions of the Cerebrum (see Figure 4).

The brain stem is the most basic structure of the brain and is located at the top of the spine and bottom of the brain. It is sometimes considered the “oldest” part of the brain because we can see similar structures in other, less evolved animals such as crocodiles. It is in charge of a wide range of very basic “life support” functions for the human body including breathing, digestion, and the beating of the heart. Amazingly, the brain stem sends the signals to keep
these processes running smoothly without any conscious effort on our behalf.

The **limbic system** is a collection of highly specialized neural structures that sit at the top of the brain stem, which are involved in regulating our emotions. Collectively, the limbic system is a term that doesn’t have clearly defined areas as it includes forebrain regions as well as hindbrain regions. These include the amygdala, the pituitary gland, the thalamus and the hypothalamus. These structures influence hunger, the sleep-wake cycle, sexual desire, fear and aggression, and even memory.

The **cerebellum** is a structure at the very back of the brain. Aristotle referred to it as the “small brain” based on its appearance and it is principally involved with movement and posture although it is also associated with a variety of other thinking processes. The cerebellum, like the brain stem, coordinates actions without the need for any conscious awareness. This is why reflexes can sometimes seem so automatic.

The **cerebrum** (also called the “cerebral cortex”) is the “newest,” most advanced portion of the brain. The cerebral hemispheres (the left and right hemispheres that make up each side of the top of the brain) are in charge of the types of processes that are associated with more awareness and voluntary control such as speaking and planning as well as contain our primary sensory areas (such as seeing, hearing, feeling, and moving). These two hemispheres are connected to one another by a thick bundle of neurons called the **corpus callosum**. There are instances in which people—either because of a genetic abnormality or as the result of surgery—have had their corpus callosum severed so that the two halves of the brain cannot easily communicate with one another. The rare **split-brain** patients offer helpful insights into how the brain works. For example, we now understand that the brain is **contralateral**, or opposite-sided. This means that the left side of the brain is responsible for controlling a number of sensory and motor functions of the right side of the body, and vice versa.

Consider this striking example: A split brain patient is seated at a table and an object such as a car key can be placed where a split-brain patient can only see it through the right visual field.
Right visual field images will be processed on the left side of the brain and left visual field images will be processed on the right side of the brain. Because language is largely associated with the left side of the brain the patient who sees car key in the right visual field when asked “What do you see?” would answer, “I see a car key.” In contrast, a split-brain patient who only saw the car key in the left visual field, thus the information went to the non-language right side of the brain, might have a difficult time speaking the word “car key.” In fact in this case, the patient is likely to respond “I didn’t see anything at all.” However, if asked to draw the item with their left hand—a process associated with the right side of the brain—the patient will be able to do so! See the outside resources below for a video demonstration of this striking phenomenon.

Besides looking at the brain as an organ that is made up of two halves we can also examine it by looking at its four various lobes of the cerebral cortex, the outer part of the brain (see Figure 5). Each of these is associated with a specific function. The **occipital lobe**, located at the back of the cerebral cortex, is the house of the visual area of the brain. You can see the road in front of you when you are driving, track the motion of a ball in the air, and recognize faces thanks to the occipital lobe. The **temporal lobe**, located on the underside of the cerebral cortex, is where sounds and smells are processed. The **parietal lobe**, at the upper back of the cerebral cortex, is where touch and taste are processed. Finally, the **frontal lobe**, located at the forward part of the cerebral cortex is where behavioral motor plans are processed as well as a number of highly complicated processes occur including speech and language use, creative problem solving, and planning and organization.

One particularly fascinating area in the frontal lobe is called the “motor strip” (okay, scientists call it the central sulcus but haven’t you had enough new vocabulary for the time being?). This strip running along the side of the brain is in charge of voluntary movements like waving goodbye, wiggling your eyebrows, and kissing. It is an excellent example of the way that the various regions of the brain are highly specialized. Interestingly, each of our various body parts has a unique portion of the motor strip devoted to it (see Figure 6). Each individual finger has about as much dedicated brain space as your entire leg. Your lips, in turn, require about as
much dedicated brain processing as all of your fingers and your hand combined!

Because the cerebral cortex in general, and the frontal lobe in particular, are associated with such sophisticated functions as planning and being self-aware they are often thought of as a higher, less primal portion of the brain. Indeed, other animals such as rats and kangaroos while they do have frontal regions of their brain do not have the same level of development in the cerebral cortices. The closer an animal is to humans on the evolutionary tree—think chimpanzees and gorillas, the more developed is this portion of their brain.

The Peripheral Nervous System

In addition to the central nervous system (the brain and spinal cord) there is also a complex network of nerves that travel to every part of the body. This is called the peripheral nervous system (PNS) and it carries the signals necessary for the body to survive (see Figure 7). Some of the signals carried by the PNS are related to voluntary actions. If you want to type a message to a friend, for instance, you make conscious choices about which letters go in what order and your brain sends the appropriate signals to your fingers to do the work. Other processes, by contrast, are not voluntary. Without your awareness your brain is also sending signals to your organs, your digestive system, and the muscles that are holding you up right now with instructions about what they should be doing. All of this occurs through the pathways of your peripheral nervous system.
The brain is difficult to study because it is housed inside the thick bone of the skull. What's more, it is difficult to access the brain without hurting or killing the owner of the brain. As a result, many of the earliest studies of the brain (and indeed this is still true today) focused on unfortunate people who happened to have damage to some particular area of their brain. For instance, in the 1860s a surgeon named Paul Broca conducted an autopsy on a former patient who had lost his powers of speech. Examining his patient's brain, Broca identified a damaged area—now called the “Broca's Area”—on the left side of the brain (see Figure 8). Over the years a number of researchers have been able to gain insights into the function of specific regions of the brain from these types of patients.

An alternative to examining the brains or behaviors of humans with brain damage or surgical lesions can be found in the instance of animals. Some researchers examine the brains of other animals such as rats, dogs and monkeys. Although animals brains differ from human brains in both size and structure there are many similarities as well. The use of animals for study can yield important insights into human brain function.

In modern times, however, we do not have to exclusively rely on the study of people with brain lesions. Advances in technology have led
to ever more sophisticated imaging techniques. Just as X-ray technology allows us to peer inside the body, neuroimaging techniques allow us glimpses of the working brain. Each type of imaging uses a different technique and each has its own advantages and disadvantages.

**Positron Emission Tomography (PET)** records metabolic activity in the brain by detecting the amount of radioactive substances, which are injected into a person's bloodstream, the brain is consuming. This technique allows us to see how much an individual uses a particular part of the brain while at rest, or not performing a task. Another technique, known as **Functional Magnetic Resonance Imaging (fMRI)** relies on blood flow. This method measures changes in the levels of naturally occurring oxygen in the blood. As a brain region becomes active, it requires more oxygen. This technique measures brain activity based on this increase oxygen level. This means fMRI does not require a foreign substance to be injected into the body. Both PET and fMRI scans have poor **temporal resolution**, meaning that they cannot tell us exactly when brain activity occurred. This is because it takes several seconds for blood to arrive at a portion of the brain working on a task.

One imaging technique that has better temporal resolution is **Electroencephalography (EEG)**, which measures electrical brain activity instead of blood flow. Electrodes are place on the scalp of participants and they are nearly instantaneous in picking up electrical activity. Because this activity could be coming from any portion of the brain, however, EEG is known to have poor **spatial resolution**, meaning that it is not accurate with regards to specific location.
Another technique, known as Diffuse Optical Imaging (DOI) can offer high temporal and spatial resolution. DOI works by shining infrared light into the brain. It might seem strange that light can pass through the head and brain. Light properties change as they pass through oxygenated blood and through active neurons. As a result, researchers can make inferences regarding where and when brain activity is happening.

**Conclusion**

It has often been said that the brain studies itself. This means that humans are uniquely capable of using our most sophisticated organ to understand our most sophisticated organ. Breakthroughs in the study of the brain and nervous system are among the most exciting discoveries in all of psychology. In the future, research linking neural activity to complex, real world attitudes and behavior will help us to understand human psychology and better intervene in it to help people.
Outside Resources

Video: Animation of Neurons
http://www.youtube.com/watch?v=-SHBnExxub8

Video: Split Brain Patient
http://www.youtube.com/watch?v=ZMLzP1VCANo

Web: Animation of the Magnetic Resonance Imaging (MRI)
http://sites.sinauer.com/neuroscience5e/animations01.01.html

Web: Animation of the Positron Emission Tomography (PET)
http://sites.sinauer.com/neuroscience5e/animations01.02.html

Web: Teaching resources and videos for teaching about the brain, from Colorado State University:
http://www.learner.org/resources/series142.html

Web: The Brain Museum
http://brainmuseum.org/

Discussion Questions

1. In your opinion is learning about the functions of various parts of the brain by studying the abilities of brain damaged patients ethical. What, in your opinion, are the potential benefits and considerations?

2. Are research results on the brain more compelling to you than are research results from survey studies on attitudes? Why or why not? How does biological research such as studies of the brain influence public opinion regarding the science of psychology?

3. If humans continue to evolve what changes might you predict in our brains and cognitive abilities?

4. Which brain scanning techniques, or combination of techniques, do you find to be the best? Why? Why do you think scientists may or may not employ exactly your recommended techniques?
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.

**Brain Stem**
The “trunk” of the brain comprised of the medulla, pons, midbrain, and diencephalon.

**Broca’s Area**
An area in the frontal lobe of the left hemisphere. Implicated in language production.

**Central Nervous System**
The portion of the nervous system that includes the brain and spinal cord.

**Cerebellum**
The distinctive structure at the back of the brain, Latin for “small brain.”

**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).

**Corpus Callosum**
The thick bundle of nerve cells that connect the two hemispheres of the brain and allow them to communicate.

**Dendrites**
Part of a neuron that extends away from the cell body and is the main input to the neuron.
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.

Limbic System
Includes the subcortical structures of the amygdala and hippocampal formation as well as some cortical structures; responsible for aversion and gratification.

Myelin Sheath
Fatty tissue, that insulates the axons of the neurons; myelin is necessary for normal conduction of electrical impulses among neurons.

Nervous System
The body’s network for electrochemical communication. This system includes all the nerves cells in the body.

Neurons
Individual brain cells

Neurotransmitters
Chemical substance released by the presynaptic terminal button that acts on the postsynaptic cell.

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.

**Peripheral Nervous System**
All of the nerve cells that connect the central nervous system to all the other parts of the body.

**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.

**Soma**
Cell body of a neuron that contains the nucleus and genetic information, and directs protein synthesis.

**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.

**Synapses**
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.

**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.
Thinking, Learning, & Memory
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.

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).

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 reinforcers 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. 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.” [Photo: dalioPhoto]
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 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. 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 disliked. 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.

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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 the Key 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.

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**.

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.

**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


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


“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.
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!

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...
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.

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).

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).

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...
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.
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.

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

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

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).

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

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

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

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

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


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

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 just learned in this module and about how you study for tests. On the basis of what you have just learned, is there something that 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


Humans are not perfect decision makers. Not only are we not perfect, but we depart from perfection or rationality in systematic and predictable ways. The understanding of these systematic and predictable departures is core to the field of judgment and decision making. By understanding these limitations, we can also identify strategies for making better and more effective decisions.

Learning Objectives

- Understand the systematic biases that affect our judgment and decision making.
- Develop strategies for making better decisions.
- Experience some of the biases through sample decisions.

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?**

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
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?

1. Yes, more than 10 in 1,000 Big Four clients have significant executive-level management fraud.
2. 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.

1. Program A: If Program A is adopted, 200 people will be saved.
2. Program B: If Program B is adopted, there is a one-third probability that 600 people will be saved and a two-thirds probability that no people will be saved.
Which of the two programs would you favor?

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)
6. 536 people (as of 2013)
7. $6.007 billion
8. 70.3 years (as of 2012)
9. 4,321
10. 52

Count the number of your 98% ranges that actually surrounded the true quantities. If you surrounded nine to 10, you were appropriately confident in your judgments. But most readers surround only between three (30%) and seven (70%) of the correct answers, despite claiming 98% confidence that each range would surround the true value. As this problem shows, humans tend to be overconfident in their judgments.

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:

1. Program C: If Program C is adopted, 400 people will die.
2. Program D: If Program D is adopted, there is a one-third probability that no one will die and a two-thirds probability that 600 people will die.

Which of the two programs would you favor?

Careful review of the two versions of this problem clarifies that they are objectively the same. Saving 200 people (Program A) means losing 400 people (Program C), and Programs B and D are also objectively identical. Yet, in one of the most famous problems in judgment and decision making, most individuals choose Program A in the first set and Program D in the second set (Tversky & Kahneman, 1981). People respond very differently to saving versus losing lives—even when the difference is based just on the “framing” of the choices.

The problem that I asked you to respond to was framed in terms of saving lives, and the implied reference point was the worst outcome of 600 deaths. Most of us, when we make decisions that concern gains, are risk averse; as a consequence, we lock in the possibility of saving 200 lives for sure. In the alternative version, the problem is framed in terms of losses. Now the implicit reference point is the best outcome of no deaths due to the Asian disease. And in this case, most people are risk seeking when making decisions regarding losses.

These are just three of the many biases that affect even the smartest among us. Other research shows that we are biased in favor of information that is easy for our minds to retrieve, are insensitive to the importance of base rates and sample sizes when we are making inferences, assume that random events will always look random, search for information that confirms our expectations even when disconfirming information would be more informative, claim a priori knowledge that didn't exist due to the hindsight bias, and are subject to a host of other
effects that continue to be developed in the literature (Bazerman & Moore, 2013).

**Contemporary Developments**

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. 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


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


Evolution, Perception, & Consciousness
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.
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. Say, for example, you are interested in aggressiveness
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. [Photo: mharrsch]

big questions are: Would the Chihuahua parents raise aggressive beagle puppies? Would the beagle parents raise nonaggressive 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. 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. 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.
What Have We Learned About Nature–Nurture?

It would be satisfying to be able to say that nature–nurture studies have given us conclusive and complete evidence about where traits come from, with some traits clearly resulting from genetics and others almost entirely from environmental factors, such as childrearing practices and personal will; but that is not the case. Instead, everything has turned out to have some footing in genetics. The more genetically-related people are, the more similar they are—for everything: height, weight, intelligence, personality, mental illness, etc. Sure, it seems like common sense that some traits have a genetic bias. For example, adopted children resemble their biological parents even if they have never met them, and identical twins are more similar to each other than are fraternal twins. And while certain psychological traits, such as personality or mental illness (e.g., schizophrenia), seem reasonably influenced by genetics, it turns out that the same is true for political attitudes, how much television people watch (Plomin, Corley, Defries, & Fulker, 1990), and whether or not they get divorced (McGue & Lykken, 1992).

It may seem surprising, but genetic influence on behavior is a relatively recent discovery. In the middle of the 20th century, psychology was dominated by the doctrine of behaviorism, which held that behavior could only be explained in terms of environmental factors. Psychiatry concentrated on psychoanalysis, which probed for roots of behavior in individuals’ early life-histories. The truth is, neither behaviorism nor psychoanalysis is incompatible with genetic influences on behavior, and neither Freud nor Skinner was naive about the importance of organic processes in behavior. Nevertheless, in their day it was widely thought that children’s personalities were shaped entirely by imitating their parents’ behavior, and that schizophrenia was caused by certain kinds of “pathological mothering.” Whatever the outcome of our broader discussion of nature–nurture, the basic fact that the best predictors of an adopted child’s personality or mental health are found in the biological parents he or she has never met, rather than in the adoptive parents who raised him or her, presents a
significant challenge to purely environmental explanations of personality or psychopathology. The message is clear: You can't leave genes out of the equation. But keep in mind, no behavioral traits are completely inherited, so you can't leave the environment out altogether, either.

Trying to untangle the various ways nature-nurture influences human behavior can be messy, and often common-sense notions can get in the way of good science. One very significant contribution of behavioral genetics that has changed psychology for good can be very helpful to keep in mind: When your subjects are biologically-related, no matter how clearly a situation may seem to point to environmental influence, it is never safe to interpret a behavior as wholly the result of nurture without further evidence. For example, when presented with data showing that children whose mothers read to them often are likely to have better reading scores in third grade, it is tempting to conclude that reading to your kids out loud is important to success in school; this may well be true, but the study as described is inconclusive, because there are genetic as well as environmental pathways between the parenting practices of mothers and the abilities of their children. This is a case where “correlation does not imply causation,” as they say. To establish that reading aloud causes success, a scientist can either study the problem in adoptive families (in which the genetic pathway is absent) or by finding a way to randomly assign children to oral reading conditions.

The outcomes of nature–nurture studies have fallen short of our expectations (of establishing clear-cut bases for traits) in many ways. The most disappointing outcome has been the inability to organize traits from more- to less-genetic. As noted earlier, everything has turned out to be at least somewhat heritable (passed down), yet nothing has turned out to be absolutely heritable, and there hasn't been much consistency as to which traits are more heritable and which are less heritable once other considerations (such as how accurately the trait can be measured) are taken into account (Turkheimer, 2000). The problem is conceptual: The heritability coefficient, and, in fact, the whole quantitative structure that underlies it, does not match up with our nature–nurture intuitions. We want to know how “important” the roles of genes and environment are to the development of a trait, but in focusing on “important” maybe we're emphasizing the wrong thing. First of all, genes and environment are both crucial to every trait; without genes the environment would have nothing to work on, and too, genes cannot develop in a vacuum. Even more important, because nature–nurture questions look at the differences among people, the cause of a given trait depends not only on the trait itself, but also on the differences in that trait between members of the group being studied.

The classic example of the heritability coefficient defying intuition is the trait of having two arms. No one would argue against the development of arms being a biological, genetic process. But fraternal twins are just as similar for “two-armedness” as identical twins, resulting in a heritability coefficient of zero for the trait of having two arms. Normally, according to the
heritability model, this result (coefficient of zero) would suggest all nurture, no nature, but we know that’s not the case. The reason this result is not a tip-off that arm development is less genetic than we imagine is because people do not vary in the genes related to arm development—which essentially upends the heritability formula. In fact, in this instance, the opposite is likely true: the extent that people differ in arm number is likely the result of accidents and, therefore, environmental. For reasons like these, we always have to be very careful when asking nature–nurture questions, especially when we try to express the answer in terms of a single number. The heritability of a trait is not simply a property of that trait, but a property of the trait in a particular context of relevant genes and environmental factors.

Another issue with the heritability coefficient is that it divides traits’ determinants into two portions—genes and environment—which are then calculated together for the total variability. This is a little like asking how much of the experience of a symphony comes from the horns and how much from the strings; the ways instruments or genes integrate is more complex than that. It turns out to be the case that, for many traits, genetic differences affect behavior under some environmental circumstances but not others—a phenomenon called gene-environment interaction, or G x E. In one well-known example, Caspi et al. (2002) showed that among maltreated children, those who carried a particular allele of the MAOA gene showed a predisposition to violence and antisocial behavior, while those with other alleles did not. Whereas, in children who had not been maltreated, the gene had no effect. Making matters even more complicated are very recent studies of what is known as epigenetics (see module, “Epigenetics” http://noba.to/37p5cb8v), a process in which the DNA itself is modified by environmental events, and those genetic changes transmitted to children.

Some common questions about nature–nurture are, how susceptible is a trait to change, how malleable it is, and do we “have a choice” about it? These questions are much more complex than they may seem at first glance. For example, phenylketonuria is an inborn error of metabolism caused by a single gene; it prevents the body from metabolizing phenylalanine. Untreated, it causes mental retardation and death. But it can be treated effectively by a straightforward environmental intervention: avoiding foods containing phenylalanine. Height seems like a trait

The answer to the nature–nurture question has not turned out to be as straightforward as we would like. The many questions we can ask about the relationships among genes, environments, and human traits may have many different answers, and the answer to one tells us little about the answers to the others. [Photo:legends2k]
firmly rooted in our nature and unchangeable, but the average height of many populations in Asia and Europe has increased significantly in the past 100 years, due to changes in diet and the alleviation of poverty. Even the most modern genetics has not provided definitive answers to nature–nurture questions. When it was first becoming possible to measure the DNA sequences of individual people, it was widely thought that we would quickly progress to finding the specific genes that account for behavioral characteristics, but that hasn’t happened. There are a few rare genes that have been found to have significant (almost always negative) effects, such as the single gene that causes Huntington’s disease, or the Apolipoprotein gene that causes early onset dementia in a small percentage of Alzheimer’s cases. Aside from these rare genes of great effect, however, the genetic impact on behavior is broken up over many genes, each with very small effects. For most behavioral traits, the effects are so small and distributed across so many genes that we have not been able to catalog them in a meaningful way. In fact, the same is true of environmental effects. We know that extreme environmental hardship causes catastrophic effects for many behavioral outcomes, but fortunately extreme environmental hardship is very rare. Within the normal range of environmental events, those responsible for differences (e.g., why some children in a suburban third-grade classroom perform better than others) are much more difficult to grasp.

The difficulties with finding clear-cut solutions to nature–nurture problems bring us back to the other great questions about our relationship with the natural world: the mind-body problem and free will. Investigations into what we mean when we say we are aware of something reveal that consciousness is not simply the product of a particular area of the brain, nor does choice turn out to be an orderly activity that we can apply to some behaviors but not others. So it is with nature and nurture: What at first may seem to be a straightforward matter, able to be indexed with a single number, becomes more and more complicated the closer we look. The many questions we can ask about the intersection among genes, environments, and human traits—how sensitive are traits to environmental change, and how common are those influential environments; are parents or culture more relevant; how sensitive are traits to differences in genes, and how much do the relevant genes vary in a particular population; does the trait involve a single gene or a great many genes; is the trait more easily described in genetic or more-complex behavioral terms?—may have different answers, and the answer to one tells us little about the answers to the others.

It is tempting to predict that the more we understand the wide-ranging effects of genetic differences on all human characteristics—especially behavioral ones—our cultural, ethical, legal, and personal ways of thinking about ourselves will have to undergo profound changes in response. Perhaps criminal proceedings will consider genetic background. Parents, presented with the genetic sequence of their children, will be faced with difficult decisions about reproduction. These hopes or fears are often exaggerated. In some ways, our thinking
may need to change—for example, when we consider the meaning behind the fundamental American principle that all men are created equal. Human beings differ, and like all evolved organisms they differ genetically. The Declaration of Independence predates Darwin and Mendel, but it is hard to imagine that Jefferson—whose genius encompassed botany as well as moral philosophy—would have been alarmed to learn about the genetic diversity of organisms. One of the most important things modern genetics has taught us is that almost all human behavior is too complex to be nailed down, even from the most complete genetic information, unless we’re looking at identical twins. The science of nature and nurture has demonstrated that genetic differences among people are vital to human moral equality, freedom, and self-determination, not opposed to them. As Mordecai Kaplan said about the role of the past in Jewish theology, genetics gets a vote, not a veto, in the determination of human behavior. We should indulge our fascination with nature–nurture while resisting the temptation to oversimplify it.
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


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.

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 needed 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.

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) in an effort to determine the threshold at which he or she begins to hear (see Additional Resources for a video demonstration of a high-frequency ringtone that can only be heard by young people). 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 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.

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:

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. During this process we become less sensitive to that stimulus. 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 is. We don't remember it being that loud last night. What happened? What happened is that we adapted to the constant stimulus of the radio volume over the course of the previous day. This required us to continue to turn up the volume of the radio to combat the constantly decreasing sensitivity. However, after a number of hours away from that constant stimulus, the volume that was once reasonable is entirely too loud. We are no longer adapted to that stimulus!

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.
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 dark adaptation. 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 light adaptation, 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

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 blindness 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).

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

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.
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.

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).

Figure 5. The Homunculus (Latin “little man”) – on the left you see a human body drawn to demonstrate the areas that possess the most sensitivity – lips, hands, genitals and feet. On the right you see the drawing of the somatosensory cortex in the brain and the areas in the human body that correspond to it - they are also drawn in proportion to the most sensitive or the most innervated parts of the body.
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 a homunculus (small human) 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.
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—yours 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. 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 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

Ghost Pepper, also known as Bhut Jolokia is one of the hottest peppers in the world, it’s 10 times hotter than a habañero, 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: Sally Crossthwaite]
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 superadditive 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

**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/


Video: Acquired knowledge and its impact on our three-dimensional interpretation of the world - 3D Street Art
https://youtu.be/GwNeukAmxJw

Video: Acquired knowledge and its impact on our three-dimensional interpretation of the world - Anamorphic Illusions
https://youtu.be/tBNHPk-Lnkk

Video: Acquired knowledge and its impact on our three-dimensional interpretation of the world - Optical Illusion
https://youtu.be/YjmHofj2da0

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=1mHlv5ToMTM
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

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  
https://vimeo.com/39138252

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  

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**  
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


No matter what you're doing--solving homework, playing a video game, simply picking out a shirt--all of your actions and decisions relate to your consciousness. But as frequently as we use it, have you ever stopped to ask yourself: What really is consciousness? In this module, we discuss the different levels of consciousness and how they can affect your behavior in a variety of situations. As well, we explore the role of consciousness in other, “altered” states like hypnosis and sleep.

Learning Objectives

- Define consciousness and distinguish between high and low conscious states
- Explain the relationship between consciousness and bias
- Understand the difference between popular portrayals of hypnosis and how it is currently used therapeutically

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. And 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.
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)—perhaps the most influential psychologist of all time—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 and hear your singing). 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 of what constitutes this “awareness of consciousness,” though, it is easy to see how slippery a topic it is. For example, are people conscious when they're daydreaming? What about when they're drunk? Clearly, consciousness is more of a continuum than an on-or-off state of being. 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 on 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. And even though it was later shown that the researcher had made up the data (he hadn't even inserted the words into the movie frame), 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**

Outside of being in a coma, you are constantly receiving and evaluating sensory information. Although any 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 in our environment, or significant sensory information, will automatically elicit a response from us even though we never consciously perceive it. For example, Öhman and Soares (1994) took participants with a fear of snakes and connected them to a machine that measured subtle variations in sweating. The researchers then flashed pictures of different items (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 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!

Yet just because our brains perceive these 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 random ones) walked more slowly down the hallway!

This effect called priming (i.e., readily “activating” certain concepts and associations from one’s memory) has been replicated in a number of other studies. For example, priming the 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.

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. This method can help uncover non-conscious biases as well as those that we are motivated to suppress. Even if the participant clicks “good” for every face shown, the IAT can still pick up minute 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).

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 is what you think of as effortful attention and decision making. For example, when you listen to a funny story on a date, 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.
Mindfulness is a state of this heightened conscious 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).

Constantly, we’re alternating between low and high thinking states: the less we’re paying attention, the more likely we’re influenced by non-conscious stimuli (Chaiken, 1980). And although these subliminal influences may have an effect on us regardless of how effortfully we’re thinking, we can use our higher conscious awareness to blunt or even reverse the effect of them. In what’s known as the Flexible Correction Model (Wegener & Petty, 1997), as long as people are aware that their thoughts or behavior is being influenced by an undue, outside
source, they will correct their attitude against the bias.

To help make this relationship between lower and higher conscious thoughts clearer, imagine the brain is like a train terminal and all of our thoughts are the different trains you can ride. Sometimes, when you have low awareness, you just jump on the first train that opens its doors for you. However, if you’re more mindful of your thoughts, you can pause to consider all the various trains and select the one that will best get you to your destination. But this analogy, and all the other research we’ve discussed, has only applied to your standard conception of consciousness. So what about other states—like sleeping, daydreaming, or hypnosis—how are these related to our conscious awareness?

**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.

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. Regardless of one’s predisposition to being hypnotized, this mental state relies on two psychological processes: a dissociation of the self, and reduction in elaborative (or “critical”) thinking (Aguado, 2015).

**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

<table>
<thead>
<tr>
<th>States of Consciousness</th>
<th>Costs</th>
<th>Benefits</th>
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<tbody>
<tr>
<td>Low Awareness</td>
<td>Influenced by subtle factors</td>
<td>Saves mental effort</td>
</tr>
<tr>
<td>High Awareness</td>
<td>Uses mental effort</td>
<td>Can overcome some biases</td>
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</tbody>
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Table 1: States of Consciousness.
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.
You may have experienced the sensation, as you are falling asleep, of falling and then found yourself jerking forward and grabbing out as if you were really falling. Sleep is a unique state of consciousness. 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. 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 5 stages of sleep, each characterized by its own unique pattern of brain activity:

- **Stage 1**: is a light sleep and is marked by theta waves
- **Stage 2**: is deeper sleep (here there are “sleep spindles,” or occasional very high intensity brain waves).
- **Stage 3**: is marked by greater muscle relaxation and the appearance of delta waves
- **Stage 4**: is very relaxed and marked by delta waves
- **Stage 5**: sleep marked by rapid eye movement (REM). It is here that people dream most vividly. Interestingly, this stage is—where brain activity is concerned—similar to
wakefulness. That is, the brain waves occur less intensely than in other stages of sleep.

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 underexplored 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, several of the United States, and a few other countries 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 endorphins 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, over intoxication 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. 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

http://www.hup.harvard.edu/catalog.php?isbn=9780674013827

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

The LSD simulator: This simulator uses optical illusions to simulate the hallucinogenic 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://www.youtube.com/watch?v=y2zBNXW7XtI

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-ldsduring-1950s-research-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.
https://youtu.be/4PQAc_Z2OfQ

Video: Clip on the rubber hand illusion, from the BBC science series "Horizon."
https://youtu.be/Qsmkgi7FgEo

Video: Clip showing a patient with blindsight, from the documentary "Phantoms in the Brain."
https://youtu.be/Cy8FSffrNDI

Video: Demonstration of motion-induced blindness - Look steadily at the blue moving pattern. One or more of the yellow spots may disappear:
https://youtu.be/4Aye9FWgxUg

Video: Howie Mandel from American Idol being hypnotized into shaking hands with people:
https://www.youtube.com/watch?v=f9dFLXV9hs0

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:
https://vimeo.com/58254376

Want a quick demonstration of priming? (Want a quick demonstration of how powerful these effects can be? Check out:
https://youtu.be/QTTbDy3AZ9A

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)
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
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
Consciousness: the awareness or deliberate perception of a stimulus

Cues
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
Depressants: a class of drugs that slow down the body's physiological and mental processes.

Dissociation
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
Euphoria: an intense feeling of pleasure, excitement or happiness.

Flexible Correction Model
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
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**
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**
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**
Implicit Associations Test (IAT): 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**
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**
Melatonin: A hormone associated with increased drowsiness and sleep.

**Mindfulness**
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**
Priming: the activation of certain thoughts or feelings that make them easier to think of and act upon

**Stimulants**
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.
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